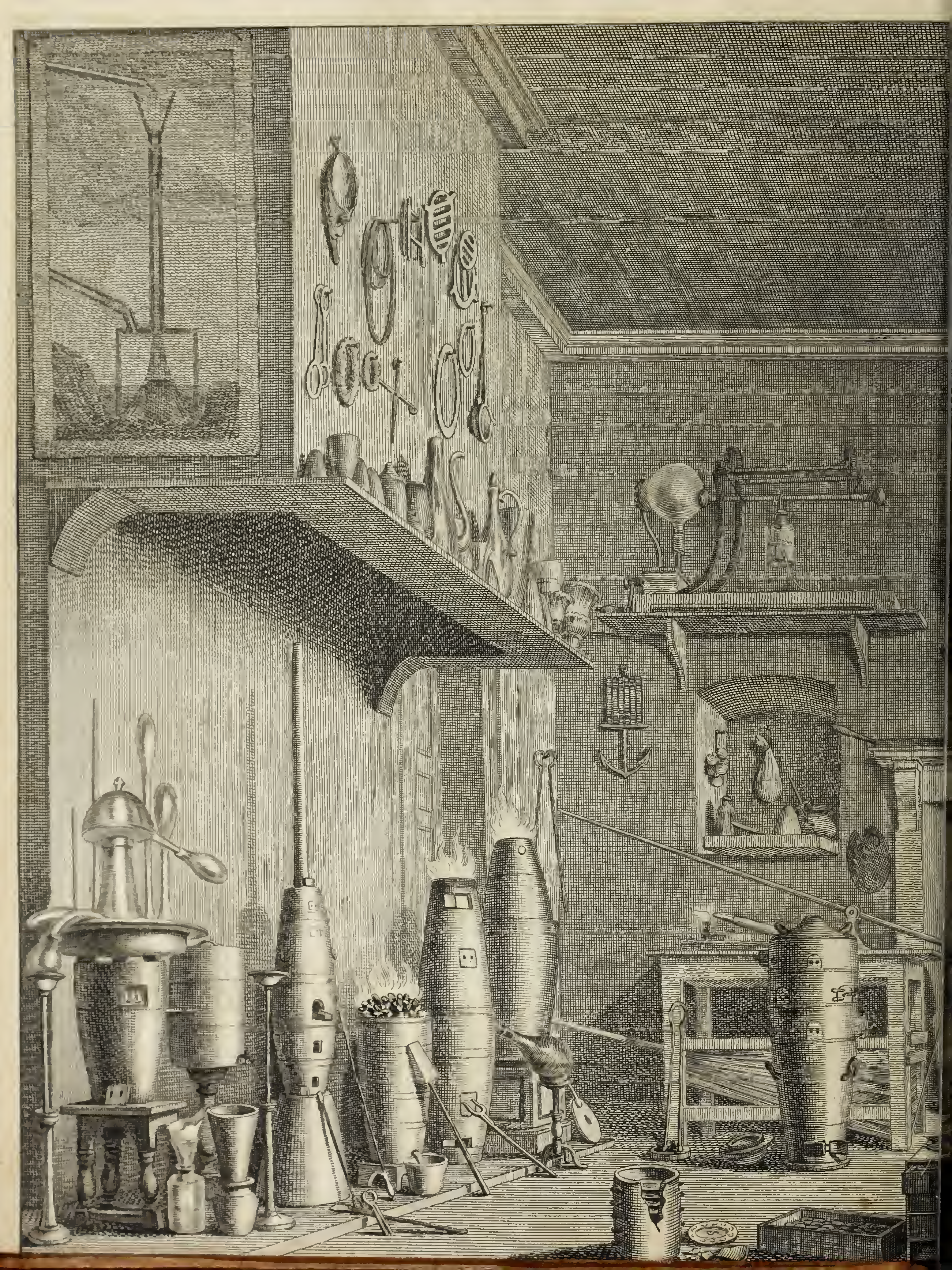
GEORGE R.

WHEREAS our truſty and well-beloved WILLIAM LEWIS, of *Kingſton*, in our County of *Surry*, M. B. has, by his Petition, humbly repreſented unto Us, that he hath been, for upwards of Fourteen Years, engaged in making Experiments, and collecting Materials, for a Work, entitled "COMMERCIUM PHILOSOPHICO-TECHNICUM, or, The "PHILOSOPHICAL COMMERCE OF ARTS; deſigned as an Attempt to "promote uſeful Knowledge;" and hath at length brought it to great Forwardneſs, ſo as to be fit for putting to the Preſs; and whereas he hath been at great Labour, Pains, and Expence, in proſecuting the ſaid Work, which he humbly preſumes will be of Service to Our Subjects concerned in *Arts*, *Trades* and *Manufactures*, as tending to promote that Kind of Knowledge on which they depend; He therefore moſt humbly prays Us to grant him Our Royal Licence and Privilege for the ſole Printing, Publiſhing, and Vending the ſaid Work, for the Term of Fourteen Years, agreeable to the Statute in that Caſe made and provided: We are graciouſly pleaſed to condeſcend to his Requeſt, and do accordingly, by theſe Preſents, as far as may be agreeable to the Statute in that Caſe made and provided, grant unto him the ſaid WILLIAM LEWIS, his Executors, Adminiſtrators, and Aſſigns, Our Royal Licence for the ſole Printing, Publiſhing, and Vending the ſaid Work, for the Term of Fourteen Years from the Date hereof; ſtrictly forbidding all our Subjects, within Our Kingdoms and Dominions, to Reprint, Abridge, or Publiſh the ſame, either in the like, or any other Volume, or Volumes, whatſoever, or to Import, Buy, Vend, Utter, or Diſtribute any Copies thereof Reprinted beyond the Seas, during the aforeſaid Term of Fourteen Years, without the Conſent and Approbation of the ſaid WILLIAM LEWIS, his Heirs, Executors, Adminiſtrators, and Aſſigns, under their Hands and Seals, firſt had and obtained, as they will anſwer the contrary at their Peril; whereof the Commiſſioners, and other Officers of Our Cuſtoms, the Maſter, Wardens, and Company of Stationers, are to take Notice, and that the ſame may be entered in the Regiſter of the ſaid Company, and that due Obedience be rendered to Our Will and Pleaſure herein declared.

Given at Our Court at *St. James's*, the Eighth Day of *February*, 1762, in the Second Year of Our Reign,

By His Majeſty's Command.

EGREMONT.



COMMERCIUM

Philosophico-Technicum;

OR, THE

PHILOSOPHICAL COMMERCE

OF

ARTS:

DESIGNED AS

AN ATTEMPT TO IMPROVE

Arts, Trades, *and* Manufactures.

By *W. LEWIS,* M. B. and F. R. S.

Fiat Experimentum. BACON.

LONDON,
Printed by H. BALDWIN, for the AUTHOR;
And Sold by R. WILLOCK, at Sir Isaac Newton's Head in Cornhill.
MDCCLXIII.

TO THE

KING.

SIR,

THE advancement of arts, trades, and manufactures, and the extension of commerce, are now become the more immediate objects of Your Royal care; as being the most certain means of attaining Your darling wishes, the rendering Your people powerful and happy, and perpetuating the blessings of peace. I have therefore presumed, with all humility, to offer to Your MAJESTY's protection, a work designed to improve and enlarge many of the arts of peace, and to promote that kind of knowledge on which they depend. The importance of the subject, and the honour, the never to be forgotten honour, which

 Your

Your MAJESTY was pleaſed to do me, by Your attention to ſome lectures and experiments, made by Your command at Kew, for ſhewing the application of chemiſtry to the improvement of practical arts as well as of philoſophy, will, I hope, excuſe this ambition in

Your MAJESTY'S

Moſt humble and devoted

Subject and Servant,

Kingſton on Thames,
7th of April, 1763.

William Lewis.

PREFACE.

As all the arts, by which matter is diverſly modified and accommodated to human uſes, have a neceſſary dependence upon the properties or qualities of the bodies on which they are exerciſed; enquiries into the properties of different bodies, and the effects reſulting from various applications of them to one another, become apparently of primary importance, as well for the illuſtration and improvement of the preſent arts and the diſcovery of new ones, as for the advancement of uſeful knowledge.

The properties of bodies make the object of two ſciences, *natural philoſophy* and *chemiſtry*; which, though in many caſes ſo cloſely interwoven, and ſo nearly allied, that perhaps no boundaries can be eſtabliſhed between them, appear in others to have eſſential and important differences. In the introduction to a work, of which enquiries into the properties and relations of bodies make a principal part, the neceſſary preciſion, in regard to matters of fact, as well as of ſcience, requires that we ſhould endeavour to diſtinguiſh them.

 Natural

Natural or mechanical philosophy seems to consider bodies chiefly as being entire aggregates or masses; as being divisible into parts, each of the same general properties with the whole; as being of certain magnitudes or figures, known or investigable; gravitating, moving, resisting, &c. with determinate forces, subject to mechanic laws, and reducible to mathematical calculation.

Chemistry considers bodies as being composed of such a particular species of matter; dissoluble, liquefiable, vitrescible, combustible, fermentable, &c. impregnated with colour, smell, taste, &c. or consisting of dissimilar parts, which may be separated from one another, or transferred into other bodies. The properties of this kind are not subject to any known mechanism, and seem to be governed by laws of another order.

To the grand active power, called *attraction*, in the mechanical philosophy, what corresponds in the chemical is generally distinguished by another name, *affinity*.

The mechanical attraction obtains between bodies considered each as one whole, and between bodies of the same as well as of different kinds. It obtains while the bodies are at sensible distances; and the comparative forces, with which they tend together at different distances, are objects of calculation. When the attracting bodies have come into the closest contact we can conceive, they still continue two distinct bodies, cohering only superficially, and separable by a determinate mechanic force.

The

The chemical attraction, or affinity, obtains between bodies as being compoſed of parts, and as being of a different ſpecies of matter from one another. It never takes place while the two bodies are at any ſenſible diſtance; and when they are brought into the cloſeſt contact, there is frequently neceſſary ſome other power, as fire, to excite their action upon one another. In proportion as this action happens, they are no longer two bodies, but one; the affinity conſiſting in the intimate coalition of the parts of one body with thoſe of the other. The properties of this new compound are not in any kind of ratio of thoſe of the compounding bodies, nor diſcoverable by any mathematical inveſtigation: two bodies, each by itſelf very eaſily fuſible in the fire, as lead and ſulphur, ſhall form a compound very difficult of fuſion; and two which cannot ſeparately be made to melt at all, as pure clay and chalk, ſhall melt with eaſe when joined together.

As the chemical union, and the properties thence reſulting, are exempt from all known mechaniſm, ſo neither can the bodies be ſeparated again by mechanic force. But a third body may have a ſtronger affinity to either of the component matters than they have to one another, in which caſe, on preſenting to the compound this third body, the former union is broken, and one of the firſt bodies coaleſces with the third, while the other is detached and ſeparated.

Thus, when quicklime is diſſolved in water, if we add to the tranſparent fluid a little vitriolic acid, the acid particles unite with the diſſolved particles of the lime into a new compound; which, notwithſtanding the pungent taſte of the one ingredient, the corroſive acidity of the other, and the ſolubility of both, proves inſipid and indiſſoluble, and which therefore, ſeparating from the water, renders it at firſt milky, and on ſtanding ſettles to the bottom, in form of powder or ſmall cryſtals, of the ſame general properties with the native gypſums or plaſter-of-paris ſtones.

If this powder be ground with inflammable matter, as powdered charcoal, no action happens between them, how exquiſitely ſoever they be mixed: the two powders continue gypſum and charcoal, and may be in great meaſure parted from one another by means of water, the charcoal powder remaining for a time ſuſpended in the fluid, while the heavier gypſum ſettles. On expoſing the mixture to a proper degree of heat, a ſtrong chemical affinity begins to take place: the acid quits the lime, and unites with the inflammable principle of the coal, forming therewith another new compound, common brimſtone, which, like the former, proves inſipid, and indiſſoluble in watery liquors, though in other properties remarkably different; melting in a ſmall degree of heat into a red fluid; in a ſomewhat greater heat, if air is excluded, riſing into the upper part of the veſſel unaltered; on the admiſſion of air changing into a blue flame, with a ſuffocating volatile acid fume, which by air and moiſture returns into the original, inodorous, ponderous, vitriolic acid.

By mixing the brimſtone with iron filings, a freſh tranſpoſition is produced; and as in the preceding caſe the action is excited by fire, ſo in this it is excited by water. The mixture,

mixture, kept perfectly dry, continues unaltered for years: on being moiftened with water, it grows fpontaneoufly hot in a few hours, and if the quantity is large, it even burfts into flame, with fuch commotion, as has induced many to afcribe earthquakes and vulcanoes to this caufe. During this action, the acid is transferred to the iron; and the inflammable matter, before combined with it, efcapes into the air. The combination of the acid with the iron forms the green vitriol or copperas of the fhops; a falt of a ftrong tafte, and of eafy folution in water, though the quantity of iron in it is very far greater than that of the inflammable matter by which, in the form of brimftone, the mifcibility of the acid with water was deftroyed.

To the green folution of the vitriol, if fome vegetable afhes, or the earth called magnefia, be added, the iron falls to the bottom, confiderably altered, in form of ochre or ruft; deprived of its attractive power to the magnet, and of all its metallic properties, which however are eafily reftored by expofing it to the fire in mixture with a little charcoal powder. In room of the iron thus thrown out from the liquor, the acid attacks the vegetable earth or magnefia; and though with one kind of earth, as we have feen above, it forms an infipid and indiffoluble concrete; with both thefe earths it compofes a bitterifh falt which diffolves eafily, and which, at leaft when magnefia is made ufe of, is the fame with that of the purging mineral waters.

If to the folution of this falt we add a volatile alcaline falt, the penetrating fmell of the alcali is fuppreffed in an inftant, the acid uniting with the alcali into a new com-

pound,

pound, and depoſiting the earth which it had taken up before.

From this compound, fixt alcaline ſalts abſorb the acid, and ſet at liberty the volatile alcali with all its original properties. Though the acid and fixt alcali, ſeparately, are very pungent and corroſive, and ſo ſtrongly diſpoſed to unite with water that they imbibe it from the air, yet the combination of the two has only a mild bitteriſh taſte, and diſſolves in water very difficultly and ſparingly.

After all theſe tranſpoſitions, the acid may ſtill be recovered pure, and made to paſs again through the ſame and through a multiplicity of other combinations. From almoſt all its combinations it may be transferred to inflammable matter, and from the inflammable matter to iron: from the brimſtone, which it forms with the one, the acid may be obtained by burning with a proper apparatus; and from the vitriol, which it forms with the other, by diſtillation.

It is obvious, that in all theſe caſes, the action is not between bodies conſidered as aggregates or maſſes, but between the inſenſible and diſſimilar parts of which they are compoſed; that the ſeveral effects can be regarded no otherwiſe than as ſimple facts, not reducible to any known mechaniſm, not inveſtigable from any principles, and each diſcoverable by obſervation only; and that the powers, on which they depend, are, ſo far as can be judged in the preſent ſtate of knowledge, of a different kind from thoſe, by which bodies tend to approach or cohere with forces proportionate to their diſtances, or to reſiſt or propel accord-

ing

ing to their quantities of matter and velocities. It ſeems of importance, that theſe two orders of the affections of bodies be kept diſtinct, as many errors have ariſen from applying to one ſuch laws as obtain only in the other.

When Archimedes obſerved, in the bath, that the bulk of a body, however irregular, might be found, by plunging it into a veſſel of water, and meaſuring the water which run over, or the ſpace which the water occupied in the veſſel more than it did before; and that gold has near twice the weight of ſilver under an equal bulk; he concluded, that if gold and ſilver were mixed together, the quantity of each metal in the mixture might be found by calculation from the bulk of the maſs compared with its weight; and on this foundation, he is ſaid to have diſcovered a fraudulent addition of ſilver made by the workman in Hieros golden crown, at a time when the chemical methods of analyſing and aſſaying metallic compoſitions appear to have been unknown.

The mechanical philoſophy has extended this way of inveſtigation to many different mixtures, and computed tables for facilitating the operation; not aware, that though the method is demonſtrably juſt if the two bodies were joined only ſuperficially, the caſe is otherwiſe when they are intimately combined together. The act of combination, whether in bodies brought into fuſion by fire, or in ſuch as are naturally fluid, is truly chemical, and the laws of the mechanical philoſophy have no place in it. There are inſtances, ſome of which will appear in the preſent volume, of bodies being dilated on mixture into a

larger

larger bulk than they had before; and, contrariwiſe, of two being contracted into leſs bulk than even one of them occupied by itſelf.

To render the proceſs anywiſe to be depended on, actual mixtures of the reſpective bodies ought firſt to be made, in different proportions, and examined hydroſtatically, that the quantity of contraction or dilatation in particular caſes may be known and allowed for. By thus borrowing from both ſciences, we are furniſhed with means of diſcovering the proportions of the ingredients in many mixtures, provided the ingredients themſelves are known, with tolerable certainty: in ſome mixtures, as of lead and tin, this method is more commodious, and perhaps more exact, than any which pure chemiſtry has afforded.

In this manner the mechanical and chemical ſciences concur, and require the aſſiſtance of one another, in their own operations, and in almoſt all the manual arts. In the greater number of the arts the chemical prevails, and many are no other than direct branches of practical chemiſtry, as the arts of dying and ſtaining, the running down of ores, the refining and compounding of metals, the making and colouring of glaſs, enamel, porcelain, &c. making wines, vinegars, ſpirits, &c. preparing indigo, ſmalt, Pruſſian blue, vermilion, lakes, and other colours for the painter. It is in thoſe arts, and in thoſe branches of arts, which are ſtrictly chemical, that the moſt important and moſt numerous diſcoveries are to be expected: chemiſtry having hitherto been the leaſt cultivated, though not the leaſt fruitful; and producing daily, not barely new applications of principles already known, but new facts or principles to be further applied.

Having for ſeveral years employed myſelf at times in experiments relative chiefly to the chemical arts, and made proper diſpoſitions for continuing ſuch enquiries, I publiſhed in 1748 propoſals for a very extenſive work, conſiſting principally of thoſe experiments, and of informations received from workmen and others. The ſeveral articles were to be printed in a miſcellaneous manner, without regard to any one being connected with that which preceded or followed it. As nothing was to be admitted but uſeful or intereſting facts, it ſeemed of little importance in what order the facts ſhould be diſpoſed, provided, by means of proper indexes, the reader could readily have recourſe to ſuch particulars as might occaſionally be wanted.

Some friends adviſed an alteration in this plan, judging it would be of more utility to the publick if the facts were methodized; and the moſt convenient method was thought to be, to give a complete hiſtory of each art by itſelf in all its branches. The difficulty of ſuch an attempt, and the impoſſibility of executing it to any good purpoſe by one hand, were apparent: nor would a ſimple detail of the manual operations of different workmen be anywiſe agreeable, either to the views, or the materials, with which I had engaged in the undertaking.

Another way occurred of procuring ſome degree of regularity, without departing from the original views, any otherwiſe than by rendering them more comprehenſive.

Many of the arts have natural and ſtrong connections with one another; working upon the ſame materials, for purpoſes either different or nearly the ſame; or producing ſimilar effects upon different or ſimilar ſubjects. One property of ſuch materials, or the production of one effect, may therefore influence ſeveral arts: a colour, which can be eaſily fixed in animal and vegetable fibres, is equally of benefit to the woollen dyer, the ſilk dyer, the dyer of linen and cotton thread, and the callico printer: a colour which will bear fire, and unite with vitreous bodies in fuſion, concerns equally the glaſs maker, the enameller, and the painter on porcelain.

The diſcoveries and improvements made in one art, and even its common proceſſes, are generally little known to thoſe who are employed in another, ſo that the workman can ſeldom avail himſelf of the advantages which he might receive from the correlative arts, and an effect wanting to the perfection of his own art may be actually produced in another. Thus, though the dyer of linen cloth, and of linen and cotton thread, wants means of communicating to them a black dye that ſhall endure wearing, the callico printer fixes both on linen and on cotton a black as durable as can be wiſhed for.

To enquire therefore by experiment into the different means of producing one effect, and trace it through all the arts in which ſuch an effect is required; to examine the chemical properties of one ſubject-matter, and conſider its uſes and applications in all the arts in which it is concerned; to proceed in this manner with the capital effects, and materials, ſo far as my own experiments, and my op-

portunities

portunities of information, ſhould enable me; appeared to be the moſt rational and direct means, not only of eſtabliſhing ſolid principles of the ſeveral arts as now exerciſed, but of procuring an uſeful intercourſe and communication of knowledge, of ſupplying many of their defects, of multiplying their reſources, of improving their products, of facilitating and ſimplifying ſome complex operations, and rejecting uſeleſs ingredients in ſundry compoſitions, of enriching one art with the practices, materials, and ſometimes even with the refuſe-matters of another.

SUCH therefore is the plan which I have choſen to follow, and of this alteration I gave notice in an advertiſement in 1761.

I have the ſatisfaction to find that the French academy of ſciences, who, with the advantage of penſions from the ſovereign, and with the aſſiſtance of experienced artiſts in different profeſſions, have been engaged for near a century in a hiſtory of arts which has but lately been begun to be publiſhed, expreſs exactly the ſame ſentiments with thoſe on which I have proceeded. In the memoirs for 1763, the hiſtorian of the academy, in giving notice of the publication of that work, obſerves that " an inconvenience to be feared is, the want of that knowledge, and of thoſe general principles, which bind arts as it were together, and eſtabliſh between them a reciprocal communication of light. All the arts, for example, that employ iron, have common principles, but it would be in vain to expect the knowledge thereof from thoſe who exerciſe theſe arts, each of whom knows only the application of thoſe principles to his own art. The farrier, the lockſmith, the cutler, know how to work iron; but each of them knows only the manner of working which he has learnt, and is perfectly ignorant that the art of working iron has general principles, which would be infinitely uſeful to him in a great number of unforeſeen caſes, to which his common practice cannot be applied.---'Tis only by bringing the arts as it were to approach to one another, that we can make advances towards their perfection: we ſhall thus put them in a condition of mutually illuſtrating one another, and perhaps of producing a great number of uſeful diſcoveries: 'tis only by this means that we can know effectually their true principles, and enable them to receive aſſiſtance from theory."

It were to be wiſhed, that convenience had permitted theſe reflections to have had their full influence in the execution of the work. The hiſtory is publiſhed in detached and independent pieces, each containing a minute detail of the whole ſeries of operations of one art, with deſcriptions and plates of all the inſtruments made uſe of: it is deſigned not only to ſupply the philoſopher with the knowledge otherwiſe obtainable only among workmen, and to entertain the mind with the hiſtory of human inventions, but likewiſe to enable perſons to exerciſe the reſpective trades in places where workmen are wanting.

It is obvious that this plan does not at all interfere with mine, and that the views of the two undertakings are eſſentially different. It is not my deſign to dwell upon deſcriptions of common and merely manual practices, to give particular

particular inſtructions for the ſetting up and conducting of common manufactures, or hiſtories of eſtabliſhments which muſt vary with times and circumſtances. The articles which make the main objects of my enquiries are founded on the invariable properties of matter; and beſides the conſideration of arts in their preſent ſtate, experiments for improving them, or reſearches in that branch of knowledge from which their more valuable improvements muſt ariſe, make a principal part of the work.

With the advantages that reſult from the abovementioned alteration in the plan, the execution becomes far more difficult. What is fact or otherwiſe in regard to the properties of bodies, or the effects reſulting from different operations on them, is to be determined by experiment. In the miſcellaneous method, we have no occaſion to enter upon any points where the determination of experiment has not been clearly obtained. But in a regular hiſtory the caſe is otherwiſe: we ſhall often be led into ſubjects with which we are not ſufficiently acquainted, and though we thought we had materials in abundance, we ſhall find ſome deficiency, greater or leſs, in almoſt every page: there are numerous particulars, which are not miſſed in the detached fragments of knowledge, but whoſe want is ſtriking when theſe fragments come to be joined and methodiſed into one whole. From this cauſe, and from the difficulty and tedioufneſs, in ſome caſes, of obtaining the neceſſary informations among different workmen, unexpected delays, if we aim at making the hiſtory tolerably complete, muſt frequently happen in the publication; nor will it be eaſy,

on

on certain occaſions, even to avoid errors: indeed in direct experimental enquiries, the effect of the operation is ſometimes ſo much influenced by circumſtances which are apt to paſs unheeded, that it is not to be wondered if errors are to be found in the writings even of the moſt accurate experimental chemiſts.

The hiſtory of each ſubject I have made as complete, as my preſent means of information, and the experiments I have hitherto made, will permit; but much remains ſtill undetermined and unexamined: if the work goes on, and the author ſhould be able to execute it to the utmoſt of his hopes, the publick is not to expect that any article will be perfect: reſearches in chemical knowledge we can never hope to make complete, every new acquiſition ſhewing new paths for our further progreſs in a province of unbounded extent. Such material deficiences as occurred upon a review of the volume, and ſome miſtakes which I had been led into either by my own inadvertence or the authority of others, are taken notice of in the appendix. It is hoped that the ſame regard for the publick, which influences the author, will prevail on thoſe who may diſcover any other miſtakes of moment, to give him an account of them, that they may be rectified in ſome future publication. It is hoped alſo, that from the communication of friends and artiſts, much of what is wanting in one publication may be ſupplied in the next.

One of the principal obſtacles to the proſecution of chemical enquiries has hitherto been the want of a proper

apparatus.

apparatus. I have therefore begun the work with an attempt to remove this impediment; to procure, at a ſmall expence, a commodious and eaſily manageable ſet of furnaces, &c. which may be all worked under a common chimney, and ſome in the middle of a room without offence, and with which moſt of the operations, that require the aſſiſtance of fire, may be performed, in the way of experiment, with great eaſe, expedition, and ſafety: if thoſe, who have been accuſtomed to the common larger and more expenſive furnaces, ſhould at firſt be at any loſs in the uſe of theſe ſmall ones, a very little practice and attention will remove all difficulties, and convince the operator of the convenience which I have long found from them in experimental purſuits, for which alone they are deſigned. The ſtructure and management of the large furnaces, kilns, &c. uſed in different buſineſſes, are intended alſo to make part of this work, and mechanical contrivances of other kinds are likewiſe occaſionally conſidered, with a view chiefly to render them more ſimple, convenient, or effectual. In the preſent volume I have given an entire eſſay on the improvement of the machines for blowing air into large furnaces, &c. by a fall of water, without moveable bellows, in virtue of the water carrying down air with it in falling through pipes; and I have the pleaſure of being informed, by a foreign correſpondent, of a machine which he has conſtructed on the principles there eſtabliſhed, which anſwers as well as can be deſired.

It would be needleſs to ſpecify in this place the ſeveral matters contained in the volume: a liſt of them may be

ſeen

ſeen in the table of contents. It is ſufficient here to have explained the principles, and the views, with which the author has engaged in the work. How far theſe principles and theſe views have a juſt foundation, or may tend to the advancement of arts and uſeful knowledge, and whether this laborious and expenſive undertaking ſhall be dropt or proſecuted, is left to the determination of the publick.

THE

THE

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V.

V.

VI.

4. *Additional*

6. *Platina*

APPENDIX.

COM-

ERRATA.

Page 89, *line* 10, 11. *for* two parts of tin and three of gold, *read* two parts of gold and three of tin.

Page 556, line 10 *from the bottom*, *for* 87 parts *read* 97 parts.

COMMERCIUM

PHILOSOPHICO-TECHNICUM.

I. *Description of a Portable Furnace for making experiments.*

PORTABLE furnaces have been generally contrived, not only with a view to the purpofes of experiment, but likewife for anfwering in fome degree the demands of bufinefs. As the fize, which procures them this laft advantage, renders them lefs fit for the firft and principal intention; I have long endeavoured to contrive a more manageable, as well as lefs expenfive furnace, for experimental enquiries; and to bring thefe kinds of inftruments as near as may be, in regard to the facility and the conveniency of their ufe, to the fame footing with the air-pump, the condenfing engine, and other like inftruments employed in philofophical refearches.

The firft hint of the apparatus here defcribed was taken from the practice of an ingenious workman in gold; who employed occafionally, as a melting furnace, two of the larger kind of black lead pots, or blue pots as they are fometimes called, one inverted over the other. Four or five fmall iron bars, paffed acrofs the under-

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moſt pot, in its lower part, through oppoſite holes made for that purpoſe, ſerved for a grate: the fuel, and the crucible containing the metal, were put in at the mouth of the pot: a hole in the ſide, made under the grate, admitted air to the fuel: and the upper inverted pot, having a hole cut in its top, ſupplied the place both of a dome and chimney. By this means he could melt, with eaſe and expedition, ſeveral ounces of gold at a time; and conveniently examine the metal, during the fuſion, by raiſing or lifting off the upper pot.

A judicious variation of this ſimple contrivance promiſed to afford furnaces of more extenſive utility. Black lead pots appeared peculiarly well fitted for this uſe; common experience having ſhewn, that they bear vehement fires without melting, repeated or continued fires without being ſo liable to fail as any of the other kinds of crucibles, and quick viciſſitudes of heat and cold without being ſo liable to crack: on theſe properties their excellence as crucibles depends. They have another quality, ineſſential to them as crucibles, but which particularly adapts them to the making of furnaces: they admit freely of being ground, drilled, ſawed with a common toothed ſaw, and cut with any kind of edged or pointed tool; ſo that the neceſſary doors, groovings, *&c.* may be readily made in them with common inſtruments, and ſtoppers for the doors formed out of broken pieces.

Having ſeen two of theſe crucibles form a convenient melting furnace where only a moderate fire was required: it was plain that a ſtronger fire might be excited in them by the means uſed for that purpoſe in other furnaces, *viz.* a bellows or a chimney; that one crucible would ſerve as a furnace for thoſe uſes in which no dome is wanted; and that if the upper crucible was fitted up in the ſame manner as the lower, it would in ſuch caſe be a diſtinct furnace of itſelf. It remained therefore to deter-

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mine the moſt proper conſtruction of the two crucibles, for adapting them to different purpoſes, ſeparately or combined.

The black lead crucibles of that ſize, which has the number 60 marked on the bottom, I have found to be the beſt ſuited for the general uſes of furnaces: their perpendicular height, in the inſide, is about twelve inches; their width at the mouth ſomewhat leſs than eight inches, and about the middle of their height ſix and a half. Theſe veſſels I have fitted up in different methods, and found the following conſtruction to be in general the moſt commodious.

Each crucible has its mouth ground ſmooth and flat, upon a ſtone, with a little ſand; and a round hole ſawed in its bottom with the common compaſs ſaw of the carpenters. In the ſide, a little above the bottom, another round hole is made; and oppoſite to this, a ſquare one; above which is cut a larger ſquare one. The places of theſe apertures, and their comparative ſizes, are repreſented in the annexed plates; in which all the figures are drawn to one ſcale, to prevent the neceſſity of embaraſſing the deſcription with an account of the particular dimenſions of the ſeveral parts.

All the apertures are fitted with ſtoppers, cut out of pieces of broken crucibles, which are eaſily procurable at thoſe places where the pots themſelves are ſold. The ſquare apertures are made, at each of their ſides, a little narrower internally than externally, by which means the ſtoppers, though their ſurface lies equal with that of the outſide of the pot, are prevented from being puſhed inwards: this ſlope is made on the ſides, and not on the top or bottom, that the ſtoppers may not be liable to fall out when the pot ſtands on either end. The round ones are in little danger of falling out, being made to fit cloſe, by grinding them into the apertures. The ſtoppers are conveniently taken out and put in by means of a kind of fork, each ſtopper being furniſhed with two ſmall holes for introducing the points: theſe holes are made at the ſame diſtance from one another, in all the ſtoppers of both the crucibles, ſo that the ſame inſtrument ſerves for them all: a ſpringineſs in its legs accommodates it to ſmall inequalities. The bottom ſtopper is better managed by the hand or tongs; a circular cavity being cut in it, ſo as to leave a knob for that purpoſe in the middle.

The grate conſiſts of an iron ring, with croſs bars fixed in it: the thickneſs or depth of the bars is conſiderably greater than their width, that they may have ſufficient ſtrength, and that the ſpaces between them may be as great as poſſible: the ring is formed of a bar, of the ſame dimenſions, turned round. Three of theſe grates, of different widths, are required for different uſes: one, of ſuch a ſize, that it may reſt againſt the converging ſides of the pot, in the lower narrow part, juſt above the lowermoſt ſquare hole; another, ſo large that it may enter no further than nearly to the top of the uppermoſt hole; and the third, of the ſame width with the outſide of the mouth of the crucible. One grate of the ſmaller ſize is neceſſary for each of the furnaces; but one of each of the other two ſizes is ſufficient for both furnaces; thoſe operations which require either of theſe grates, requiring at the ſame time both the pots. For more effectually keeping the lower and middle grates in their places, either grooves are cut for their edges to reſt upon, all round the pot; or three notches are made, for each, at equal diſtances, in the pot, and correſponding knobs or pins on the circumference of the grate; which pins are rivetted into the ring. This laſt method is the moſt

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eligible, as it admits of moſt interſtices for the air to paſs through, and the aſhes to fall down; for here, as great a ſpace may be left between the rim of the grate and the ſides of the pot, as between the bars; and this vacuity round the ſides is the more uſeful, as the aſhes are there moſt liable to be accumulated, and the fire to be languid. In whatever manner the grate is ſupported, care muſt be taken that it have ſufficient freedom, and that neither the grate itſelf, nor its knobs, bear hard againſt the ſides; leſt the expanſion of the metal, when heated, ſhould not only make the grate difficult to be got out, but likewiſe damage the furnace.

To render the furnaces ſufficiently durable, they are bound round, in three or four different parts, with copper wire, ſo as not to interfere with the doors or holes. The wire is about the ſize of a crow quill, or ſomewhat larger, and is ſoftened and made pliable by nealing or heating it on live coals: it is prevented from ſlipping by a ſlight groove made for it round the furnace; and its ends are drawn together, and twiſted tight, with pincers. The mouth is moſt effectually ſecured by a thin copper hoop, which prevents the edges from being broken or worn off: the flexibility of the thin copper admits of its accommodating itſelf to the figure of the furnace; and what ſmall ſpace remains between the furnace and its upper edge, is filled with a little moiſt loam, or with clay mixed with ſome powdered pots. The crucibles thus armed, continue ſerviceable, after they have been ſo much cracked that they would otherwiſe fall in pieces.

Theſe furnaces are conveniently lifted or carried by means of a moveable handle, made of an iron rod, or a piece of ſtrong iron wire, about three feet long, bent, like the bale of a pail, to the width of the furnace, with the two ends turned inwards, ſo as to enter into two ſmall oppoſite holes made in the furnace, through the copper hoop: the ſpringineſs of the iron rod admits of the extremities being eaſily drawn aſunder ſufficiently for the introducing or withdrawing of the hooks.

Besides the black lead crucibles which make the body of the furnace, there are required, a foot for them to ſtand upon, a chimney, and an iron hoop.

The beſt ſort of foot is a flat, heavy, iron ring, with three legs five or ſix inches high: in one of the legs of this trevet is a ſcrew, by which it may be occaſionally raiſed or lowered, ſo that the furnace is made to ſtand level though the floor be uneven. A foot may be formed alſo of the lower part of another black lead crucible inverted; by making a ſuitable aperture in the bottom, and ſawing three arches, at equal diſtances, in the ſides, ſo as to leave between them legs of ſufficient ſtrength. One of the furnaces, inverted, makes likewiſe a convenient foot for the other. Where either of theſe feet is uſed, the aſhes, that fall down, are received in an iron pan, ſuch as a frying pan with the handle cut off, placed underneath. If the furnace is ſet on a ſtone, an iron plate, or any other ſolid ſupport, the aſhes, accumulated in long operations, are raked out at the lower aperture in the ſide, by means of a piece of narrow iron plate conveniently bent at one end.

The chimney is compoſed of three pipes of forged iron plate, which ſhould not be thinner than one eighth of an inch, that they may not ſoon be bent or deſtroyed by the fire. Each pipe is a foot and a half or two feet long. The undermoſt, that it may ſtand ſteady, has a broad heavy ring round it, about an inch above the lower end, which lower part enters into the hole in the top of the inverted pot: the upper end of the pipe is received into the lower end of the next, and the end of this is in like manner received by the third; ſo that the chimney is nearly of the ſame width, or only inſenſibly converging from the bottom to the top. It is convenient to have the upper end made ſquare, that it may fit into the larger door of the furnace, and thus ſerve occaſionally as a lateral chimney.

The hoop is formed of a forged iron plate, not leſs than one ſixth of an inch thick, turned round, and welded together at the ends. It is about ſix inches deep; and of the ſame width externally with the top of the furnaces, but its thickneſs being leſs than that of the furnaces, it is internally wider. One end of this hollow cylinder has an iron ring paſſing round it withinſide: this is the end on which it moſt commonly ſtands, upon the mouth of one of the pots; and the ring contributes to make it ſtand ſteady, as well as to ſtrengthen it. Near to this end is a ſemicircular aperture whoſe door is rivetted on a large iron plate, which opens downwards on hinges, and drops no lower than to an horizontal ſituation. There is no occaſion for the hoop being luted; for if made of good hammered iron, of the thickneſs above directed, it will be ſufficiently durable, without any defence, in the greateſt degrees of heat which it is intended to ſupport.

One of the black lead crucibles, prepared as above deſcribed, with the lower ſmall grate introduced into it, is a furnace for open fire: the lower ſquare aperture, immediately under the grate, is the door of the aſh-pit; and the upper one, above the grate, is a door to the fire-place: which laſt, in the intentions this furnace is deſigned for, is kept ſhut. The fuel, which muſt in all

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cafes be charcoal, and of which the confumption is in thefe kinds of furnaces inconfiderable, is put in at the top, and is fupplied with air through all or any of the apertures beneath the grate: by more or lefs clofing or opening thefe apertures, the fire is diminifhed or increafed.

This open furnace, befides its ufe for keeping fuel ready lighted to be employed in others, affords the conveniency of nealing metals when grown hard or rigid by hammering or rolling; of fetting any fmall veffel occafionally upon the coals, as a crucible or iron ladle for the melting of the more fufible metals, and ferves for many other like purpofes that occur in practice.

By introducing into the open furnace an iron pot, empty or containing fand; it becomes a furnace for a capella vacua as it is called, or a fand furnace; in which the only variation from the preceding is, that the mouth of the furnace being occupied by the iron pot, the fuel is put in through the fire-place door or the aperture above the grate.

An iron ladle, with its handle cut fhort, ferves extremely well for the capella or fand pot. It is fupported over the fire by means of a flat iron ring, into which the ladle is inferted fo as to bear againft the ring by its upper wide part. It is neceffary to have feveral of thefe rings, of different internal diameters for receiving ladles and other veffels of different fizes, but all of them wide enough externally to reft upon the top of the furnace. Between the furnace and the ring are inferted, at equal diftances, three iron fupporters, about a quarter of an inch thick, an inch long, and equal in breadth to the thicknefs of the fides of the furnace. Through the fpace thus procured beneath the ring, the burnt air paffes off; and being permitted to iffue freely on all fides, the heat is diftributed,

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and the veſſel heated all round : whereas, in thoſe furnaces, where the air paſſes off by an elbow or chimney at one ſide, the action of the fire is chiefly upon one ſide of the veſſel, and conſequently, beſides an inequality of the heat, a greater quantity of fuel becomes neceſſary for producing in the veſſel the ſame degree of heat. The admiſſion of the air by the bottom hole, perpendicularly under the grate, has likewiſe ſome advantage in this reſpect above the lateral admiſſion of it by the door.

Instead of the foregoing kinds of veſſels, narrower than the furnace ſo as to be received into it, a much broader one may be placed upon the top, with the three iron ſupporters under it to procure a ſpace for the paſſage of the air. The flat iron pan, which on other occaſions is ſet underneath the furnace for receiving the aſhes, may be uſed in this manner as a veſſel for calcinations, for the evaporation of ſolutions of lixivial ſalts, &c.

For veſſels of a deeper kind, as a copper ſtill, the capacity of the furnace is increaſed by placing over it the iron hoop; by which it is enabled to receive the body of a ſtill, of a ſize ſufficient for the purpoſes of an experimental elaboratory. In other reſpects, there is no variation from the preceding form : the fuel is put in through the door above the grate; and the ſtill or other veſſel hangs, like the capella or ſand-pot, in an iron ring, which reſts upon the three iron ſupporters placed upon the hoop.

With regard to the diſtilling veſſels, their ſtructure differs from that of the large ones in common uſe. The body of the ſtill is a wide copper pan; and, for diſtillation in a water bath, another veſſel of the ſame figure is received into it almoſt to the top, as repreſented in the firſt plate, the ſpace between them being nearly filled with water. Both theſe veſſels are of the ſame width at the mouth, ſo that the ſame breaſt fits them both, and either may be uſed as a ſtill equally with the other: either of them ſerves alſo, on other occaſions, as an evaporating pan, a boiler, for experiments in dying, and other like purpoſes. All the parts are made of thin copper plate, and well tinned on the inſide with pure tin: in conſequence of their thinneſs, they admit of ſome alteration of their figure about the edges, ſo that, though they ſhould not be perfectly round, they are readily accommodated to one another, and fit cloſe: the juncture is eaſily made perfectly tight by applying round it narrow ſlips of moiſtened bladder; which are more convenient than luting, as being readily ſtript off when the operation is finiſhed. A ſhort pewter pipe, with a pewter ſtopper fitted to it, for returning the diſtilled liquor, or pouring freſh liquor occaſionally into the ſtill, without the trouble of unluting and ſeparating the veſſels, is ſoldered into the top of the head; which, in theſe kinds of inſtruments, is the moſt convenient place for it. For ſeparating, by diſtillation, ſpirituous from watery liquors, or the rectification of ſpirit of wine, the head is raiſed, by inſerting, between it and the breaſt, a thin copper pipe about two feet long. A worm and refrigeratory are neceſſary, as for the common ſtill: and a glaſs head is requiſite for ſome uſes, particularly for the diſtillation of vinegar, and ſuch other liquors, as would corrode a copper one, and impregnate themſelves with the metal; in which caſe, the uſe of the metalline worm alſo is to be avoided, and the glaſs or ſtone-ware receiver joined to the pipe of the head.

The above apparatus is as commodious, as can be wiſhed, for diſtillation in the way of experiment. Contrivances for expediting and accelerating the proceſs do not belong to the preſent deſign: but as this is an affair

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of great importance in ſundry caſes, particularly for procuring freſh water eaſily at ſea, I was engaged by the late Dr. Hales, whoſe extenſive philanthropy will ever render him dear to mankind, and who had this ſalutary object greatly at heart, to undertake a ſet of experiments directly with this view; the reſult of which ſhall be communicated in a ſeparate article of ſome of our future publications.

A Wind-furnace, for the fuſion of metals, the aſſaying of ores, and other like uſes, is formed by inverting one pot over the other; and placing on the top either the entire chimney, or two or one of its pipes, according as the fire is wanted to be more or leſs ſtrong. The ſecond grate, in the middle of the undermoſt pot, is generally, in theſe intentions, more proper than the lower ſmall one made uſe of in the former caſes, on account of its having more interſtices for admitting air to the fuel. The crucible, containing the ſubject-matters, is placed upon a circular ſlip of brick, or of a broken pot, a little wider than its bottom, laid upon the middle of the grate, to prevent the cold air from ſtriking on it. The charcoal is put in through the fire-place door, or larger aperture, of the dome or upper pot, which ſhould always be cloſed after each ſupply of fuel. The furnace ſtands on its trevet or open foot; with the flat iron pan underneath, not only for receiving the aſhes, but that, if the crucible ſhould happen to fail during the fuſion, its fluid contents may be preſerved. The two oppoſite holes in the upper part of the dome afford the conveniency of paſſing an iron rod through, for ſafely and commodiouſly lifting it when intenſely heated.

The round hole in the ſides of theſe furnaces gives an opportunity of introducing the noſe of a pair of double bellows; ſo that one pot ſingly, or two combined together as in the foregoing article, may be readily converted into a blaſt furnace; in which caſe all the other apertures beneath the grate muſt be cloſed while the bellows acts, to prevent the air forced in by it from eſcaping. It is of great advantage, in ſundry operations, to be thus able, at certain periods, to ſuddenly animate the fire.

One pot inverted over the other, with the iron hoop placed between them, make a furnace for cupellation, calcination under a muffle, and the other purpoſes of what is called the aſſay furnace; as alſo for experiments of enamelling, of baking colours on earthen ware and glaſs, &c. The chimney, or a part of it, is occaſionally ſet upon the top for raiſing the fire when it proves too languid.

In want of the muffle made for operations in the aſſay furnace, its office may be ſupplied by a common crucible laid upon its ſide, with a bed of loam in it to form a flat ſurface for the cupels or other veſſels to ſtand on. The largeſt of the three grates is ſet upon the lower pot, which it wholly covers; and the iron hoop, which of courſe bears upon the rim of the grate, is placed with its door lowermoſt. The muffle, or its ſubſtitute, is laid upon a ſlip of brick on the grate, with its mouth fronting the opening in the hoop, through which the cupels, &c. are introduced. In proceſſes which require frequent inſpection of the ſubject-matters, and the admiſſion of heated air; the plate, on which the door of this aperture is rivetted, is let down to an horizontal ſituation, and ſome pieces of lighted charcoal, with ſufficient interſtices between them for the cavity of the muffle to be ſeen, are laid upon the plate,

plate, which, for this purpofe, is made about two inches wider than the door, and as long as the height of the hoop will admit it to be. The fuel is put in, as before, through the fire-place door of the dome. As the part of the furnace above the grate widens downwards, the coals generally of themfelves fall properly round the muffle: if this fhould not happen, they are eafily pufhed down by means of a crooked iron wire introduced through the door. The dome is lifted off, as in the wind-furnace, by an iron rod paffed through its oppofite apertures.

The foregoing combination, of the two pots and the iron hoop, with or without the chimney or a part of it according as a greater or lefs degree of heat is required, ferves alfo as a reverberatory, for diftillation in coated glafs retorts, earthen retorts, or longnecks; with only this variation in their difpofition, that inftead of the large grate, the middle one is introduced into the undermoft pot, and in its upper part two iron bars are laid acrofs: the bottom of the diftilling veffel refts upon thefe bars, and its neck comes out at the door of the hoop, which is accommodated to veffels of greater or lefs height by placing it with the door uppermoft or lowermoft. Both the reverberatory and the affay furnace are, in effect, no other than the wind-furnace; with a muffle or a retort fet in the fire inftead of a crucible.

These furnaces may be ufed likewife as a common ftove, for keeping a room warm with a little quantity of fuel. There are three general intentions which have been purfued in contrivances for this purpofe; (1) making the fuel take fire by degrees, and confume flowly; (2) conducting its heat, or the air warmed by it, through a number of paffages or circumvolutions, that the heat, inftead inſtead of being carried up the chimney, and thus loſt, may be detained in theſe paſſages, and thence communicated to the air of the room to which they lie expoſed; and (3) applying to the fire a quantity of ſolid matter, which, being once heated, preſerves its heat long. Some ingenious furnaces, on theſe principles, are deſcribed in the Tranſactions of the Swediſh Academy, and in the ſecond edition of Reaumur's Art of hatching Birds. All theſe contrivances are united in the following combination of the two pots and the hoop.

The undermoſt pot has the ſmall grate introduced into its lower part, the fire-place door cloſed, and the aſh-pit door or the bottom hole open for admitting air. Being then charged with ſmall pieces of charcoal, and ſome lighted coals thrown above them, its top is covered by the largeſt of the grates, and on this is placed the hoop and dome, filled with balls of baked earth, or with pieces of bricks, ſo diſpoſed as to leave ſmall vacuities between them. If the ſtove is placed in the middle of a room, its injurious burnt air may be carried off, by a pipe inſerted laterally into the larger door of the dome, and communicating at the other end, which ſhould be raiſed eight or ten inches, with the chimney of the room; all the other apertures of the dome being cloſed.

The furnace, thus charged, will keep up a moderate and nearly equal warmth for many hours, without injury or offence; the charcoal burning down exceeding ſlowly; and the heated balls or bricks continuing the warmth for a conſiderable time after the fuel is conſumed. Freſh charcoal may be occaſionally ſupplied through the door above the grate: the check, which the balls give to the motion of the air through the furnace, renders the conſumption of this alſo ſlow, and it may ſtill be made more ſo, at pleaſure, by ſtopping a part of the aperture which admits the air, or of the pipe or chimney which carries it off.

It appears from the foregoing account, that two black lead crucibles, fitted up in a manner which any common workman can eaſily execute, with a few additional parts as eaſily procurable, are ſufficient for forming almoſt any kind of furnace which experimental enquiries have occaſion for; and that they not only unite, like the different parts of other portable furnaces, into one furnace, but likewiſe, for ſundry uſes, form two diſtinct ones. It will be extremely convenient to have a third crucible prepared in the ſame manner: in which caſe, as no operation requires more than two; whatever kind of furnace is required for one operation, there will always be at leaſt one left at liberty for another; ſo that two very different kinds of experiments may thus be going on at the ſame time, without hindrance, and without interfering one with another.

For enquiries of any conſiderable extent or multiplicity, it is neceſſary to be provided with ſeveral of theſe crucibles; and though, for general uſe, we have given the preference to thoſe marked 60 on the bottoms, yet other ſizes may be occaſionally employed, and have their advantages for particular purpoſes: much ſmaller ones, down as far as number 20, will make, for ſome uſes, very convenient furnaces. Thoſe of number 60 may be conſidered as the mean ſize: they are as large as are wanted, in experimental practice, for a capella or bath; and they are the ſmalleſt, and moſt manageable, that will anſwer effectually as a wind furnace or blaſt furnace for ſtrong fire. The largeſt black lead crucibles are marked 100: their internal height is about thirteen inches and a half, and their internal width at the mouth ten inches and a half. The next

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ſizes are marked 90, 80, &c. without any intermediate numbers between the tens. All theſe are half an inch or more narrower one than the other, though not with any exact regularity in the diminution of the ſizes, or in the dimenſions of the pots of one number. Thoſe of 90 or 100, with a hoop and rings adapted to them, will receive ſand-pots, ſtills, &c. large enough for the purpoſes of the apothecary: but furnaces for experimental purſuits being the preſent object, it is ſufficient here to have given a hint of this application of them.

It is expedient likewiſe, in a well-appointed elaboratory, to have ſome furnaces of a different conſtruction as well as of different magnitudes, ſet apart for particular uſes, eſpecially for thoſe which demand great vehemence or continuance of fire.

In all caſes where vehement fire is to be continued for any conſiderable length of time, the furnace may be ſtrengthened by inſerting one of the crucibles into another of a larger ſize. Some of the thick bottom part of the inner crucible is to be ſawed off, and the remainder rounded with a raſp, that its ſurface may in ſome meaſure correſpond to the cavity of the outer one; and the mouth of this laſt is to be widened, if it does not ſufficiently admit the wide part of the other, by raſping off a little from its inſide all round the converging edge. Any crucible may thus be made to fit conveniently into the ſecond ſize above it; that of number 60 into 80, 70 into 90, and 80 into 100. Such vacuity, as may remain between the two, is to be filled with dry ſand dropt in at the ſides; or rather with ſlaked lime, or fine ſifted wood-aſhes, diluted with ſo much water as will render them of a due conſiſtence for being poured in. This mixture ſoon ſets, without ſhrinking conſiderably, and without growing hard

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in the fire: thus it uniformly fills the interſtices, and joins the pots ſufficiently together, yet not ſo firmly but that upon occaſion they may be eaſily ſeparated again.

The fuel, for producing or continuing vehement fire, ſhould be the moſt ponderous and compact kind of charcoal, as that of the oak or beech, free from bark, and in pieces about the ſize of hens eggs. It ſhould be kept ready lighted, for continual ſupplies, in another veſſel, ſuch as the open furnace formerly deſcribed; and freſh quantities of the burning charcoal thrown in every ſeven or eight minutes, or in proportion to the quickneſs of the conſumption, that the crucible may always continue covered. Where a dome is uſed, a ſupply of lighted fuel is commodiouſly obtained by means of an iron plate, turned up at the ſides into a kind of ſquare trough, and hooked on the fire-place door: the trough being filled with charcoal, the inner part of the coals is kindled by the vicinity of the fire, and this is moved into the furnace by ſucceſſively puſhing forward the unlighted part. Some have imagined that the ſupplying of fuel previouſly made red hot could affect only thoſe kinds of operations, in which the veſſel is ſet over the fire, and the freſh fuel interpoſed between the fire and its bottom; and that this practice could be of no advantage in the melting furnace, where the crucible is placed in the middle of the fire. But though, in this laſt circumſtance, the previous kindling of the fuel has much leſs influence than in the other, it is by no means to be diſregarded: the upper part of the crucible may ſometimes be nearly bare, and ſome of the pieces thrown in may drop down through vacuities about the ſides; in which caſes it is obvious, that the injection of cold or unlighted coals, muſt neceſſarily, for a time, diminiſh the heat about the veſſel, and likewiſe endanger its cracking.

If a pot is to be fitted up on purpoſe for a blaſt furnace, no other aperture is required than a round one in the ſide for the noſe of the bellows to enter, the fuel being here thrown in at the top: all other apertures needleſsly weaken the furnace. The pot ſhould be of the largeſt ſize: if a cover or dome, or an additional part for enlarging its capacity, is wanted, another pot of the ſame ſize, with a portion of its lower narrow part ſawed off, makes a very convenient one; and this narrow part, as we ſhall ſee hereafter, will be of uſe for another purpoſe. A round plate or ſlip, ſawed from the ſolid part of the bottom, ſerves very commodiouſly both for a grate, and for a ſupport to the crucible: eight or nine holes, about three quarters of an inch in diameter, are bored round the outer part of the plate, for the tranſmiſſion of the air forced in by the bellows; and four or five ſmall crucibles may be placed together in the middle: the holes are made to widen downwards, to prevent their being choaked up by pieces of the fuel.

The bellows I have chiefly employed is the organ bellows; with this variation in its ſtructure, that the upper board, inſtead of riſing obliquely on hinges at one ſide, riſes equally on all ſides, and continues always horizontal. On account of the flexibility or pliableneſs of the leather of this kind of bellows, it is not only moved far eaſier than the common ones, whoſe leathers are ſtiff, but is likewiſe free from their inconvenience of reſiſting unequally according to the greater or leſs extenſion of the folds. The board is preſſed down, and the air forced out, by a weight on the top: in the common bellows this weight, preſſing on an inclined plane, whoſe inclination is continually changing, has its force changing in

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like manner, and thus produces an irregular blaſt, and an unſteady heat: in ours, the weight, acting always perpendicularly, has always an equal power, and the air is propelled in one unvaried current. The ſame advantage may be procured alſo to bellows of the common conſtruction, by an alteration only in the diſpoſition of the weight; which, inſtead of being placed on the top, ſhould be hung at the extremity, upon an arc, furniſhed with a groove for receiving the cord, and whoſe center is the point on which the board moves: the weight being thus made to act always in a perpendicular direction, and at an equal diſtance from the center of motion, an equality of its power is effectually ſecured. By theſe means, the heat is kept up uniform; and may be eaſily increaſed at pleaſure, by increaſing the weights, to the greateſt degree that can be excited in furnaces; in which intention it will be of advantage to have the nozzle of the bellows wider than uſual, that the air may be the more freely diſcharged from it. The bellows is of no incumbrance in the elaboratory, being incloſed in a wooden caſe, whoſe cover does the office of a common table: to the nozzle, which juſt comes through the croſs bar at the bottom of the table, is occaſionally fitted a pipe reaching to the furnace.

The bellows thus diſpoſed ſerves likewiſe for impelling and concentrating the flame of a lamp upon bodies expoſed to it. For this purpoſe, an upright tin pipe is fitted on the nozzle by a ſhort elbow at its lower end; and at its upper end is a moveable elbow, into which is inſerted a leſſer pipe, having a very ſmall aperture in its extremity: this aperture being applied to the flame of a lamp placed upon the table, and the pipe blown through; the flame lengthens in the direction of the blaſt, and converges into a ſmall ſpace, producing there a very intenſe heat. This application of a lamp is common among ſundry artiſts, for melting or ſoftening glaſs or metalline bodies in any particular part, without affecting the reſt of the maſs; as in ſoldering metals, making balls for thermometers, &c. It is likewiſe very commodious for the expeditious performance of many kinds of experiments, where only a ſmall quantity of matter is to be acted upon by the heat: a little gold or ſilver, laid in a cavity made in a ſolid piece of charcoal, and expoſed to the concentrated flame, melts almoſt inſtantaneouſly; and a little lead, placed in a cupel, may thus be quickly worked off or turned to ſcoria, ſo as to diſcover whether it contains any conſiderable proportion of the noble metals.

A bellows of the above conſtruction is worked with very little labour. It is made ſtill lighter and more commodious, by uſing a ſtiff rod, for moving the lower board, inſtead of the flexible cord or chain commonly employed. By the rod, its motion is made to follow that of the hand: whereas, with the cord or chain, it cannot ſink faſt enough without a conſiderable additional weight, and, in raiſing it again, the hand has this weight to overcome at the ſame time with the weight on the upper board by which the air is forced out.

The trouble of uſing bellows has by ſome been propoſed to be diſpenſed with, by ſubſtituting the æolipile. This inſtrument is a ſtrong copper veſſel, with a neck turned to one ſide, and terminating in a very ſmall aperture. The veſſel being about half filled with water, and ſet on ſome burning charcoal, in any convenient little furnace, ſuch as one of our pots, with its neck directed to, and placed at a ſmall diſtance from, the fire to be excited; as ſoon as the water begins to boil, an elaſtic vapour iſſues with vehemence through the ſmall orifice, and the fire is animated in the ſame manner as by air impelled by bellows; whence this inſtrument has been called the æolian bellows and philoſophers bellows. From this effect of the æolipile on an open fire, it has been imagined that it would perform the ſame office when its neck was inſerted, like the noſe of a common bellows, into the cavity beneath the grate of a furnace, and accordingly ſome practical writers have given figures of it as employed in this uſe. But on trial, I have conſtantly found it, when thus applied, inſtead of exciting, to extinguiſh the fire; and the event was the ſame, in all other caſes, where the vapour did not paſs through a portion of the atmoſphere before its admiſſion to the burning fuel. From this obſervation it may be preſumed, that it is not the included matter, or any particular element in it, that animates fire, but the common air of the atmoſphere which the watery vapour imbibes or propels before it. This mention is here made of the æolipile, to prevent others from being put to the expence and diſappointment of ſuch an apparatus as gave riſe to theſe obſervations.

A CLOSE-bottomed pot, ſuch as that uſed for the foregoing blaſt furnace, but without a grate, makes a furnace for the fuſion of metals, the revival of metallic calces, and the ſmelting or aſſaying of ores, *trans carbones* as it is called, or in contact with the burning fuel, as practiſed in the large works. The furnace being intenſely heated, and almoſt filled with fuel, ſome of the ſubject-matter is ſprinkled upon the coals, chiefly about the middle, and towards the ſide oppoſite to the bellows, but with care that it no where touch the ſide: more charcoal is thrown over it; the fire, according to the nature of the ſubject, is either kept up ſtrong, or abated a little, by leſſening the

the weight upon the bellows; and the alternate injection of the ſubject-matter and of charcoal continued. The metal and ſlag, melting and dropping down through the coals, are collected in the bottom: when they are of ſuch a kind as to melt with difficulty, it is neceſſary, in order to their being continued in thin fuſion, to direct the pipe of the bellows downwards, toward the oppoſite ſide of the bottom: the aperture is made to admit of the bellows being readily thus directed, without widening it in the middle, by ſloping off a little, from its upper edge on the outſide, and from the lower edge within.

When iron is thus to be melted (an intention for which this furnace is extremely well adapted) or copper to be purified, among the coals, the black lead pot performs the office both of a crucible and of a furnace. In this caſe it is neceſſary to have its bottom ſurrounded on the outſide with burning fuel: the ſiftings and ſmall fragments of charcoal, unfit for other uſes, anſwer ſufficiently for this purpoſe, for they are ſoon ſet on fire by the heat of the pot, and ſerve, as well as the larger pieces, to maintain and augment its heat: they may be placed in a cavity made in the ground, or in the bottom of another veſſel. When the proceſs is finiſhed, the melted metal may be poured out, by inclining the pot, through the hole where the pipe of the bellows entered.

But when litharge is to be revived, or the ores of lead or of the other more fuſible and deſtructible kinds of metals to be ſmelted, the metal, in proportion as it is collected in the bottom, muſt be ſuffered to run off from the vehement heat and blaſt of air; for which purpoſe a paſſage is to be made for it in the moſt depending part, and a baſon filled with coals placed conveniently on the outſide for receiving it. The lower part of a black lead pot, ſawed off at a proper height, as three or four inches above the

the bottom of its internal cavity, makes a commodious bafon for this ufe; and is eafily made to join to the floping canal in the furnace, by rafping off a little at one fide, and forming a channel in the lip correfponding to the hole in the furnace: the juncture is fecured by the interpofition of a little foftened loam or clay.

The more fulphureous ores are commonly freed, by roafting, from great part of their fulphur, before they are fubmitted to this operation: for, by this procefs alone, the fulphur would not be completely feparated; and the metal, after the fufion, would prove impure and brittle, or be retained in great part among the flag. With our apparatus, the roafting is more particularly neceffary, for the fake of the furnace as well as of the ore: for black lead crucibles, though they long fuftain the action of vehement fire and of metals made fluid by it, are foon preyed upon and deftroyed by fulphureous bodies in fufion.

The pot, employed as a furnace for thefe ufes, fhould, like the preceding blaft furnace, be of the largeft fize: and its height may be increafed, by inverting over it a ring fawed from the upper part of another pot of the fame fize. By this addition to its height, the fuel thrown on the top will be kindled, and the fubject heated, before they fink down into the body of the furnace; and the convergency of the upper part of the ring prevents the heat from fpreading and annoying the operator, as it does from furnaces of a diverging mouth.

As the blaft furnace, defigned for intenfe fire, is made ftronger than the pots of the general conftruction, by having no other aperture than that which receives the bellows pipe; it is in like manner expedient, for fome particular ufes, to have a ftronger wind-furnace, with only

only ſuch holes as are eſſentially neceſſary, that it may be better able to ſupport a long continuance of vehement fire.

The furnace for this intention conſiſts of two large pots: the lowermoſt of which has only a round hole in the bottom for admitting air; and the upper one, or dome, a ſimilar hole correſponding to the chimney, with a door in the ſide through which the fuel is put in. The furnace is placed upon an inverted pot, which has a hole in its top anſwering to that in the bottom of the furnace, another large one in its ſide, and its mouth ground ſmooth that it may apply itſelf every where cloſe upon the flat ſtone or iron plate which ſerves as a ſtand for it. Into the ſide aperture of this lower pot, which is both the foot and aſh-pit of the furnace, an iron pipe is inſerted, ſomewhat wider than the wideſt part of the chimney, and two or three feet long, on the end of which may be fitted a wooden one of more conſiderable length. The whole of this pipe may be laid horizontal, ſo as to reach into an adjoining apartment; or rather, if there is a conveniency, the wooden pipe may be ſunk perpendicularly through the floor into a room underneath, and the horizontal iron one joined laterally to it at the top: its uſe is for conveying into the furnace, inſtead of the adjacent air rarefied by the heat, the colder and denſer air at a diſtance; and its effect in animating the fire will be in proportion to the coldneſs and denſeneſs of the air to which it reaches.

In the above conſtruction, I have endeavoured to give the wind furnace all the advantages it appears capable of receiving; and to ſupply, with black lead pots, the wind furnace, contrived by Mr. Pott, of the academy of ſciences at Berlin, on purpoſe for experiments that require the utmoſt vehemence of fire, as the vitrification of earthy

earthy and ſtony bodies. I nevertheleſs apprehend, that furnaces on this principle, with all the advantages that can be given to them, will not be found equal, in regard to the intenſity of the heat, to the blaſt furnace above deſcribed; and that air may be ſupplied more effectually by a well contrived wide-noſed bellows, than by any other means whatever. The preſſure of the atmoſphere, which actuates the wind furnace, is variable, and ſubject to many irregularities in its effect: but the power which animates the blaſt furnace, is entirely in the operators hands, and its effect may be increaſed or diminiſhed, with certainty and regularity, by increaſing or diminiſhing the force artificially applied. The wind furnace however has its conveniencies; as the fire may be raiſed in it to a degree ſufficient for moſt purpoſes that commonly occur, and continued without any other trouble than that of ſupplying fuel.

The ſtructure of our general furnace, already deſcribed, unites in ſome meaſure the advantages of both kinds; by affording an opportunity, when the wind furnace is at work, of occaſionally animating its fire by the blaſt. The ſame convenience may be procured alſo in the wind furnace above deſcribed for vehement fire: a hole, made in the ſide of the foot or aſh-pit, ſerves for admitting the bellows-pipe; and the air-pipe is at the ſame time ſtopt by means of a moveable regiſter in the end next the furnace. This regiſter is a circular iron plate, fixt on an axis, which is placed acroſs the pipe: the extremity of the axis projecting on the outſide, the plate is thereby readily turned, ſo as either to allow a free paſſage for the air, or to cloſe the whole bore of the pipe.

It is, in many caſes, a very deſirable point, to be able to collect the heat, diffuſed through a furnace, into one particular part, or to concentrate its force upon the ſubject. Some have thought to effect this, by making the ſides and dome of an elliptical or parabolic figure; expecting, from the mathematical properties of thoſe figures, that the rays of fire, ſtriking all over the internal ſurface, would be reflected back into a ſmall focal ſpace, in the ſame manner as the ſolar rays are concentrated by burning concaves. On the authority of thoſe, who had recommended theſe kinds of furnaces, I prepared, many years ago, an elliptical one; which was figured with great care, not only in a moiſt ſtate, but after it had been dried and burnt, by the revolution of a ſemi-elliptical plane about its axis. In the effects of this furnace, I was greatly diſappointed: for it could not be obſerved, that any focal reflexion obtained in it; or that any advantage reſulted from the exactneſs of its figuration, or from the preciſe ſpecies of its curvature. And indeed many cauſes, which it is foreign to the preſent purpoſe to enter into a diſcuſſion of, concur in preventing both the regular reflection of the rays of heat in furnaces, and the collection and union of thoſe which have been ſo reflected.

Others have attempted this concentration of fire upon a different principle. By blowing a ſtream of air through the flame of a lamp or candle, the flame, as already obſerved, is made to converge into a kind of focal point, and acts there with a great increaſe of its force: by multiplying theſe ſtreams of flame, or impelling a number of flames into one point, the heat may be augmented to a very high degree. In furnaces alſo, the flame, and the moſt conſiderable part of the heat, follow the direction of the current of air: and hence it has been propoſed to impel ſtreams of air, from different parts of the circumference of the fuel, to the middle, by means of ſeveral bellowſes placed round the furnace. Though the principle,

ple, however, appears to be a juſt one, the application of a number of bellowſes is too incommodious to be put in practice; and by their diſpoſition in one plane, round the furnace, great part of the fuel lies without their reach. I have therefore endeavoured to improve the contrivance; to multiply the ſtreams of air, to throw them in from almoſt all parts of the ſurface, to ſupply them all from one bellows, and in ſuch a manner that they may not obſtruct one another, but conſpire as it were into one ſtream about the crucible.

The pot, which ſerves as a furnace for this purpoſe, has a number of holes, bored at ſmall diſtances, in ſpiral lines, all over it, from the bottom, up to ſuch a height as the fuel is deſigned to reach to. The crucible is placed, upon a proper ſupport, in the bottom; and the holes are made, not in a perpendicular direction to it, but oblique, that the ſtreams of air forced in through them may but juſt touch it: by this means, the crucible ſtands out of danger of being cracked by the blaſt, and the impelled heat plays in a kind of ſpiral upon its ſurface. The pot, which ſerved before for the blaſt-furnace, with an iron ring on its top, receives this perforated pot ſo far, that all its holes hang in the cavity; which cavity having no other outlet than the round aperture for the bellows, the air, blown in through this aperture, neceſſarily diſtributes itſelf through the perforations of the inner pot. The inner pot may be of the largeſt ſize, as well as the outer one, the lower narrow part of the former falling into the upper wide one of the latter: it wants no addition to increaſe its height, but on the contrary will be more commodious, in regard to the inſpection and taking out of the crucible, if all the part above where the fuel reaches to is ſawed away: the moſt convenient cover for it is an iron plate,

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with a round hole in the middle, and a handle projecting at one ſide for lifting it by.

The force of the fire being thus, in great meaſure, concentrated upon the crucible in the middle of the fuel; the crucible is heated, expeditiouſly, and with a little quantity of fuel, to a very intenſe degree, while the exteriour parts of the fuel are of no great heat, and permit the operator to approach without incommoding him.

In the uſe of the furnaces hitherto deſcribed, the attendance of the operator is neceſſary, both for inſpecting the proceſſes, and for ſupplying and animating the fuel. There are ſome operations of a ſlower kind; which require a gentle heat to be continued for a length of time; which demand little attendance in regard to the operations themſelves; and in which, of conſequence, it is extremely convenient to have the attendance in regard to the fire, as much as poſſible, diſpenſed with. This end is anſwered by the furnace called the athanor; an account of which is referred to another part of this work, as it cannot well be formed out of black lead pots, and does not fall in with the ſimplicity of the preſent contrivances.

Sundry attempts have been made for keeping up a continued heat, with as little trouble as in the athanor, by the flame of a lamp; but the common lamp-furnaces have not anſwered ſo well as could be wiſhed. The lamps require frequent ſnuffing, and ſmoke much; and the ſoot, accumulated on the bottom of the veſſel placed over them, is apt, at times, to fall down and put out the flame. The largeneſs of the wick, the irregular ſupply of oil from the reſervoir by jets, and the oil being ſuffered to ſink conſiderably in the lamp, ſo that the upper part of the wick burns to a coal, appeared to be the principal cauſes caufes of thefe inconveniences; which, accordingly, were found to be in great meafure remedied by the following conftruction.

The lamp confifts of a brafs pipe, ten or twelve inches long, and about a quarter of an inch wide, inferted at one end into the refervoir of the oil, and turned up at the other to an elbow, like the bole of a tobacco-pipe, the aperture of which is extended to the width of near two inches. On this aperture is fitted a round plate, having five, fix or feven fmall holes, at equal diftances, round its outer part, into which are inferted as many pipes about an inch long: into thefe pipes are drawn threads of cotton, all together not exceeding what in the common lamps form one wick: by this divifion of the wick, the flame expofes a larger furface to the action of the air, the fuliginous matter is confumed and carried off, and the lamp burns clear and vivid.

The refervoir is a cylindric veffel, eight or ten inches wide, compofed of three parts, with a cover on the top. The middle partition communicates, by the lateral pipe, with the wicks; and has an upright open pipe foldered into its bottom, whofe top reaches as high as the level of the wicks; fo that, when this part is charged with oil, till the oil rifes up to the wicks in the other end of the lamp, any further addition of oil will run down through the upright pipe into the lower divifion of the refervoir. The upper divifion is defigned for fupplying oil to the middle one; and, for that purpofe, is furnifhed with a cock in the bottom, which is turned more or lefs, by a key on the outfide, that the oil may drop faft enough to fupply the confumption, or rather fafter, for the overplus is of no inconvenience, being carried off by the upright pipe; fo that the oil is always, by this means, kept exactly at the fame height in the lamp. For common ufes, the

the middle divifion alone may be made to fuffice; for, on account of its width, the finking of the oil will not be confiderable in feveral hours burning. In either cafe, however, it is expedient to renew the wicks every two or three days; oftener or feldomer, according as the oil is more or lefs foul; for its impure matter, gradually left in the wicks, occafions the flame to become more and more dull. For the more convenient renewing of them, there fhould be two of the perforated plates; that, when one is removed, another, with wicks fitted to it, may be ready to fupply its place.

One of the black lead pots, defcribed at the beginning of this paper, makes a proper furnace for the lamp. If one is to be fitted up on purpofe for this ufe, it requires no other aperture than one in the bottom for admitting air, and one in the fide for the introduction of the elbow of the lamp: the refervoir ftands on any convenient fupport without the furnace. The ftopper of the fide aperture confifts of two pieces, that it may be conveniently put in after the lamp is introduced; and has a round hole at its bottom fitting the pipe of the lamp. By thefe means, the furnace being fet upon a trevet or open foot, the air enters only underneath, and fpreads equally all round, without coming in ftreams, whence the flame burns fteady. It is not advifable to attempt raifing the heat higher than about the 450th degree of Fahrenheit's thermometer, a heat fomewhat more than fufficient for keeping tin in perfect fufion. Some have propofed giving a much greater degree of heat in lamp furnaces, by ufing a number of large wicks; but when the furnace is fo heated, the oil emits copious fumes, and its whole quantity takes fire. The balneum, or other veffel including the fubject-matters, is fupported over the flame by an iron ring, as already defcribed in the fand bath

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and ſtill : a bath is here particularly neceſſary, as the ſubject would otherwiſe be very unequally heated, only a ſmall part of the veſſel being expoſed to the flame.

The uſe of baths in general is for defending the glaſs or other veſſels, placed in them, from the immediate action of the fire, and for preventing their being ſuddenly affected by variations of the heat. There is one imperfection in ſand and other ſolid intermedia; that their heat is by no means uniform, but different in their different parts, decreaſing gradually from the bottom to the top; this is always the caſe, even when the fire is uniformly diſtributed round the veſſel by the contrivances formerly deſcribed. In thoſe circumſtances therefore, wherein it is expedient to ſecure with certainty an equality of the heat, recourſe muſt be had to fluid intermedia. The water bath, commonly employed in this intention, is confined to low degrees of heat; a boiling heat being the utmoſt that water is ſuſceptible of. I have therefore, on ſome occaſions, made uſe of another fluid, quickſilver; which bears a degree of heat exceeding that of boiling water, above twice as much, as the heat of boiling water does that of freezing water.

The mercurial bath is prepared with two iron pots or ladles, of ſuch ſizes, that one may be received into the other, ſo as to leave a vacuity between them all round: this ſpace is filled with quickſilver, the two veſſels being properly ſecured together by pins paſſed through the edges, to prevent the inner one from being buoyed up by the quickſilver. The vacuity may be ſo ſmall, that a little quantity of mercury ſhall ſuffice; and the expence of this article may be further leſſened, by uſing, inſtead of pure mercury, a compoſition of it with about half its weight of lead, or with ſo much as it will bear without loſing its fluidity in a moderate warmth. In this kind of bath, all the parts of the inner veſſel will be equally heated, how unequally ſoever the fire be applied underneath; and the heat may be increaſed nearly as far as that in which lead begins to melt, without any danger of the mercury evaporating. The mercurial thermometer of Fahrenheit, whoſe 32d diviſion is the point at which water freezes, and the 212th that at which water boils, is raiſed by the heat in which lead melts to about the 550th diviſion, and by the heat of quickſilver boiling and evaporating to the 600th.

Though the heat, of which mercury is ſuſceptible, is great in compariſon with that of boiling water, it is far too little for many purpoſes for which baths are wanted. Some curious workmen, for communicating theſe greater degrees of heat equally to different ſubjects, as where a number of ſmall ſteel inſtruments is to be equally tempered, employ melted lead as an intermedium. A plate of iron floats upon the melted lead, and receives therefrom, in all its parts, an equal heat: the pieces of ſteel, laid upon this plate, acquire all at once the ſame degree of heat, and are at once quenched in water; the blue or other colours, which they ſucceſſively aſſume, affording ſure marks of the proper points of heat at which they are to be quenched, according to the different degrees of hardneſs required in them.

From this practice I took the hint of another metallic bath, which ſupplies at once both the mercurial and the lead baths. As the imperfection of mercury conſiſts in its not bearing ſo great a heat, and that of lead in its not becoming fluid with ſo ſmall a one, as many purpoſes require; I have ſubſtituted one of the fuſible metallic mixtures, mentioned by Sir Iſaac Newton in the Philoſophical Tranſactions, compoſed of two parts of lead, three of tin, and five of bifmuth, melted together: one pot or ladle being fixed into another, in the fame manner as for the mercurial bath, the fpace between them is filled with the melted compound. This mixture proves fluid in a heat very little greater than that in which water boils; and confequently ferves as an intermedium for all degrees of heat above this period, up to that in which the metal itfelf grows red hot and boils; a heat greater than baths are ever wanted for in practice.

The foregoing furnaces I have ufed with pleafure for many years; and experienced their commodioufnefs, in public as well as private operations, for continued and extenfive enquiries, as well as for occafional experiments. Eight or ten pots have ftood at work together, under a common chimney; and others, upon a ftand, in the middle of the room, with a copper dome, of a conical figure, over them, which communicated with the chimney by a pipe bent at right angles: by this means the proceffes could be freely infpected, without any danger of injury or offence from burnt air or fumes, which, as foon as the chimney became fomewhat warm, were completely carried off. It is convenient to have the dome made to flide eafily up and down the perpendicular part of the pipe; which may be effected by fufpending it to two chains paffed over pullies fixed to the ceiling and loaded with a counterpoife.

We flatter ourfelves, that the publication of a fimple apparatus, eafy of conftruction, of little expence, commodious in its ufe, and eafily manageable in all its forms and combinations, will contribute to remove one of the chief obftacles to chemical refearches, and to promote thofe kinds of experimental purfuits in which furnaces are a principal inftrument.

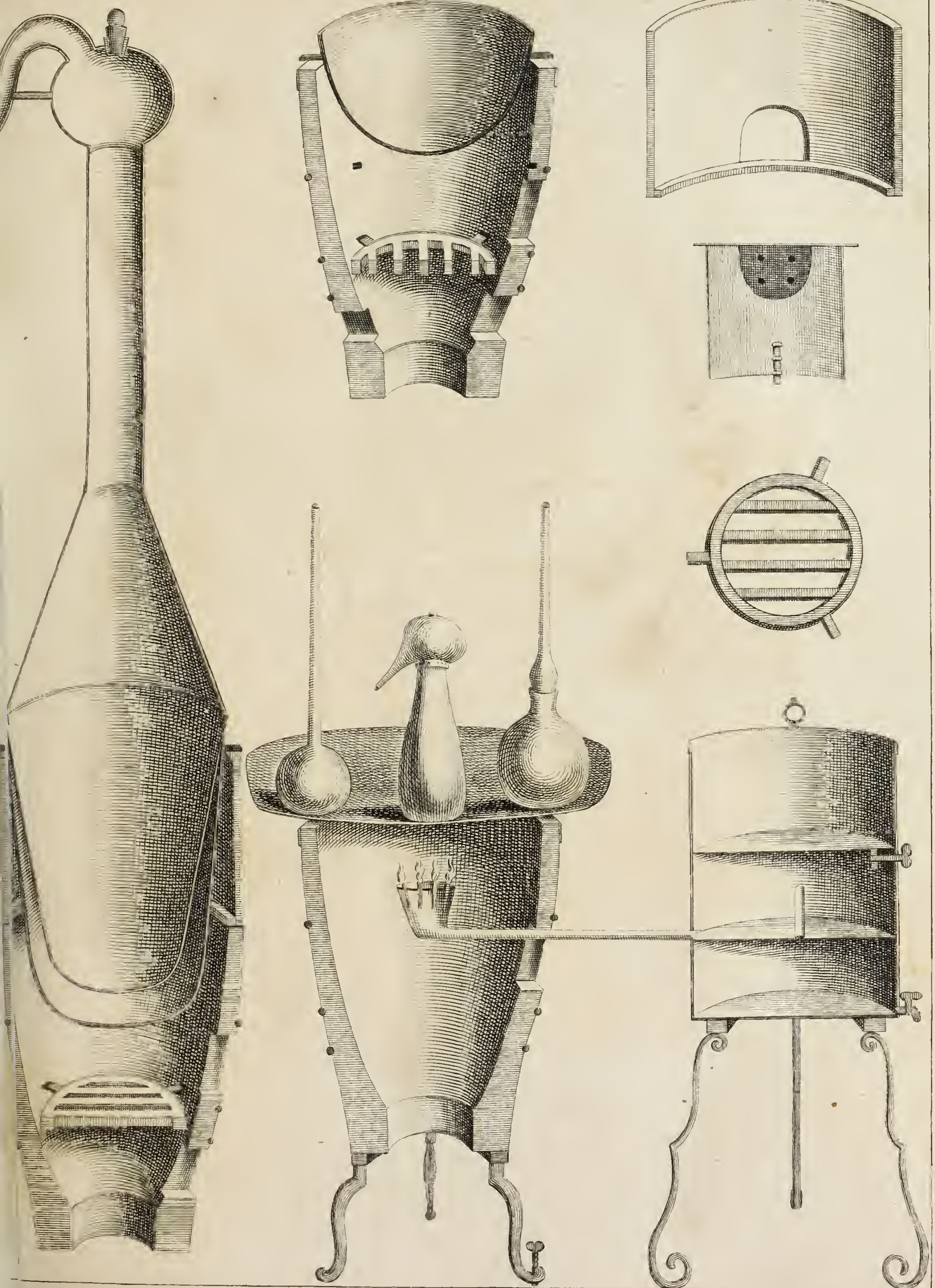
Explanation of PLATE I.

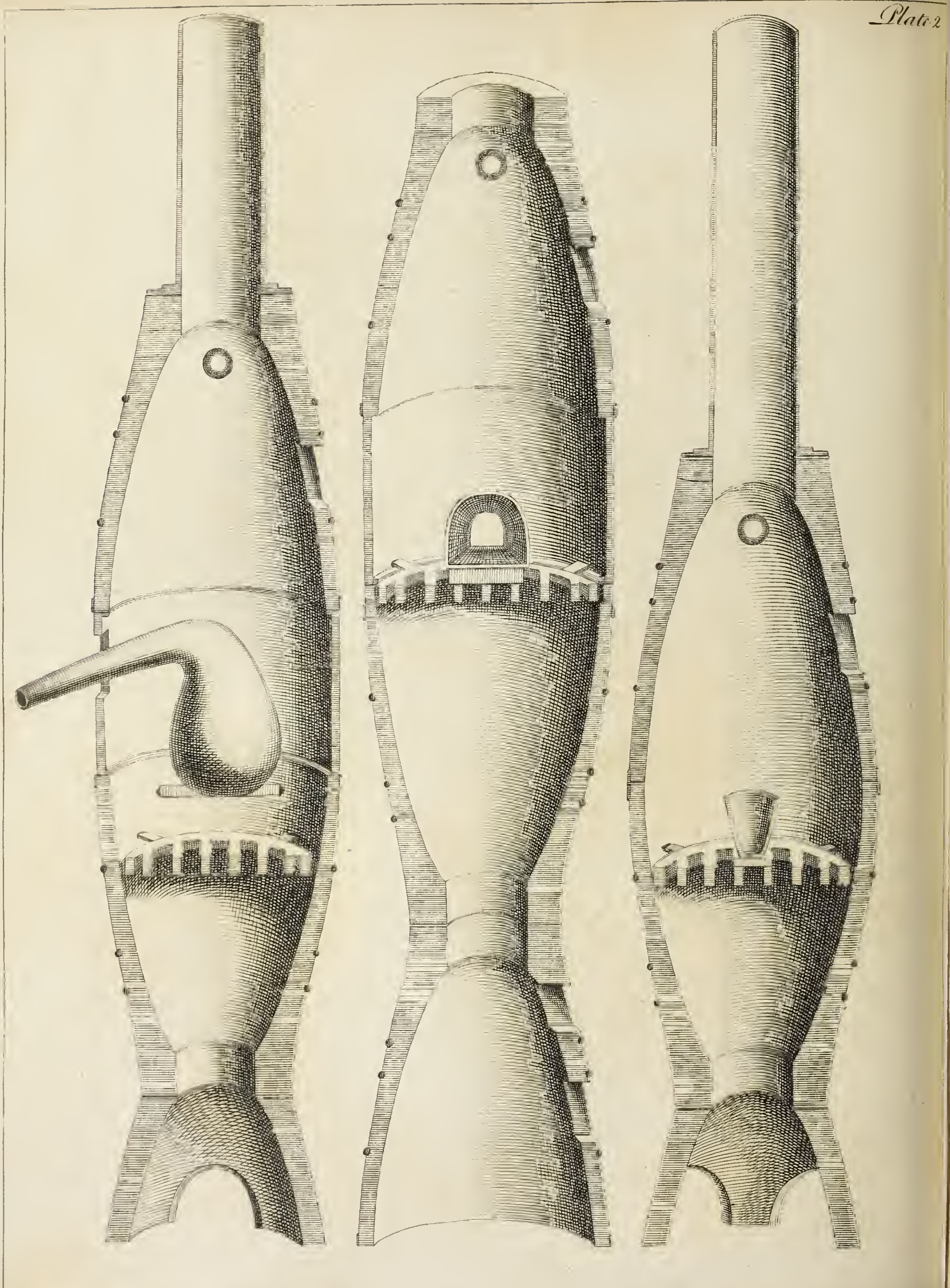
THE upper figure on the right ſide of the plate is a perpendicular ſection of the iron hoop, ſee page 7, with the aperture ſhewn in its back part. Under it is a plan of the door of the aperture, rivetted on an iron plate.

Under this, is a plan of the middle grate, with three pins projecting from its circumference. The lower grate differs only in being ſmaller; and the upper one, in being larger, and having no pins.

The middle figure in the upper part of the plate is a perpendicular ſection, with a perſpective view of the back part, of one of the black lead pots, of the ſize marked 60, as fitted for the general purpoſes of furnaces; with the ſmaller grate, cut acroſs the bars, in its lower part; and an iron pot hung in its mouth, ſee page 8. It is drawn, as all the other figures in this and the following plates, to about one fifth of the real ſize. The notches for the grates, and all the apertures, are here expreſſed: but in the other figures, only thoſe apertures are ſhewn, which are neceſſary for the reſpective uſes to which the furnaces are applied. They are all bound, in three places, with copper wire; and round the mouth is a thin copper hoop, which preſerves the outer edge from wearing off.

On the left ſide of the plate is repreſented the apparatus for diſtillation, deſcribed in page 9: and on the right is the lamp, communicating with its reſervoir (ſee page 29) by a lateral pipe, which is here made a little too ſhort for want of room on the plate. Over the lamp furnace is a broad pan; which is here employed as a water-bath, and contains a long-necked matras or bolthead; a more commodious veſſel of the ſame kind compoſed of a glaſs receiver with a long pipe inſerted into its mouth; and a cucurbit or body with a glaſs head for diſtillation.





Explanation of PLATE II.

IN this plate are ſhewn different combinations of the pots for different uſes, with and without the iron hoop between them. In the back part of the upper pot or dome is expreſſed the round hole, through which, and the oppoſite aſh-pit door, an iron rod is paſſed for conveniently lifting it off when hot.

On the right hand is the wind melting furnace (page 11) with a ſection of the grate and crucible. It ſtands upon a portion of another pot, in the ſides of which three arches are ſawed (page 6).

In the middle is the aſſay furnace (page 12) with a ſection of the muffle above the grate. This furnace ſtands upon another entire pot inverted, that it may be raiſed to a proper height for the inſpection of the cupels, &c. under the muffle.

On the left hand is a reverberatory, with a coated glaſs retort for diſtillation. It ſtands on the ſame kind of foot as the wind furnace on the right ſide; and in its back part is ſhewn one of the two bars on which the bottom of the retort is ſupported.

Explanation of PLATE III.

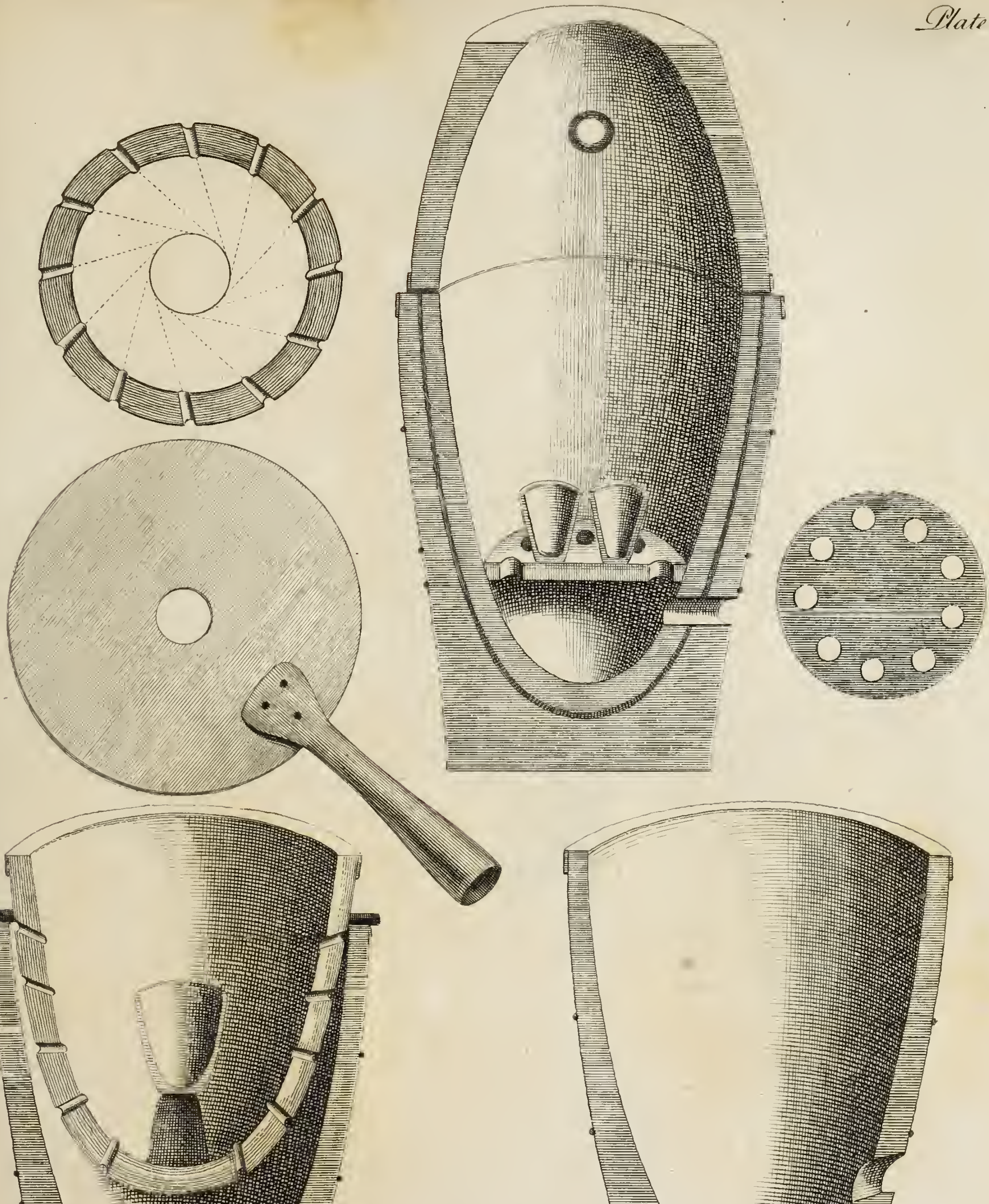
THE three furnaces in this plate are different kinds of blaſt furnaces; with holes bored in the ſides for receiving the noſe of the bellows.

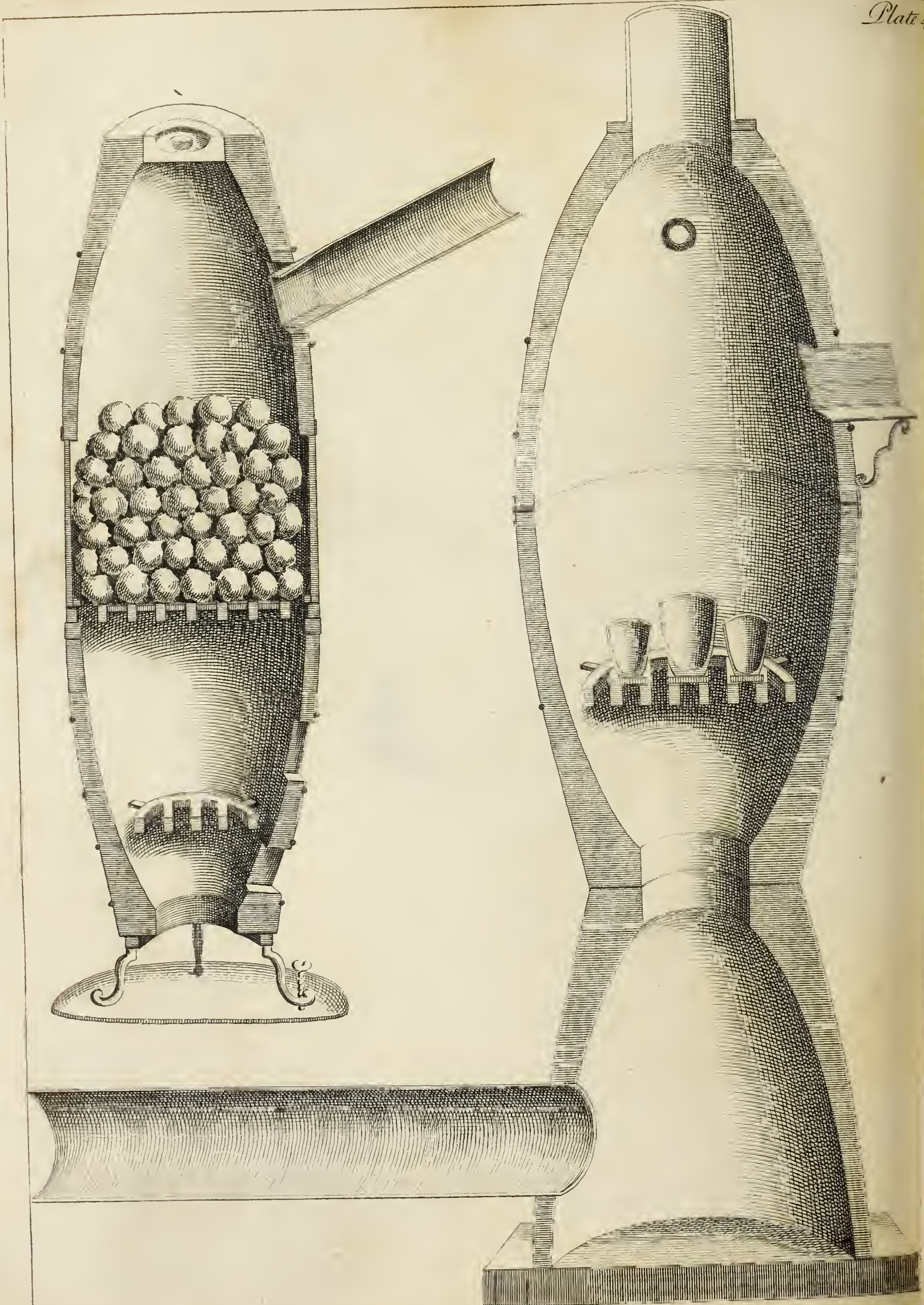
The uppermoſt conſiſts of a pot of the ſize marked 80, fitted into one of 100; with a portion of another of 100 inverted over it for a dome. So much of the bottom of this laſt is ſawed off as to procure a ſufficient aperture; and ſo much is ſawed from the mouth, that the remainder may be of a proper width to fit upon the mouth of the leſſer pot. A round ſlip, ſawed from the bottom, ſerves both for a grate and for a ſupport to the crucible (page 18). A ſection of this grate is ſhewn in the furnace, and a plan of it on the right hand.

The right ſide furnace at the bottom of the plate is for fuſion without a grate or among the fuel. The pot is of the largeſt ſize, and its height may be occaſionally enlarged by the ring cut off from the dome of the foregoing furnace. To the ſloping canal in its bottom is fitted the lower part of another pot. See page 21.

The lowermoſt furnace on the left hand is that deſcribed in page 27, in which ſtreams of air are impelled from different parts of the fuel upon the crucible in the middle. The lower pot is that which ſerves for the blaſt furnace in the upper part of the plate; and the perforated pot is of the ſize 90, with its bottom rounded, and a part of the top cut off for the greater convenience of inſpecting or taking out the crucible. The circular plane over it is an iron plate, with a hole in the middle, which ſerves as a cover for the pot; and over this is a tranſverſe ſection of the perforated pot and crucible, to ſhew the direction of the ſtreams of air.

Plate 3





Explanation of Plate IV.

THE furnace on the right ſide of the plate is the wind-furnace deſcribed in page 24; compoſed of the largeſt-ſized black lead pots; and conſtructed on the model of that uſed by Mr. Pott in his experiments of the vitrification of earthy bodies. A portion of the air pipe is ſhewn inſerted into the foot, and five little crucibles upon the grate. To the door is fitted an iron plate, turned up at the ſides, for receiving the fuel, which is kindled faſt enough by the vicinity of the fire, to afford a conſtant ſupply of burning charcoal: the kindled part at the door is moved into the furnace by puſhing the reſt forward with an iron rod, and more unlighted charcoal is ſucceſſively ſupplied behind.

The figure on the left ſide of the plate is that of the ſtove for warming a room, page 14. It ſtands on the iron trevet, with the flat iron pan underneath for receiving the aſhes. The hoop is filled with balls of baked earth, which are ſupported by the large grate on the top of the lower pot. Into the door of the dome is inſerted the ſquare end of the iron pipe, the other end of which communicates with the chimney of the room.

II. History of GOLD,

And of the various Arts and Businesses depending thereon.

SECT. I.

Of the colour of Gold, and the methods of reſtoring its luſtre, when ſullied.

THE bright deep yellow colour of gold, commonly diſtinguiſhed by its name, is one of the moſt obvious characters of this metal. Its colour and beauty are of great durability, being injured neither by air nor moiſture, nor by any kind of exhalations that uſually float in the atmoſphere; as may be obſerved in the gildings of ſome public edifices, which have reſiſted the weather, and the vapours of London, and other populous cities, for half a century or more. In this property conſiſts great part of the excellence of this metal for ornamental and ſome mechanic uſes: there is no other malleable metallic body, ſo little ſuſceptible of tarniſh or diſcoloration, or ſo little diſpoſed to communicate any ſtain to the matters which it lies in contact with.

As inſtruments or ornaments of pure gold are liable to be ſullied only from the ſimple adheſion of extraneous ſubſtances; their beauty may be recovered, without any injury to the metal, however exquiſitely figured, or without any abraſion of its ſurface, however thin and delicate, by by means of certain liquids which diſſolve the adhering foulneſs; as ſolution of ſoap, ſolution of fixt alkaline ſalts or alkaline ley, volatile alkaline ſpirits, and rectified ſpirit of wine.

In the uſe of the alkaline liquors, ſome caution is neceſſary in regard to the veſſels; thoſe of ſome metals being, in certain circumſtances, corroded by them, ſo as remarkably to diſcolour the gold. A gilt ſnuff-box, boiled with ſoap-boilers ley in a tin pot, to clean it from ſuch foulneſs as might adhere in the graved figures, and to prevent any deception which might hence ariſe in a hydroſtatic examination of it, became ſoon of an ill colour, and at length appeared all over white as if it had been tinned: ſome pieces of ſtandard gold, treated in the ſame manner, underwent the ſame change: and on trying volatile alkaline ſpirits, prepared with quick-lime, the ſame effect was produced more ſpeedily. On boiling the pieces, thus whitened, with ſome of the ſame kind of alkaline liquors, in a copper veſſel, the extraneous coat diſappeared, and the gold recovered its proper colour.

For laces, embroideries, and gold thread woven in ſilks, the alkaline liquors are in no ſhape to be uſed; for, while they clean the gold, they corrode the ſilk, and change or diſcharge its colour. Soap alſo alters the ſhade, and even the ſpecies of certain colours. But ſpirit of wine may be uſed without any danger of its injuring either the colour or quality of the ſubject, and in many caſes proves as effectual, for reſtoring the luſtre of the gold, as the corroſive detergents. A rich brocade, flowered with a variety of colours, after being diſagreeably tarniſhed, had the luſtre of the gold perfectly reſtored by waſhing it with a ſoft bruſh dipt in warm ſpirit of wine; and ſome of the colours of the ſilk, which were likewiſe ſoiled, became at the ſame time remarkably bright and lively. Spirit of wine

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feems to be the only material adapted to this intention, and probably the boafted fecret of certain artifts is no other than this fpirit difguifed: among liquids, I do not know of any other, that is of fufficient activity to difcharge the foul matter, without being hurtful to the filk: as to powders, however fine, and however cautioufly ufed, they fcratch and wear the gold, which here is only fuperficial and of extreme tenuity.

But though fpirit of wine is the moft innocent material that can be employed for this purpofe, it is not in all cafes proper. The golden covering may be in fome parts worn off; or the bafe-metal, with which it had been iniquitoufly alloyed, may be corroded by the air, fo as to leave the particles of the gold difunited; while the filver underneath, tarnifhed to a yellow hue, may continue a tolerable colour to the whole: in which cafes it is apparent, that the removal of the tarnifh would be prejudicial to the colour, and make the lace or embroidery lefs like gold than it was before. A piece of old tarnifhed gold lace, cleaned by fpirit of wine, was deprived, with its tarnifh, of greateft part of its golden hue, and looked now almoft like filver lace.

Though no one of the other metallic bodies, fingly, has any degree of the beautiful yellow colour which glows in gold, the true gold yellow may, neverthelefs, be pretty nearly imitated, by certain combinations of other metals, particularly of copper with zinc. But how nearly foever thefe compofitions approach to gold in degree or fpecies of colour, they differ greatly in its durability; and their differences in other refpects are ftill more ftrongly marked, and of more eafy difcovery, as will appear in the fequel of this treatife.

SECT.

SECT. II.

Of the gravity of Gold.

FINE gold, immerfed in water, weighs near one nineteenth part lefs than in air, and confequently it is upwards of nineteen times heavier than equal its own volume of water. All the other kinds of matter, that have been known till of late years, are of remarkably lefs gravity; mercury, the next in weight, being only about fourteen times heavier than water, and lead, the next of the folid bodies, little more than eleven times. Hence the gravity of gold has been univerfally reckoned one of its moft certain and inimitable characteriftics: and accordingly it has been laid down as an axiom, that whatever body exceeded the weight of water above fourteen times, how unpromifing foever in appearance, muft neceffarily contain gold. The difcovery of the ponderous metal platina has now afforded an exception to this axiom, and fhewn that weight alone is no certain criterion of gold; for pure platina, perfectly void of gold, is nearly as ponderous as the precious metal itfelf.

The fpecific gravity of gold, or its comparative weight to an equal volume of water, is by fome reported to be 19,640, and in a paper in the Swedifh tranfactions it is made no lefs than 20,000; that of water being 1,000. But in the experiments of Mr. Ellicott, whofe accuracy and fkill are unqueftionable, made upon gold fuppofed to be fine, it did not exceed 19,207; and of different maffes of gold, which I had refined to the greateft degree of purity that I apprehend gold capable of being brought to, and well hammered, I found the gravity, on many different trials, between 19,300 and 19,400. A mafs of fine gold, weighing in air 13447, being weighed in diſtilled water of the temperature of fifty three degrees of Fahrenheit's thermometer, or twenty one 180ths of the interval between freezing and boiling; the loſs in water was 694, whence the gravity turns out 19,376; the balance, thus loaded, turned ſenſibly with half of one of the weights, ſo that the true loſs in water could not be half a weight more or leſs than the apparent, and the gravity, of conſequence, could not be ſo little as 19,362, or ſo much as 19,390. It were to be wiſhed that thoſe, who have examined metals hydroſtatically, had ſpecified the ſenſibility of the balance, and the quality and warmth of the water. An increaſe of heat rarefying water much more than it does gold, the gold muſt turn out proportionably heavier than an equal volume of the expanded fluid; and this difference is perhaps more conſiderable than it has generally been ſuppoſed. From freezing to boiling water, or by an augmentation of heat equivalent to one hundred and eighty degrees of Fahrenheit's thermometer, a rod of gold appears to be lengthened about one part in 700, and conſequently its volume is increaſed about one part in 233, while the volume of water is increaſed one 26th or more: hence by an augmentation of forty degrees of the thermometer, or from a little above freezing to the ſummer heat, the volume of gold, if its expanſion be uniform, is increaſed one part in 1048, and that of water one in 117; and the gravity of gold, weighed in the water ſo warmed and expanded, ſhould be greater than when the gold and water are forty degrees colder, in the proportion of about 19,265 to 19,400. This calculation gives a difference, in the gravity, of 0,034 for every ten degrees of the thermometer, but ſome trials ſeemed to make it greater. A piece of gold being weighed in water of fifty degrees, and afterwards in the ſame water made eighty eight degrees hotter, in which

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it was kept immerſed for ſome time to acquire its warmth, the gravities turned out 19,372 and 19,769; whence the difference for every ten degrees comes to be 0,045—If the mean gravity of gold be reckoned 19,300; as a cubic inch of water weighs about 254 grains, a cubic inch of gold will weigh of conſequence about 4902 grains or ten ounces and a hundred and two grains.

As air reſiſts the deſcent of bodies more or leſs in proportion to its own gravity and the ſurface of the deſcending body, and as the braſs, of which weights are made, is more than double in volume to an equal weight of gold; it follows, that if gold be counterpoiſed with braſs weights in light air, the gold will preponderate when the air grows heavier, the addition made to the air's gravity reſiſting the braſs above twice as much as it does the gold. It has hence been imagined, that the comparative gravity of gold to braſs weights muſt be ſo far influenced by the variable gravity of the atmoſphere, that there muſt be an advantage in buying gold by weight when the air is lighteſt. The difference appears however too inconſiderable to be regarded in a commercial view. For the loſs of weight of the two metals in the air being as much leſs than their loſs in water, as air is lighter than water; and air, as appears from an experiment of Mr. Hawkſbee, being in its lighteſt ſtate about a 937th, and in its heavieſt about an 848th part of the weight of water; it will be found on calculation, that the gold preponderates above the braſs, in the heavieſt more than in the lighteſt air, only by one part in 145000, or one grain in about three hundred and two ounces: a difference too minute to be ſenſible in the tendereſt balance.

Notwithſtanding the great denſity of gold, and its containing, under an equal volume, the greateſt quantity of ſolid parts of all known bodies; it is ſaid, that it not only freely tranfmits the magnetic effluvia, but that even water, by ftrong preffure, may be fqueezed through its pores. A hollow fphere of gold being filled with water, foldered up, and preffed with great force, the water was found to tranfude in multitudes of fmall drops, which covered the outfide of the fphere like dew. This experiment was made by the Florentine academy, and is mentioned by Sir Ifaac Newton on the teftimony of an eyewitnefs. It may be queftioned however, whether the interftices, through which the water iffued, were the pores proper to the gold in its natural ftate; or whether they were not rather an enlargement of its natural pores, occafioned by the parts of the metal having been forced afunder by the incompreffibility of the water, and the violence of the preffure.

SECT. III.

Of the ductility of Gold, and the arts depending on this property: Gold-beating, wire-drawing, gilding with gold-leaf on different fubjects.

FINE gold is a foft metal; eafily chiffeled, cut, or graved; very flexible; and fo tough, that when at length made to break by repeated bendings backwards and forwards, the fracture, on each of the pieces, appears drawn out in the middle like a wedge. It takes impreffions from dyes in great perfection; does not file freely, but fticks in the teeth; has little elafticity or fonoroufnefs; receives great fplendor from the burnifher, but does not appear fo bright from the polifhing ftone. It yields freely to the hammer, both when hot and cold, and admits of being ftretched to a vaft extent.

The great value which has at all times been fixed on gold, its beautiful colour, incorruptibility, and compactnefs, render its ductility an object of primary importance:

on

on this depend ſundry arts and manufactures, in which we ſee it extended to an amazing tenuity, and variouſly applied on the ſurface of other bodies, both for their ornament and preſervation.

Preparation of Gold leaf.

THE gold is melted in a black lead crucible, with ſome borax, in a wind furnace, called by the workmen a wind-hole: as ſoon as it appears in perfect fuſion, it is poured out into an iron ingot mould, ſix or eight inches long, and three quarters of an inch wide, previouſly greaſed, and heated, ſo as to make the tallow run and ſmoke, but not to take flame. The bar of gold is made red hot, to burn off the unctuous matter, and forged on an anvil into a long plate, which is further extended, by being paſſed repeatedly between poliſhed ſteel rollers, till it becomes a ribbon, as thin as paper. Formerly the whole of this extenſion was procured by means of the hammer, and ſome of the French workmen are ſtill ſaid to follow the ſame practice: but the uſe of the flatting mill both abridges the operation, and renders the plate of more uniform thickneſs. The ribbon is divided by compaſſes, and cut with ſheers into equal pieces, which conſequently are of equal weights: theſe are forged on an anvil till they are an inch ſquare, and afterwards well nealed, to correct the rigidity which the metal has contracted in the hammering and flatting. Two ounces of gold, or 960 grains, the quantity which the workmen uſually melt at a time, make an hundred and fifty of theſe ſquares, whence each of them weighs ſix grains and two fifths; and as 4902 grains of gold make a cubic inch, the thickneſs of the ſquare plates is about the 766th part of an inch.

In order to the further extenſion of theſe pieces into fine leaves, it is neceſſary to interpoſe ſome ſmooth body between

between them and the hammer, for ſoftening its blow, and defending them from the rudeneſs of its immediate action: as alſo to place between every two of the pieces ſome proper intermedium, which, while it prevents their uniting together, or injuring one another, may ſuffer them freely to extend. Both theſe ends are anſwered by certain animal membranes.

The gold-beaters uſe three kinds of membranes; for the outſide cover, common parchment, made of ſheep-ſkin; for interlaying with the gold, firſt the ſmootheſt and cloſeſt vellum, made of calves-ſkin; and afterwards the much finer ſkins of ox-gut, ſtript off from the large ſtreight gut ſlit open, curiouſly prepared on purpoſe for this uſe, and hence called gold-beaters ſkin. The preparation of theſe laſt is a diſtinct buſineſs, practiſed by only two or three perſons in the kingdom, ſome of the particulars of which I have not ſatisfactorily learnt. The general proceſs is ſaid to conſiſt, in applying one upon another, by the ſmooth ſides, in a moiſt ſtate, in which they readily cohere and unite inſeparably; ſtretching them on a frame, and carefully ſcraping off the fat and rough matter, ſo as to leave only the fine exteriour membrane of the gut; beating them between double leaves of paper, to force out what unctuoſity may remain in them; moiſtening them once or twice with an infuſion of warm ſpices; and laſtly drying and preſſing them. It is ſaid, that ſome calcined gypſum, or plaſter-of-paris, is rubbed with a hares-foot both on the vellum and the ox-gut ſkins, which fills up ſuch minute holes as may happen in them, and prevents the gold leaf from ſticking, as it would do to the ſimple animal membrane. It is obſervable, that notwithſtanding the vaſt extent to which the gold is beaten between theſe ſkins, and the great tenuity of the ſkins themſelves, yet they ſuſtain continual repetitions of the procefs for feveral months, without extending or growing thinner. Our workmen find that after feventy or eighty repetitions, the fkins, though they contract no flaw, will no longer permit the gold to extend between them; but that they may be again rendered fit for ufe by impregnating them with the virtue which they have loft, and that even holes in them may be repaired by the dextrous application of frefh pieces of fkin: a microfcopical examination of fome fkins that had been long ufed plainly fhewed thefe repairs. The method of reftoring their virtue is faid in the *Encyclopedie* to be, by interlaying them with leaves of paper moiftened with vinegar or white wine, beating them for a whole day, and afterwards rubbing them over as at firft with plafter-of-paris. The gold is faid to extend between them more eafily, after they have been ufed a little,* than when they are new.

The beating of the gold is performed on a fmooth block of black marble, weighing, from two hundred to fix hundred pounds, the heavier the better, about nine inches fquare on the upper furface, and fometimes lefs, fitted into the middle of a wooden frame, about two feet fquare, fo as that the furface of the marble and the frame form one continuous plane. Three of the fides are furnifhed with a high ledge; and the front, which is open, has a leather flap faftened to it, which the gold-beater takes before him as an apron, for preferving the fragments of gold that fall off. Three hammers are employed, all of them with two round and fomewhat convex faces, though commonly the workman ufes only one of the faces: the firft, called the cutch hammer, is about four inches in diameter, and weighs fifteen or fixteen pounds, and fometimes twenty, tho' few workmen can manage thofe of this laft fize: the fecond, called the fhodering hammer, weighs about twelve pounds, and is about the fame diameter: the third, called

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the gold hammer, or finiſhing hammer, weighs ten or eleven pounds, and is near of the ſame width. The French uſe four hammers, differing both in ſize and ſhape from thoſe of our workmen: they have only one face, being in figure truncated cones: the firſt has very little convexity, is near five inches in diameter, and weighs fourteen or fifteen pounds: the ſecond is more convex than the firſt, about an inch narrower, and ſcarcely half its weight: the third, ſtill more convex, is only about two inches wide, and four or five pounds in weight: the fourth or finiſhing hammer is near as heavy as the firſt, but narrower by an inch, and the moſt convex of all. As theſe hammers differ ſo remarkably from ours, I thought proper to inſert them, leaving the workmen to judge what advantage one ſet may have above the other.

A hundred and fifty of the pieces of gold are interlaid with leaves of vellum, three or four inches ſquare, one vellum leaf being placed between every two of the pieces, and about twenty more of the vellum leaves on the outſides; over theſe is drawn a parchment caſe, open at both ends, and over this another in a contrary direction, ſo that the aſſemblage of gold and vellum leaves is kept tight and cloſe on all ſides. The whole is beaten with the heavieſt hammer, and every now and then turned upſide down, till the gold is ſtretched to the extent of the vellum; the caſe being from time to time opened for diſcovering how the extenſion goes on, and the packet, at times, bent and rolled as it were between the hands, for procuring ſufficient freedom to the gold, or, as the workmen ſay, to make the gold work. The pieces, taken out from between the vellum leaves, are cut in four with a ſteel knife; and the ſix hundred diviſions, hence reſulting, are interlaid, in the ſame manner, with pieces of the ox-gut ſkins, five inches ſquare. The beating being repeated, with a lighter hammer, till the golden plates have again acquired the extent of the ſkins, they are a ſecond time divided in four: the inſtrument uſed for this diviſion is a piece of cane cut to an edge, the leaves being now ſo light, that the moiſture of the air or breath, condenſing on a metalline knife, would occaſion them to ſtick to it. Theſe laſt diviſions being ſo numerous, that the ſkins neceſſary for interpoſing between them would make the packet too thick to be beaten at once, they are parted into three parcels, which are beaten ſeparately, with the ſmalleſt hammer, till they are ſtretched for the third time to the ſize of the ſkins: they are now found to be reduced to the greateſt thinneſs they will admit of, and indeed many of them, before this period, break or fail. The French workmen, according to the minute detail of this proceſs given in the *Encyclopedie*, repeat the diviſion and the beating once more; but as the ſquares of gold, taken for the firſt operation, have four times the area of thoſe uſed among us, the number of leaves from an equal area is the ſame in both methods, to wit, ſixteen from a ſquare inch. In the beating, however ſimple the proceſs appears to be, a good deal of addreſs is requiſite, for applying the hammers ſo as to extend the metal uniformly from the middle to the ſides: one improper blow is apt not only to break the gold leaves, but to cut the ſkins.

After the laſt beating, the leaves are taken up by the end of a cane inſtrument, and being blown flat on a leather cuſhion, are cut to a ſize, one by one, with a ſquare frame of cane made of a proper ſharpneſs, or with a frame of wood edged with cane: they are then fitted into books of twenty five leaves each, the paper of which is well ſmoothed, and rubbed with red bole to prevent their ſticking to it. The French, for ſizing the leaves, uſe only the cane knife; cutting them firſt ſtreight on one ſide, fitting them into the book by the ſtreight ſide, and then paring off the ſuperfluous parts of the gold about the edges of the book. The ſize of the French gold leaves is from ſomewhat leſs than three inches to three and three quarters ſquare; that of ours, from three inches to three and three eighths.

The proceſs of gold-beating is conſiderably influenced by the weather. In wet weather, the ſkins grow ſomewhat damp, and in this ſtate make the extenſion of the gold more tedious: the French are ſaid to dry and preſs them at every time of uſing; with care not to over-dry them, which would render them unfit for further ſervice. Our workmen complain more of froſt, which appears to affect the metalline leaves themſelves: in froſt, a gold leaf cannot eaſily be blown flat, but breaks, wrinkles, or runs together.

Gold leaf ought to be prepared from the fineſt gold; as the admixture of other metals, though in too ſmall a proportion to ſenſibly affect the colour of the leaf, would diſpoſe it to loſe of its beauty in the air. And indeed there is little temptation to the workman to uſe any other; the greater hardneſs of alloyed gold occaſioning as much to be loſt in point of time and labour, and in the greater number of leaves that break, as can be gained by any quantity of alloy that would not be at once diſcoverable by the eye. All metals render gold harder and more difficult of extenſion: even ſilver, which in this reſpect ſeems to alter its quality leſs than any other metal, produces with gold a mixture ſenſibly harder than either of them ſeparately, and this hardneſs is in no art more felt than in the gold-beaters. The French are ſaid to prepare what is called green gold leaf, from a compoſition of one part of copper and two of ſilver with eighty of gold; but this is probably a miſtake, for ſuch an admixture gives no greenneſs to gold, and I have been informed by our workmen, that this kind of leaf is made from the ſame

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fine gold as the higheſt gold-coloured ſort, the greeniſh hue being only a ſuperficial teint induced upon the gold in ſome part of the proceſs: this greeniſh leaf is little otherwiſe uſed than for the gilding of certain books.

But though the gold-beater cannot advantageouſly diminiſh the quantity of gold in the leaf by the admixture of any other ſubſtance with the gold, yet means have been contrived, for ſome particular purpoſes, of ſaving the precious metal, by producing a kind of leaf called party-gold, whoſe baſis is ſilver, and which has only a ſuperficial coat of gold upon one ſide: a thick leaf of ſilver and a thinner one of gold, laid flat on one another, heated and preſſed together, unite and cohere; and being then beaten into fine leaves, as in the foregoing proceſs, the gold, though its quantity is only about one fourth of that of the ſilver, continues every where to cover it, the extenſion of the former keeping pace with that of the latter.

Preparation of gold or gilt wire.

THERE is very little wire made entirely of gold; and this chiefly for one particular purpoſe, that of filligree work. What is commonly called gold wire has only an exteriour covering of gold, the internal part being ſilver. A rod of ſilver, above an inch thick, two feet in length, and weighing about twenty pounds, is coated with gold; and then reduced into wire, by drawing it ſucceſſively through a number of holes, made in metalline plates, diminiſhing inſenſibly in a regular gradation.

The purity of the gold, employed for this uſe, is a point of the utmoſt conſequence; for on this principally depends the beauty, and durability of the colour, of the laces, brocades, and other commodities prepared from it; and unhappily there is more room for abuſe here than in gold leaf, the extenſion of the metal in this form being lefs affected by an addition of alloy. The boafted fuperiority of the French laces to the generality of thofe made in England, for which various caufes have been falfely affigned, appears to be wholly owing to a difference in the finenefs of the gold: our workmen have of late years had finer gold put into their hands than formerly, and the product has been judged not inferiour to that of France; nor is it to be doubted that the Englifh artift, acknowledged not to be wanting in manual dexterity, will, with equal or fuperiour materials, produce an equal or fuperiour commodity. It fhould feem therefore neceffary, for the purpofes of fo important a manufacture, where fo much depends upon the purity of the gold, not only to employ it in the pureft ftate to which it can be brought by the common methods of refining, but even to feek for means of purifying it to a greater degree than any of the common proceffes are capable of doing: fuch means the fequel of this effay will afford.

With regard to the filver, which makes the internal body of the wire, its finenefs is of lefs importance. I have been informed by fome experienced workmen, that there is an advantage in its being alloyed; that fine filver, on being nealed in the fire, becomes fo foft, as to fuffer the golden coat in fome meafure to fink into it; and that the admixture of a little copper communicates a fufficient hardnefs, for preventing this inconvenience. Accordingly the French filver for gilding is faid to be alloyed with five or fix pennyweight, and ours with twelve pennyweight, of copper, in the pound troy. Some have thought, that this over-foftening of the filver might be equally prevented, by ufing lefs heat; and that fine filver, receiving a fmoother furface than fuch as is alloyed, muft fhew the golden covering to better advantage. How far thefe prefumptions are well founded, or how far ſar the manufacture is affected by the above differences in the quantity of alloy, I cannot take upon me to determine.

The gold is employed in thick leaves, prepared on purpoſe for this uſe; which are applied all over the ſilver rod, and preſſed down ſmooth with a ſteel burniſher. Several of the gold leaves are laid over one another, according as the gilding is required more or leſs thick. The ſmalleſt proportion allowed by act of parliament is 100 grains of gold to a pound or 5760 grains of ſilver. The largeſt proportion, for the beſt double-gilt wire, as Dr. Halley was informed by the workmen, is 120 grains to a pound; though I am told, that of late the proportion of gold has been increaſed.

The firſt part of the drawing proceſs, as well as the preparation and gilding of the ſilver rod, is performed by the refiner; who uſes plates of hardened ſteel, with a piece of tough iron welded on the back to prevent the ſteel from breaking. In this back part, the holes are much wider than the correſponding ones in the ſteel, and of a conical ſhape; partly, that the rod may not be ſcratched againſt the outer edge; and partly, for receiving ſome bees-wax, which makes the rod paſs more freely, and preſerves the gold from being rubbed off. The plate being properly ſecured, one end of the rod, made ſomewhat ſmaller than the reſt, is puſhed through ſuch a hole as will admit it, and laid hold of by ſtrong pincers called clamps, whoſe chaps are toothed, ſomewhat like a file, to keep the rod from ſlipping out by the violence neceſſary for drawing it: the handles or branches of the clamps are bent upwards, and an oval iron loop put over the curvature, ſo that the force, which pulls them horizontally by the loop, ſerves at the ſame time to preſs them together: to the loop is faſtened a rope, whoſe further

further end goes round a capſtan, or upright cylinder, with croſs bars, which requires the ſtrength of ſeveral men to turn it. The rod, thus drawn through, is well nealed, then paſſed in the ſame manner through the next hole, and the nealing and drawing repeated, leſs and leſs force ſufficing as it diminiſhes in thickneſs : when reduced to about the ſize of a large quill, it is delivered in coils to the wire-drawer.

The remainder of the proceſs requires plates of a different quality ; thoſe of ſteel, whether in a hard or a ſoft ſtate, being now found to fret the wire, or to raiſe a bur upon its ſurface, and ſtrip off the gold. The plates for this part of the work are brought from Lyons in France: the holes are drilled in them here. They are formed of a metallic maſs, whoſe compoſition is kept a ſecret, but whoſe prevailing ingredient is plainly iron : I have begun an examination of this metal, and ſhall communicate the reſult of the experiments in one of the future numbers of this work. There are two ſorts of theſe plates ; one of conſiderable thickneſs, for the wire in its larger ſtate ; the other, only about half as thick, for the finer wire, where leſs force is ſufficient in the drawing. There are conſiderable differences alſo in the quality of the metal itſelf, not to be diſtinguiſhed by the eye, or any otherwiſe than by repeated trials : ſuch of the thicker plates, as are found good, are valued at a high price. The Lyons plates, though brittle, have ſufficient toughneſs to admit of the holes being beaten up, or contracted, by a few blows of a hammer ; ſo that when any of them have been widened by a length of wire being drawn through, they are thus reduced again to the proper dimenſions for preſerving the gradation : the holes, after each beating up, are opened by a long ſlender inſtrument, called a point, made of refined ſteel ; one end of which, to the length of about five inches,

inches, is round, and ſerves as a handle; the reſt, about twice as long, is ſquare, and tapered to a fine point. The firſt holes being ſooneſt gulled, or ſo far worn, as to be unfit for bearing further reductions; the next to them, grown likewiſe wider, ſupply their places, and are themſelves ſucceſſively ſupplied by thoſe which follow; whence, as each plate is furniſhed with ſeveral more of the ſmall holes than are wanted at firſt, it continues to afford a complete ſeries after a conſiderable number of the larger has become unſerviceable. Great part of the dexterity of the workman conſiſts in adapting the hole to the wire; that the wire may not paſs ſo eaſily, as not to receive ſufficient extenſion, or ſo difficultly as to be broken in the drawing. For determining this point with greater certainty than could be done from the mere reſiſtance of the wire, he uſes a braſs plate called a ſize, on which is meaſured, by means of notches like ſteps cut at one end, the increaſe which a certain length of wire ſhould gain in paſſing through a freſh hole: if the wire is found to ſtretch too much or too little, the hole is widened or contracted. As the extenſion is adjuſted by this inſtrument, there are others for meaſuring the degree of fineneſs of the wire itſelf: ſlits of different widths, made in thick poliſhed iron rings, ſerve as gages for this uſe.

The wire-drawers proceſs begins with nealing the large wire received from the refiner: this is performed by placing it, coiled up, on ſome lighted charcoal, in a cylindrical cavity, called the pit, made for this purpoſe, under a chimney, about ſix inches deep, and throwing more burning charcoal over it: the pit having no apertúre at bottom to admit air, the fuel burns languidly, affording only ſufficient heat to make the metal red-hot, without endangering its melting. Being then quenched in water for the ſake of expedition in cooling it, though the

the metal would doubtlefs be foftened more effectually if fuffered to cool leifurely, one end of it is paffed through the firft hole in the thick plate, and faftened to an upright wooden cylinder fix or eight inches in diameter: in the top of the cylinder are fixed two ftaples, and through thefe is paffed the long arm of a handle, by which the cylinder is turned on its axis by feveral men. In the continuation of this part of the procefs, called degroffing, the wire is frequently nealed and quenched, after every hole or every other hole, till it is brought to about the fize of the fmall end of a tobacco-pipe: and in this ftate it is cut into portions for the fine wire-drawer.

In this laft part of the wire-drawing procefs, nealing is not needful; but it is ftill as neceffary as before to wax the wire at every hole. Much lefs force being now fufficient for drawing it through the plate, a different inftrument is ufed: a kind of wheel, or circular piece of wood, much wider than the foregoing cylinder, is placed horizontally: in its upper furface are fome fmall holes, at different diftances from the axis, and into one or another of thefe, according to the force required, is occafionally inferted the point of an upright handle, whofe upper end is received in a hole made in a crofs bar above. From this the wire is wound off upon a fmaller cylinder, called a rochett, placed on the fpindle of a fpinning-wheel; and this laft cylinder being fixed on its axis behind the plate, the wire is again drawn through upon the firft; and being at length brought to the proper finenefs, it is nealed to fit it for the flatting-mill. This nealing is performed in a different manner from the foregoing ones, and with much lefs heat; for if the wire was now made red hot, it would wholly lofe its golden colour, and become black, bluifh, or white, as I have often experienced in different parcels of gilt wire. Being wound upon a large hollow

copper

copper bobin, the bobin is ſet upright, ſome lighted char-coal or ſmall-coal placed round it and brought gradually nearer and nearer, and ſome more ſmall-coal put in the cavity of the bobin; the wire being carefully watched, that as ſoon as it appears of the proper colour, it may be immediately removed from the heat. This is an operation of great nicety, and is generally performed by the maſter himſelf. The wire, though it in good meaſure retains the ſpringineſs which it had acquired in the drawing, and does not prove near ſo ſoft as it might be made by a greater heat, is nevertheleſs found to be ſufficiently ſo for yielding with eaſe to the flatting mill.

The flatting-mill conſiſts of two rolls, turned in a lathe to perfect roundneſs, exquiſitely poliſhed, placed with their axes parallel one over another, ſet by ſcrews till their circumferences come almoſt into contact, and both made to go round by one handle: the lowermoſt is about ten inches in diameter; the upper commonly little more than two, though ſome make it conſiderably larger, and indeed it would be more convenient if made as large, or nearly ſo, as the lower: their width or thickneſs is about an inch and a quarter. The wire, unwinding from a bobin, and paſſing firſt between the leaves of an old book, preſſed by a ſmall weight, which keep it ſomewhat tight, and then through a narrow ſlit, in an upright piece of wood called a ketch, which gives notice of any knot or doubling, is directed by means of a ſmall conical hole in a piece of iron, called a guide, to any particular part of the width of the rolls; that if there ſhould be any imperfection or inequality of the ſurface, the wire may be kept from thoſe parts; and that when one part is ſoiled by the paſſage of a length of wire, the wire may be ſhifted, till the whole width of the rolls is ſoiled, ſo as to require being cleaned and poliſhed anew with the ſine powder, called putty, prepared by calcining a mixture of lead and tin: the workmen value the rolls from the number of threads they will receive, that is from the number of places which the wire can thus be ſhifted to: good rolls will receive forty threads. The wire, flatted between the rolls, is wound again, as it comes through, on a bobin; which is turned by a wheel, fixt on the axis of one of the rolls, and ſo proportioned, that the motion of the bobin juſt keeps pace with that of the rolls.

The rolls, as well as the drawing plates, have been often procured from France; and it has been thought that the wire received from the French rolls an additional beauty and luſtre; though it does not appear that the French have any durable advantage in this reſpect above the Engliſh, or that the gloſſineſs communicated by either is of any real advantage to the manufacture; for it quickly goes off. The moſt important point in their preparation is, the giving them that perfect truth and equability of ſurface, which the flatting of ſo fine wire demands. The internal part is formed of iron, and a plate of refined ſteel is lapped round and welded over the iron: where the two ends of the ſteel plate meet there is frequently an imperfection, the juncture being generally viſible acroſs the face of the roll. In rolls of great width, ſome curious artiſts have obviated the inconveniences ariſing from this cauſe, by uſing, inſtead of a broad plate, a long narrow bar of the ſteel, and twiſting it round the roll in ſeveral circumvolutions, that the little inequalities, in hardneſs and ſolidity, happening at the junctures, might be in the direction of the ribbon that paſſes between the rolls, and not tranſverſe to it. In the narrow rolls uſed for the flatting of wire, a practice of this kind would be very difficult; but the ſame end might perhaps be anſwered, and even more effectually, by caſting the ſteel, inſtead

inſtead of a ſtreight bar, into the form of a hoop or ring, of a ſomewhat leſs diameter than the ſize of the intended roll; then forging the hoop, on the round beak and flat of the anvil alternately, to procure it the requiſite uniformity of its parts and the due extenſion; afterwards placing it in a proper mould, fixing the axis in its due poſition, and running into the intermediate ſpace ſome caſt iron, which, from its known property of expanding, as it ſets or becomes ſolid, will continue every where to fill the cavity, and irremoveably fix itſelf both to the hoop and to the axis.

The degree of extenſion of gold in wire and leaf.

THE vaſt extent, to which gold is apparently ſtretched in the foregoing operations, has induced ſeveral perſons to make experiments for determining its exact degree by menſuration and weight. In an experiment of Reaumur's, forty-two ſquare inches and three tenths of gold leaf weighed one grain troy; and Mr. Boyle found that fifty and ſeven-tenths weighed but a grain. As a cubic inch of fine gold weighs 4902 grains, the thickneſs of the gold leaf examined by the one was the 207355th, and of that by the other only the 248532nd part of an inch.

Dr. Halley found, that of ſuperfine gilt wire ſix feet weighed a grain: M. de Reaumur makes about four inches more go to the ſame weight; and Mr. Boyle is ſaid, if there be no error in the numbers, to have had gilt wire much finer than any of theſe. Allowing ſix feet to make a grain, and the proportion of gold to be that commonly uſed by our wire-drawers; the length to which a grain of gold is extended on the wire, comes to be near 352 feet.

In flatting, the wire is extended, according to M. de Reaumur, one ſeventh part of its length, and to the width

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of one ninety-ſixth of an inch: in ſome trials I have ſeen made by the workmen, the extenſion in length appeared leſs, but that in breadth ſo much greater, that the ſquare extenſion was at leaſt equal to that aſſigned by Reaumur. Hence one grain of gold is ſtretched on the flatted wire, to the length of above 401 feet, to a ſurface of above 100 ſquare inches, and to the thinneſs of the 492090th part of an inch.

M. de Reaumur carries the extenſion of gold to a much greater degree. He ſays the wire continues gilded when only one part of gold is uſed to 360 of ſilver; and that it may be ſtretched, in flatting, one fourth of its length, and to the width of one forty-eighth of an inch. In this caſe, a grain of gold muſt be extended to 2900 feet, or upwards of half a mile, and cover an area of more than 1400 ſquare inches. He computes the thickneſs of the golden coat, in the thinneſt parts of ſome gilt wire, to be no more than the fourteen millionth part of an inch, ſo that it is only about a hundredth part of the thickneſs of gold leaf.

Yet notwithſtanding this amazing tenuity, if a piece of the gilt wire be immerſed in warm aqua fortis, which will gradually diſſolve and eat out the ſilver, the remaining golden coat will ſtill hang together, and form, while the fluid prevents it from collapſing, a continuous opaque tube. To ſucceed in this experiment, the aqua fortis muſt not be very ſtrong, nor the heat great; for then the acid, acting haſtily and impetuouſly upon the ſilver, would diſunite the particles of the gold.

Whether any other metal can be extended to an equal degree is not as yet clear; for as it is the great value of gold which engages the workmen to endeavour as much as poſſible to ſtretch it to the largeſt ſurface, the ſame efforts have not been made in regard to the leſs valuable metals: to make a fair comparifon, trial fhould be made of extending filver upon the furface of gold in the fame manner as gold is extended upon filver. It may be obferved alfo, that as gold is near as heavy again as filver, or contains near double the quantity of matter under an equal volume; fo, if equal weights of the two metals be ftretched to equal extents, the filver will be little more than half the thinnefs of the gold; and converfely, if filver could be brought to equal tenuity with gold in regard to bulk, it would, in regard to quantity of matter, be near of double extenfibility.

Application of gold leaf and wire on other bodies.

THERE are various methods of applying the gold, thus extended, to cover the furface of other bodies. For laces and brocades, the flatted gilt wire is fpun on threads of yellow filk approaching as near as may be to the colour of gold itfelf. The wire, winding off from a bobin, twifts about the thread, as it fpins round; and, by means of curious machinery, too complex to be defcribed here, a number of threads is thus twifted at once by the turning of one wheel. The principal art confifts, in fo regulating the motion, that the feveral circumvolutions of the flatted wire on each thread may juft touch one another, and form, as it were, one continued covering.

It is faid that, at Milan, there is made a fort of flatted wire gilt only on one fide, which is wound upon the thread, fo that only the gilt fide appears; and that the preparation of this wire is kept a fecret, and has been attempted in other places with little fuccefs. There is alfo a gilt copper wire, made in the fame manner as the gilt filver: Savary obferves, that this kind of wire, called falfe gold, is prepared chiefly at Nuremberg; and that the ordinances of France require it to be fpun, for its

diftinction

diſtinction from the gilt ſilver, on flaxen or hempen threads. One of our writers takes notice, that the Chineſe, inſtead of flatted gilt wire, uſe ſlips of gilt paper, which they both interweave in their ſtuffs, and twiſt upon ſilk threads: this practice he inconſiderately propoſes as a hint to the Britiſh weaver. Whatever be the pretended beauty of the ſtuffs of this kind of manufacture, it is obvious that they muſt want durability: the Chineſe themſelves, according to Du Halde's account, ſenſible of this imperfection, ſcarcely uſe them any otherwiſe, than in tapeſtries, and ſuch other ornaments, as are not intended to be much worn, or expoſed to moiſture.

Paper, wood, and other like ſubjects, are gilded, by ſpreading upon them ſome adheſive ſubſtances, and when almoſt dry, ſo as but juſt to make the gold ſtick, applying gold or gilt leaf, and preſſing it down with a bunch of cotton, or the bottom of a hare's foot: when grown thoroughly dry, the ſuperfluous or looſe gold is wiped off, and the fixed golden coat burniſhed with a dog's tooth, or with a ſmooth piece of agate or pebble. Different kinds of adheſive matters are employed for this uſe: where reſiſtance to rain or moiſture is required, oil paints; in moſt other caſes, a ſize, made from cuttings of parchment or white leather, by boiling them in water.

The compoſition commonly uſed for oil gilding conſiſts of yellow ochre, finely powdered, and a ſuitable quantity of drying oil, ground together till they unite into an uniform mixture, of ſuch a conſiſtence, that it may be freely laid on with the pencil, without ſpreading beyond the part on which it is applied, and that it may ſettle ſmooth with a gloſſy ſurface.

For gilding on wood, &c. with what is called water-ſize, the parchment or leather ſize above-mentioned is mixed with whiting, and ſeveral layers of the mixture

ſpread

ſpread upon the piece, one after another is dry, ſo as to cover the grain of the wood, and the imperfections left by the tool, and form a perfectly ſmooth ſurface for applying the gold upon : over this is commonly ſpread ſome of the ſame ſize mixed with yellow ochre. Theſe compoſitions do not well admit of the gold being burniſhed ; and therefore, where burniſhed gilding is required, another mixture, called gold-ſize, is either laid above theſe, or applied on the wood at firſt. The gold-ſize is compoſed of tobacco-pipe clay, or bolar earths, ground with a ſmaller proportion of ruddle and black lead, and tempered with a little tallow and oil olive. In theſe points there is little uniformity among the workmen, the ſame end being obtainable by different means, among which we cannot perhaps diſtinguiſh any ſuperiority in the effect of one to that of another, and of which fancy or prejudice have often choſen the more compounded in preference to the more ſimple. The principal caution, in regard to the gold-ſize, ſeems to be, to uſe no more of the unctuous materials than is neceſſary for procuring the due conſiſtence ; and to make a trial of the preparation previous to its being employed in any work of conſequence.

For ſome purpoſes, the gold is uſed in powder, which, from its being kept in ſhells, is called ſhell gold. This is prepared by grinding gold leaves, or gold-beaters fragments, with a little honey ; and afterwards ſeparating the honey from the powdered gold by means of water. Gold may be reduced alſo, by diſſolving it in mercury, and evaporating the mercury in the fire, or by diſſolving it in aqua regis, and precipitating with certain additions, of which hereafter, into a powder, more ſubtile than can eaſily be obtained by mechanical comminution.

Gilt

Gilt letters or figures on paper may be formed of ſhell gold, tempered with gum water: or the characters may be drawn with a milky ſolution of gum ammoniacum, made in water, and gold leaf applied upon them when almoſt dry: if they have become quite dry, they may again be ſufficiently moiſtened for receiving the gold by breathing on them. For raiſed letters, ſuch as are ſeen in ſome ancient manuſcripts, whiting, yellow ochre, or other earthy powders, are tempered with ſtrong gum water, and the letters formed of this compoſition, by a pen, or more commodiouſly, by means of a type or ſtamp, previouſly oiled, as hinted in a pamphlet on drawing and painting in water-colours, publiſhed in 1731; when dried to a due degree of tenacity, the gold leaf is laid on. If the characters are formed of hard bodies, as powdered glaſs or cryſtal, they may be covered with a burniſhed golden coat, by carefully rubbing them with a piece of ſolid gold.

On the covers of books, the gildings are depreſſed beneath the ſurface, and cemented with whites of eggs. The part being rubbed with this liquid, the gold leaf is applied all over it, and the letters or figures made afterwards by heated ſtamps or rollers, which, at the ſame time that they form the cavities, preſs down and fix the gold in them; while the gold, on the prominent or ſmooth ſurface, adheres ſo looſely as to be eaſily wiped off.

In the poſthumous papers of Mr. Hooke, a method is deſcribed of gilding live craw-fiſh, carps, &c. without injuring the fiſh. The cement for this purpoſe is prepared, by putting ſome Burgundy pitch into a new earthen pot, and warming the veſſel till it receives ſo much of the pitch as will ſtick round it; then ſtrewing ſome finely powdered amber over the pitch when growing cold, adding

ing a mixture of three pounds of linſeed oil, and one of oil of turpentine, covering the veſſel, and boiling them for an hour over a gentle fire, and grinding the mixture, as it is wanted, with ſo much pumice ſtone in fine powder as will reduce it to the conſiſtence of paint. The fiſh being wiped dry, the mixture is ſpread upon it, and the gold leaf being then laid on, and gently preſſed down, the fiſh may be immediately put into water again without any danger of the gold coming off, for the matter quickly grows firm in water. As the qualities of this cement excellently fit it for ſome other purpoſes, it was thought worth while to inſert the whole proceſs.

Drinking-glaſſes, gilt on the edges, have of late been much admired: the beſt of theſe are brought from Germany; thoſe hitherto made in England, though equal in beauty to the foreign, being greatly inferiour in the durability of the gilding. It is ſuppoſed that the German glaſſes are gilt by fire: and it is certain that gold leaf may be made to adhere firmly to glaſs ſoftened by heat, and that the effect may be promoted by the interpoſition of ſome vitreſcent bodies more fuſible than the glaſs itſelf: a piece of glaſs pipe being moiſtened with a weak ſolution of borax, then covered with gold leaf, dried, and heated to a full red heat, the gold was found cemented more ſtrongly than that on the German glaſſes, ſo as ſcarce at all to be ſcraped off with a knife; though in ſome parts it appeared ſpecky or full of ſmall holes, probably from want of ſufficient addreſs in the application of it. But how firmly ſoever the gold may be thus cemented, it would be very difficult to gild the edges of a glaſs in this method without damaging the reſt; and a careful examination of ſome of the German glaſſes ſhewed pretty plainly that the gold had been fixed on them by other means. The glaſſes had evidently been ground and poliſhed; yet the poliſh even of the part under the gold had not ſuffered any injury, which it doubtleſs would have done from a degree of fire ſufficient to ſoften its ſurface, or from any vitreous intermedium melted to it. The gold could be ſcraped off pretty eaſily with a knife; and by ſteeping for a little time in heated ſpirit of wine or oil, particularly in the latter, it became more eaſily ſeparable. One ſide being thus cleared from the gold, there appeared a ſmear upon the glaſs under it; and this being cleaned off, there appeared a like ſmearineſs between the gold and the glaſs on the oppoſite ſide; whereas, on viewing in the ſame manner the glaſs which I had gilt by fire, the ſurface of the gold next to it looked remarkably bright, without the leaſt cloudineſs upon the glaſs. From theſe obſervations it may be preſumed, that the gold is cemented to the German glaſſes on the ſame principle with the foregoing gildings; and that the only ſecret conſiſts in finding a matter, which will adhere to glaſs, ſo as not to be eaſily rubbed off. I have tried maſtich and ſome other reſinous bodies rubbed warm upon the glaſs, and ſeveral ſpirituous varniſhes; but all of them were attended with ſome inconveniencies, particularly with the grand one of not adhering ſufficiently to the glaſs. I recommend to the trial of the artiſts concerned in this affair the harder oil varniſhes; and ſhall myſelf proſecute the enquiry, and when ſucceſsful, communicate the reſult.

S E C T. IV.

Of the effects of Fire on gold.

I. *Of the melting of gold.*

GOLD melts in a low white heat, and, when in fuſion, appears on the ſurface of a luminous bluiſh green colour. Though its expanſion by ſmall degrees of heat, as from freezing to boiling water, is leſs than that

that of moſt of the other metals, yet in fuſion it ſeems to expand more than any of the others; riſing up with a more convex or elevated ſurface, as it becomes fluid ; and ſubſiding, and growing more concave or depreſſed, as it ſets again or returns to ſolidity. From this property it follows, that gold is leſs fit for receiving ſharp and perfect figures when caſt into moulds, than ſilver, copper, lead, or tin, which do not ſhrink ſo much, and far leſs ſo than iron or biſmuth, which expand in their paſſage from a fluid to a ſolid ſtate.

The workmen, for the melting of gold, chuſe generally a black lead crucible, on account of its being ſmoother than the Heſſian or other common ſorts, and conſequently leſs apt to retain any particles of the coſtly metal : it is likewiſe much leſs liable to crack, may be uſed for ſeveral fuſions, and does not require the precautions neceſſary to be obſerved where the others are employed.

When the gold is divided into ſmall parts, as filings, though all the particles be brought to perfect fluidity, they do not eaſily reunite into one maſs, many of them continuing frequently in diſtinct drops. This repugnance is judged to proceed from ſmall atoms of duſt, or other extraneous matters, adhering to the ſurfaces of the particles, and preventing their cloſe contact : the addition of certain fuſible ſaline ſubſtances, which diſſolve and vitrefy earthy bodies in the fire, is found to remove the impediment, and to collect and unite the gold however divided. The uſe of fluxes is abſolutely neceſſary in theſe circumſtances; and from their apparent utility here, it has been thought that they were needful in other caſes, and hence they are often employed where they ſeem to be little wanted.

Borax, one of the moſt powerful diſſolvents of earthy matters, is, in this reſpect, one of the beſt fluxes for gold; but the gold melted with it, however fine, is commonly obſerved to have its colour made ſomewhat paler. From what cauſe this ſlight diminution of the colour proceeds, I have not been able to diſcover: nor do the workmen find the diminution cónſiderable enough to prevent their uſing borax more generally than any other kind of flux. Nitre, added to the borax, prevents this effect; and gold previouſly made pale by borax has its colour reſtored by melting it with an addition of nitre: hence this ſalt is uſefully employed where the gold is deſigned for the high coloured ſort of leaf, for gilding, or other purpoſes where the high colour of the metal is a principal object. When gold is alloyed with copper, and the full proportion of the copper is to be preſerved, nitre is never to be uſed, the baſe metals being ſcorified or deſtroyed by it: in this caſe it will be adviſeable to add to the borax a little charcoal in fine powder, which will preſerve the copper from being ſcorified by the heat.

There is another material point, in melting gold, the preſervation of its malleability; which is very liable to be injured, either from an exceſs, or deficiency, or too ſudden an abatement of the heat, occaſioning an undue arrangement of its parts at the time of its becoming ſolid. When the gold is made exceſſively hot, and the mould, into which it is to be poured, is warmed but little or not at all, the metal almoſt always contracts a degree of hardneſs and rigidity; whereas by duly proportioning the heat of the mould to that of the metal, its ſoftneſs and toughneſs may generally be ſecured. The gold-beaters, to whom theſe qualities are of more importance than in any other art, heat the mould, as already obſerved,

obſerved, till the tallow, which it is rubbed with, runs and ſmokes, without taking flame ; and pour out the gold as ſoon as its ſurface appears of a bright green colour : the clearneſs of the colour ſerves them as a mark both of the gold being of a proper degree of heat, and of its being fine. Thoſe who work in alloyed gold judge alſo from the appearance of the ſurface, whether the metal is of ſuch a heat, or ſuch a diſpoſition, as to prove tough or eager when cold ; taught, by uſe, marks which cannot eaſily be deſcribed. It is ſuppoſed by ſome, that gently ſhaking or ſtriking the crucible, ſo as to communicate a kind of undulatory motion to the fluid metal juſt before it is poured out, contributes to its toughneſs.

It is a general opinion among metallurgic writers, that fine gold, in fuſion, is made brittle by the contact of vegetable coals not thoroughly burnt, or by their fume ; and what is pretty ſingular, that gold alloyed with copper is not ſo ſubject to receive this injury. But it is probable that the brittleneſs, aſcribed to this cauſe, depended rather upon others : for the gold-beaters, who leave their crucible open, do not find, that the toughneſs of the gold is at all diminiſhed, either by the vapour of the charcoal, or by a coal in ſubſtance falling in ; though, if any ſuch diminution happened, it could not be ſuppoſed to eſcape their notice. There appears to be little danger to the malleability of gold from any kind of fumes but metallic ones.

When gold is made brittle by a ſmall admixture of baſe metals, or by their fumes, its malleability may be reſtored by melting it with a little nitre, which ſcorifies and diſſolves all the other metals except ſilver and platina. The nitre ſhould be thrown upon the gold juſt as it is going to melt ; and the metal poured out as ſoon as it flows thin. A long continuance of the fuſion is apt

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to deſtroy the effect of the nitre, and render the gold as brittle as it was before: for ſo much of the nitre, as has acted upon the baſe admixtures of the gold, is changed by that action into an alkaline ſalt; and the ſlighteſt acceſs of any inflammable matter is ſufficient to revive the ſcorified metallic particles from the alkali, and render them again miſcible with the gold. Corroſive mercury-ſublimate, thrown by a little at a time upon gold in fuſion, with care to avoid its noxious fumes, anſwers the ſame end with nitre, and is commonly preferred to it by the workmen: on what foundation the effect of ſublimate depends, will appear hereafter.

II. *Of the alterations ſaid to be producible in gold by fire.*

The greateſt degrees of artificial fire, continued for a length of time, have not been obſerved to make any alteration in gold. Gaſto Claveus, in an apology for the alchemiſts, printed in the ſecond volume of the *Theatrum chymicum*, relates, that he put an ounce of pure gold, in an earthen veſſel, into that part of a glaſs-houſe furnace where the glaſs is kept conſtantly melted, and continued it there in fuſion for two months together; and Kunckel mentions a like experiment, made in the glaſs furnace of the duke of Holſatia, in which the gold was expoſed to the fire for almoſt thirty weeks. Theſe vehement and continued degrees of heat it was found to ſupport, without ſuffering any ſenſible alteration of its quality, or diminution of its weight; whereas the other metals, platina and ſilver excepted, are ſoon deprived by fire of their metallic aſpect, and either diſſipated in fumes, or changed to an earthy or glaſſy form.

What common fire effects in the baſe metals has been ſaid to be effected in gold by the more intenſe heat collected in the focus of large burning-glaſſes. Mr. Hom-

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berg reports, in the memoirs of the French academy for the year 1702, that he expoſed gold, on a piece of charcoal, to a burning lens, about thirty-three inches in diameter, whoſe activity was further increaſed by the interpoſition of a ſmaller lens placed at a proper diſtance for contracting the focus into a leſs compaſs: that this vehement heat produced a powdery matter on the ſurface of the gold, which, gathering together, formed a vitreous drop in the middle, and then run off to the ſides; that the ſurface, now bright, became again gradually covered with a like duſt, which in like manner vitrefied and run off; that freſh drops of glaſs continued to be thus produced; and that at the ſame time great part of the gold evaporated in fumes.

This experiment, as Cramer very juſtly remarks, does not ſeem to have been made with ſufficient care, or carried to a ſufficient length, to warrant the conſequences that have been drawn from it. The purity of the gold ought to have been ſcrupulouſly examined, which it does not appear to have been at all; and ſuch part of it as remained unaltered after the operation, ought to have been further ſubmitted to the ſame treatment; for if any part of the gold was really changed, the whole would doubtleſs have ſuffered the ſame change from a continuance of the ſame cauſe. The author, ſenſible of this, ſays indeed, that if the gold be expoſed long to the heat, it will at length be totally vitrefied or evaporated: but he does not affirm that this actually did happen, and ſeems only to have judged from the firſt appearances that it would happen. To attempt the revival of the glaſs into gold again, which Cramer and Macquer require for the ſatisfactory proof of its having been produced from gold, was not perhaps to be expected from him; ſince, according to his theory, the glaſs conſiſted only of the earthy part of the

the gold, the ſpecificating principles of the metal being ſuppoſed to have evaporated in the intenſe heat: yet, if he really believed that it proceeded from the gold at all, it is extremely ſtrange, that ſo curious a chemiſt ſhould paſs over a product ſo extraordinary, and ſo intereſting to his favourite purſuits, without the leaſt examination, and even neglect to repeat and verify the ſingular experiment by which it was obtained; eſpecially as he had all poſſible opportunities of proſecuting the enquiry, the apparatus being at his command, and the materials provided for him by royal munificence. From one of his ſubſequent papers publiſhed in the ſame memoirs for the year 1707, it appears, that this vitrification of the gold was called in queſtion by one who had been witneſs to the experiment; who took notice that ſome aſhes, flying off from the charcoal on which the gold was placed, fell from time to time upon the ſurface of the metal; and hence judged, that the little quantity of glaſs obtained was no other than a vitrification of theſe aſhes. An objection ſo well founded required ſurely a repetition of the proceſs, and a more attentive obſervation of the phenomena; but the author anſwers only by another experiment, which appears alſo to be ſingle in its kind, that when ſilver was expoſed on a piece of charcoal in the ſame manner, no vitrification happened; as if the aſhes could not be caſually accumulated on the metal, ſo as to produce a ſenſible vitrification, in one inſtance, without being ſo in another.

I have been the more particular in the account of this experiment, becauſe it has been relied on by many as an indubitable proof of gold being alterable in its nature; and becauſe a due attention to what the author himſelf has thought fit to communicate, ſhews it to be at beſt too imperfect for any ſtreſs at all to be laid upon it. The want of a proper apparatus here is an inſuperable obſtacle

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to my repeating the experiment: but it is ſaid that others have repeated it, and found ſtrong reaſons to believe that Homberg was deceived. M. Macquer relates, that ſeveral perſons have expoſed gold to the focus of the ſame burning lens, and even of others ſtill ſtronger, without ever being able to vitrefy it: and that, though the gold did indeed decreaſe in weight, yet the diminution appeared to happen, not from any of the principles of the metal being ſeparated, but from minute globules of it forced off in ſubſtance; many of which were catched on a piece of paper placed underneath, and found to be perfect gold unchanged. It is probable, that theſe globules were forced off from the liquefied gold, not by the action of the heat upon the metal itſelf, but upon its veſſel or ſupport; for all the common veſſels, or other ſubſtances that can be employed for this purpoſe, on being expoſed ſuddenly to a great degree even of artificial fire, crackle or fume, and throw up a part of their contents.

The earlier chemiſts, finding gold to be proof againſt the vehemence of their fires, thought milder means might be more effectual, for looſening the cloſe union of its component parts, and producing changes in it ſimilar to thoſe producible in the baſe metals. Accordingly they expoſed it, for ſeveral weeks or months together, to the immediate action of a gentle fire or flame not much greater than that in which lead melts: by this method it is ſaid to have been notably altered in its properties, and to have aſſumed ſeveral new ones: Kunckel, in his *Laboratorium Chymicum*, affirms that he has ſucceeded in this experiment, and ſays that the gold ſwells up into a ſpongy ſubſtance, like iron treated in the ſame manner. The obſcure and imperfect accounts given of the proceſs prevent our being able to repeat it ſo as to determine with certainty its true effect: but there appears as little reaſon to believe, in this as in the other caſe, that the gold ſuffered any permanent change. The gold is required to be previouſly prepared: if this preparation conſiſts, as it moſt probably does, in combining it with any other kind of matter that will abide with it in the fire, and reducing it into ſubtile powder, a heat of no long continuance will occaſion a remarkable alteration in its aſpect, though its other properties remain entire. If gold leaf be divided by grinding it with an admixture of earthy powders, as calcined hartſhorn or chalk, or with ſaline ones of the more fixed and leſs fuſible kind, as vitriolated tartar, and expoſed, for ſixteen or twenty hours, to a moderate heat, ſcarce ſufficient to keep the veſſel red hot; the gold wholly loſes its metallic brightneſs, and changes its yellow colour to a red or purple. On ſeparating, by means of water or acids, the ſoluble ſalt or earth, the remaining golden powder recovers by ſimple fuſion its proper metallic form; a ſtrong heat diveſting it of thoſe ſuperficial appearances which a weaker one had induced.

SECT. V.

Of the Mixture of gold with other metals.

THE repugnancy or contrariety, which obtains in ſundry inſtances, between different metallic bodies made fluid by fire, and which is no leſs ſtrongly marked than that betwixt oil and water, is no where obſerved in regard to gold; this metal uniting readily with all the other known metallic bodies, and ſeeming to have a ſtrong, though not equal, affinity to them all.

I. *Of*

I. *Of the mixture of gold with mercury: Gold powder, water-gilding,* &c.

Mercury, in the greateſt cold that obtains in our atmoſphere, adheres readily to gold, totally conceals its colour, communicating a ſilver whiteneſs to every part it touches, and by degrees penetrates and diſſolves it. Some of the chemiſts ſpeak of an animation of mercury, by which its activity on gold is greatly increaſed; and Mr. Boyle relates, that he had himſelf prepared mercury, ſo as to diſſolve half or even equal its weight of gold leaf, and to produce, during the diſſolution, a ſenſible heat, ſometimes conſiderable enough to be offenſive to the hand: but an enquiry into this point belongs rather to the hiſtory of mercury than of gold.

In order to obtain a ſmooth amalgam, or uniform mixture, of gold and common mercury, the union is expedited, by reducing the gold into thin plates or grains; which are heated red hot, and in this ſtate thrown into as much mercury, as will cover them, previouſly heated in another crucible, till it begins to ſmoke: on ſtirring them together with an iron rod, the gold ſoon diſſolves and diſappears. If the amalgam is deſigned for any nice uſes, it ſhould be cleanſed, from any filth it may have contracted, by grinding it in a glaſs, ſtone, or wooden mortar, with ſome common ſalt and water, and occaſionally renewing the water, till the amalgam ceaſes to diſcolour it, and appears of a pure vivid brightneſs.

When the proportion of mercury is large, ſo that the mixture continues fluid when cold, a conſiderable part may be ſeparated by preſſing it through ſoft leather, as the thicker kind of waſh-leather or doe-ſkin: ſo much of the quickſilver may be ſqueezed out, as to leave a butyraceous or conſiſtent maſs, containing little more than one part of mercury to two of gold, but ftill of a filver whitenefs, as if there was no gold in it. The confiftent amalgam grows foft on being warmed or worked between the fingers, and hardens on lying in the cold, whence it has been propofed as a proper material for making feals from impreffions in wax: the amalgam of gold appears however to have no advantage in this refpect above thofe of the inferiour metals, as is well known to fome impoftors, who have fold amalgams of bafe metals, for this ufe, as curious preparations of gold. The mercury, ftrained off from the amalgam, fhould be referved for the like purpofes again, as the leather, though no vifible imperfection happens in it, may have its pores fo far dilated by the preffure, as to fuffer fome fmall particles of the gold to pafs through with the mercury: this may be difcovered by evaporating a little of the quickfilver over the fire, which in this cafe will leave a yellow fpot on the bottom of the veffel.

Mercury, one of the moft volatile of the metallic bodies, is expelled from gold by a fire not fufficient to make the mixt red hot. If the amalgam is expofed haftily to this degree of heat, it is apt to fwell up and leap about, and part of it to be thrown over the veffel: if the fire is gentle at firft, and increafed by degrees, the mercury exhales quietly. The impalpable atoms, into which the gold had been divided by its diffolution in the quickfilver, continue difunited after the quickfilver has exhaled; provided due care is taken in the regulation of the fire, and in ftirring and rubbing the matter, towards the end of the procefs, fo as to expofe it equally to the heat, and prevent its running into lumps. By this method a powder of gold may be obtained, much finer than that prepared by the grinding of gold leaf, and which has likewife this advantage, for the purpofes of painting, that

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it admits better of being burnifhed. It is obvious, that for ufes of this kind, the mercury ought to be pure, as well as the gold : for the lead or other bafe metals, with which mercury is too frequently impregnated, will be left behind, and difcolour the gold.

If an amalgam of gold be fpread upon copper, and the mercury evaporated by fire, the gold will remain fixed all over the furface of the metal, and thus afford a firm and durable gilding. The workmen rarely chufe pure copper for gilding upon in this manner, but generally mix with it about a feventh part of brafs, that is, of a compofition of copper and zinc : they fuppofe that this addition renders the copper lefs porous, and makes a lefs quantity of gold to ferve : whatever there may be in this notion, the brafs is plainly of ufe on another account, to facilitate the adhefion of the mercury; for mercury unites exceeding difficultly with pure copper, and much more eafily, as I have often found in experiments of amalgamation, with copper divided by zinc.

The piece to be gilt being well cleaned, fome mercury, fhaken with a little aqua fortis, is fpread upon it, till the furface appears all over white, as filver : being then heated, and re-touched in thofe parts which have efcaped the mixture, the amalgam of gold is laid on : the heat, foftening the amalgam, makes it fpread the more freely; and the intervention of the mercury and aqua fortis occafions it to adhere more uniformly. The piece, thus covered with the amalgam, is placed on a convenient fupport, over a charcoal fire; and examined from time to time, as the mercury evaporates, that if any deficiencies appear, they may be fupplied with a little more of the amalgam before the procefs is completed. If a thicker gilding is required, than can refult from fo much of the amalgam as is applied at once, the piece,

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after the firſt quantity has left its gold fixed upon the ſurface, is rubbed afreſh with the mixture of mercury and aqua fortis, and more of the amalgam ſpread upon it : after the evaporation of the mercury from this, another and another quantity may be applied in the ſame manner. The golden coat, left after theſe operations, is ſometimes of a pale dead colour ; occaſioned perhaps, partly, by impurities in the mercury, and partly, by a little of the mercury itſelf left unevaporated. Whatever be the cauſe, the workmen find a remedy in rubbing upon the piece, while warm from the fire, (after the looſe particles of gold have been wiped off with a clean ſcratch bruſh, made of very fine braſs wire bound together,) a compoſition, called gilding wax, which being burnt off, ſome more of it is rubbed on, and this application repeated till the gold appears of a proper colour. The gilding wax is compoſed of bees-wax, red ochre or ruddle, verdegris, vitriol or alum, and ſometimes other additions : the acid of the ſalts and the cupreous part of the verdegris ſeem to be the materials on which the effect of the compound chiefly depends. I have been informed by an ingenious artiſt, that he has employed for many years a ſaline compoſition without wax, and found it to anſwer extremely well : equal quantities of nitre, ſal ammoniac, green vitriol, and verdegris in fine powder, are mixed together, moiſtened with water, and applied upon the piece ; which is then heated till the mixture ſmokes, and quenched in urine.

There are two principal inconveniencies in this buſineſs : one, that the workmen are expoſed to the fumes of the mercury, and generally, ſooner or later, have their health greatly impaired by them : the other, the loſs of the mercury ; for though part of it is ſaid to be detained in cavities made in the chimney for that purpoſe, yet the greateſt part of it is loſt. From ſome trials I have made it appeared that both theſe inconveniencies, particularly the firſt and moſt conſiderable one, might in good meaſure be avoided, by means of a furnace of a due conſtruction. If the communication of a furnace with its chimney, inſtead of being over the fire, is made under the grate, the aſh-pit door or other apertures beneath the grate cloſed, and the mouth of the furnace left open; the current of air, which otherwiſe would have entered beneath, enters now at the top, and paſſing down through the grate to the chimney, carries with it completely both the vapour of the fuel, and the fumes of ſuch matters as are placed upon it: the back part of the furnace ſhould be raiſed a little higher above the fire than the fore part, and an iron plate laid over it, that the air may enter only at the front, where the workman ſtands, who will thus be effectually ſecured from the fumes, and from being incommoded by the heat, and at the ſame time have full liberty of introducing, inſpecting and removing the work. If ſuch a furnace is made of ſtrong forged (not milled) iron plate, it will be ſufficiently durable: the upper end of the chimney may reach about a foot and a half higher than the level of the fire: over this is to be placed a larger tube, leaving an interval of an inch or more all round between it and the chimney, and reaching to the height of ten or twelve feet, the higher the better. The external air, paſſing up between the chimney and the outer pipe, prevents the latter from being much heated, ſo that the mercurial fumes will condenſe againſt its ſides into running quickſilver, which falling down to the bottom, is there catched in a hollow rim formed by turning inwards a portion of the lower part, and conveyed, by a pipe at one ſide, into a proper receiver.

Mr. Hellot communicates, in the Memoirs of the French academy for the year 1745, a method of making raiſed figures

figures of gold on works of gold or silver, found among the papers of Mr. du Fay, and of which Mr. du Fay himself had seen several trials. Fine gold in powder (such as results from the parting of gold and silver by aqua fortis, as described hereafter) is directed to be laid in a heap on a levigating stone, a cavity made in the middle of the heap, and half its weight of pure mercury put into the cavity : some of the fetid spirit, obtained from garlick root by distillation in a retort, is then to be added, and the whole immediately mingled and ground with a muller, till the mixture is reduced into an uniform grey powder. The powder is to be ground with lemon juice to the consistence of paint, and applied on the piece previously well cleaned and rubbed over with the same acid juice: the figures drawn with it may be raised to any degree by repeating the application. The piece is exposed to a gentle fire till the mercury is evaporated so as to leave the gold yellow, which is then to be pressed down, and rubbed with the finger and a little sand, which makes it appear solid and brilliant: after this it may be cut and embellished. The author observes, that being of a spongy texture, it is more advisable to cut it with a chisel than to raise it with a graver; that it has an imperfection of being always pale, and that it would be a desirable thing to find means of giving it colour, as by this method ornaments might be made of exquisite beauty and with great facility. As the paleness appears to proceed from a part of the mercury retained by the gold, I apprehend it might be remedied by the prudent application of a little warm aqua fortis, which dissolving the mercury from the exteriour part, would give at least a superficial high colour : if the piece is silver, it must be defended from the aqua fortis by covering it with wax. Instruments or ornaments of gold, stained by mercury, where the gold is connected with substances

ſubſtances incapable of bearing fire, may be reſtored to their colour by the ſame means.

The foregoing proceſs is given entirely on the authority of the French writer. I have had no experience of it myſelf, but have ſeen very elegant figures of gold raiſed upon ſilver, on the ſame principle, by a different procedure. Some cinnabar was ground, not with the diſtilled ſpirit, but with the expreſſed juice of garlick, a fluid remarkably tenacious: this mixture was ſpread all over the poliſhed ſilver; and when the firſt layer was dry, a ſecond, and after this a third was applied. Over theſe were ſpread as many layers of another mixture, compoſed chiefly of aſphaltum and linſeed oil boiled down to a due conſiſtence. The whole being dried, with a gentle heat, on a kind of wire grate, the figures were traced and cut down to the ſilver ſo as to make its ſurface rough: the inciſions were filled with an amalgam of gold, raiſed to different heights in different parts according to the nature of the deſign; after which a gentle fire, at the ſame time that it evaporated the mercury, deſtroyed the tenacity of the gummy juice, ſo that the coating, which ſerved to confine the amalgam and as a guide in the application of it, was now eaſily got off. The gold was then preſſed down and embelliſhed as in the former method, and had this advantage, that the ſurface of the ſilver under it having been made rough, it adhered more firmly, ſo as not to be in danger of coming off, as M. du Fay ſays the gold applied in his way ſometimes did. The artiſt however found the proceſs ſo troubleſome, that though he purchaſed the receipt for a conſiderable ſum, he has laid the practice aſide.

Mercury and amalgams rubbed on iron do not at all adhere to it: there are however means of applying the mercurial gilding on this metal, as well as on copper and ſilver. If the iron be dipt in a ſolution of the blue vitriol of copper, or rubbed with the vitriol itſelf ſomewhat

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moiſtened, it becomes immediately covered with a cupreous coat, and now receives the gilding in the ſame manner as ſolid copper.

II. *Of the mixture of gold with ſilver, copper and other metals; the alterations produced by different proportions of different metals, and the effects of ſtrong or continued fire on the mixtures.*

All the metals, which melt eaſier than gold, diſſolve it in a leſs heat than the gold would melt in; and gold, brought into fuſion, diſſolves in like manner thoſe which are more difficultly fuſible. It is particularly diſpoſed to unite with iron, of which, if the iron be pure, it diſſolves twice or thrice its own weight in a degree of heat very far leſs than that in which iron melts: if ſtirred in fuſion with an iron rod, it corrodes a part of the iron, and a large portion of the gold adheres to the inſtrument: hence Cramer, Schlutter, and other writers on aſſaying, prudently caution againſt the uſe of an iron rod for the ſtirring of melted gold. In virtue of this property, gold proves an excellent ſolder for the finer kinds of iron and ſteel inſtruments: a ſmall thin plate of gold being wrapped round the parts to be joined, the gold is ſoon made to melt by a blow-pipe, and ſtrongly unites the pieces together, without any injury to the inſtrument, however delicate.

On copper, its apparent action is much leſs conſiderable; yet, when once it is united with this metal, the increaſe of fuſibility is more ſtrongly marked, mixtures of gold with a little copper being found to melt with leſs heat than pure gold itſelf. Hence mixtures of this kind ſerve as ſolders for gold: two pieces of fine gold are ſoldered by gold that has a ſmall admixture of copper; and gold alloyed with copper is ſoldered by ſuch as is alloyed with more

more copper: the workmen add a little ſilver as well as copper, and vary the proportions of the two to one another, ſo as to make the colour of the ſolder correſpond, as nearly as may be, to that of the piece: copper alone, in the quantity requiſite to procure the due fuſibility, would incline the maſs too much to its own colour.

Silver, mixed with gold, dilutes its yellow colour more or leſs according to its quantity. One twentieth or leſs of ſilver renders gold very ſenſibly paler; and the addition of a twentieth more makes it ſenſibly paler than the former proportion: but when the ſilver is increaſed to a tenth or an eighth of the gold, ſo ſmall differences in the quantity ſcarce occaſion ſenſible variations in the colour, and ſtill leſs ſo when the ſilver exceeds the gold; a little gold not near ſo much affecting the colour of ſilver, as a little ſilver does that of gold. All the mixtures are very malleable, though ſomewhat harder, firmer, and more ſonorous, than either of the metals ſeparately: in this reſpect, as in the colour, a little ſilver affects gold more than a little gold does ſilver.

Copper, in ſmall quantity, renders the gold ſomewhat harder than ſilver does, and ſomewhat heightens the colour, by ſuperadding its own reddiſhneſs to the gold yellow; but if the quantity of copper is conſiderable, the coppery hue prevails: a little gold mixed with copper makes no remarkable alteration either in its colour or ductility. The high colour which a ſmall proportion of copper communicates to gold, has been obſerved in different circumſtances, and given riſe to ſundry proceſſes for the exaltation of the colour of the noble metal. Some recommend for this purpoſe the ſuperficial application of verdegris, blue vitriol, or other preparations of copper; which indeed are often uſed by the workmen, but whoſe effect ſeems to be, not the heightening of the colour of the metal itſelf, but the removal of the ſuperficial tarniſh or diſcoloration which alloyed gold is apt to receive from the fire; and this effect appears to proceed, not from the copper, but from the acid which theſe preparations contain. Others, for communicating a high colour to the whole maſs, direct the gold to be melted with three or four times its weight of the higheſt coloured copper, the mixture to be granulated or flatted into plates, then boiled in weak aqua fortis, in order to ſeparate as much of the copper as the acid will extract, the remaining gold to be melted with freſh copper, and this proceſs repeated ſeveral times. It is apprehended, that by this method only a ſmall portion of the copper will be left in the gold, and that this little will be ſo intimately commixt with it as to reſiſt the action of acids and of the air; and that the gold will thus receive the admired colour, without being made much more liable to tarniſh, or to change its colour on waſhing or boiling, than fine gold.

Platina, next to the two foregoing metals, injures the malleability of gold the leaſt. Mixtures of gold with one twentieth of its weight of platina I have drawn into moderately fine wire: mixtures of it with one fourth its weight were forged into pretty thin plates: and a mixture of equal parts (which is as large a proportion of platina as can be eaſily united with gold) was indeed brittle, but bore ſeveral ſtrokes, and ſtretched conſiderably under the hammer, before it began to crack about the edges. With regard to the colour, ſmall proportions of the platina, as one ſixtieth, make little alteration: in larger proportions, as one twelfth, it communicates, not its own whiteneſs, but a particular and remarkable dull hue, the compound approaching more to the colour of bad copper than of gold:

gold: in the quantity of one fourth and upwards, it gives a dull whitiſhneſs.

Iron or ſteel, in very ſmall proportion, render gold hard and eager, and on increaſing the quantity of the iron, the mixt continues brittle: ſome of theſe mixtures are of ſuch a degree of hardneſs and cloſeneſs, as adapts them for receiving a fine edge, and it is ſaid that they have been formed into razors. The colour of the gold is made pale by a ſmall quantity of the iron: equal parts of the two form a grey maſs: if the quantity of the iron is three or four times greater than that of the gold, the mixt proves of a white colour, approaching to that of ſilver.

All the reſt of the metallic bodies give paleneſs, dullneſs, and brittleneſs, in different degrees, ſome more than others in the ſame quantities. Of tin and lead the moſt minute proportions, even the vapours which riſe from them in the fire, though not ſufficient to add to the gold any weight ſenſible in the tendereſt balance, make it ſo brittle that it flies in pieces under the hammer; though gold, contrariwiſe, mixed with a ſmall proportion of the lead or tin, does not appear to injure their malleability. Something of the ſame kind ſeems to happen in the mixtures of gold with the metals which of themſelves are brittle, as zinc, biſmuth, and regulus of antimony; a ſmall proportion of theſe metals rendering gold extremely brittle, whereas, when the brittle metal is in large proportion, its fragility is diminiſhed by the gold: thus Mr. Hellot obſerves, in a paper on zinc publiſhed in the French memoirs for the year 1735, that a mixture of three parts of zinc and one of gold does not break ſo eaſily as a mixture of equal parts of the two. Some of theſe mixtures, particularly one of equal parts of gold and zinc, bear a fine poliſh, and probably, as the above mentioned author takes notice, would

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be excellent for making ſpecula, being leſs ſubject to tarniſh in the air than the compoſitions of which copper is the baſis.

It is ſuppoſed by many, that gold, melted with other metals, is always diffuſed equally through their whole volume, inſomuch, that the quantity of gold, obtainable from any part of the mixt, ſhall bear exactly the ſame proportion to that part, as the whole of the gold does to the whole maſs. There appears, however, in many caſes, a ſenſible inequality in the diſtribution. M. Hellot, in his French tranſlation of Schlutter's German work on the ſmelting and aſſaying of ores and metals, gives an account of an experiment which clearly ſhewed this inequality: a quantity of ſilver, amounting to upwards of twenty pounds, containing about a fifty-ſixth part of gold, was melted in a crucible, and poured into cold water, in order to its being reduced into grains: by dipping at different times an iron ladle into the water, under the ſtream of metal, he received a part of the firſt running, a part of the middle, and a part of the laſt: the three parcels, aſſayed ſeparately, were all found to differ in their content of gold.

There is a curious experiment of Mr. Homberg's, related in the French memoirs for the year 1713, which, though I have not yet tried it, I ſhall venture to inſert on account of its ſingularity. Equal parts of gold and ſilver, melted together and reduced into fine grains, were put into a crucible, with a mixture of about equal parts of decrepitated ſea ſalt and rough nitre under them: the crucible being kept in a ſmall fire, in a wind-furnace, for about a quarter of an hour, and then ſuffered to cool and broken, the gold was found in one lump at the bottom, and the ſilver above it in two pieces, with ſome grains,

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wrapped up in the ſalts, which had not entirely melted: the ſilver was perfectly pure, and without the leaſt mixture of gold, but the gold retained about a ſixth part of ſilver. He repeated the experiment with different mixtures of the two metals, and found the ſilver to be always pure from gold, but that the gold retained a little of the ſilver, except in two inſtances, in which this alſo was pure. He obſerves, that unleſs the gold and ſilver are nearly in equal quantities, the ſeparation does not ſucceed; and that the only nicety in the proceſs conſiſts in hitting the due point of fuſion, for if the fire is too long continued, or the mixt made to flow thin, the two metals, after they have parted from one another, mingle again together.

We have already ſeen that mercury may be evaporated from gold by a gentle heat: there are ſome other metallic bodies alſo, which may be totally diſſipated from gold by fire, but with conſiderable differences in regard to the circumſtances of the ſeparation. Arſenic, though of itſelf very volatile, adheres ſo ſtrongly to gold as not to be eaſily expelled: if the mixture is urged haſtily with a violent fire, a part of the gold is carried off by the arſenical fumes. Zinc, in open veſſels, burns, changes into white flowers, and throws up along with its own fumes a ſmall portion of the gold, which tinges a part of the flowers of a yellowiſh colour inclining to purple: theſe flowers do not riſe high, part of them forms about the ſurface of the maſs, and when once they are formed, they reſiſt the fire; ſo that though the whole of the zinc, by frequent ſtirring and ſtrong fire, ſhould be thus changed, yet, unleſs the proportion of gold be large, the noble metal remains divided and interſperſed among the flowers. In cloſe veſſels, or where the external air has no acceſs, the zinc, by force of fire, may be totally made to ſublime: it may be expelled alſo in an open crucible, by keeping the mixt covered with powdered charcoal, which, ſo far as it reaches, prevents the above change of the zinc.

The diſſipation of regulus of antimony from gold requires, on the contrary, not only an open veſſel and free acceſs of air, but the artificial impulſe of a blaſt of air upon the ſurface : if the fire is vehement, the crucible ſhallow, and the air ſtrongly impelled, the gold is volatilized by this metal more conſiderably than by either zinc or arſenic ; but with proper care, the regulus may be blown off without any ſenſible loſs of the gold. Some have propoſed regulus of antimony inſtead of mercury for gilding on copper ; as alſo on earthen ware and glaſs, on which the mercurial gilding cannot be applied : the regulus and gold, firſt melted together, are directed to be ground into fine powder, which being ſpread upon the piece, the whole is expoſed to a ſtrong red heat, ſo as to evaporate the regulus. The inconveniencies of this method are, that the powder does not of itſelf adhere to the ſubject, and can ſcarce be equably ſpread, and that part of the gold is waſted : that glaſs melts in the heat neceſſary for the exhalation of regulus of antimony, and that copper is liable to be corroded by the regulus, and have its ſurface rendered uneven.

The baſe metals in general, which calcine or change to an earthy form in the fire, ſuffer the ſame change when mixed with gold, though with ſome differences in the degree of facility. If gold, mixt with a ſmall proportion of theſe metals, be kept for a conſiderable time in fuſion, the baſe metal, gradually ſcorifying, riſes to the ſurface, no longer miſcible with the gold. If the gold is in leſs quantity, and the fire inſufficient to bring the maſs into fuſion, the whole mixt loſes by degrees its metallic aſpect, and the gold remains intermingled among the calx of the baſe metal, in a more attenuated ſtate than it can perhaps be brought to by other means: by long continuance of a moderate fire, the calx acquires more or leſs of a purple hue, according to the quantity of the gold and the natural colour of the calx of the metal it is mixed with.

Tin, which when calcined by itſelf is neither vitreſcible nor fuſible in the fire, and which cannot be perfectly vitrefied by the moſt active ſubſtances commonly made uſe of in this intention, is remarkably affected by the admixture of gold. Dr. Brandt relates, in the tranſactions of the Swediſh academy for the year 1753, that two parts of tin, and three of gold, being melted together, reduced into fine powder, and calcined only to an aſh grey colour, the calx melted with eaſe into a yellow glaſs, at the bottom of which was found a metallic regulus. I ſhall examine this curious experiment on another occaſion.

Though gold, in the highly attenuated ſtate into which it is thus reduced by calcination with baſe metals, is by ſome bodies otherwiſe acted upon than in its groſſer form, as appears from its habitude to tin in the preceding paragraph, and to the marine acid in the following ſection, it is by no means diveſted of its metallic properties, or changed into a calx. Mercury, which does not diſſolve metallic calces, any more than unmetallic earths and ſtones, on being triturated with the compound powder, imbibes the gold; and on this foundation, gold, blended with the baſe metals, may in ſome caſes be advantageouſly extracted from them.

If mixtures of gold and lead be continued in a fire ſufficient to keep them in perfect fuſion, the lead, calcining and riſing to the ſurface, changes into a fluid ſcoria, eaſily ſeparable from the gold by means to be deſcribed hereafter. Biſmuth alſo ſcorifies and ſeparates in the ſame manner; and both theſe metals, promoting the ſcorification, or fuſion of the calces, of the other baſe metallic bodies, promote their ſeparation from gold in the fire.

SECT. VI.

Of the action of acid and ſulphureous bodies on gold; various ſolutions of it, and their properties.

I. *Gold with the nitrous acid.*

THE acid ſpirit extracted from nitre, whether in its concentrated ſtate, or in the more dilute one, in which it is commonly called aqua fortis, has not been found to have any action on pure gold. Hence gold is freed, by this acid, from ſilver, copper, lead, zinc, mercury, and ſuch other metallic bodies as the acid diſſolves: but that this ſeparation may ſucceed, the quantity of the inferiour metal muſt be conſiderably greater than that of the gold, for otherwiſe its particles will be enveloped by the gold ſo as to be entirely defended from the acid.

When nitre in ſubſtance is mixed with certain bodies containing the vitriolic acid, as calcined vitriol, and the mixture made red hot, the acid of the nitre is extricated in yellowiſh red fumes. If the impure gold is interlaid with ſuch a mixture, and expoſed to the fire along with it, in a cloſe veſſel that the fumes may be confined; the baſe metal will be in part corroded, though its quantity is far leſs than would be acted upon by the acid in its liquid ſtate, but in this caſe the acid penetrates only a little way into the maſs. Hence, for the purification of gold by this method, the operation muſt be two or three times repeated, the metal being each time melted and reduced into thin plates, that freſh ſurfaces may be expoſed to the fumes: and in the proceſs by aqua fortis, if the baſe metal does not amount to a certain quantity, more baſe metal muſt be added. The method of con-

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ducting the operations will be described in the eighth and ninth Sections.

As pure gold has been always found to resist the nitrous acid, and as gold divided by silver or other metals has not been observed to be acted upon by that acid in the common processes of assaying or refining; it has been universally laid down as an axiom, that the pure nitrous acid can in no case have any action on gold, and that, in whatever manner it be applied to mixtures of gold with other metals, it can dissolve only the inferiour metal, and will always leave behind the full quantity of gold which the mixt contained. Here it may be observed, once for all, that as the mutual relations of bodies are multifariously modified by the circumstances in which the subjects are applied to one another, sundry bodies discovering strong repugnancies in some circumstances, and strong affinities in others; we never can infer, from the constancy and uniformity of the action or inaction of two bodies on each other in all the circumstances in which they have been applied, that their relations will be the same in any other circumstances; and consequently, unless all possible means of application were known and experienced, no axiom, in regard to the chemical affections of bodies, ought to be admitted as universal. Though the assayer and refiner depend upon the absolute indissolubility of gold by the nitrous acid, yet there are circumstances, in which gold is dissolved by this acid in considerable quantity.

This curious and important discovery was made by Dr. Brandt, and published in the Swedish transactions for the year 1748. In order to part a mixture of gold and silver, amounting to about fifteen pounds, in which the proportion of the silver to the gold was as sixteen to three (including with the silver a little copper which it contained) he boiled it with freſh portions of ſtronger and ſtronger aqua fortis, in a glaſs body, to which was fitted a head and recipient for collecting the acid vapours that aroſe: this method ſhould ſeem at firſt to be a notable improvement on the common proceſs, in which the vapours, that iſſue plentifully during the action of the acid, exhale and are loſt. Nearly all the ſilver and copper being diſſolved, and the ſolution poured off from the gold, the next portion of aqua fortis was boiled down till the matter at the bottom looked like a dry ſalt; which being judged to have been ſo much deprived of the acid, that there was not enough left to render the little remaining ſilver diſſoluble by water, he added more aqua fortis; which, after boiling for ſome time, appeared yellow, and was poured off into a ſeparate glaſs, its yellowneſs being looked upon as a mark of its having become exceeding ſtrong by the loſs of its watery parts in the proceſs.

This yellow aqua fortis he uſed afterwards for diſſolving ſome ſilver, when, to his aſtoniſhment, a conſiderable quantity of gold was found at the bottom of the glaſs, though the ſilver had before been very carefully purified from gold. This experiment was many times repeated, in the preſence of ſeveral aſſayers, and at a meeting of the Swediſh academy, and always with the ſame event; pure ſilver, which gave no mark of gold with common aqua fortis, precipitating from the above yellow aqua fortis a ſpongy lump of gold. In keeping, a part of the gold ſeparated ſpontaneouſly, in form of a brown powder: after it had been long kept, and depoſited much of its gold, it was found on an aſſay to contain more gold than ſilver, in the proportion of 19 to 12: in this ſtate, a quantity of it ſufficient to diſſolve four parts of ſilver yielded during the diſſolution one part of gold; ſo that the nitrous acid is capable of diſſolving above one fourth part as much gold as it is of ſilver. The nitrous ſpirit made uſe of in this operation had been prepared from pure nitre, and the experiment itſelf affords a convincing proof, that it was by the pure nitrous acid that the gold was diſſolved; for if the diſſolution of this metal had been produced, as might be ſuſpected, by means of an admixture of marine acid, the menſtruum could not, in the above method of application, have diſſolved the ſilver.

The foregoing proceſs differs from that commonly followed for the parting of gold and ſilver, in the veſſel being cloſe ſo as to exclude the external air, and in the heat being continued at laſt till the matter became dry, ſo that as the watery parts of aqua fortis riſe firſt in diſtillation, the acid muſt in this caſe have been greatly concentrated. Though the applying a head upon the veſſel may ſeem to be a very immaterial circumſtance in regard to the diſſolution of the metal, it is perhaps one of the moſt eſſential, for both diſſolution and precipitation are in many caſes remarkably influenced by the admiſſion or excluſion of air: after the gold has been diſſolved, if the veſſel be well ſhaken, ſo that air may be copiouſly introduced and mingled with the liquor, the gold, as Mr. Scheffer obſerves, falls quickly to the bottom.

The importance of this experiment, in the way of caution to thoſe concerned in the parting of gold and ſilver by aqua fortis, is apparent. It is probable, that gold has been often diſſolved in aqua fortis, without being known to be ſo; and that this was the true cauſe of the deception of Becher and other chemiſts, who report that they had ſeen ſilver tranſmuted into gold by diſſolution in ſome particular kinds of aqua fortis. Had Dr. Brandt's ſolution paſſed into other hands than his own, it might poſſibly have been looked upon as another inſtance of theſe pretended graduating or tranſmuting menſtruums.

II. *Gold with the marine acid.*

THE pure acid of ſea ſalt has no action on gold, ſo long as the gold retains its metallic form; whether the metal be boiled with it in open or in cloſe veſſels, or expoſed in the fire to its fumes; in which laſt circumſtance, this acid diſſolves or corrodes all the other known metallic bodies, except platina. Hence, though there are ſeveral metallic bodies, as ſilver, which the marine acid in its liquid ſtate does not diſſolve or extract from gold, yet gold may be purified from thoſe metals by the fumes of this as well as of the nitrous acid. On this foundation, the brittleneſs, which a ſmall admixture of lead or tin produces in gold, is remedied, by repeatedly injecting upon it in fuſion a little corroſive mercury-ſublimate; the marine acid of the ſublimate uniting with the lead or tin, and either volatilizing, or changing them into a ſcoria, which is thrown off to the ſides of the veſſel. Small proportions of moſt of the other metals are in like manner ſeparated from gold by ſublimate; the acid having leſs affinity to the mercury of the ſublimate than it has to the others, and accordingly parting from the former to join itſelf to the latter.

When gold is changed to the appearance of a calx, by precipitation from aqua regia with volatile or fixt alkalies, of which hereafter; or by calcination in mixture with tin or biſmuth, as mentioned towards the end of the preceding ſection, the pure marine acid, by the aſſiſtance of a moderate heat, perfectly diſſolves it. I have found that even a weak ſpirit of ſalt will take up gold ſo prepared, though in no great quantity; and that the gold does not precipitate from this as from the nitrous acid, but continues durably ſuſpended.

III. *Gold with the Vitriolic acid.*

THE vitriolic acid, in whatever manner applied, has not been obſerved to have any action on gold, or to promote the action of other acids. Hence, as oil of vitriol diſſolves ſilver by a boiling heat, ſilver and gold may be parted from one another by this acid, as effectually, though not ſo commodiouſly, as by the nitrous. If the compound be reduced into grains or thin plates, and boiled in about twice its weight of oil of vitriol to dryneſs, the ſilver will be ſo far corroded, as to be eaſily waſhed off by a little more of the acid; or if the maſs, after the corroſion, be melted in a crucible, the gold will ſeparate and ſubſide, the ſilver forming a ſcoria above it. Gold may thus alſo be purified from ſeveral other metallic bodies: Mr. Scheffer ſays, that this is the moſt direct way of ſeparating tin from gold.

IV. *Gold with compound menſtrua.*

GOLD is ſaid to be diſſolved by the marine acid mixed with a ſmall proportion of ſpirit of urine; by a mixture of the vitriolic acid with the ſame urinous ſpirit; by a mixture of the vitriolic acid with a little fixt alkaline ſalt; by the vapour, which ariſes during the efferveſcence of the vitriolic acid with fixt alkaline ſalt, collected by diſtillation; in a ſpirit, prepared by ſaturating the vitriolic acid with volatile alkaline ſalt, exſiccating the mixture, diſſolving it in twice or thrice its quantity of aqua fortis, and diſtilling the ſolution. In my experiments, not one of theſe liquors appeared to have any action on gold.

The moſt effectual menſtruum of gold is a mixture of the nitrous and marine acids, called aqua regia; which, in a moderate heat, readily and totally diſſolves it into a

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tranſparent yellow liquor. As this compound does not at all diſſolve ſilver, the gold may be extracted by it from a mixture of gold and ſilver, in the ſame manner as the ſilver is extracted by aqua fortis ; and as the extraction of the ſilver by aqua fortis requires the quantity of ſilver in the mixt to exceed that of the gold, ſo the extraction of the gold by aqua regia requires the gold to exceed the ſilver : the two metals may be ſo proportioned, that neither aqua fortis nor aqua regia ſhall be able to diſſolve either, till an addition is made to the quantity of one or the other metal.

When the quantity of gold in the mixt amounts to ſo much as a third part of the ſilver, aqua fortis leaves always a ſmall portion of the ſilver undiſſolved along with the gold ; and in like manner, when the quantity of gold amounts to ſo much as a third of the ſilver, aqua regia leaves a little of the gold undiſſolved along with the ſilver : when either metal is in ſmall proportion, the other appears to be completely extracted by its proper menſtruum. If the gold, remaining after the parting with aqua fortis, be diſſolved in aqua regia, the ſilver it had retained will ſeparate and be left undiſſolved : and if the ſilver, remaining after the parting with aqua regia, be diſſolved in aqua fortis, the gold it had retained will in like manner ſeparate. This experiment affords a method of determining the preciſe quantity of either metal retained by the other, and a proof of the erroneouſneſs of the opinion of ſome writers, that ſo much ſilver, as gold retains in parting, is actually tranſmuted into gold.

Aqua regia may be prepared, by diſſolving powdered ſea ſalt or ſal ammoniac in four times their weight of aqua fortis, or by diſſolving nitre in four times its weight of ſpirit of ſalt, or by mixing the pure ſpirits of nitre and ſea ſalt together. The firſt is the method moſt commonly followed.

followed. Kunckel obſerves, that by putting the gold into the aqua fortis firſt, and then adding the ſalt by little and little at a time, leſs of the menſtruum will ſuffice than if the ſalt was previouſly diſſolved in the acid ; the conflict, excited by each addition of the ſalt, promoting the diſſolution of the gold : this method appeared upon compariſon to have a ſenſible advantage above the other, whether the ſal ammoniac directed by Kunckel, or common ſalt was uſed : the common ſalt is to be preferred ; for ſal ammoniac, eſpecially when a ſtrong heat is called in aid to haſten the ſolution, is apt to occaſion ſome ſmall part of the gold to be diſſipated during the effervеſcence.

A ſolution in water of common ſalt, nitre and alum, boiled with leaf gold to dryneſs; or the ſalts in ſubſtance, mixed with the gold leaf, and urged with a ſlight red heat for ſome hours in a cloſe veſſel; corrode a conſiderable quantity of the gold into a ſaline form ſo as to be diſſolved upon adding water. The mixture of theſe ſalts, from its acting inſenſibly and without effervеſcence, has been commonly called *menſtruum ſine ſtrepitu:* it can be conſidered no otherwiſe than as an impure aqua regia, acting only by virtue of the acids of the nitre and marine ſalt, which are extricated from their baſes by the acid of the alum.

V. *General properties of ſolutions of gold.*

Solution of gold, whether made in ſpirit of ſalt, or in any of the foregoing aquæ regiæ, is of a bright yellow colour, reſembling that of gold itſelf. It ſtains the ſkin of a deep purple colour, which cannot be waſhed out; and gives a like durable ſtain, though with ſome variations in the ſpecies of the colour, to ſundry animal and vegetable ſubſtances, as dreſſed leather, ivory and bones, feathers, woollen cloth, ſilk, linen, cotton, wood :

to marble it imparts a violet or purplifh colour, which penetrates to a confiderable depth, but on the harder ftones, as agates, it makes little impreffion, communicating only a fuperficial brown tinge. The folution for thefe purpofes, fhould be prepared in Kunckel's method, that the acid may be fully faturated with the metal, and have as little admixture as may be of the faline matter: it fhould be diluted with three or four times its quantity of water, and if the colour is required deep, the piece, when dry, is to be repeatedly moiftened with it. Animal fubftances fhould be previoufly well cleanfed from their unctuofity, and foaked for fome time in water: the others require no preparation of this kind. The colour does not take place till a confiderable time, fometimes feveral days, after the liquor has been applied, and on fome fubjects it is more flow than on others: to haften its appearance, the fubject fhould be expofed to the fun and free air, and occafionally removed into a moift place, or moiftened with water.

When folution of gold in aqua regia is foaked up in linen cloths, and the cloths dried and burnt, the particles of gold remain blended in the brown coaly powder, which, being moiftened with a little water, and rubbed on filver well cleaned from any unctuous matter, gilds it, without the application of heat, or the intervention of any other body: this is a ready but not a frugal way of applying gold on filver.

If the menftruum has been prepared with an addition of fea falt, nitre, or fal ammoniac, and the folution is fet in a warm place, in a veffel flightly covered, fo as to keep out duft, without preventing the evaporation of the watery part of the liquor; the gold, combined with the faline matter, fhoots into yellow cryftals, commonly fmall and irregular. Solutions in the pure marine acid, and in mixtures of the pure acids of nitre and ſea ſalt, are very difficultly made to cryſtallize : in order to the cryſtallization of theſe, the liquor ſhould be evaporated till only about one half of it remains, and then ſet by in the cold with the addition of a few drops of pure ſpirit of wine. The cryſtals obtained from high coloured ſaturated ſolutions are generally of a red colour, and ſometimes, as is ſaid, of a deep ruby red.

On diſtilling with a gradual fire a ſolution of gold made in ſtrong aqua regia, an acid ſpirit comes over, which, from its riſing in red fumes, and from its diſſolving ſilver, appears to be the nitrous acid. On continuing the diſtillation, whitiſh fumes ſucceed, a mark that part of the marine acid begins to riſe; though, after the operation has been protracted till the reſiduum becomes dry, the gold ſtill retains ſo much of the acid as to be diſſoluble in water : it appears to be chiefly, if not ſolely, the marine acid which thus remains combined with the gold; on which foundation, the nitrous acid, employed for the diſſolution of the gold, may be nearly all recovered, and its place ſupplied by an equal quantity of common water; the marine ſpirit, though ineffectual for procuring the diſſolution of the metal in its common form, being ſufficient for keeping it diſſolved. When the matter has juſt become dry, it appears of a deep red colour : on further increaſing the fire, the acid is totally diſſipated, and the gold remains in powder, extremely ſubtile, and of its proper hue. This is a convenient method of obtaining a fine powder of gold : if the aqua regia has been made with an addition of nitre or ſea ſalt in ſubſtance, the ſaline matter, left with the gold, may be ſeparated by water. The moſt eligible aqua regia, for the above purpoſe, is a mixture of the pure acids, or of the nitrous acid and ſal ammoniac; for theſe will be wholly diſſipated by fire, and the gold alone left. If the powder is moiſtened with a ſolution of borax, it may be applied with a pencil on glaſs or porcelane, and by a ſuitable heat durably fixed upon them.

On inſpiſſating nearly to dryneſs a ſolution of gold made in an aqua regia prepared with common ſal ammoniac, abſtracting from the reſiduum ſeveral freſh quantities of the ſame kind of aqua regia, and at length increaſing the fire ſomewhat haſtily towards the end of the diſtillation; the acid carries over with it a portion of the gold, ſufficient to communicate a yellow or a red tinge; and a more conſiderable quantity of the gold, united with the more concentrated acid, ſublimes, of a deep red colour, into the neck of the retort, concreting partly into long ſlender cryſtals, and partly into a firm ſubſtance cloſely applied on the glaſs: the cryſtals lie ſo looſe, that they are apt to fall down again on moving the veſſel; though, if this ſhould happen, after the matter has become cold, they may be eaſily ſeparated again, the reſiduum growing firm as it cools: both the cryſtals and the compact ſublimate diſſolve eaſily in water, deliquiate in the air, and melt with a ſmall heat. By adding to the reſiduum more aqua regia, and repeating the diſtillation ſeveral times, the whole of the gold may thus be made to riſe.

Common aqua regia, prepared with rough ſal ammoniac, appears to volatilize the gold as effectually, as any of the more operoſe compoſitions recommended for this purpoſe by the chemical writers. The rough ſal ammoniac muſt neceſſarily be uſed, not ſuch as has been purified, as it is called, by ſublimation; for Dr. Brandt obſerves, that if the ſal ammoniac be firſt ſublimed with a ſufficiently ſtrong heat, and then diſſolved in ſpirit of nitre, the aqua regia thus prepared will not make gold volatile. He finds, that when the gold has been diſſolved, and the menſtruum diſtilled off, there remains in the retort a ſaline maſs, containing the gold; that on every freſh ſolution and diſtillation with the ſame kind of aqua regia, the matter increaſes more and more in its weight, and looks like a foul dark brown ſalt very hard of fuſion; that the liquor which diſtils is clear as water, and that nothing of the gold ſublimes. He obſerves alſo, that an aqua regia made with nitre in ſubſtance and the acid ſpirit of ſea ſalt, and with ſea ſalt in ſubſtance and the acid of nitre, have leſs effect in volatilizing gold than that with rough ſal ammoniac above mentioned.

Though many have expected, from this volatilization of gold, a reſolution of it into diſſimilar parts, it is not found to have ſuffered any real change. If the diſtilled liquor, or the cryſtals, or the ſublimate, be expoſed to a heat gradually increaſed, the acid riſes, without carrying with it any part of the metal, the gold being left entire behind. The menſtruum is leſs diſpoſed to elevate the gold a ſecond time, than it was at firſt.

VI. *Separation of gold from acids by inflammable liquors.*

The very ſubtile inflammable fluid, obtained from a mixture of vitriolic acid with vinous ſpirits, commonly called æther, or æthereal ſpirit of wine, poured into a ſolution of gold made in aqua regia or in ſpirit of ſalt, floats diſtinct upon the ſurface, being far lighter than the acid liquor and not at all miſcible with it. The æther, of itſelf colourleſs, quickly becomes yellow, and the acid underneath loſes proportionably of its yellowneſs; the æther imbibing the gold, keeping it permanently diſſolved, and, when loaded with the ponderous metal, continuing ſtill to float upon the acid. Gold is the only one, of the known metals, which the æther takes up from acids, and hence this fluid affords a ready method of diſtin-

diſtinguiſhing gold contained in acid ſolutions: whether a ſmall quantity of ſome other metals may not, in certain circumſtances, accompany the gold in this ſeparation from the acid, or whether very large quantities of ſome metals will not defend a minute portion of gold from the action of the æther, may deſerve further enquiry; though ſuch experiments, as we have hitherto made, incline us to think that they will not. The æther imbibes the gold, though it lies only on the ſurface of the acid ſolution: nevertheleſs, to haſten the effect, and to ſecure againſt any particles of the gold eſcaping its action, it is expedient to ſhake them lightly together, the veſſel being cloſely ſtopt to prevent the evaporation of this very volatile fluid. If the ſolution in æther, poured off from the acid, be expoſed to the open air, the æther exhales in a few minutes, leaving the gold behind; if kept for ſome months in a ſlender glaſs ſtopt ſo as that the æther may exhale exceeding ſlowly, the gold does not reſume its proper form, but ſhoots, as is ſaid in the Swediſh tranſactions, into cryſtals, of a tranſparent yellow colour, a long priſmatic figure, and an auſtere taſte.

Eſſential oils, ſhaken with ſolution of gold, imbibe the gold in like manner, and carry it up to the ſurface, but keep it diſſolved only for a little time: the metal gradually ſeparates, and is thrown off to the ſides of the glaſs in bright yellow films, which on ſhaking the veſſel fall to the bottom. The oil, though of itſelf colourleſs, continues coloured after the gold has parted from it, eſſential oils receiving from the pure acid, firſt a yellow, and afterwards a reddiſh hue. Hence where theſe oils are employed as a teſt of gold in ſolutions, it is not the colour which the oil acquires, but the ſeparation of the golden films, that is to be regarded. The

oils

oils appear to be more ſluggiſh than the æther in taking up the gold, and hence require to be well ſhaken with the ſolution.

Rectified ſpirit of wine mingles uniformly with the acid ſolution, and does not, for a time, occaſion any other apparent change than rendering its colour more dilute. When the ſolution of gold has been inſpiſſated to dryneſs, the metal, with the acid that remains combined with it, diſſolves in ſpirit of wine : if the menſtruum was either the pure marine acid, or a mixture of the pure nitrous and marine acids, or a mixture of the nitrous acid and ſal ammoniac, the inſpiſſated matter diſſolves totally in the vinous ſpirit : if the aqua regia was made by diſſolving ſea ſalt in aqua fortis, or by diſſolving nitre in ſpirit of ſalt, the neutral ſaline compounds contained in theſe menſtrua not being diſſoluble in vinous ſpirits, remain perfectly white after the extraction of the gold. From all theſe mixtures, as from eſſential oils, the gold ſeparates by degrees, though leſs ſpeedily. On ſtanding for ſome days, eſpecially if the glaſs is but lightly covered, the metal is ſeen floating in fine bright yellow pellicles upon the ſurface. The addition of a little eſſential oil to the ſpirit haſtens the ſeparation of the gold.

Here it may be obſerved, that many of thoſe, who have buſied themſelves in the purſuit of medicinal preparations from gold, have been greatly deceived in the reſult of their operations, from not being acquainted with the above properties of the metal. Finding that eſſential oils imbibe gold from aqua regia, and receive with the gold a high colour, and that rectified ſpirit of wine, by digeſtion with the oil, diſſolves it, and becomes impregnated with its colour ; they imagined they had thus obtained an *aurum potabile,* or true tincture of the gold,

which

which they ſuppoſed to be endowed with extraordinary medicinal powers; not aware, that the gold conſtantly ſeparated in the proceſs, and that the colour of the preparation was no other than that which concentrated acids produce with eſſential oils however pale or colourleſs.

Liquors containing a groſſer inflammable matter, as wine, vinegar, ſolution of tartar, are likewiſe found to extricate gold from aqua regia in its metallic form; with this difference from the preceding, that the gold, inſtead of floating on the ſurface, falls here generally to the bottom.

VII. *Precipitation of gold by alkaline ſalts.*

On adding to ſolution of gold a ſolution of any fixt alkaline ſalt or a volatile alkaline ſpirit, in ſufficient quantity to ſatiate the acid; the mixture becomes turbid, and on ſtanding for ſome hours, the gold falls to the bottom, in form of a browniſh yellow muddy ſubſtance, retaining ſome of the ſaline matter, great part of which may be ſeparated by repeated waſhing with hot water. That the gold may precipitate the more freely, the ſolution ſhould be diluted with three or four times its quantity of water, or more. The alkaline liquor ſhould be added by degrees, in little quantities at a time, till the mixture, after the gold has ſettled, appears colourleſs, and a freſh addition of the alkali occaſions no further precipitation or turbidneſs.

When gold has been thus totally precipitated by volatile alkaline ſpirits, as ſpirit of ſal ammoniac, the addition of more of the ſpirit renders the liquor again yellow, occaſioning a part of the gold to be rediſſolved: by adding a large quantity of the alkaline ſpirit, almoſt all the precipitate is taken up; and even when the precipitated gold has been waſhed from as much of the adhering ſaline matter

matter as water will eafily extract, a confiderable part of it will ftill diffolve in pure volatile fpirits, but not fo much as before the ablution : I have not obferved the whole of the gold to be taken up in either cafe, though fome report that they have found it to be fo in both. Pure fixt alkalies, added in large quantity after the precipitation, do not appear to rediffolve any of the gold.

If the aqua regia has been prepared with fal ammoniac, or if the precipitation is performed with a volatile alkali, the unwafhed precipitate explodes, on being heated, with a bright flafh and a fmart noife; whence its name *aurum fulminans*. If the aqua regia has been made without fal ammoniac, and the precipitation is performed with a fixt alkali, the precipitated gold makes no explofion : gradually heated, it changes its dull yellowifh to a bright purple or purple-violet colour, and on further increafing the heat refumes its metallic afpect. A volatile alkaline falt, either in the diffolvent or in the precipitant, feems to be effentially neceffary to the fulmination.

Aurum fulminans weighs about one fourth part more than the gold employed, three parts of gold yielding four of the fulminating powder : this I relate on the authority of Lemery, Kunckel, and other practical writers, for though I have often made the preparation myfelf, I have never examined the increafe of its weight. Part of the increafe proceeds from the volatile alkali; for on adding to the aurum fulminans a little vitriolic acid, the volatile falt rifes in fublimation, fatiated with the acid : the remaining powder is found to be diverted of its fulminating power. From the coalition of the volatile alkali with the nitrous acid in the menftruum refults an ammoniacal nitre, a falt which of itfelf detonates on being heated : by what power or mechanifm its detonating quality is fo remarkably increafed in the aurum fulminans, is unknown.

The explofion of aurum fulminans is more vehement than that of any other known kind of matter: it goes off in a lefs degree of heat than any of the other explofive compofitions; and even grinding it fomewhat fmartly in a mortar is fufficient for making it explode. Some inftances are mentioned in the Breflau collections, and the *ephemerides naturæ curioforum*, of a very fmall quantity burfting in pieces the marble mortar in which it was rubbed; and an accident of the fame kind happened fome years ago to a fkilful chemift here. The operator cannot be too much on his guard in the management of fo dangerous a preparation.

It has been reckoned, that a few grains of aurum fulminans act with as much force as feveral ounces of gunpowder: but the actions of the two are of fo different kinds, that I cannot apprehend in what manner their ftrength can be compared. The report of aurum fulminans is of extreme acutenefs, offending the ear far more than that of a much larger quantity of gunpowder, but does not extend to fo great a diftance; feeming to differ from it as the found of a fhort or tenfe mufical ftring from that of a long one or of one which is lefs ftretched. In fome experiments made before the royal fociety and mentioned in the firft volume of Dr. Birch's hiftory, aurum fulminans clofed up in a ftrong hollow iron ball and heated in the fire, did not appear to explode at all; while gunpowder treated in the fame manner burft the ball. On the other hand a little aurum fulminans, exploded on a metalline plate in the open air, makes an impreffion or perforation in the plate; an effect which gunpowder could fcarcely produce in any quantity.

This remarkable effect of aurum fulminans on the body which ferves for its fupport, has induced fome to believe that its action is exerted chiefly or folely downwards.

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It appears however to act in all directions: for a weight, laid upon it, either receives a like impreſſion, or is thrown off; and in the collections above mentioned an account is given of a large quantity (ſome ounces) which exploding from too great heat uſed in the drying of it, broke open the doors and ſhattered the windows in pieces. Mr. Hellot found, that when a few grains of the powder were placed between two leaves of paper, and cemented to one of them by gum water, only the leaf which touched the powder was torn by the exploſion, and the other ſwelled out; and that when both were brought into cloſe contact with it, by preſſing them together, it tore them both; from whence he concludes, that the action of the aurum is greateſt on the bodies which it immediately touches. Both this property, and the acuteneſs of the report, may poſſibly depend upon one cauſe, the celerity of the expanſion: experiments have ſhewn, that the reſiſtance of the air to bodies in motion increaſes with the velocity of the body in a very high ratio; and perhaps the velocity with which aurum fulminans explodes may be ſo great, that it is reſiſted by the air as by a ſolid maſs.

The exploſion of this preparation does not appear to make any change in the gold. When the powder is ſpread exceeding thin between leaves of paper, and ſlowly heated, the detonation, as Mr. Hellot obſerves, is ſlight and ſucceſſive, the powder becomes purple, and appears of the ſame quality with the precipitate above mentioned which has no fulminating power. When a quantity is made to explode at once, in a large veſſel, or under a proper cover, for confining the particles violently diſperſed, the gold is found in fine duſt, partly purpliſh and partly of its proper yellow colour: it is ſaid that when the explosion is performed between silver or copper plates, the revived gold adheres to and gilds some part of their surface.

If aurum fulminans be washed with fresh portions of hot water, that as much as possible of the saline matter may be extracted, its fulminating quality will be greatly diminished. If ground with oil of vitriol, which expels the nitrous acid, and unites with the volatile alkali, or boiled in a solution of fixt alkaline salt, which expels the volatile alkali, and unites with the nitrous acid, it no longer makes the least explosion, and the gold may be recovered by simple fusion. When mixed with sulphur, and exposed to a gentle fire, the sulphur gradually burns off, and leaves the gold in like manner recoverable without danger of fulmination. In all these cases, if treated with a slow fire, it generally assumes a purple colour before it returns to its metallic form.

VIII. *Precipitation of gold by metallic bodies.*

ALL the metallic bodies that dissolve in aqua regia, platina excepted, precipitate gold from it; the acid parting from the gold, and dissolving a portion of the others in its room. Some of them precipitate it also when they are previously dissolved in other acids, and even in aqua regia itself.

Iron, in certain circumstances, becomes covered with the gold which it extricates from the acid, particularly where vinous spirits have been mixed with the solution. A liquor prepared by boiling gold leaf in water with nitre, sea salt, and alum, till the matter becomes dry, and then digesting the mixt in rectified spirit of wine, is said to answer the best for the gilding of iron in this way; tho' it does not appear to have any different effects from those of other mixtures of spirit of wine with solution of gold.

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A ſolution of gold in common aqua regia being largely diluted with ſpirit of wine, a poliſhed iron, dipt in the mixture, became immediately coated with a fine golden pellicle: the gold ſolution without the ſpirit of wine corroded the iron, and raiſed a ſcurf upon the ſurface. Theſe mixtures ſhould be prepared only as they are wanted, for on ſtanding for a day or two the gold begins to ſeparate.

Iron diſſolved in the vitriolic acid, or common green vitriol diſſolved in water, precipitates gold in form of a duſky brown-red powder. As the vitriolic ſolutions of iron do not precipitate from aqua regia any known metallic body beſides gold, this experiment affords a commodious method of purifying gold from the ſmalleſt admixture of other metals: the particular way of managing the proceſs will be given under the head of refining gold, in the ninth ſection.

On adding copper to a ſolution of gold in aqua regia diluted with water, the copper became inſtantly of a blackiſh red colour; and on ſtanding, the gold fell in ſubtile powder, of its proper metallic aſpect, and of a high reddiſh colour, which probably proceeds from ſome cupreous atoms intermixed: it is remarkable in this experiment, that the liquor, after the precipitation of the gold, appears colourleſs as water, a proof that the quantity of copper, taken up in the place of the gold, muſt be extremely minute. Solutions of copper in the vitriolic acid, or of blue vitriol in water, produced no precipitation or turbidneſs in ſolution of gold. Copper or verdegris diſſolved in vinegar occaſioned the gold to ſeparate in bright films, which covered the ſides of the glaſs, forming an almoſt continuous golden pellicle: this ſeparation however ſeems to depend, not ſo much upon the copper, as on the inflammable matter of the vinegar.

A plate of pure tin, put into a ſolution of gold largely diluted with water, changes the yellowiſh colour of the liquor to a beautiful purple or red : by degrees, a powder of the ſame colour ſlowly ſubſides, and leaves the menſtruum colourleſs. Solutions of tin, made in aqua regia, have the ſame effect with tin itſelf, in regard both to the precipitation and the colour ; and hence characters, drawn on paper with a diluted ſolution of gold, not viſible when dry, become immediately red or purple on paſſing over them a diluted ſolution of tin. With the undiluted ſolutions, no redneſs is produced : after the red powder has fallen from the diluted liquor, if the whole be ſet in a moderate warmth till the water has exhaled, the gold is taken up again, the liquor becomes yellow as at firſt, and only a white powder remains, which appears to be a calx of tin. The red liquor, ſet to evaporate before the gold has fallen, yields only a yellow maſs; from which rectified ſpirit of wine extracts the gold combined with the acid, leaving, as in the other caſe, a white calx of tin.

Mercury, diſſolved in the vitriolic, nitrous, or marine acids, is a precipitant for gold, as well as in its metallic form ; and in all caſes, a part of the mercury is apt to fall down along with the gold. When mercury in ſubſtance is uſed, and the ſolution of gold largely diluted, the undiſſolved mercury gradually imbibes the gold.

On dropping a ſolution of ſilver into one of gold, both metals precipitate : the ſilver, parting from the nitrous, unites and falls with the marine acid, and the gold falls for want of it : the matter which ſeparates firſt is white, then the liquor grows opake and a dark coloured powder ſubſides, which leaves the menſtruum clear and capable of diſſolving ſilver. The ſame double precipitation happens,

pens, and on the ſame principle, on mixing ſolution of gold with ſolution of lead in aqua fortis.

IX. *Gold with ſulphureous bodies.*

PURE ſulphur, whoſe fumes corrode, and which in fuſion diſſolves and ſcorifies moſt metallic bodies, has no action on gold. Hence the uſe of gold for ſome mechanic purpoſes, where other metals are in time deſtroyed by ſulphureous fumes; as in the touch-holes of guns. And hence by fuſion with this concrete, gold may be ſeparated from moſt of the other metals. From ſilver and copper it may be extracted, on this principle, where the proportion of gold is too ſmall to bear the expences of the other common methods of ſeparation: ſome particular managements and additions, however, are requiſite, to render the proceſs ſucceſsful; ſee ſection the ninth.

Though gold reſiſts pure ſulphur, it unites perfectly with a mixture of ſulphur and fixt alkaline ſalt, commonly called *hepar ſulphuris.* As ſoon as the hepar melts, it begins to diſſolve the gold, with a lucid ebullition: two or three parts of ſulphur, and three of the alkaline ſalt, are ſufficient for one of gold. Great part of the compound diſſolves in water, ſo as to paſs through a filter without any ſeparation of the metal: Stahl obſerves, that this ſolution is leſs offenſive in ſmell than that of the hepar itſelf, but of a more bitter nauſeous taſte.

The addition of any acid to this ſolution, abſorbing the alkaline ſalt, precipitates the gold united with the ſulphur; which laſt may be diſſipated by fire, or more readily ſeparated by adding a little copper for abſorbing the ſulphur. A like ſeparation may be obtained by adding copper or iron to the mixture of gold and hepar in fuſion; theſe metals precipitating the gold, and uniting with the hepar in its place. Mr. Hellot recommends detonation

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with nitre as the eaſieſt method of recovering the gold from the ſulphureous mixture: the beſt way of managing this proceſs appears to be, by making the matter red hot in a deep crucible, and dropping in the nitre, which ſhould be previouſly well dried and heated, by a very little at a time, as the addition of any conſiderable quantity at once would occaſion the deflagration to be ſo ſtrong as to force off ſome particles of the gold: this is the only inconvenience in the proceſs, and it is not to be wholly avoided without great precaution; for in many experiments of melting gold with nitre, when inflammable bodies had been mixed with the gold, I have almoſt always obſerved numerous globules of the metal thrown up about the ſides of the crucible: when a freſh addition of the nitre produces no further deflagration, the fire is to be increaſed ſo as to bring the whole into fuſion; and the crucible being then ſuffered to cool, the gold is found at the bottom of the ſaline maſs, pure and of a high colour.

A neutral ſalt, compoſed of fixt alkaline ſalt ſaturated with the vitriolic acid, being brought into fuſion in a cloſe crucible, with the addition of a little ſoot or powdered charcoal; the vitriolic acid and inflammable principle unite together, and form ſulphur, the ſame with common brimſtone, which remaining combined with the alkali, the compound proves a true hepar ſulphuris: and accordingly gold, melted with theſe ingredients, is diſſolved by them in the ſame manner as by a hepar already made.

Dr. Brandt gives an account of an experiment, from which he concludes, that gold, by being diſſolved in the above mixture, and afterwards recovered from it, ſuffers a conſiderable change. About a grain of gold and two hundred grains of ſilver were melted with the mixture,

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and precipitated by adding twice as much copper : the ſcoria, containing the copper, was melted with calx of lead, and the lead revived from the compound, that if any of the gold and ſilver ſhould have remained in the ſcoria, they might be imbibed by the lead : the precipitated maſs was cupelled with the revived lead, and then parted by aqua fortis : the gold powder, which the aqua fortis left undiſſolved, differed ſomewhat in appearance from that which commonly remains in parting, and being melted with a pure white fixt alkaline ſalt, the gold turned out pale and almoſt like ſilver. I have not yet repeated this experiment, and do not apprehend that it will bear any great ſtreſs to be laid upon it. It is more probable that the gold retained a part of the extraneous matter, than that it ſuffered itſelf any real change. The author obſerves that the crucible, in which the gold powder was melted, had a green tinge round its edge, and that the alkaline ſalt was coloured yellow, but that the gold after the fuſion was found to be of its full weight; ſo that a part of the gold might have been diſſolved and retained by the ſalt, and an equal quantity of other matter remained blended with the reſt of the gold.

The phoſphorus of urine has been ſaid by ſome to reduce gold into a red mucilage. By digeſtion or diſtillation in cloſe veſſels, as a retort and receiver, the phoſphorus appears to have no action on gold : this I relate on the authority of Mr. Margraff, whoſe experiments, in the *Miſcellanea Berolinenſia* for the year 1740, have ſaved me the trouble of this examination : gold filings were digeſted with thrice their weight of phoſphorus for four weeks, and the fire being then increaſed, part of the phoſphorus ſublimed, and part remained above the gold, in appearance like fine glaſs : this laſt grew moiſt on the admiſſion of air, and diſſolved in water, leaving the gold

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unchanged. Nor does gold appear to be affected by the fumes of phoſphorus ſet on fire. But the flowers or ſaline acid matter remaining after the inflammable principle of the phoſphorus has been conſumed, and the microcoſmic ſalt or eſſential ſalt of urine, which contains this acid, being melted along with gold in a moderately ſtrong fire, manifeſtly corrode the metal, and receive from it a purple tinge.

S E C T. VII.

Of the alloy of gold; and the methods of judging of the quantity of alloy it contains, from the colour and weight.

I. *Of the alloy of gold.*

GOLD, in its pure ſtate, is reckoned too ſoft and flexible for the common purpoſes of coins and utenſils; and hence, to increaſe its hardneſs, and render it better adapted to theſe uſes, it is allowed to be mixed with a certain quantity of inferiour metals; which, in reſpect to the gold, are called alloy, and whoſe proportion is ſettled by law. That theſe admixtures are of ſo much advantage, in regard to the uſe of the metal, as has been commonly thought, may perhaps be queſtioned : for though fine gold may be ſcratched or bent eaſier than ſuch as is alloyed, yet (as is obſerved in a judicious Eſſay on money and coins publiſhed in 1758) the alloyed appears to be diminiſhed more by wearing than the fine.

There are caſes in which an admixture of alloy appears abſolutely neceſſary, as particularly in gold plates for being enamelled. If the plates are made of fine gold, they bend, and change their figure, in the heat requiſite for making the enamel melt : the workmen find, that the quantity of alloy, permitted in coins, prevents this inconvenience;

venience; and that a greater quantity cannot be employed, as it would occaſion the gold to melt.

From the account given in the fifth ſection, of the effects of different metals upon gold, it appears, that ſilver and copper are the only ones fit for ſerving as its alloy; all the others debaſing its beauty, and greatly injuring or deſtroying its malleability. Happily alſo theſe are the two metals which are ofteneſt naturally blended with it in the mines, ſo that the trouble and expence of refining it are thus greatly leſſened. As the natural alloy is frequently in a ſmaller proportion than the ſtandard quantity, as well as in a greater, it is plain that gold below the ſtandard fineneſs may frequently be brought to the ſtandard, without any refining at all, by melting it with a due proportion of ſuch as is above the ſtandard. In this view, the admitting of alloy, for all thoſe intentions in which it is not injurious, is of manifeſt advantage.

The degree of fineneſs of gold, or the proportion of alloy it contains, is accounted by imaginary weights called carats. The whole maſs is conceived to be divided into twenty-four carats; and ſo many twenty-fourth parts as it contains of pure gold, it is called gold of ſo many carats, or ſo many carats fine. Thus gold of eighteen carats is a mixt, of which eighteen parts in twenty-four are pure gold, and the other ſix parts an inferiour metal; and in like manner gold of twenty carats contains twenty parts of pure gold to four of the alloy. This is the common way of reckoning in Europe, and at the gold mines in the Spaniſh weſt Indies, but with ſome variation in the ſubdiviſion of the carat: among us, it is divided into four grains; among the Germans, as appears from the treatiſes of Ercker, Cramer, and other German aſſayers, into twelve parts; and by the French, according to Mr. Hellot, into thirty-two. The Chineſe reckon by a different diviſion, called touches, of which the higheſt number, or that which denotes pure gold, is one hundred ; ſo that a hundred touches correſpond to our twenty-four carats, ſeventy-five touches to eighteen carats, fifty touches to twelve carats, and twenty-five to ſix ; from whence any number of the one diviſion may be eaſily reduced to the other.

The ſtandard gold of this kingdom is of twenty-two carats, that is, it conſiſts of twenty-two parts of fine gold and two of alloy : the alloy is more commonly a mixture of ſilver and copper, than either of them alone ; ſilver alone, in ſo conſiderable a quantity, giving too great a paleneſs to the gold, and copper alone too great a redneſs. It is difficult for the aſſayer, as we ſhall ſee hereafter, to determine with minute exactneſs the fineneſs of a given maſs of gold ; and it is not to be expected that the workman, in every piece intended for ſtandard gold, ſhould be able to attain to the exact ſtandard proportion of alloy. In the Engliſh coinage, which all poſſible precautions are taken to keep as near as may be to the ſtandard, a certain latitude is allowed in this reſpect, called the remedy for the maſter of the mint. Out of every fifteen pounds of gold coined at the mint, (according to the account publiſhed by the learned Mr. Folkes, late preſident of the royal ſociety, in his curious tables of Engliſh ſilver coins) ſome pieces are taken at random, and depoſited in a ſtrong box called the pix : at certain intervals, ſometimes of one year and ſometimes ſeveral years, the pix is opened at Weſtminſter, in the preſence of the lord chancellor, the lords commiſſioners of the treaſury and others ; portions taken from the pieces of each coinage are melted together, and an aſſay made of the collective maſs by a jury of the goldſmiths company. At this trial the mint-maſter is held excuſable, though the

the moneys be either too baſe or too light, provided the imperfection and deficiency together are leſs than the ſixth part of a carat, which amounts to forty grains of fine gold on the pound of ſtandard, or the one hundred and thirty-ſecond part of the value. It is ſaid that this remedy is contained within as narrow limits, as any workers can reaſonably be ſuppoſed to make themſelves anſwerable for.

The proportion of alloy in other nations is various. According to the aſſays of ſundry foreign coins, made at the Tower by the direction of Sir Iſaac Newton, and publiſhed in Arbuthnot's tables of coins, the moidores of Portugal and their ſubdiviſions, and the old piſtoles and doublons of Spain and Italy, are a little worſe than our ſtandard, but within the latitude allowed to our own mint-maſter: the new louis d'or of France is about a fifth of a carat below that latitude. The ducats of Germany, Holland, Sweden and Denmark are a carat and a half better than ſtandard; and the ſequin of Venice, the fineſt of all the modern European coins, is a carat and ſeven eighths better, or only an eighth of a carat worſe than fine gold.

The ſtandard gold of England was formerly of the ſame fineneſs with the Venetian ſequin, to wit, twenty-three carats three grains and a half. Our preſent ſtandard of twenty-two carats, was introduced in 1527, (about 270 years after the commencement of our gold coinage) for a particular ſort of coin called crowns, of equal value with thoſe of the ſame name which have ſince been formed of ſilver, and hence this kind of gold has been frequently diſtinguiſhed by the name of crown gold. Both the old and the new ſtandard were continued to 1642, ſince which period only the latter has been uſed. The remedy for the maſter of the mint has been almoſt always

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an eighth part of a carat for the old ſtandard, and a ſixth of a carat for the new.

A pound of ſtandard gold, in the Engliſh coinage, is cut into forty-four guineas and a half; ſo that the mint price of fine gold is four pounds four ſhillings and eleven pence halfpenny an ounce nearly. Lower than this the price of gold bullion cannot fall, the mint being always ready to exchange it on that footing for coin; but there are ſundry cauſes which may render it higher, and which it does not belong to the preſent purpoſe to examine: the reader may conſult on this ſubject the eſſay on money and coins already quoted, where he will meet with abundant ſatisfaction.

A pound of ſtandard ſilver, containing eleven ounces two pennyweights of fine ſilver, is cut into ſixty-two ſhillings: whence the proportional value of fine gold to fine ſilver is, in our coinage, as fifteen and one fifth to one. Sir Iſaac Newton obſerves, in a repreſentation to the lords of the treaſury in the year 1717, that in the mints of Spain and Portugal, the value of gold is ſixteen times that of ſilver; but that in thoſe countries, payments in ſilver bearing generally a premium of ſix per cent. the proportion may be looked upon as fixed by commerce at fifteen and one twenty-fifth to one: that in the other parts of Europe, the value of gold is at moſt fifteen, and in China and Japan but nine or ten times, that of ſilver: ſo that gold is rated higher in England than in any other part of Europe, and higher in Europe than in the eaſtern countries. Hence, in great meaſure, ariſe the profits of exchanging gold for ſilver in one place, and re-exchanging them in another; and hence the greater diſparity between the relative quantities of gold and ſilver in one commercial nation than in another, that metal being brought in moſt abundance which is rated higheſt in proportion to the other, and that which is rated loweſt being drained away.

The alloy of gold, though it conſiſts of ſilver, and though its quantity be greater than that of the ſtandard proportion, down to certain limits, is reckoned as of no value: the value of the maſs is eſtimated only from the quantity of fine gold it contains; and from this, for every carat that it is below the ſtandard fineneſs, there is commonly a deduction made, of four pence an ounce, for the charges of refining. A certain quantity of gold, mixed with ſilver, loſes alſo its own value, and is reckoned only as a part of the ſilver. There can be no fixt limits for the proportions in which the value of one metal is thus abſorbed by the other; as they muſt depend on the expence of ſeparating the two metals, in different places, by the operations there commonly practiſed. The author of the eſſay on money and coins above mentioned ſays he has been informed, that a pennyweight of gold in a pound of ſilver, or one part in two hundred and eighty-eight, is reckoned among us the leaſt proportion of gold that will pay for refining, and that in this there is a profit only of about one farthing on the ounce.

II. *Method of judging of the fineneſs of gold from its colour.*

Those who are accuſtomed to the inſpection of gold variouſly alloyed, can judge nearly, from the colour of any given maſs, the proportion of alloy it contains, provided the ſpecies of alloy is known. Different compoſitions of gold with different proportions of the metals which it is commonly alloyed with, are formed into oblong pieces, called needles, and kept in readineſs, for aſſiſting in this examination, as ſtandards of compariſon.

The proportions, in the compoſition of the ſeveral needles, are adjuſted, in a regular ſeries, according to the carat weights as explained in the preceding article. The firſt needle conſiſts of fine gold, or of twenty-four carats; the ſecond, of twenty-three carats and a half of fine gold and half a carat of alloy; the third, of twenty-three carats of fine gold to one carat of alloy, and ſo on, the gold diminiſhing, and the alloy increaſing, by half a carat in each needle, down to the twentieth carat: all below this are made at differences of whole carats, half a carat being ſcarcely diſtinguiſhable by the colour of the maſs when the proportion of alloy is ſo conſiderable. Some make the needles no lower than to twelve carats, that is, a mixture of equal parts of gold and alloy: others go as low as one carat, or one part of gold to twenty-three of alloy.

Four ſets of theſe needles are commonly directed; one, in which pure ſilver is uſed for the alloy; another with a mixture of two parts of ſilver and one of copper; the third with a mixture of two parts of copper to one of ſilver; and the fourth with equal parts of the two: to which ſome add a fifth ſet, with copper only, an alloy which ſometimes occurs, though much more rarely than the others. If needles ſo low as three or four carats can be of any uſe, it ſhould ſeem to be only in the firſt ſet: for in the others, the proportion of copper being large, the differences in colour of different ſorts of copper itſelf will be as great, as thoſe which reſult from very conſiderable differences in the quantity of gold. When the copper is nearly equal in quantity to the gold, very little can be judged from the colour of the maſs.

In melting theſe compoſitions, the utmoſt care muſt be taken, that no loſs may happen to any of the ingredients, ſo as to alter the proportions of the mixtures. The crucibles ſhould be of the ſmootheſt kind, that no particle of the metal may lodge about the ſides. The copper

ſhould

ſhould be taken in one round lump, that its ſurface being as ſmall as poſſible, it may be the leſs diſpoſed to be ſcorified: that this may be the more effectually guarded againſt, ſome inflammable matter, as pitch, reſin, or a little charcoal in fine powder, ſhould be added to the borax uſed as a flux; and the fuſion ſhould be expeditiouſly performed, ſo as that the copper may be no longer expoſed to the fire, than is abſolutely neceſſary for its due union with the others. The flux being previouſly melted in the crucible, and brought to a ſtrong heat ſuch as is ſufficient for the melting of copper, the metals are to be dropt in: as ſoon as they appear perfectly fluid, the crucible, after being gently jogged or ſhaken to promote the collection and ſettling of the metal, is to be taken out of the fire, and ſet on ſome warm ſupport, that the mixture may not cool too haſtily. The fuſion may be commodiouſly performed alſo, the quantity of the metals employed for this uſe being commonly ſmall, by placing them in a cavity made in a piece of charcoal, and directing upon them, by a blow-pipe, the flame of a lamp: thoſe who are accuſtomed to the uſe of the blow-pipe, will find this method rather more ſecure than that by the crucible, as well as more convenient and expeditious. In whatever manner the proceſs is performed, the ſeveral maſſes muſt be weighed after the fuſion; and if the leaſt diminution has happened in any, freſh mixtures muſt be prepared in their room.

The colours are beſt examined by means of ſtrokes drawn with the metals on a particular kind of ſtone, brought chiefly from Germany, and called from this uſe a touchſtone; the beſt ſort of which is of a deep black colour, moderately hard, and of a ſmooth but not poliſhed ſurface. If it is too ſmooth, ſoft gold will not eaſily leave a mark upon it; and if rough, the mark proves imperfect. If very hard, the frequent cleaning of it from the marks, by rubbing it with tripoli or a piece of charcoal wetted with water, gives the furface too great a fmoothnefs; and if very foft, it is liable to be fcratched in the cleaning. In want of the proper kind of ftone, moderately fmooth pieces of flint are the beft fubftitutes: the more thefe approach in colour to the other, the better.

The piece of gold, to be examined, being well cleaned in fome convenient part of its furface, a ftroke is to be made with it on the ftone; and another, clofe by it, with fuch of the touch-needles as appears to come the neareft to it in colour. If the colour of both, upon the ftone, is exactly the fame, it is judged that the given mafs is of the fame finenefs with the needle: if different, another and another needle muft be tried, till fuch a one is found as exactly correfponds to it. To do this readily, practice only can teach.

In making the ftrokes, both the given piece, and the needle of comparifon, are to be rubbed feveral times backwards and forwards upon the ftone, that the marks may be ftrong and full, not lefs than a quarter of an inch long, and about a tenth or an eighth of an inch broad: both marks are to be wetted before the examination of them, their colours being thus rendered more diftinct. A ftroke, which has been drawn fome days, is never to be compared with a frefh one, as the colour may have fuffered an alteration from the air; the fine atoms, left upon the touchftone, being much more fufceptible of fuch alterations than the metal in the mafs. If the piece is fuppofed to be fuperficially heightened by art in its colour, that part of it, which the ftroke is defigned to be made with, fhould be previoufly rubbed on another part of the ftone, or rather on a rougher kind of ftone than the common touchftones, that a frefh furface of the metal may be expofed.

expoſed. If it is ſuſpected to be gilt with a thick coat of metal finer than the internal part, it ſhould be raiſed with a graver, to ſome depth, that the exteriour coat may be broken through : cutting the piece in two is a leſs certain way of diſcovering this abuſe; the outer coat being frequently drawn along by the ſheers or chiſel, ſo as to cover the divided parts.

The metallic compoſitions, made to reſemble gold in colour, are readily known by means of a drop or two of aqua fortis, which has no effect upon gold, but diſſolves or diſcharges the marks made by all its known imitations. That the touchſtone may be able to ſupport this trial, it becomes a neceſſary character of it not to be corroſible by acids; a character which ſhews it to be eſſentially different from the marbles, whereof it is by many writers reckoned a ſpecies. If gold is debaſed by an admixture of any conſiderable quantity of theſe compoſitions, aqua fortis will in this caſe alſo diſcharge ſo much of the mark as was made by the baſe metal, and leave only that of the gold, which will now appear diſcontinued or in ſpecks. Silver and copper are in like manner eaten out from gold on the touchſtone, and hence ſome judgement may thus be formed of the fineneſs of the metal from the proportion of the remaining gold to the vacuities.

Ercker obſerves that hard gold appears on the touchſtone leſs fine than it really is. It may be preſumed that this difference does not proceed from the ſimple hardneſs: but from the hardneſs being occaſioned by an admixture of ſuch metallic bodies, as debaſe the colour in a greater degree than an equal quantity of the common alloy. Silver and copper are the only metals uſually found mixed with gold whether in bullion or in coins; and the only ones, whoſe quantity is attempted to be judged of by this method of trial.

The Chineſe are ſaid to be extremely expert in the uſe of the touchſtone, ſo as to diſtinguiſh by it ſo ſmall a difference in the fineneſs as half a touch, or a two hundredth part of the mixt. The touchſtone, as I am informed, is the only teſt, by which they regulate the ſale of their gold to the European merchants; and in thoſe countries it is ſubject to fewer difficulties than among us, on account of the uniformity of the alloy, which there is almoſt always ſilver; the leaſt appearance of copper being uſed in the alloy gives a ſuſpicion of fraud. As an aſſay of the gold is rarely permitted in that commerce, it behoves the European trader to be well practiſed in this way of examination: by carefully attending to the above directions, and by accuſtoming himſelf to compare the colours of a good ſet of touch-needles, it is preſumed he will be able to avoid being impoſed on, either in the touch itſelf, or by the abuſes, ſaid to be ſometimes committed, of covering the bar or ingot with a thick coat of finer metal than the interiour part, or of including maſſes of baſe metal within it. A ſet of needles may be prepared, for this uſe, with ſilver alloy, in the ſeries of the Chineſe touches; or the needles of the European account may be eaſily accommodated to the Chineſe, by means of a table formed for that purpoſe on the principles already explained. It may be obſerved, that the gold ſhoes of China have a depreſſion in the middle, from the ſhrinking of the metal in its cooling, with a number of circular rings, like thoſe on the balls of the fingers, but larger: I have been told, that when any other metallic maſs is included within, the fraud is diſcoverable at ſight, by the middle being elevated inſtead of depreſſed, and the ſides being uneven and knobby; but that the ſame kind of fraud is ſometimes practiſed in the gold bars, where it is not diſcoverable by any external mark.

III. *Of eſtimating the fineneſs of gold from its gravity.*

THE great exceſs of the weight of gold, above that of the metals uſed for its alloy, affords another method of judging of the quantity of alloy or debaſement, in any given mixture where the ſpecies of alloy is known.

It may here be proper to caution the reader againſt an error which has ſometimes been fallen into, in computing the ſpecific gravities of mixts from thoſe of their ingredients. If the gravity of one metal was nine, and that of another eighteen, it has been inadvertently reckoned that the gravity of a mixture of equal parts of the two would be the medium between nine and eighteen, or thirteen and a half. If by equal parts were meant equal bulks, this would indeed be the caſe; but when the parts are taken by weight, as they are always underſtood to be in mixtures of this kind, it is otherwiſe. For eighteen weights of the one metal, on being immerſed in water, will loſe two, and eighteen of the other will loſe one; ſo that thirty-ſix of the mixt will loſe three: whence the ſpecific gravity (which is found by dividing the weight in air by the loſs in water) inſtead of being thirteen and a half, turns out but twelve.

Fine gold, as we have ſeen before, loſes in water one grain in every nineteen and three tenths nearly; whereas fine ſilver loſes one grain in about eleven: from whence it is eaſy to find the loſs of any number of grains of each, and conſequently of any aſſignable mixture of the two metals. Thus fifty grains of gold will loſe above two and a half, and fifty grains of ſilver ſomewhat more than four and a half; ſo that a mixture of equal parts of the two will loſe above ſeven in a hundred, or one in fourteen. In like manner, a mixture of gold with half its weight of ſilver will be found to loſe one part in fifteen

fifteen and four tenths; with a third of filver, one in fixteen and two tenths; with a fourth, one in fixteen and feven tenths; and with an eleventh of filver, which is the ftandard proportion of alloy, one in eighteen and one tenth. On this principle, the fpecific gravity, or proportional lofs in water, of gold alloyed with different quantities of filver, copper, and mixtures of both, may be computed, and formed into tables, for abridging the trouble of calculation in the trial of given maffes.

A perfon, faid to have made large profits in the purchafe of gold from the Chinefe, made ufe of this method for eftimating the finenefs of the gold. With the affiftance of tables, now in my hands, he could readily determine by the balance the quality of the whole compound, or the quantity of fine gold it contained; without any danger of being impofed on by a fuperficial coat, however thick, or by any bafer materials, that were there known, being included within the mafs. The Chinefe alloy being, as already obferved, almoft always filver, contributed not a little both to the facility and accuracy of the examination.

The above method of calculation fuppofes, that when the two metals are melted together, each of them ftill retains its own proper gravity, as if they were joined only by fimple appofition. In mixtures of gold with filver, this appears to be the cafe, but in mixtures of it with other metals there are fome variations. Gold and copper, melted together, prove fpecifically lighter, or lofe a greater proportion of their weight in water, than if they were weighed feparately: Mr. Gellert, in a treatife of metallurgic chemiftry publifhed in 1750, obferves, that the fame thing happens in mixtures of gold with zinc, tin, and iron; but the reverfe in mixtures of it with lead and bifmuth. In fome of the compofitions of gold with platina, a dilatation of the volume (whence neceffarily reſults a diminution of the ſpecific gravity, or of the weight under an equal volume) is apparent to the eye; the mixture, in its return from a fluid to a ſolid ſtate, inſtead of ſhrinking and becoming concave, expanding and becoming convex. Platina, purified by ſolution in aqua regis and precipitation with quickſilver, being melted with twice its weight of fine gold, and the fuſion repeated upwards of twelve times ſucceſſively, the ſurface of the maſs, when cold, was every time convex: the gold being gradually increaſed, the convexity continued ſenſible till the quantity of gold was upwards of ten times greater than that of the platina; but when the gold was in very large proportion, the mixture ſhrank and became concave like pure gold.

From theſe dilatations and contractions of volume, which happen in different mixtures, it may be preſumed, that the hydroſtatic balance cannot diſcover, with certainty, the exact fineneſs of gold, unleſs when ſilver is the metal mixed with it. When the alloy is copper, ſome allowance muſt be made, not only for the diminution of gravity ariſing from mixture, but likewiſe for the differences in the gravity of copper itſelf, that of ſome ſorts being about nine, and that of others, though ſeemingly of equal fineneſs, ſcarce eight and three fourths. When gold is alloyed with both copper and ſilver, though the foregoing cauſes had no influence, the quantity of gold could not be found to any exactneſs unleſs the proportions of copper and ſilver to one another were known.

S E C T. VIII.

Of the aſſaying of gold.

THE quantity of gold allowed for an aſſay is among us ſix grains; in France, as we learn from Hellot, nearly the ſame; in Germany, according to Schlutter, about

about three times as much. It is evident that great nicety is requiſite, in regard both to the weights, and the conduct of every part of the operation, where the value of a large maſs of gold is to be determined by an experiment on ſo ſmall a quantity. Care muſt be taken alſo that the portion to be aſſayed is of equal fineneſs with the reſt of the maſs: we have already [illegible] that the alloy may in ſome caſes be unequally [illegible]buted in fuſion, and the upper and lower parts of the mixt prove different in richneſs: in large ingots or pieces of caſt gold, a little ſhould therefore be collected from the bottom, and a little from the top, ſo as to obtain a mixt correſponding as nearly as may be to the quality of the whole maſs.

The aſſaying of gold conſiſts of two proceſſes; one for ſeparating it from ſilver, the other from baſe metals. The ſeparation of ſilver from gold is effected by aqua fortis, which diſſolves the ſilver, and leaves the gold entire behind: but that this ſeparation may ſucceed, it is neceſſary that the mixt contain conſiderably more ſilver than it does gold; for otherwiſe the particles of ſilver are enveloped by the gold, and defended from the action of the acid. Some judgement muſt therefore be previouſly formed of the contents of the maſs, from its colour on the touchſtone or by the hydroſtatic balance: if it appears to be about the ſtandard fineneſs, it is melted with about twice its weight of ſilver: if it is finer, a little more ſilver is added, and if coarſer leſs; ſo that the alloy and additional ſilver together may always amount to ſomewhat more than twice the quantity of the gold. The writers on aſſaying in general direct three parts of ſilver to one of gold: but a leſs proportion is found to be ſufficient, and more than is ſufficient ſhould never be uſed, for reaſons which will appear in the ſequel of the proceſs.

The ſeparation of baſe metals is effected, by keeping the mixt in fuſion for ſome time upon a cupel with the addition of lead. The lead by degrees turns to a ſcoria or droſs, which riſing to the ſurface and liquefying, looks like oil, and is no longer miſcible with any metallic body in its perfect metallic ſtate: all the metals, ſilver and platina excepted, change into droſs, and ſeparate from the gold, along with the lead. As ſilver ſtands this operation, equally with gold itſelf, the gold and the additional ſilver are ſubmitted to it together: and indeed though there was no baſe metal to be ſeparated, the little quantities of gold and ſilver employed for an aſſay, are more commodiouſly mixed, form a neater bead, and with leſs danger of loſs, upon a cupel with a little lead, than by fuſion in a crucible. It is obvious that both the ſilver and lead ought to be pure from any admixture of gold.

I. *Cupellation with lead.*

THE cupel is a ſmall veſſel, which abſorbs metallic bodies when changed by fire into a fluid ſcoria, but retains them ſo long as they continue in their metallic ſtate. One of the moſt proper materials, for making a veſſel of this quality, is the aſhes of animal bones: there is ſcarcely any other ſubſtance, which ſo ſtrongly reſiſts vehement fire, which ſo readily imbibes metallic ſcoriæ, and which is ſo little diſpoſed to be vitrefied by them. In want of theſe, ſome make uſe of vegetable aſhes, freed, by boiling in water, from their ſaline matter, which would occaſion them to melt in the fire.

The bones, burnt to perfect whiteneſs, ſo as that no particle of coaly or inflammable matter may remain in them, and well waſhed from filth, are ground into moderately fine powder, which, in order to its being formed into cupels, is moiſtened with juſt ſo much water as is ſufficient to make it hold together when ſtrongly preſſed between the fingers; ſome direct glutinous liquids, as whites of eggs or gum water, in order to give the powder a greater tenacity: but the inflammable matter, however ſmall in quantity, which accompanies theſe fluids, and which cannot eaſily be burnt out from the internal part of the maſs, is apt to revive a part of the metallic ſcoria that has been abſorbed, and to occaſion the veſſel to burſt or crack. The cupel is formed in a braſs ring, from three quarters of an inch to two inches in diameter, and not quite ſo deep, placed upon ſome ſmooth ſupport: the ring being filled with the moiſtened powder, which is preſſed cloſe with the fingers, a round-faced peſtle, called a monk, is ſtruck down into it with a few blows of a mallet, by which the maſs is made to cohere and rendered ſufficiently compact, and a ſhallow cavity formed in the middle: the figure of the cavity is nearly that of a portion of a ſphere, that a ſmall quantity of metal, melted in it, may run together into one bead. To make the cavity the ſmoother, a little of the ſame kind of aſhes, levigated into an impalpable powder, and not moiſtened, is commonly ſprinkled on the ſurface, through a ſmall fine ſieve made for this uſe, and the monk again ſtruck down upon it. The ring or mould is a little narrower at bottom than at top, ſo that by preſſing it down on ſome of the dry powder ſpread upon a table, the cupel is looſened and forced upwards a little, after which it is eaſily puſhed out with the finger, and is then ſet to dry in a warm place free from duſt.

Another kind of veſſel is required in cupellation, called a muffle, formed of any clayey earth that will bear a ſtrong fire, with a flat bottom, arched at top, and open in the front: it is made nearly of a ſemicylindrical figure, its

 length

length about double to its height, and the height ſomewhat leſs than the width of the bottom. This is placed upon a grate, in a proper furnace, ſuch as that deſcribed in page 12 and 35, with its mouth facing the door, and fitting as cloſe to it as may be. The furnace being filled up with fuel, ſome lighted charcoal is thrown on the top, and what fuel is afterwards neceſſary is ſupplied through a door above. One or more cupels are ſet in the muffle, and being gradually heated by the ſucceſſive kindling of the fuel, they are kept red hot for ſome time, that the moiſture, which they ſtrongly retain, may be completely diſſipated; for if any vapours ſhould iſſue from them after the metal is put in, they would occaſion it to ſputter, and a part of it to be thrown off in little drops. In the ſides of the muffle are ſome perpendicular ſlits, with a knob over the top of each to prevent any ſmall pieces of coals or aſhes from falling in. The door, or ſome apertures made in it, being kept open, for the inſpection of the cupels, freſh air enters into the muffle, and paſſes off through theſe ſlits: by laying ſome burning charcoal on an iron plate before the door, the air is heated before its admiſſion; and by removing the charcoal, or ſupplying more, the heat in the cavity of the muffle may be ſomewhat diminiſhed or increaſed, more ſpeedily than can be effected by ſuppreſſing or exciting the fire in the furnace on the outſide of the muffle. This renewal of the air is neceſſary alſo for promoting the ſcorification of the lead.

The cupel being of a full red heat, the lead caſt into a ſmooth bullet that it may not ſcratch or injure the ſurface, is laid lightly in the cavity: it immediately melts, and then the gold and ſilver are cautiouſly introduced, either by means of a ſmall iron ladle, or by wrapping them in paper and dropping them on the lead with a tongs. The quantity of lead ſhould be at leaſt three or four times that of the gold : if the gold is very impure, ten or twelve times its quantity will be neceſſary. It is reckoned that copper requires for its ſcorification about ten times its weight of lead ; that when copper and gold are mixed in equal quantities, the copper is ſo much defended by the gold, as not to be ſeparable with leſs than twenty times its quantity of lead ; and that when the copper is in very ſmall proportion, as a twentieth or thirtieth part of the gold and ſilver, upwards of ſixty parts of lead are neceſſary for one of the copper. The cupel muſt always weigh at leaſt half as much as the lead and copper, for otherwiſe it will not be ſufficient for receiving all the ſcoria : there is little danger however of cupels being made too ſmall for the quantity of a gold aſſay.

The mixture being brought into thin fuſion, the heat is to be regulated according to the appearances, and in this conſiſts the principal nicety in the operation. If a various-coloured ſkin riſes to the top, which liquefying runs off to the ſides, and is there abſorbed by the cupel, viſibly ſtaining the parts it enters ; if a freſh ſcoria continually ſucceeds, and is abſorbed nearly as faſt as it is formed, only a fine circle of it remaining round the edge of the metal ; if the lead appears in gentle motion, and throws up a fume a little way from its ſurface ; the fire is of the proper degree, and the proceſs goes on ſucceſsfully.

Such a fiery brightneſs of the cupel as prevents its coloured parts from being diſtinguiſhed, and the fumes of the lead riſing almoſt up to the arch of the muffle, are marks of too ſtrong a heat ; though it muſt be obſerved, that the elevation of the fumes is not always in proportion to the degree of heat, for if the heat greatly exceeds the due limits, both the fumes and ebullition will

entirely

entirely ceafe. In thefe circumftances, the fire muft neceffarily be diminifhed: for while the lead boils and fmokes vehemently, its fumes are apt to carry off fome part of the gold, the cupel is liable to crack from the hafty abforption of the fcoria, and part of the gold and filver is divided into globules, which lying difcontinued on the cupel after the procefs is finifhed, cannot eafily be collected: if there is no ebullition or fumes, the fcorification does not appear to go on. Too weak a heat is known by the dull rednefs of the cupel, by the fume not rifing from the furface of the lead, and the fcoria like bright drops in languid motion, or accumulated and growing confiftent all over the metal. The form of the furface affords alfo an ufeful mark of the degree of heat; the ftronger the fire the more convex is the furface, and the weaker the more flat: in this point however regard muft be had to the quantity of the metal, a large quantity being always flatter than a fmall one in an equal fire.

Towards the end of the procefs, the fire muft be increafed; for greateft part of the fufible metal lead being now worked off, the gold and filver will not continue melted in the heat that was fufficient before. As the laft remains of the lead are feparating, the rainbow colours on the furface become more vivid, and varioufly interfect one another with quick motions: foon after, difappearing all at once, a fudden luminous brightnefs of the button of gold and filver fhews the procefs to be finifhed. The cupel is then drawn forwards, towards the mouth of the muffle; and the button, as foon as grown fully folid, taken out.

It is obfervable, that when fine gold is thus cupelled with lead, it retains always a portion of the lead, very minute indeed, but fufficient to render it pale and brittle. Ercker endeavours to prevent this inconvenience, by patting the cupel with the tongs, fo as to produce a tremu-

lous

lous motion in the gold juſt before it hardens; but though this practice may be of uſe in ſome caſes, it cannot procure a total ſeparation of the lead, when the gold has no other admixture. Mr. Scheffer obſerves, in the tranſactions of the Swediſh academy for the year 1752, that if the gold is mixed with a little copper, as one twenty-fourth of its weight, it parts in cupellation with all the lead, and retains nearly all the copper; that if a ſmall proportion of ſilver be ſuperadded, greater than that of the copper, it contrariwiſe parts with the copper, and retains a little of the lead; but that if the quantity of ſilver is nearly equal to, or greater than, that of the gold, as in the preſent proceſs, both the copper and lead may be completely worked off, and only the gold and ſilver left.

The metal principally intended to be ſeparated by cupellation is copper. If the gold contained any tin, the proceſs does not ſucceed well, the tin calcining with a part of the lead, and riſing up in a powdery or ſpongy maſs, which is apt to retain a part of the gold, and which cannot eaſily be made to melt, the calx of tin being extremely refractory. In this caſe, which rarely occurs to the aſſayer, the addition of a little iron filings is of uſe; the tin having a ſtrong affinity to iron, and forming with it a new compound, which works off pretty freely with the lead.

Though the lead continues to emit fumes during the cupellation, yet little of its ſubſtance is diſſipated. The cupel, after it has abſorbed the ſcoria of the lead, weighs as much as the cupel and lead did at firſt; and even more, metallic bodies being found to gain weight in their ſcorification. Several experiments of this kind, made at the Tower by the direction of lord Brouncker, are inſerted in Sprat's hiſtory of the royal ſociety: when lead, or a mixture of lead and copper, were worked off in a cupel, there

there was always an increaſe of weight, though not quite ſo great as lead commonly acquires in the proceſs of ſlow calcination.

II. *Parting with aqua fortis.*

AQUA FORTIS is an acid ſpirit prepared from nitre by the intervention of other bodies. The principle, on which the extraction of the acid depends, has been but lately underſtood; and hence in the earlier writers on theſe ſubjects, as Ercker and Agricola, we meet with many incongruous compoſitions; ſome containing powdered flint, ſand, and other ingredients which ſerve only to take up room in the diſtilling veſſel; ſome, quicklime, which can do no more, than to leſſen the produce of acid, by abſorbing and detaining a part of it; and ſome, common ſalt, whoſe acid, mingling with the nitrous, forms with it a menſtruum of a quite different nature from that here required. What is wanted is the pure acid of nitre; and the extrication of this, from the alkaline baſis of the nitre, is effected by the acid of vitriol.

Thoſe, who prepare aqua fortis in quantity, uſe frequently green vitriol uncalcined or undried. This method is accompanied with two capital inconveniences: the watery parts, which the vitriol abounds with, being expelled firſt by the heat, together with a portion of the acid, this part of the vitriolic acid is thus ſo far diluted, as not to act ſufficiently upon the nitre, and riſing over into the receiver, fouls the aqua fortis that ſucceeds: at the ſame time the vitriol, which at firſt liquefies in the veſſel along with the nitre, concretes, on the diſſipation of its watery moiſture, into a hard maſs, from which the full quantity of acid cannot be forced out by any violence of fire.

The more judicious workmen calcine the vitriol, before its mixture with the nitre, till it is freed from its phlegm,

and

and will no longer liquefy in the fire. For this purpoſe, a quantity of the vitriol may be put into an iron pot, ſuch as one of thoſe which are uſed as ſand-pots for the portable furnaces already deſcribed: The veſſel is ſet over a gentle fire, which is gradually increaſed when the vitriol melts, till the matter thickens again, and acquires an aſh grey colour: the vitriol is to be conſtantly ſtirred, till it becomes dry and powdery, and is then to be taken out whilſt hot; for if ſuffered to cool in the veſſel, without ſtirring, it concretes ſo hard, as ſcarce to be beaten off with a hammer. Some calcine the vitriol in an earthen pan: the pan is at firſt about half filled, and when this has ſunk down, and incruſtated about the ſides, more is added, till the veſſel is full, which muſt afterwards be broken for getting the matter out.

Eight pounds of vitriol thus calcined to about four, and three pounds of nitre made likewiſe very dry, are to be reduced ſeparately into very fine powder, and thoroughly mixed together. The mixture is to be put into the ſame iron pot in which the vitriol was calcined, a ſtone-ware head with a large glaſs receiver fitted to it, and the junctures luted with Windſor loam, or a mixture of clay and ſand, beaten up with ſome cut tow, and moiſtened with a ſolution of fixt alkaline ſalt. In the receiver may be placed a pint of water, which will promote the condenſation of the nitrous fumes, without rendering the acid too dilute for the purpoſes which it is here deſigned for. During the diſtillation, there ariſes a quantity of elaſtic vapour, which muſt be ſuffered to eſcape, as it would otherwiſe either force the luting, or burſt the receiver. The moſt convenient way of procuring an outlet for it, without endangering any loſs of the acid, appears to be, by making a hole in that part of the receiver which is to be placed uppermoſt, and inſerting into it a ſlender glaſs pipe,

pipe, four feet long or more, which is to be ſecured by the ſame lute as the juncture of the head and receiver: the pipe allows a free paſſage to the air or unconfinable vapours, while little or nothing of the more ſluggiſh acid fumes will ariſe ſo high. The hole in the receiver may be made, by paſting on it a piece of thick leather, having a hole of the intended ſize cut in it, then filling the cavity with emery, and turning round in it a ſteel inſtrument, with a hollow in the point for retaining the emery, till the glaſs is worn through.

A gentle fire being made under the pot, the receiver ſoon grows warm, and appears covered with dewy drops, which are the more watery part of the mixture. The receiver beginning to grow cool again, the fire is to be gradually increaſed, till yellow or reddiſh fumes appear, and when theſe ceaſe, it is to be further urged by degrees, till the pot becomes red hot, and nothing more can be forced over.

This proceſs is nearly the ſame with that commonly followed in the way of buſineſs; differing little otherwiſe than in the ſize of the veſſels, and the quantity of the materials uſed at once. But as the effect of the vitriol depends wholly upon its acid, and as the acid of ſulphur is the ſame, and is now to be procured at a very cheap rate, the moſt advantageous way of making ſpirit of nitre or aqua fortis is, to uſe the acid ſpirit inſtead of vitriol. Two pounds of oil of vitriol are to be mixed with an equal quantity of water, in a ſtone-ware veſſel, by a little at a time; for if the acid is added all at once to the water, the mixture becomes ſo hot, as to be apt to make the veſſel crack. Three pounds of nitre being put into a glaſs retort, the mixture is to be poured on it through a long-necked funnel, that none of the vitriolic acid may adhere to the neck, and foul the nitrous ſpirit as it diſtils. The retort being placed in an iron pot on a little ſand, and a receiver with its upright pipe luted on, the fire is to be gradually increaſed, ſo long as any red fumes ariſe, or any drops fall from the neck of the retort.

In either of theſe methods, a portion of the vitriolic acid frequently riſes along with the nitrous; and frequently alſo, as nitre has often an admixture of ſea ſalt, the diſtilled ſpirit partakes of marine acid. If a piece of ſilver be put into this impure aqua fortis, ſome part of the ſilver will be diſſolved by the nitrous acid, but the other acids will immediately ſeize it, and form with it an indiſſoluble white powder. For this uſe therefore, the aqua fortis muſt be previouſly purified from theſe extraneous acids: and their property of uniting with and precipitating diſſolved ſilver affords a commodious and effectual means of its purification. A little ſolution of ſilver, already made, is dropt at intervals into a quantity of the aqua fortis; which, if it contains any marine or vitriolic acid, becomes inſtantly milky: when the addition of a freſh drop or two of the ſolution occaſions no further milkineſs or cloudineſs, we may be ſure that thoſe acids are completely abſorbed by the ſilver: the whole is ſuffered to ſtand till the white matter has perfectly ſettled to the bottom, and the clear liquor is then poured off. The ſolution of ſilver, from its carrying down, and fixing as it were, the heterogene acids, is called by the workmen *fixes*.

Care muſt be taken alſo that the common water, made uſe of in the proceſs of parting, have no impregnation that would impede the diſſolution of ſilver, or precipitate it when diſſolved. Spring waters have generally ſuch an impregnation, moſt of them producing a ſtrong milkineſs with ſolution of ſilver: rain water, collected with proper care, is for the moſt part ſufficiently pure, as is likewiſe that

that of moſt rivers, though the preference is always to be given to ſuch as has been diſtilled. Thoſe waters, which turn milky with ſolution of ſilver, may be made fit for this uſe, in the ſame manner as the impure aqua fortis, by dropping in a little of the ſolution, till all the matter, that is capable of precipitating the ſilver, is ſeparated: in this caſe, great care muſt be taken, not to uſe more than is neceſſary of the ſolution; for ſo much of the diſſolved ſilver, as is added after the marine and vitriolic acids have ſatiated themſelves, will continue diſſolved in the water; and as the gold is at laſt to be waſhed in the water, the moiſture, that hence adheres to the gold, containing a proportionable part of the diſſolved ſilver, will on drying leave it in the gold.

Beſides the purity of the aqua fortis, a good deal of caution is requiſite in regard to its ſtrength. The only ſure mark of its due ſtrength, for the parting aſſay, is its effect in the proceſs itſelf; and the manner of adjuſting it will be the more intelligible after the proceſs has been deſcribed.

The little bead of gold and ſilver, remaining after the cupellation, is carefully hammered a little, and paſſed ſeveral times between poliſhed ſteel rollers, ſcrewed gradually cloſer and cloſer, till it is extended into a very thin plate, which is coiled up into a ſpiral form, ſo as that the ſeveral circumvolutions may not touch one another: by this means it lies in a ſmall compaſs, ſo as to be covered by a quantity of aqua fortis ſufficient for diſſolving the ſilver, and yet expoſes a large ſurface to the action of the diſſolvent. The metal is now and then nealed during the flatting; and after this part of the proceſs is finiſhed, it is again made red hot, both to burn off any unctuous matter that may have adhered to it, and to ſoften the ſilver, which in this ſtate is ſuppoſed to yield more eaſily to the menſtruum. The coiled plate is put into a ſmall glaſs veſſel, called a parting glaſs, broad at the bottom and tapering upwards; with twice its weight or more of the prepared aqua fortis. The veſſel is ſet in a ſand-bath or other moderate heat, not exceeding that of boiling water; and its mouth ſtopt lightly with paper, or covered with a plate of glaſs, ſo as to keep out duſt, without preventing the eſcape of the elaſtic vapours which riſe during the diſſolution. So long as the acid continues to act, the metal appears every where encompaſſed with minute bubbles, which iſſue from it in jets: the diſappearance of theſe, or their uniting into a few large ones, is a mark that the acid is ſatiated.

The coiled plate, after the ſilver is thus eaten out from it, ſhould ſtill retain its original form: for if the gold falls into powder, it can ſcarcely be collected without the loſs of ſome particles, which, though ſmall in bulk, may amount to a conſiderable proportion of the little quantity of metal made uſe of. This coheſion of the gold depends, partly, upon the quantity of ſilver not being ſo large as to leave the golden particles diſcontinued; and partly on the action of the acid not being ſo violent, as to divide and diſunite the gold by its impetuous extraction of the ſilver. The ſtrength of the acid is to be aſcertained by previous trials on gold and ſilver mixed together in the aſſay proportions: if it is found to diſunite the gold, it muſt be lowered with water till it leaves the plates entire. Theſe trials are to be made exactly in the ſame manner as the aſſay proceſs itſelf.

The liquor is poured off whilſt hot, leſt ſome of the diſſolved ſilver ſhould cryſtallize in cooling upon the reremaining gold. To the golden plate, which appears ſpongy and of a dark reddiſh brown colour, a little freſh

aqua

aqua fortis is added, and heated more confiderably than before, to extract what filver may ftill be left in it ; this may be repeated a fecond or a third time ; after which fome water is poured on, and renewed two or three times, to wafh off the faline matter. The parting glafs being then full of water, a fmall gold veffel (a filver one will do) is applied clofely on its top ; and both being nimbly inverted, and the parting glafs carefully raifed a little at one fide, the golden plate is wafhed down into the lower veffel : if this laft is infufficient for receiving all the water, the glafs is to be lifted up a little, fo as that the thumb or a piece of ftiff paper can be applied to its orifice under the water, after which it may be removed without difturbing the liquor, or damaging the brittle plate. The water being poured off, the plate is dried, and gradually heated till the gold refumes its proper colour, which happens foon after its becoming red hot. Some make ufe of an earthen crucible; but in this cafe, fmall particles of the earth are apt to adhere imperceptibly to the gold, whence the affay becomes lefs certain.

If the gold, after having paffed through thefe operations, is found to be of the fame weight as at firft, it is reputed nearly fine, but not entirely fo : for the aqua fortis leaves always in the gold a fmall portion of the filver, amounting commonly to above a three hundredth, and fometimes to a hundredth part of its weight ; whence, if the gold was at firft fine, it will in this procefs receive an increafe. If it is required to determine exactly the proportion of this increafe, it may be done by fubmitting to the fame operation an equal quantity of gold known to be fine, mixed with the fame proportion of filver. The differences in the quantity of filver, thus left in the gold, are fuppofed to proceed from unheeded differences in the quality of the aqua fortis, particularly in its ftrength ; fo that

that the aſſayer ought to examine in this view each parcel of aqua fortis he employs, and deduct, from the weight of the gold remaining in the aſſay, the proportion of ſilver which that particular aqua fortis is found to leave.

The aſſayer's report, of the fineneſs of the gold which he has examined, expreſſes the number of carats, with the odd grains or fourths of a carat, and quarters of theſe, by which it is finer or coarſer than the ſtandard. Thus ſtandard gold being of twenty-two carats, that is, twenty-four parts of it loſing two in the purification; if the maſs aſſayed loſe one leſs, it is reported *B.* 1 *car.* or one carat better; and if it loſes one more, it is reported *Wo.* 1 *car.* or one carat worſe.

By theſe proceſſes gold is ſeparated from all the known metallic bodies, platina excepted: if any of this was mixed with it, nearly the whole of the platina will ſtill remain, not deſtructible by the lead, and not diſſoluble by the aqua fortis. If the quantity of platina is conſiderable, it may be diſtinguiſhed by the brittleneſs and ill colour of the mixt: but there are proportions of it, not ſufficient to ſenſibly affect the gold in theſe reſpects, though they may nevertheleſs deſerve regard. If the gold is ſuſpected to be thus debaſed, the abuſe may be diſcovered by the following means.

After the golden plate has been weighed, and its fineneſs determined in the common method, a part of it is to be diſſolved in a little aqua regia, and a filtered colourleſs ſolution of any fixt alkaline ſalt gradually dropt into the liquor, ſo long as it occaſions any turbidneſs or precipitation: all the gold will fall to the bottom, with a part of the platina, but ſo much of the platina will continue diſſolved, as to diſcover itſelf by communicating a yellow tinge. This intention may be anſwered ſtill more effectually by the æther, which imbibing the gold, and carrying it up to the ſurface, leaves the full quantity of the platina to ſhew its colour in the acid liquor. By this method, a moſt minute proportion of platina may be diſtinguiſhed, a little of this metal giving a high colour to a ſurprizingly large quantity of the menſtruum.

The method of preparing the æther is deſcribed by many chemical writers, but the moſt ſafe, eaſy, and certain proceſs I have met with, is that which Dr. Morris has favoured the publick with in the medical obſervations and inquiries of a ſociety of phyſicians in London. Nine parts by weight of oil of vitriol are poured, by two ounces at a time, at intervals of a quarter of an hour, into eight parts by weight of rectified ſpirit of wine, in a large ſtone bottle: after ſtanding for a night, the mixture is decanted from one veſſel to another three or four times, and then conveyed, through a long-necked funnel, into a retort capable of containing three times the quantity. The retort is ſet on a little ſand in an iron pot, and more ſand put round it up to the height of the mixture: a larger receiver being luted on, with ſome ſtrips of wet bladder, a ſmall hole is made in the luting with a pin: the fire is raiſed ſomewhat haſtily, till an ebullition accompanied with large bubbles is obſerved in the mixture; after which the fire is to be entirely removed, the heat of the ſand being ſufficient for completing the diſtillation. The diſtilled liquor is put into a clean retort, with two or three ounces of fixt alkaline ſalt: about half the liquor is drawn off, by a very gentle heat, into a large receiver; and this being ſhaken with an equal quantity of pump water, the pure æther riſes immediately to the top.

SECT. IX.

Of the refining of gold; and the ſeparation of ſmall portions of gold from other metals.

I. *Separation of gold from baſe metals by teſting with lead.*

THE proceſſes deſcribed in the preceding ſection, for the aſſaying of gold, are uſed alſo for refining it in the way of buſineſs; with ſuch variations, in the manner of conducting them, as the greater quantities operated upon, and the requiſite cheapneſs and diſpatch, render neceſſary.

The teſt is a large kind of cupel, formed of the ſame materials with the ſmall ones. Some of the German writers recommend, both for teſts and cupels, a ſort of friable opake ſtone, called white ſpath, which appears to be a ſpecies of gypſum, or of the ſtones from which plaſter-of-paris is prepared. The ſpath is directed to be calcined with a gentle fire, in a covered veſſel, till the ſlight crackling, which happens at firſt, has ceaſed, and the ſtone has fallen in part into powder: the whole is then reduced into ſubtile powder, which is paſſed through a fine ſieve, and moiſtened with ſo much of a weak ſolution of green vitriol, as is ſufficient for making it hold together: Gellert however finds, that if the ſtone is of the proper kind, which can be known only by trials, calcination is not neceſſary. Scheffer obſerves, that theſe kinds of teſts are liable to ſoften or fall aſunder in the fire, and that this inconvenience may be remedied, by mixing with the uncalcined ſtone ſomewhat leſs than equal its weight, as eight ninths of ſuch as has been already uſed and is penetrated by the ſcoria of the lead, taking only that part of the old teſt which appears of a green-grey colour, and rejecting the red cruſt on the top. Teſts or cupels made of the ſpath are ſaid not to require ſo much caution, in nealing and heating them, as the common ones: it appears however from Scheffer's account, that they are leſs durable than thoſe made of the aſhes of bones, though greatly ſuperiour to thoſe of wood aſhes. Vegetable aſhes, which ſtand pretty well the teſting of ſilver, can ſcarcely bear any great quantity of gold, this metal requiring a conſiderably ſtronger fire than the other: but bone aſhes anſwer ſo effectually, and are among us ſo eaſily procurable, that it is not needful for the refiner to ſearch for any other materials; though thoſe who work off large quantities of lead, in order to gain a little ſilver or gold contained in it, may poſſibly, in places remote from populous cities, avail themſelves of ſubſtances ſimilar to the ſpath above mentioned.

The teſt, for its greater ſecurity, is kept fixed in the mould in which it was formed; which is ſometimes a ſhallow veſſel made of crucible earth or caſt iron, more commonly an iron hoop, with three bars arched downwards acroſs the bottom, about two inches deep, and of different widths, from three or four inches to fifteen or more, according to the quantity of metal to be teſted at once. The aſhes or earthy powder, moiſtened as for making cupels, are preſſed down in the mould ſo as to completely fill it or riſe a little above the ſides; with care to make the maſs equally ſolid, and to put in at once, or at leaſt after the bottom has been preſſed cloſe, as much of the matter as will be ſufficient for the whole, for any additional quantity will not unite thoroughly with the reſt, but be apt to part from it in the fire. The edges are pared ſmooth, and a portion cut out from the middle with a bent knife, ſo as to leave a proper cavity, which is ſmoothed by ſtrewing ſome dry powder on the ſurface, and rolling on it a wooden or rather a glaſs ball.

The procefs of tefting is often performed in the fame manner as that of cupellation : but where great quantities of bafe metal are to be worked off from a little gold, recourfe is had to a more expeditious method, that of tefting before the bellows.

An oval teft is placed in a cavity, made in a hearth of a convenient height, and fome moiftened fand or afhes preffed round it to keep it fteady : the nofe of a bellows is directed along its furface, in fuch a manner, that if afhes are fprinkled in the cavity of the teft, the bellows may blow them completely out : fome have an iron plate fixed before the bellows, to direct the blaft downwards. To keep the furface of the teft from being injured in putting in the metal, fome clothes or pieces of paper are interpofed. The fuel confifts of billets of barked oak, laid on the fides of the teft, with others laid crofswife on thefe : the bellows impels the flame on the metal, clears the furface of afhes or fparks of coal, haftens the fcorification of the lead, and blows off the fcoria, as faft as it forms, to one end of the teft, where it runs out through a notch made for that purpofe. About two thirds of the fcorified lead may thus be collected, the reft being partly abforbed by the teft, and partly diffipated by the action of the bellows. Care muft be taken not to urge the blaft too ftrongly, left fome portion of the gold fhould be carried away by the fumes impetuoufly forced off from the lead, and fome minute particles of it entangled and blown off with the fcoriæ.

In the hiftory of the French academy of fciences for the year 1727, a procefs is given for purifying a particular kind of debafed gold, which is faid to be quite brittle and intractable, not to flow thin enough to be poured completely out of the crucible, to appear on the furface of a livid hue, and which is fuppofed by du Fay and Hellot to

receive

receive theſe imperfections from an admixture of emery. The gold is to be melted with equal its weight of biſmuth, and ſo much poured out as is fluid enough to run : to the remainder is to be added equal its weight more of biſmuth, and this procedure repeated till the whole of the gold has run thin from the crucible. The mixt is put into a large thick cupel or teſt, included in a mould of crucible earth ; by a ſuitable fire, the biſmuth works off as lead does, leaving the gold ſtill impure and covered with a livid ſkin. For every eight ounces of gold, two or three ounces of lead are then to be added, and the fire continued till the lead is worked off: the gold is ſtill found not ſufficiently fine, though leſs brittle and leſs livid than it was before. It is now to be melted in a forge or blaſt furnace, and the flame impelled by the bellows upon the ſurface of the metal, till it begins to grow clear ; after which the repeated injection of ſome mercury-ſublimate, with a little borax towards the end, completes the purification.

I have not had an opportunity of examining this proceſs, having never met with any gold that had the characters of impurity above deſcribed, except ſuch as was mixed with platina, which I did not find to be benefited by this treatment.

II. *Separation of gold from ſilver by aqua fortis.*

PARTING with aqua fortis is one of the moſt common operations, both for purifying gold from a little ſilver, and for extracting a little gold from a large proportion of ſilver. Frequently both intentions are anſwered at once : for when gold is thus to be purified, it requires, as we have already ſeen, an addition of ſilver, and ſuch ſilver as contains gold is always preferred for this uſe ; ſo that the

the gold is got out from the ſilver, without any additional expence, in the ſame operation by which the other gold is refined.

The moſt deſirable proportions of the two metals are, one part of gold to three of ſilver, or one part of gold in four of the mixt, whence the proceſs is ſometimes called quartation. When ſilver is added to gold, merely with a view to the purifying of the gold, theſe proportions ſhould be kept to, as nearly as may be: for if the quantity of ſilver is leſs, the diſſolution of it will not go on with ſufficient diſpatch; and if greater, it will occaſion an unneceſſary expence of acid. Silver containing only a ſmall portion of gold is frequently ſubmitted to this operation: but in ſuch caſes, there are leſs expenſive methods, which will be deſcribed in the ſequel of this ſection, for ſeparating great part of the ſilver, ſo as to leave only a moderate quantity to be diſſolved by the aqua fortis.

The metal, inſtead of being flatted into plates, as for the parting aſſay, is reduced, with leſs trouble, into ſmall grains, by melting it in a crucible, and pouring it into cold water. Some interpoſe a number of twigs, or a birch broom, wetted, between it and the water, to divide the fluid metal into ſlender ſtreams: Cramer deſcribes a machine for this purpoſe, compoſed of a wooden roller, laid acroſs the veſſel of water, with its lower ſurface touching the water, covered all over with twigs, and made to turn by a handle. The granulation may be performed very ſucceſsfully without any contrivance of this kind, by nimbly ſtirring the water round, ſo as to communicate to it a rapid circular motion, and pouring in the metal at one ſide.

The granulated metal, with a ſuitable quantity of aqua fortis, is put into parting glaſſes, which are commonly about twelve inches high, ſeven inches wide at the bottom, and tapering upwards: ſeveral of theſe veſſels are placed along an iron range covered with ſand to the thickneſs of about two inches. Great care ſhould be taken that the glaſs be well nealed, as equal as may be in thickneſs, and free from blebs, for otherwiſe it generally cracks in the proceſs. The aqua fortis muſt be purified as for the parting aſſay, though it is not needful to be ſo curious in adjuſting its ſtrength: it ought to be ſtrong enough to begin to act ſenſibly on ſilver in the cold, and not ſo ſtrong as to act with violence.

A gentle fire is made under the ſand bath, which is increaſed or diminiſhed, according as the diſſolution appears to proceed ſlowly or haſtily. Care muſt be had not to apply too much heat at the beginning, the liquor being very liable to ſwell up and run over the veſſel; but towards the end, when moſt of the ſilver is diſſolved, and the acid nearly ſatiated, there is no danger of this accident. When the menſtruum has ceaſed to act, which is known by its growing clear, and no more air bubbles riſing in it, the ſolution is poured off; and if, on ſtirring the remaining matter, any grains are perceived in it, a little more aqua fortis is added, to complete the extraction of the ſilver: ſome uſe a ſmooth wooden rod for the ſtirring, and what diſſolved ſilver the wood imbibes, they recover by burning it. The blackiſh mud, into which the gold is reduced by the diſſolution of the ſilver from it, is waſhed five or ſix times with water, and afterwards melted.

One of the principal inconveniencies, attending this operation, is, that the parting glaſſes are extremely liable to crack, from the contact not only of a cold body, but even of the hand. Schlutter reports, that in the Hungarian refineries, where great quantities of gold-holding ſilver are parted, the glaſſes are ſecured by a ſtrong coating, up

to

to ſuch a height, as not to hinder the operator from obſerving how the diſſolution goes on: ſome quicklime, ſlaked with beer, and mixed with whites of eggs, is ſpread on a linen cloth, which being wrapped round the glaſs, a compoſition of clay and hair is applied over it. He gives alſo a contrivance of his own, which he ſeems to have introduced into the works of the lower Hartz, for preſerving the diſſolved ſilver, as well as the gold, when the glaſſes happen to break, or the liquor to run over. His parting glaſſes are fifteen inches high, ten or twelve inches wide at the bottom, and at the top about as wide as the mouth of a common bottle: for each of theſe he has a copper pan, twelve inches wide at bottom, fifteen at top, and ten in height, which ſtands on a trevet, with ſome charcoal under it: ſome water is put into the pan, and two pieces of wood placed croſswiſe in its bottom, as a ſupport for the glaſs, to prevent it from hitting againſt the copper. Into one of theſe glaſſes he puts about eighty ounces of gold-holding ſilver, with twice as much aqua fortis, without danger of any loſs though the glaſs ſhould break: the heat may likewiſe be ſpeedily diminiſhed, if the acid ſhould act too impetuouſly, by pouring cold water into the pan. Great care muſt be taken in the addition of the cold water: it ſhould be poured againſt the ſides of the pan, and ſtirred with the reſt, that it may be equally mixed before it reaches the glaſs.

The ſilver is recovered from its ſolution by means of copper. The ſolution, diluted with water, being put into a copper veſſel, or into a glaſs one along with copper plates (the refiners uſe commonly a wooden bowl-diſh lined with copper) the ſilver begins immediately to ſeparate from the liquor in form of fine grey ſcales or powder; a part of the copper being diſſolved in its place, ſo as to tinge the fluid more and more of a blue colour. The

plates

plates are now and then ſhaken, that ſuch part of the ſilver as is depoſited upon them, may fall off and ſettle to the bottom, for otherwiſe the copper would be defended by it from the acid, and the precipitation of the ſilver would not go on. The digeſtion is continued, till a freſh bright copper plate, kept for ſome time in the hot liquor, is no longer obſerved to contract any powdery matter upon the ſurface : the liquor is now poured off, the precipitated ſilver waſhed with freſh portions of boiling water, and afterwards melted with nitre to ſcorify ſuch particles of the copper as have fallen with it. Without the aſſiſtance of heat, the precipitation is ſcarcely completed in ſeven or eight days : Schlutter obſerves, that the diſpatch requiſite for buſineſs, can ſcarcely be obtained without a boiling heat. Great part of the ſilver indeed ſoon ſeparates, but in proportion as the acid loads itſelf with the copper, its action becomes more and more languid, and is at length ſo weak, that ſome ſmall portion of the ſilver is frequently at laſt retained : this may be diſcovered by adding to a portion of the ſolution a drop or two of a ſolution of common ſalt : if the liquor contained any ſilver, it will grow turbid on this addition, and depoſite the ſilver combined with the acid of the common ſalt. I have been ſometimes ſurprized to find copper plates produce no precipitation at all in ſolution of ſilver : this happened when the menſtruum was loaded with as much ſilver as it could be made to diſſolve ; and on adding a drop or two of freſh acid, the precipitation went on as uſual.

From the ſolution of copper is prepared a blue pigment called verditer, by which the expence of refining is leſſened. According to Dr. Merret's account, a quantity of whiting is put into a tub, the copper ſolution poured on it, and the mixture ſtirred every day for ſome hours together, till the liquor loſes its colour, the copper being depoſited in the whiting, and a part of the whiting taken up in its room. The liquor is then poured off, more of the copper ſolution added, and this repeated, till the matter appears of the due colour, after which it is ſpread on large pieces of chalk, and laid in the ſun to dry. Boyle obſerves that the proceſs often miſcarried, and that heating the liquor before it is poured on the whiting, has been found to contribute to its ſucceſs. It is ſtill however, as I am informed, very apt to fail, in the hands of the moſt ſkilful workmen, the preparation, inſtead of a fine blue, turning out of a dirty green.

From the liquor poured off in making verditer, conſiſting of the nitrous acid ſaturated with the whiting, great part of the acid is recovered, by evaporating the watery part, and adding the remaining thick matter in the diſtillation of the next quantity of aqua fortis. The acid may be extracted alſo either from the ſolution of copper or ſilver, and the metals recovered, the ſilver by fuſion without any addition, the copper by the addition of inflammable matter. The following proceſs is given for this purpoſe in the French memoirs for the year 1728, as the communication of an experienced artiſt.

The copper ſolution is put into a copper veſſel placed in a furnace, and evaporated to about half: the veſſel is then filled up with more of the liquor, and the evaporation continued till the fumes begin to ſmell of aqua fortis. The acid, being already ſatiated with copper, does not act on the veſſel, or ſo little, that du Fay ſays he has ſeen one veſſel bear almoſt conſtant work for near a year: the veſſel ſhould be raiſed out of one plate, not formed of pieces, for if it is rivetted or ſoldered, the liquor will ſoon make its way through the junctures, as I have often obſerved in this and other ſolutions of the ſame kind. On decanting off the liquor, a portion of ſilver is found at the

the bottom, which the acid had before retained, and which the long boiling has difengaged. Stone ware cucurbits, coated with lute, are charged with the liquor to about two thirds of their height : the French have a kind of ware *(pots de grais)* which is faid to anfwer extremely well for this ufe : fuch of our common ftone wares as I have formerly tried, frequently failed. Five or fix of thefe veffels are let into one furnace, up to the height of the liquor, and the bottoms made to reft on iron bars : the furnace is long and narrow, with a door at one end for putting in the fuel, and the chimney at the other. On each jar is luted a ftone ware head with two fpouts and receivers. The fire is raifed to fuch a degree as to make the diftillation go on with fufficient difpatch, with care only not to increafe it fo far, as to endanger the matter fwelling up into the head. When about three fourths have come over, the fire is fuffered to decay, and the veffels to cool, that the heads may be unluted, and more of the copper folution poured in. This is repeated three or four times, till it is judged that the calx of copper in each jar rifes to about a fourth of its height, after which the fire is ftrongly urged, till the bottoms of the jars become red hot, and nothing more will diftil. This troublefome procefs might be improved by fubftituting to the cucurbits the copper pan in which the evaporation is performed ; which may be converted into a diftilling veffel, by fitting to it a ftone-ware breaft and head, in the fame manner as the copper breaft and head are fitted to the ftill in the firft plate : there is no occafion for two fpouts, as one, of a proper width, will fupply the place of the two : the copper pan fhould be let into the furnace almoft to its upper edge ; and the breaft fhould enter the pan nearly to the furface of the liquor. The aqua fortis thus obtained is perfectly free from any admixture of the vitriolic or marine acids, so as not to require the purification necessary for the common sorts: it is generally too strong for the common purposes of aqua fortis, and is therefore to be diluted with a proper quantity of pure water. The calx of copper may be revived, without much loss, by melting it, in a suitable furnace, in contact with the burning charcoal.

III. *Purification of gold from silver and base metals by cementation.*

THOUGH the nitrous acid in its liquid state does not extract silver from gold, unless the quantity of silver greatly exceeds the gold; yet in cementation, where the acid, resolved into fumes, is applied to the metal at the same time strongly heated, it attacks and corrodes a part of the silver though its proportion be very minute.

For this purpose, nitre in substance is mixed with equal its weight of common green vitriol calcined, or dried as for the making of aqua fortis, and with twice its weight of powdered bricks; the one to extricate its acid when sufficiently heated, and the other to prevent the mixture from growing fluid in the fire. The metal is flatted into thin plates, which are surrounded and interlaid with this powder, in a crucible, or in an earthen vessel made on purpose for this use called a cementing pot: the vessel is closely covered, and the juncture secured with a mixture of soft clay and sand, or other proper clayey compositions; and being placed in any convenient furnace, a moderate heat is kept up for twelve or sixteen hours. The silver, and most of the base metals along with it, are corroded by the nitrous vapour into a saline concrete, which partly adheres in the pores of the gold, and

and is partly diſperſed through the mixture. From the gold, the corroded ſilver may be boiled out with water, and afterwards recovered from the liquor in the ſame manner as from its ſolution in aqua fortis: from the mixture, it is much more difficultly extracted, by boiling the matter in melted lead, and afterwards working off the lead, into which the ſilver has thus transferred itſelf, upon a cupel or teſt. The quantity of ſilver however, which cementation is employed for ſeparating from gold, is commonly ſo ſmall as to be entirely diſregarded.

The acid of ſea ſalt, applied in the ſame manner, corrodes all the metallic bodies except gold and platina. Hence either ſea ſalt or nitre may be uſed in this proceſs indifferently; but they muſt never be taken together, as ſome have directed them to be, for the two acids in conjunction would diſſolve the gold itſelf. The mixture of ſea ſalt with the calcined vitriol and brickduſt has been commonly called the regal cement, from gold, before the diſcovery of platina, having been the only known metallic body that was capable of reſiſting it.

The gold plates cannot be wholly freed from their alloy by one operation either with the nitrous or marine cements, the vapours penetrating but a very little way into their ſubſtance. Hence for the effectual purification of gold by this method, the metal is to be remelted, flatted into plates, and again expoſed to the fumes. The proceſs indeed appears upon the whole to be incommodious, whether conſidered as a method of purifying gold or of aſcertaining its purity; and accordingly, though once in much eſteem, it is now rarely practiſed. Its principal uſe is for extracting ſilver or baſe metals from the ſurface of gold, and thus giving ſuperficial purity and high colour to alloyed or pale gold.

IV. *Refining of gold from ſilver and baſe metals by antimony.*

ANTIMONY conſiſts of a metallic ſubſtance united with ſulphur. Sulphur has leſs affinity to the antimonial metal than to ſilver, copper, or the other metals commonly mixed with gold: and accordingly when antimony and alloyed gold are melted together, the ſulphur of the antimony unites with and ſcorifies the alloy of the gold, while the gold falls to the bottom blended with the metal of the antimony, which laſt may be afterwards diſſipated from it by fire.

One of the greateſt difficulties in this proceſs regards the crucibles, which are very liable to crack, and to be corroded by the ſulphureous matter. Scheffer relates, that the crucibles he has found to be moſt durable are thoſe which had been ſteeped ſeveral days in linſeed oil; then cleared from the oil, ſo as to remain only of ſuch a degree of moiſtneſs, that ſome borax in fine powder may adhere and be ſpread all over the inner ſurface; and afterwards ſet by to dry ſlowly: in a crucible thus prepared he ſays he can perform two or three hundred fuſions. It is nevertheleſs adviſable, in a caſe where the veſſel is ſo apt to fail, to take precautions for preſerving its contents in caſe of ſuch an accident; as inſerting it into another crucible, or placing a baſon underneath.

The gold being melted in the crucible, about twice its weight of powdered antimony is thrown upon it, in different parcels, one parcel after another is melted; with care to prevent the falling in of any pieces of charcoal, which would occaſion the antimony to ſwell and froth up, ſo as to be apt to run over the veſſel: as this ſwelling up cannot be wholly avoided, the crucible ought to be large. If the gold is very impure, or contains above one fourth

fourth its weight of alloy, the antimony is previoufly mixed with about a fourth part of common fulphur; becaufe if antimony itfelf was ufed in fufficient quantity to fcorify all the alloy, the quantity of metal afforded by the antimony would be fo large as to render its diffipation from the gold extremely tedious. As foon as the mixture fparkles upon the furface, and appears perfectly fluid, it is poured into a conical brafs or iron mould, greafed, and equably heated all over till it fmokes; and the fupport, which the mould ftands on, is gently ftruck or jogged fo as to produce a tremulous motion of the fluid matter, by which the fettling of the gold is promoted. When the matter is fixed or grown folid, it is eafily got out, by inverting the mould and ftriking a few blows on it with a hammer: the metallic mafs, which had fubfided into the lower part of the cone, if it does not feparate, in coming out, from the fulphureous fcoria, is beaten off by a flight blow.

This metallic mafs confifts of the gold, mixed, inftead of its former alloy, with the metal of the antimony. But as part of its alloy may have ftill efcaped the action of the fulphur; if the gold is required to be of a high purity, it muft be melted in the fame manner with the fame quantity of frefh antimony, and the procefs repeated a third or even a fourth time. The gold does not receive much addition from the antimony in thefe laft fufions; the antimonial metal uniting with the gold only in proportion as the fulphur of the antimony is abforbed from its proper metal by the alloy of the gold.

In order to feparate the antimonial metal from the gold, the mixt is put into a ftrong crucible, which being placed in a proper furnace, a fire is kept up, juft fufficient to make the matter flow thin with a clear furface. A blaft of air being directed upon the mixt, by means of a bent copper pipe applied to the nofe of a pair of double hand-bellows, the antimonial matter gradually exhales in copious white fumes, which ceafe on difcontinuing the blaft, and reappear upon renewing it. The fire muft from time to time be increafed; for the mafs being cooled by the air impelled upon it, a hard fkin forms on the furface, and in this ftate the evaporation does not fucceed. When frefh fuel is to be fupplied, the crucible fhould be covered, that no pieces of the charcoal may fall in; and as foon as the metal has come again into fufficient fufion, the blaft on its furface is to be repeated, till no more fumes can be made to rife from it, and the gold remains of a clear bright green colour without the leaft cloudinefs.

If the procefs is continued, as it ought to be, to this point, there will be no occafion for remelting the gold with nitre and borax, as the writers on thefe fubjects generally direct. Where a little of the antimonial matter left in the gold, difcoverable by its palenefs and brittlenefs, renders this laft operation neceffary, the nitre and borax fhould be added by a little at a time, the matter being extremely apt to fwell up and run over the veffel: it is the more difpofed to fwell up as the antimonial remains are the more confiderable.

This procefs has been commonly fuppofed to afford the higheft purification of gold; and hence antimony has been diftinguifhed by the title of *balneum folius folis*, or the bath which gold alone can fupport, and by which it is wafhed from all its impurities. But befides that platina cannot thus be feparated from it; if gold containing filver be highly refined by antimony, it will ftill, on being diffolved in aqua regia, difcover a little of the filver, which had been defended by the gold from the action of the antimony. It may be obferved in general, that gold cannot be fo effectually purified by fubftances which operate

rate upon the alloy and not upon the gold, as by thoſe which act on the gold itſelf and not on the alloy.

A ſmall portion of the gold is commonly retained in the ſulphureous ſcoriæ, along with the ſilver or other metals with which it had been debaſed. The ſcoriæ of the laſt fuſions, in which the ſulphur and metal of the antimony have ſuffered little ſeparation, are therefore to be reſerved for the ſame purpoſes again. From thoſe of the firſt, both the gold and ſilver may be recovered, by keeping them in fuſion in a crucible, and blowing off the antimonial matter, in the manner above directed for diſſipating it from gold.

V. *Purification of gold from platina, ſilver and baſe metals by aqua regia.*

Aqua regia, in diſſolving gold, leaves behind what ſilver the gold had been mixed with; and certain bodies, added to the ſolution, ſeparate the gold from it, without being able to ſeparate any metal beſides; ſo that on this principle gold may be brought with eaſe to its ultimate purity.

The gold, flatted into thin plates or reduced into grains, is to be put into about thrice its weight of moderately ſtrong aqua fortis, and the veſſel being ſet in a gentle heat, a little ſea ſalt is to be added: the diſſolution will immediately begin, with a conſiderable efferveſcence, and when the action ceaſes, the addition of a little more ſea ſalt will renew it: the injection of ſea ſalt is to be continued, by a little at a time, till the whole of the gold appears to be diſſolved; the quantity of ſalt requiſite is generally about a third of the aqua fortis. The clear part of the ſolution is to be poured off, and the remainder paſſed through a double filter of paper: the undiſſolved matter is to be waſhed two or three times with water in the filter, and this liquor poured to the reſt.

For recovering the gold from the ſolution, Cramer directs two methods, diſtilling off the menſtruum, and precipitating the gold by mercury. But in either of theſe ways we cannot be certain of having the gold pure. For though it has been previouſly cupelled with lead, yet, if it contained any platina, it will retain the whole of the platina after the cupellation, and in ſome circumſtances, as we have already ſeen, it will retain alſo a little copper: both the platina and copper will diſſolve with it in aqua regia; mercury will precipitate the platina along with the gold; and the abſtraction of the menſtruum will leave with it both the platina and copper.

The purity of the gold is ſecured by precipitation with common green vitriol. The vitriol is to be diſſolved in cold water, the ſolution paſſed through a filter, and added in large quantity to the ſolution of gold: the quantity of vitriol, before its diſſolution, ſhould be ten or twelve times greater than that of the gold. As the precipitate falls ſlowly, the mixture is to be ſet by for twenty four hours or more: the liquor, then become clear, though of a deep colour, is to be poured off; the browniſh powder at the bottom, boiled in a little aqua fortis, then waſhed with water, and melted with the addition of a little nitre.

Gold, thus purified, appears to be perfectly fine; a point not obtainable by any other known means that can be practiſed in the way of buſineſs. Nor does the proceſs ſeem to be ſo expenſive as the imperfect one by aqua fortis; for there, three parts or more of ſilver being added to one of gold, at leaſt ſix parts of aqua fortis are required for diſſolving the ſilver; whereas the gold, in the above proceſs, may be diſſolved by half that quantity of the menſtruum: great part of the acid may like-
wiſe

be recovered by diſtillation from the liquor which remains after the gold has fallen.

Kunckel is the firſt who has taken notice of this precipitation by vitriol: but having uſed a vitriol which partook of copper as well as iron, he ſeems to have thought that the effect depended on the copper, and recommends the blueſt and moſt venereal of the common ſorts of vitriol as the beſt: accordingly moſt of thoſe, who have mentioned this proceſs, direct blue vitriol or vitriol of copper. I have not found that blue vitriol produces the leaſt precipitation in ſolution of gold; ſo that, by this miſapprehenſion in regard to the nature of the precipitant, Kunckel's diſcovery was rendered uſeleſs, till Brandt happily obſerved, that green vitriol produces the effect which had been aſcribed to the blue.

VI. *Extraction of a ſmall portion of gold from a large quantity of ſilver.*

THE moſt advantageous method of ſeparating a ſmall proportion of gold from a large one of ſilver appears to be by means of ſulphur, which unites with and ſcorifies the ſilver, without affecting the gold. But as ſulphurated ſilver does not flow thin enough to ſuffer the ſmall particles of gold, diffuſed through it, to reunite and ſettle to the bottom, ſome addition is neceſſary for collecting and carrying them down.

In order to the commixture with the ſulphur, fifty or ſixty pounds of the mixt metal, or as much as a large crucible will receive, are melted at once, and reduced into grains by lading out the fluid matter, with a ſmall crucible made red hot, and pouring it into cold water ſtirred with a rapid circular motion. From an eighth to a fifth of the granulated metal, according as it is richer or poorer in gold, is reſerved; and the reſt well mingled with an eighth of powdered ſulphur; which eaſily adheres to the moiſt grains. The grains, enveloped with the ſulphur, are put again into the crucible, and the fire kept gentle for ſome time, that the ſilver, before it melts, may be thoroughly penetrated by the ſulphur: if the fire was haſtily urged, great part of the ſulphur would be diſſipated, without acting upon the metal.

If to ſulphurated ſilver in fuſion, pure ſilver be added, the latter falls to the bottom, and forms there a diſtinct fluid, not miſcible with the other any more than water is with oil. The particles of gold, having no affinity to the ſulphurated ſilver, join themſelves to the pure ſilver, where-ever they come in contact with it, and are thus tranſferred from the former into the latter, more or leſs perfectly according as the pure ſilver was more or leſs thoroughly diffuſed through the mixt. It is for this uſe that a part of the granulated matter was reſerved.

The ſulphurated maſs being brought into perfect fuſion, and kept melted for near an hour, in a cloſe covered crucible, one third of the reſerved grains is thrown in, and as ſoon as this is melted, the whole is well ſtirred, that the freſh ſilver may be diſtributed through the mixt to collect the gold from it: the ſtirring is performed with a wooden rod: an iron one would be corroded by the ſulphur, ſo as to deprive the mixt of its due quantity of the ſulphur, and likewiſe render the ſubſequent purification of the ſilver more troubleſome. The fuſion being continued an hour longer, another third of the unſulphurated grains is added, and an hour after this, the remainder; after which the fuſion is further continued for ſome time, the matter being ſtirred at leaſt every half hour from the beginning to the end, and the crucible kept cloſely covered in the intervals.

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The ſulphurated ſilver appears in fuſion of a dark browniſh colour. After it has been kept melted for a certain time, a part of the ſulphur having eſcaped from the top, the ſurface becomes white, and ſome bright drops of ſilver, about the ſize of peas, are perceived on it. When this happens, which is commonly in about three hours after the laſt addition of the reſerved grains, ſooner or later according as the crucible has been leſs or more cloſely covered, and the matter more or leſs ſtirred, the fire muſt be immediately diſcontinued; for otherwiſe more and more of the ſilver, thus loſing its ſulphur, would ſubſide, and mingle with the part at the bottom in which the gold is collected. The whole is poured out into an iron mortar greaſed and duly heated; or if the quantity is too large to be ſafely lifted at once, a part is firſt laded out from the top with a ſmall crucible, and the reſt poured into the mortar. The gold, diffuſed at firſt through the whole maſs, is now found collected into a part of it at the bottom, amounting only to about as much as was reſerved unſulphurated. This part may be ſeparated from the ſulphurated ſilver above it by a chiſel and hammer; or more perfectly, the ſurface of the lower maſs being generally rugged and unequal, by placing the whole maſs, with its bottom upwards, in a crucible: the ſulphurated part quickly melts, leaving unmelted that which contains the gold, which may thus be completely ſeparated from the other. The ſulphurated ſilver is aſſayed, by keeping a portion of it in fuſion in an open crucible, till the ſulphur is diſſipated, and then diſſolving it in aqua fortis: if it ſhould ſtill be found to contain any gold, it is melted again, as much more unſulphurated ſilver added, as was employed in each of the former injections, and the fuſion continued about an hour and a half.

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The gold, thus collected into a part of the ſilver, may be further concentrated into a ſmaller part, by granulating the maſs, and repeating the whole proceſs. The operation may be again and again repeated, till ſo much of the ſilver is ſeparated, that the remainder may be parted by aqua fortis without too much expence.

The foregoing proceſs, according to Schlutter, is practiſed at Rammelſberg in the lower Hartz. The prevailing metal in the ore of Rammelſberg is lead: the quantity of lead is at moſt forty pounds on a quintal or hundred pounds of the ore: the lead, worked off on a teſt or concave hearth, yields about a hundred and ten grains of ſilver, and the ſilver contains only a three hundred and eighty fourth part of gold: yet this little quantity of gold, amounting ſcarcely to a third of a grain in a hundred pounds of the ore, is thus collected with profit. The author above mentioned confines this method of ſeparation to ſuch ſilver as is poor in gold, and reckons parting with aqua fortis more advantageous where the gold amounts to above a ſixty fourth of the ſilver: he adviſes alſo not to attempt concentrating the gold too far, as a portion of it will always be taken up again by the ſilver. Mr. Scheffer however relates, that he has by this method brought the gold almoſt to perfect fineneſs, and that he has likewiſe collected all the gold which the ſilver contained; the ſilver of the laſt operations, which had taken up a portion of the gold, being reſerved to be worked over again with a freſh quantity of gold-holding ſilver. The ſulphurated ſilver is purified by continuing it in fuſion for ſome time, with a large ſurface expoſed to the air; the ſulphur gradually exhales, and leaves the ſilver entire: the particular method of managing this operation will be given hereafter in the hiſtory of ſilver.

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Mr. Eller, in the memoirs of the Berlin academy for the year 1747, deſcribes a proceſs ſomewhat different from the foregoing; which has been kept a ſecret in a few hands; and from which, he ſays, Saxony has for ſeveral years reaped conſiderable profits, by the ſeparation of gold from gilt laces.

The metal being granulated, a part of the grains is mixed with half their weight of litharge and an eighth of ſandiver: this is called the precipitating mixture. The reſt are mingled as above with powdered ſulphur, and expoſed to a gradual fire till they are brought into fuſion, which is known to be perfect, when the ſurface, on lifting up the cover of the crucible, appears coloured, chiefly with red and yellow, and the colours come and go, as if ſomething attracted them. To every thirty-two ounces of the ſulphurated metal, one ounce of the precipitating mixture is added, at three different times, at intervals of at leaſt five or ſix minutes; after which, the crucible is covered again, and the fuſion continued ſeven minutes. Part of the matter being now laded out, the reſt is poured off, till a metallic maſs ſhews itſelf at the bottom: this is eaſily diſtinguiſhable, by its bright fiery aſpect, from the ſulphurated mixt, which is of a leaden brown colour.

The ſilver poured off, ſtill containing a little gold, is treated in the ſame manner a ſecond and a third time, except that in the third another precipitant muſt be uſed; for that employed in the two firſt, being partly compoſed of ſilver not freed from its gold, would add to the ſulphurated ſilver, now almoſt entirely purified from gold, more gold. The precipitant is now a mixture of equal parts of pure copper and lead, melted together and reduced into grains. If aqua fortis ſhould ſtill diſcover a little gold in the ſilver, which never happens unleſs the ſilver contained

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a large quantity at firſt, the precipitation is repeated a fourth time.

The ſeveral metallic maſſes, thus precipitated, are to be granulated, ſulphurated, and further concentrated by the ſame precipitants as before; about an eighth part of lead being added, before the granulation, which is ſaid to render the mixt more fuſible, and promote the ſeparation of the gold. It is probable that biſmuth would anſwer better in this intention, as it forms both with the metals and with the ſulphur a much more fuſible compound than lead does, and poſſeſſes alſo all the other properties of lead that appear to be here required.

The matter which now ſubſides is again granulated, mixed with a ſixteenth of ſulphur, kept in fuſion about half an hour, the ſcoria poured off, and the remaining maſs treated in the ſame manner, without any precipitant, a ſecond or a third time. The gold being now ſo far concentrated as to exhibit a yellow colour, the maſs is melted with a ſixteenth of copper, then granulated, the grains mixed with a ſixteenth of ſulphur, cemented for ſome time in a heat below ignition, after which, the fire being raiſed, the matter is kept in fuſion about fifteen minutes, and then poured out into a greaſed and heated mould: the gold is found at the bottom, commonly of a braſs colour, and about the fineneſs of eighteen carats: if too pale, the laſt operation is repeated with half the quantity of copper; after which the gold is further refined by antimony as already deſcribed.

VII. *Extraction of gold from copper.*

For ſeparating gold from large proportions of copper, as from the gilt clippings left by the button-maker, ſome of our refiners have recourſe to cupellation or teſting with lead. But the long continuance of fire and great quantity of lead neceſſary for ſcorifying ſo large a proportion of copper, and the difficult revival of the copper from the ſcoria, render the proceſs too expenſive for the produce of gold.

Some have melted the gold-holding copper with about thrice its quantity of lead, and caſt the mixture into cakes; which being ranged in the higher part of a ſloping canal, and moderately heated, it was expected that the lead, melting out and running down from the copper, would carry the gold with it. But though this proceſs ſucceeds for the ſeparation of ſilver from copper, it is otherwiſe in regard to gold: if the copper contains both gold and ſilver, only the ſilver melts out with the lead, the gold remaining behind in the unmelted maſs of copper.

Alonſo Barba gives a method which may in ſeveral caſes be practicable to advantage. The copper is calcined with ſulphur, till it becomes pulverable, and the powder ground with quickſilver in the ſame manner as earthy or ſtony bodies containing gold: the mercury imbibes the gold, without acting upon the calcined copper, which may now be waſhed off with water.

Many proceſſes have been given for ſeparating gold from copper by precipitating powders, which are compoſed of very diſcordant materials, as antimony, lead, ſulphur, crocus of iron, mercury-ſublimate, arſenic, vitriol, verdegris, alum, nitre, ſal ammoniac, wood aſhes, quicklime. Though theſe proceſſes, a number of which is collected by Swedenborg in the third volume of his *regnum ſubterraneum*, are apparently ſo injudicious, that an artiſt can have no inducement to make trial of them, yet they are not altogether without foundation: lead and ſulphur, as Barba intimates, and as an experiment of Mr. Scheffer's has ſhewn more ſatisfactorily, are the uſeful ingredients; and by means of theſe ingredients, gold may be extracted

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from copper more advantageoufly than by any other known method.

The way of procedure is as follows. Some litharge, or any other calx of lead, is melted with about an equal quantity of fulphur, with which it unites into a fparkling mafs, of a femimetallic afpect, and nearly of the fame quality with the common lead ores. The copper being brought into fufion, this mixture is thrown upon it, by a little at a time, till the quantity of lead becomes nearly equal to that of the copper: the copper abforbs the fulphur from the lead, and the lead, being in a ftate of calx, remains uniformly blended with the fulphurated copper. A little powdered charcoal is then thrown in, and the whole well ftirred with an iron rod: the lead is immediately revived into its metallic form, and finking to the bottom carries the gold with it; neither lead nor gold having any affinity to fulphurated copper. The effect is the fame when the copper is firft fulphurated, and the litharge or calx of lead added to this mixture; and probably gold might be feparated in the fame manner from fulphurated iron.

VIII. *Separation of gold from gilt works.*

THE folubility of gold and the indiffolubility of filver in aqua regia affords a principle on which gold may be feparated from the furface of filver; and on this foundation different proceffes have been contrived, of which the two following appear to be the beft. Some powdered fal ammoniac, moiftened with aqua fortis into the confiftence of a pafte, is fpread upon the gilt filver, and the piece heated, till the matter fmokes and becomes nearly dry: being then thrown into water, it is rubbed with a fcratch brufh, compofed of fine brafs wire bound together, by which the gold eaſily comes off. The other way is, by putting the gilt ſilver into common aqua regia, kept ſo hot as nearly to boil, and turning the metal frequently till it becomes all over black: it is then to be waſhed with a little water, and rubbed with the ſcratch bruſh, to get off what gold the aqua regia may have left. This laſt method appears preferable to the other; as the ſame aqua regia may be made to ſerve repeatedly till it becomes ſaturated with the gold, after which the gold may be recovered pure by precipitation with ſolution of vitriol, as directed in the fifth article of this ſection.

For ſeparating gold from gilt copper, ſome direct a ſolution of borax to be applied on the gilt parts, but no where elſe, with a pencil, and a little powdered ſulphur to be ſprinkled on the places thus moiſtened; the principal uſe of the ſolution of borax ſeems to be to make the ſulphur adhere; the piece being then made red hot, and quenched in water, the gold is ſaid to be ſo far looſened, as to be wiped off with a bruſh. Others mix the ſulphur with nitre and tartar, and form the mixture with vinegar into a paſte, whicy is ſpread upon the gilt parts.

Schlutter recommends mechanical means, as being generally the leaſt expenſive, for ſeparating gold from the ſurface both of ſilver and copper. If the gilt veſſel is round, the gold is conveniently got off by turning it in a lathe and applying a proper tool, a ſkin being placed underneath for receiving the ſhavings: he ſays it is eaſy to collect into two ounces of ſhavings all the gold of a gilt veſſel weighing thrice as many pounds. Where the figure of the piece does not admit of this method, it is to be properly fixed, and ſcrapers applied, of different kinds according to its ſize and figure, ſome large and furniſhed with two handles, one at each end, others ſmall and narrow for penetrating into depreſſed parts. If the gold cannot be got off by either of theſe ways, the file muſt be had recourſe to, which takes off more of the metal underneath than the turning tool or the ſcraper, particularly than the former. The gold ſcrapings or filings may be purified from the ſilver or copper they contain by the methods deſcribed in the preceding part of this ſection.

The editors of the *encyclopedie* give a method of recovering the gold from wood that has been gilt on a water ſize: this account is extracted from a memoir on the ſame ſubject preſented to the academy of ſciences by M. de Montamy. The gilt wood is ſteeped for a quarter of an hour, in a quantity of water, ſufficient to cover it, made very hot: the ſize being thus ſoftened, the wood is taken out, and ſcrubbed, piece by piece, in a little warm water, with ſhort ſtiff briſtle bruſhes of different ſizes, ſome ſmall for penetrating into the carvings, and others large for the greater diſpatch in flat pieces. The whole mixture of water, ſize, gold, &c. is to be boiled to dryneſs, the dry matter made red hot in a crucible to burn off the ſize, and the remainder ground with mercury, either in a mortar, or, where the quantity is large, in a mill, as deſcribed hereafter, in the eleventh ſection: ſome clean ſand is directed to be added, which is ſaid to occaſion the gold to be eaſier laid hold of by the mercury.

SECT. X.

Of tinging glaſs and enamel by preparations of gold.

THE tinging of glaſs and enamels by preparations of gold appears to have been firſt attempted about the beginning of the laſt century, Libavius, whoſe works compoſe a valuable body of the chemical knowledge of his own time, conjectures, in one of his tracts entitled *Alchymia*, printed in 1606, that the colour of the ruby proceeds

proceeds from gold, and that gold diſſolved and brought to redneſs might be made to communicate a like colour to factitious gems or glaſs. Neri, in his art of glaſs dated 1611, gives a proceſs on this principle, which he ſays was found to ſucceed: he directs the gold to be diſſolved in aqua regia, the menſtruum to be evaporated or drawn off by diſtillation, more aqua regia added, and the abſtraction repeated five or ſix times: the remaining matter is to be calcined till it becomes purple, and then mixed with a proper quantity of the fineſt white or cryſtal glaſs. But though this proceſs may be ſuppoſed to have ſometimes proved ſucceſsful, it doubtleſs very often miſcarried; inſomuch that the introduction of this deſirable colour into glaſs was very little known for many years after.

Glauber, in the ſecond part of his philoſophical furnaces publiſhed in 1648, gives another method of producing a red colour by gold in a matter which is of the vitreous kind, though not perfect glaſs. When powdered flint or ſand is well ground with four times its weight of fixt alkaline ſalt, the mixture melts in a moderately ſtrong fire, and when cold looks like glaſs, but on account of its over-proportion of alkaline ſalt it runs into a liquid ſtate on being expoſed to the air: on adding this liquor to ſolution of gold in aqua regia, the acid, which held the gold diſſolved, unites with the alkali which held the flint diſſolved, and the gold and flint precipitate together, in form of a yellow powder, which by calcination becomes purple: this powder being mixed with three or four times its weight of the alkaline ſolution of flint, the mixture dried, and kept melted in a ſtrong fire for an hour, a maſs is obtained, of a tranſparent ruby colour, and of a vitreous appearance, though ſtill ſoluble in water or by the moiſture of the air, on account of the redundance of ſalt.

Boyle, in his treatiſe on the poroſity of bodies, and in the appendix to his ſceptical chymiſt publiſhed in 1680, mentions an experiment, in which a like colour was introduced into glaſs without fuſion. A mixture of gold and mercury having been kept in digeſtion for ſome months, the fire was at laſt immoderately increaſed, inſomuch that the glaſs burſt with a violent exploſion: the lower part of the glaſs was found tinged throughout of a tranſparent red colour, which ſeemed, he ſays, to emulate that of a not common ruby.

About the ſame time Caſſius diſcovered the precipitation of gold by tin, and that glaſs might be tinged of a ruby colour by melting it with this precipitate. I can give no further account of his experiments, having never had the good fortune to meet with his treatiſe.

The proceſs was ſoon after brought to perfection by Kunckel, who ſays he prepared the ruby glaſs in large quantity, and ſold it for about forty ſhillings an ounce; and that he made a chalice of it for the elector of Cologn, weighing no leſs than twenty four pounds, a full inch thick, and of an uniform fine colour throughout. He has no where communicated the proceſs he followed, but ſome uſeful obſervations relating to it are diſperſed through his writings: he ſays, that one part of the precipitate by tin is ſufficient to give a ruby colour to twelve hundred and eighty parts of glaſs, and a ſenſible redneſs to upwards of nineteen hundred parts: that the ſucceſs is by no means conſtant, and that after long practice, he ſtill frequently failed: that oftentimes the glaſs comes out of the fire colourleſs as cryſtal, and receives its ruby colour on being afterwards expoſed to a ſmoky flame, inſomuch that he imagines the diſcovery of the ruby glaſs did not ariſe from ſimply melting the gold precipitate with glaſs, but from the ſubſequent ſoft-

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ening and working of the glaſs in the flame of a lamp, in the uſe of which Caſſius was very converſant: that the addition of nitre and ſal ammoniac calls forth the colour, and that the colour produced by ſal ammoniac is more beautiful than that by nitre, but quickly diſappears on a continuance of the fire.

Orſchal, in a treatiſe entitled *ſol ſine veſte*, gives a proceſs, by which he ſays he obtained a very fine ruby. He directs the purple precipitate, made by tin, to be ground with ſix times its quantity of Venice glaſs in very fine powder, and this compound to be exquiſitely mingled with the fritt or vitreous compoſition to be tinged: his fritt conſiſts of equal parts of borax, nitre, and fixt alkaline ſalt, and four times as much calcined flint as of each of the ſalts; but in what proportion the gold precipitate is to be mixed with the fritt, and in what manner the fuſion is to be performed, he does not mention. He reports that he had found the muddy matter, obtained in poliſhing gold by a pumice ſtone, to impart likewiſe a ruby colour to glaſs.

Grummet, who had been operator to Kunckel in making the red glaſs, publiſhed a tract in oppoſition both to him and Orſchal, under the title of *ſol non ſine veſte*, in which he obſerves, that the furnace ought to be ſo conſtructed, that the operator may have full liberty of examining the glaſs in the fire, and of removing it as ſoon as it appears to have acquired the proper colour: he ſays the enamellers obtain a ruby colour, by melting, with a large proportion of Venice glaſs, the browniſh powder precipitated from ſolution of gold in aqua regia by fixt alkaline ſalts. But he imagines that the gold is nowiſe concerned in the production of the colour. Venice glaſs, and moſt of the finer colourleſs kinds of glaſs, have an addition of manganeſe, without which it would be very diffi-

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cult to render them perfectly void of colour: the manganese communicates at first a purplish hue, which on continuing the fire disappears, and at the same time suppresses or discharges any other tinge that the glass may be impregnated with: the addition of a little nitre revives the purplish colour of the manganese, and Grummet is of opinion that the colour with which glass becomes tinged, by the admixture of preparations of gold, is no other than that of the manganese extricated by the nitrous salt which the gold has retained in its precipitation. He affirms that the same purplish red colour will be obtained on melting Venice glass with an eighth part of nitre, without any gold; that in a hundred repetitions of this experiment, it scarcely fails once; and that neither nitre nor the gold-precipitate were found to give any thing of the admired colour to those kinds of glass which have no manganese in their composition.

The colours which manganese imparts to glass, it belongs not to this place to examine: but that precipitates of gold will communicate, in certain circumstances, a purplish red colour, I have several times experienced; having myself tinged of this colour fritts composed of calcined flint, nitre and borax, without the addition of any manganese or of glasses containing it. Though gold, dissolved in common aqua regia, exhibits its own yellow colour; yet, when the menstruum is separated by fire to a certain point, or when the gold is precipitated by tin, or when it is precipitated by alkaline salts and afterwards moderately heated, or when the gold is barely divided by mechanical means into subtile powder, and exposed for some time, in mixture with earthy bodies, to a slight heat, it assumes, in different circumstances, a violet colour, a purple, or a red verging to purple: in a strong fire, these colours vanish, and the gold melts into a mass of its ori-

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ginal appearance. All theſe colours I have introduced into glaſs by preparations of gold; and I have found them to be nearly as periſhable in the fire when the coloured gold powder was thus diffuſed through the glaſs, as when expoſed to the fire by itſelf: when the fire was raiſed to any great degree, and the glaſs made to flow thin, there was generally a button of revived gold collected at the bottom.

A ſolution of gold in aqua regia being inſpiſſated to dryneſs in the bottom of a Florence flaſk, and the heat further increaſed till the gold reſumed its proper colour, the lower part of the glaſs was by this ſimple proceſs tinged purpliſh: pieces of it being expoſed to the flame of a lamp, they became in ſome parts violet coloured, in ſome of a bright purple, and in others purpliſh red; and the parts which in one poſition looked violet or purpliſh, in another appeared red.

A colour nearly of the ſame kind is impreſſed on glaſs by gold leaf in ſome electrical experiments; a fact which we are obliged to Mr. Franklin for the firſt knowledge of. A narrow ſtrip of gold leaf being placed between two ſlips of glaſs, with both the ends hanging out a little, and the glaſs well tied round with ſilk thread, a ſtrong electrical exploſion is made to paſs through the gold leaf. On examining the glaſs, the gold leaf, he obſerves, will be found miſſing in ſeveral places, and inſtead of it a reddiſh ſtain on both the glaſſes, exactly ſimilar on both in the minuteſt ſtroke, though ſometimes ſpread a little wider than the breadth of the leaf: the ſtain appears to have penetrated into the ſubſtance of the glaſs, ſo as to be protected by it from the action of aqua regia. I have had this experiment ſeveral times repeated with plate glaſs, and found it tinged, as above deſcribed, in ſome parts violet, in ſome purpliſh, and in ſome reddiſh; the colours could not be ſcraped off,

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and refifted aqua regia and fpirit of falt. If the electric explofion is made very ftrong, the glafs commonly flies in pieces, with fuch force, that it is neceffary for the operator to have his face fkreened from them.

The preparation of gold which has been principally recommended for tinging glafs is Caffius's precipitate by folution of tin. To obtain this precipitate of the due colour, a good deal of care is neceffary both in diffolving the tin, and in diluting the folutions. A mixture of two parts of aqua fortis and one of fpirit of falt is fuppofed to be the beft menftruum for the tin: into this mixture fome fine block tin, granulated, is to be let fall, grain by grain, waiting till one grain is diffolved before another is dropt in, that the diffolution may go on flowly, without any heat or difcharge of fumes. The gold is diffolved in common aqua regia; and a few drops of this folution being mixed with fome ounces of pure water, as many drops of the folution of tin are added. If the mixture changes immediately to a clear bright purplifh red colour, the due degree of dilution has been hit; if the colour appears dull, a greater quantity of water muft be added for the reft of the folutions. After the mixture has depofited its red matter, and become clear, a little more of the tin folution is to be dropt in, for difcovering, and precipitating, any gold that may ftill remain in it: the liquor being then poured off, the precipitate is wafhed and dried.

Kunckel mentions another purple gold-powder, made nearly like that of Neri already mentioned, by infpiffating folution of gold to drynefs, abftracting from it frefh aqua regia three or four times till the matter looks almoft like oil, then precipitating with ftrong alkaline ley, and wafhing the precipitate with water. By diffolving this powder in ſpirit of ſalt, and precipitating again, it becomes, he ſays, extremely fair, and in this ſtate he directs it to be mixed with a due proportion of Venice glaſs.

Hellot deſcribes a preparation which in mixture with Venice glaſs was found to give a beautiful purple enamel. Equal parts of ſolution of gold, and of ſolution of zinc in aqua regia, are mixed together; and a volatile ſpirit, prepared from ſal ammoniac by quicklime, added to the mixture in ſufficient quantity to precipitate the two metals. The precipitate is to be gradually heated, till it acquires a violet colour: it does not fulminate, making only a ſlight dull decrepitation without any of its particles flying about.

Though a purple, or a red colour approaching to that of the ruby, may by the foregoing means be baked upon glaſs or enamels, and introduced into the maſs by fuſion, the way of equally diffuſing ſuch a colour through a quantity of fluid glaſs is ſtill a ſecret.

I was once, many years ago, fortunate enough to ſucceed, at a glaſs-houſe, in a ſmall pot of glaſs, of which a ſalver was blown of a fine ruby red: the tinging matter was the precipitate of gold by tin; the particulars of the proceſs cannot now be recollected. I have ſince tried the remainder of the ſame preparation, with common flint glaſs, with green glaſs, with various fritts compoſed of flint, borax, pure fixt alkaline ſalt, nitre, ſal ammoniac. When flint was uſed, it was ſeveral times made red hot, and quenched in water, to render it more eaſily pulverable: both the flint and glaſſes were powdered in an iron mortar, and the powders well waſhed with diluted oil of vitriol, to extract ſuch particles of iron as they might have worn off in the trituration; the gold precipitate was ground with the other ingredients, in agate or glaſs mortars; its proportion was varied from an eighth part to an eight hundredth of the vitreous materials; and the fire was continued, in a wind furnace, from ſix to thirty hours. All the glaſſes came out conſiderably coloured; ſome of a deep duſky yellow; ſome of a fine pale tranſparent yellow; ſome of a brown colour, greatly reſembling that which the glaſs mentioned in the following page acquired under a muffle: ſome appeared yellowiſh or browniſh when looked down upon, and of a purple-violet or reddiſh purple when held between the eye and the light: ſome had ſpecks and veins of a fine red; no one was either red or purple throughout. Several of theſe glaſſes were melted again and again, by themſelves, and with the addition of more vitreous matter: ſome were worked in the flame of a lamp: ſome were laid in a mixture of powdered charcoal and ſoot, and made red hot in a cloſe crucible; and others being laid in the ſame manner, the fire was increaſed till they melted. The colours were by theſe means altered, but did not become uniform, or more approaching to the ruby colour than before: ſome pieces, which had at firſt very conſiderable ſpecks of a ruby luſtre, loſt them on a repetition of the fuſion.

At the ſame time that theſe experiments were tried, the ſame kinds of vitreous compoſitions, mixed with different metallic preparations, were expoſed to the fire in different parts of the ſame furnace, and were all found to receive beautiful and uniform colours, of which an account will be given in their places. To what cauſe the miſcarriage of thoſe with gold was owing, whether the ſucceſs, in regard to this metal, is influenced by the quantity of the matter, by the unſteadineſs of the heat in a ſmall furnace, by the fuſibility of the vitreous compoſition, by the metallic matter being ground with the ingredients before their expoſure to the fire or added to them

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in fuſion, by the continuance of the fire, by the fluid matter being kept unmoved or ſtirred with an iron rod, by the crucible being covered or open, or other like circumſtances, or whether the admixture of a little mangaueſe, though gold will certainly give a ruby colour without it, does not contribute to ſecure the ſucceſs, I have not yet diſcovered. The proportion of the gold precipitate to the vitreous matter is perhaps of principal importance. Solution of gold, as we have ſeen already, produces no redneſs with tin unleſs diluted with a very large quantity of water, in which circumſtance the whole mixture acquires that beautiful colour which we here want to tranſfer from the watery fluid into fluid glaſs: it ſhould ſeem therefore that the quantity of gold precipitate, for communicating the admired colour to a certain volume of glaſs, ought to be the ſame with that, which communicated a like colour to an equal volume of water in the precipitation: a quantity extremely minute, and much leſs than that employed in any of my experiments.

I have lately been favoured with ſome pieces of glaſs, in greateſt part colourleſs, with one or two large red ſpots, ſeveral ſmall ſtreaks of violet, and ſome of a light browniſh yellow. The perſon from whom I received them informs me that he had "found that in a heat not very ſtrong, under a muffle, the glaſs becomes of an opake brown, and, if then poliſhed, appears variegated like a fine pebble." I expoſed a colourleſs piece to the flame of a lamp, impelled by a blow pipe, and on working it about, ſometimes in the ſmoke and ſometimes in the flame, found it change to a true ruby red, perfectly tranſparent, and free from veins of any other colour. Another piece, kept for two hours under a cloſe muffle, in ſuch a heat as made it juſt ſoft enough to bend and receive an impreſſion, became on the ſurface green, brown and pale yellow in different parts, greatly reſembling the coat of ſome pebbles: in this ſtate, looked through againſt the ſun, it appeared of a beautiful ruby colour, and on breaking it, the internal part was found throughout of an uniform dark red when looked down upon, and of the ruby red when placed between the eye and the light. A large piece being continued under the muffle for four hours, its figure was found ſcarcely altered, the coat was much thicker and beautifully veined with various colours, which were all loſt in a glorious red when the piece was viewed between the light.

All I have been able to learn in regard to the preparation of this glaſs is, that the quantity made at once is about ſix hundred weight; that the tinging matter is mixed with the vitreous materials before they are put into the melting pot, the mixture being brought to the glaſs-houſe in tubs; that the matter is not ſtirred in fuſion; and that it is kept no longer in the fire than is neceſſary for perfecting the glaſs, which, as ſoon as fine, is caſt into a kind of bricks. Some imagine that this glaſs has no mixture of calx of lead, of which a large proportion is uſed in the compoſition of the common flint glaſs, and that the principal vitrefying ingredient is nitre: others judge it to be compoſed of the ſame materials as the common ſort; its weight ſeeming to be a proof of its containing lead, for it is found to be nearly of the ſame ſpecific gravity with flint glaſs, which is greater than that of the glaſſes made without lead in the proportion of above ſix to five. This point I have determined in a more ſatisfactory manner: four hundred grains of the glaſs, made red hot and quenched in water, were reduced into powder, and mingled with about twice as much black flux and a little alkaline ſalt: the mixture being melted in a crucible, and the veſſel ſuffered to cool, a lump of metal was found at the bottom, weighing ninety grains. The metal appeared to be ſomewhat ſtiffer than pure lead, and experiments convinced me that it contained ſome tin and a little gold.

SECT. XI.

The mineral hiſtory of gold.

GOLD is found in its perfect metallic ſtate; ſometimes in maſſes of conſiderable magnitude; more frequently in duſt or minute grains, intermingled among earths and ſands; or in little drops and veins, bedded in different coloured ſtones, which ſtrike fire with ſteel, and are not ſoluble in aqua fortis. It is never debaſed into a true ore, as other metals generally are, by the coalition of arſenical or ſulphureous bodies; though it is often very intimately combined in the compoſition of ſands and ſtones, and blended, in ſmall proportion, with the ores of other metals. It is ſcarcely ever free from ſome admixture of other metals, particularly of ſilver: Cramer obſerves, that ſuch as is found looſe in earths and ſands generally contains more ſilver than what is lodged in a ſolid matrix. To ſuch an admixture is apparently owing the paleneſs of ſome kinds of gold: and probably the Malacaſſean gold, ſaid by Flacourt, in his hiſtory of Madagaſcar, to be not only paler but much more fuſible than that of Europe, and which has hence been ſuppoſed by ſome to be in its own nature diſtinct, is no other than a mixture of gold with a certain quantity of ſilver: it is ſaid to be of conſiderably leſs value than the European gold, from which circumſtance, omitted by Boyle and others who have quoted Flacourt's account, it may be preſumed that it is not regarded, upon the ſpot, as being pure gold.

The

The Brafils, the Spanifh Weft Indies, fome parts of the Eaft Indies and the coaft of Africa affo·d the largeft quantities of gold. Some parts of Europe alfo appear to be rich in this metal: the mines of the upper Hungary, which feem to be the moft confiderable in this quarter of the world, have continued to yield gold for upwards of ten centuries.

Peru, Mexico, Chili, and other provinces of the Spanifh Weft Indies, abound with gold in a variety of forms. It is found both in the fands of rivers, and in mines; intermixed with loofe earth, lodged in fiffures of rocks, and bedded in hard ftones; at the furface of the earth, and at great depths; in duft, in grains like the feeds of apples, called pepitas, and fometimes in maffes of an extraordinary fize. Reaumur reports that a piece was fhewn to the French academy, which was faid to weigh fifty-fix marcs, or four hundred and forty-eight ounces; and Feuillée fays he faw one, in the cabinet of Antonio Portocarero, which weighed upwards of fixty-fix marcs or five hundred and twenty-eight ounces. Both thefe pieces were affayed, and found to be of different finenefs in different parts of the mafs: the firft was in one part twenty-three carats and a half, in another twenty-three, and in another only twenty-two: the fecond was in one part twenty-two carats, in another twenty-one, and in another but feventeen and a half. It is, however, rare to meet with maffes of the weight even of an ounce: the largeft in the Britifh mufeum weighs but fifteen pennyweight. Notwithftanding the extenfive diffemination of it through thofe provinces, yet the quantity of the gold, in proportion to the earthy and ftony matter mixed with it, appears to be in general exceeding fmall. According to Frezier in his voyage to the fouth fea, and Captain

Bretagh's

Bretagh's account printed in Harris's collection, the common yield is no more than five or fix ounces of gold upon the caxon or fifty hundred pounds of the mineral : the richeft mines afford only ten or twelve ounces, and thofe which are but juft rich enough to pay the charges of working of them, yield only two ounces on that quantity. It may be obferved in general, that the quantity of gold in minerals is more variable than that of other metals in their ores, and the profits of a gold mine more precarious ; this metal not being formed into any regular veins, or uniformly diftributed through any particular kind of earth or ftone, but fcattered as it were here and there through different mineral bodies : when united with other metals in their ores, its proportion is by no means conftant, though in this cafe it is fubject to much lefs variation than when it is barely bedded in earths or ftones.

Of the fource of the gold of the Eaft Indies and of Africa, we know but little. From Cape-coaft on the coaft of Guinea we receive yearly between two and three thoufand ounces of gold duft, which is fuppofed to be collected from the fands of rivers ; and fome European traders are faid to have been witneffes of the richnefs of the fands in certain parts of that coaft. In Hook's pofthumous papers an account is given of a perfon having met with great quantities of gold in the fands of one of the rivers, the fand feeming to grow richer and richer as he advanced further up : in fome places he fays he gained fixty-three grains of gold from five pounds of fand, and he feems afterwards to have met with much more profitable fpots. Three or four hundred ounces, as I am informed, are collected yearly from the fands of the Gambia, and caft into bars at James-fort, one of our fettlements on that river.

I

It

It is ſaid, that the gold duſt from Africa, in its pureſt ſtate, is from twenty-one to upwards of twenty-two carats fine; but that the natives frequently mix with it filings of braſs. This admixture may be diſtinguiſhed by the hydroſtatic balance, the ſpecific gravity of braſs not being half ſo great as that of the gold duſt: in this way of examination great care muſt be taken to make the water penetrate as perfectly as poſſible into all the interſtices ſo as to come into cloſe contact with every particle. A little aqua fortis alſo, poured on the mixture, will immediately diſcover the fraud, receiving, from the copper in the braſs, a blue tincture. It has been ſuſpected, that if the gold be naturally alloyed with a little copper, this trial will prove fallacious, and that the natural copper will tinge the menſtruum equally with that which is added by art: of this, however, there is no danger, the natural alloy not being in diſtinct particles, but diffuſed through each maſs or particle of the gold, ſo as to be covered by the gold, and protected from the action of the menſtruum. There are ſeveral other means by which this abuſe may be diſcovered: if the duſt be ſpread thin on a piece of white paper, and moiſtened with any volatile alkaline ſpirit, as that of hartſhorn, of ſal ammoniac, or of urine, the ſpirit will in a few minutes diſſolve ſo much of the copper as to ſtain the paper blue: ſtale urine itſelf has a like effect, in an inferiour degree; and a ſolution of crude ſal ammoniac, applied in the ſame manner, produces a greeniſh ſtain.

There are ſundry European rivers which roll particles of gold with their ſands, in no great quantity, yet ſuch, that the neighbouring inhabitants, at certain ſeaſons, find their account in collecting them. M. de Reaumur, in an eſſay in the French memoirs for 1718, drawn up from materials furniſhed by the intendants of the ſeveral pro-

vinces

vinces in purſuance of the orders of the duke of Orleans, gives an account of ten rivers or rivulets in the territories of France that have gold mixed with their ſands in certain parts of their courſe: the Rhine, from Briſac down to Straſburg ſparingly, from thence to Philipſburg more abundantly, and moſt of all ſo between Fort Louis and Germeſheim: the Rhone, in the pais de Gex, from the conflux of the Arve, from which it is ſuppoſed to receive its gold, to about five leagues lower down: the rivulets of Ferriet and Benagues, which riſe from the heights on the left hand of the deſcent from Varilhere to Palmiers: the Ariege, *aurigera*, about Palmiers, below where it receives the two foregoing rivulets: the Garonne, ſome leagues from Toulouſe, below where it receives the Ariege: the Salat, which riſes, as the Ariege, in the Pyreneans: the Ceze and the Gardon, which come from the Cevennes; and the Doux in Franche-Compté. The laſt of theſe rivers is the pooreſt, the gold having hitherto been collected from it rather in the way of curioſity than in a lucrative view: the greateſt quantities are obtained from the Rhine, not that this is really the richeſt, but on account of its ſands being the moſt induſtriouſly ſearched, for ſome of the others, particularly the Ceze and the Gardon, appear to be at leaſt equal to it in richneſs. The quantity got from the Rhine, in an extent of near two leagues below Straſburg, is ſaid to amount to no more than four or five ounces in a year: this is the quantity brought to the magiſtrates of Straſburg, who farm out the right of collecting it on condition of its being ſold to them at a price conſiderably under its value, ſo that it may be preſumed that a part is otherwiſe diſpoſed of, and that the quantity really obtained is conſiderably greater.

There are many other rivers reported to yield gold, as the Tagus, the Danube, the Elb, the Oder, the Inn, the

 Sala,

Sala, &c. The Schwartz, in the county of Schwartzburg in upper Saxony, is ſaid to be rich in this metal, and its ſands to be worked with great profit: Stahl mentions a piece found in it as broad as a middling bean, though not ſo thick, and ſuppoſes that the Sala receives all its gold from this river; the gold of the Sala being found only below where the Schwartz enters it, and being leſs plentiful and in ſmaller grains. It is generally reckoned that the gold particles, in all auriferous rivers, are waſhed out by the ſtream from ſome rich beds, and afterwards reſt or ſettle where the current is languid, or in places where they eſcape its force: from what particular ſources the gold in different rivers proceeds, does not ſeem to have been examined.

The richeſt parts of rivers, within the extent in which they roll gold, are thoſe where their courſe is ſlow and interrupted, where they widen or change their direction: the moſt favourable ſeaſon is when the water has ſubſided after a flood. The appearance of the ſand affords an uſeful mark for diſtinguiſhing the richeſt ſpots; the gold being always moſt plentiful where the ſand is reddiſh or blackiſh, or of a colour ſomewhat different from what is ſeen elſewhere; not that the red or black ſands have any natural connexion with the gold; but on account of their being more ponderous than the white, ſo that the ſame cauſe, which determines the particles of gold, determines theſe alſo to ſubſide. The black ſand abounds with iron, being vigorouſly attracted by the magnet; the red, viewed in a microſcope, appears, as Reaumur obſerves, a beautiful congeries of coloured cryſtals, imitating all the gems known to the jeweller, among which thoſe of the ruby and hyacinth teints are the moſt common, whence the reddiſh colour of the ſand to the naked eye; the particles of gold are of irregular figures,

figures, but conſtantly flat, ſmooth, and with the edges rounded off.

Some gold has been diſcovered in Britain, at different times, though hitherto in little quantity. Inſtances are mentioned in Houghton's collections, from Camden, Sibbald, and Gerard de Malines, of gold found in Scotland, about the head of the Clyde, in Crawford-moor; and Boyle ſays he had from ſome part of Scotland divers large grains of gold, taken up near the ſurface of the earth, over a lead mine, one of which, clear from ſpar, weighed two hundred and one grains. Mr. Boyle had alſo an Engliſh tin ore, wherein there lay, in little cells, a number of ſmall leaves or chips of gold: he obſerves that though the tinmen, unable to ſeparate them to profit, uſually melted both metals together, he was aſſured that one perſon advantageouſly employed his children to pick out the gold from the ore ſkilfully broken. Some earlier writers mention alſo gold found in the tin ores of Cornwall, and about the beginning of the preſent century a patent is ſaid to have been obtained "for ſeparating gold "and ſilver from tin by precipitation in a reverberatory "furnace with ſome peculiar fluxes": what ſucceſs this ſcheme met with, I have not learnt. Mr. Borlaſe, in his natural hiſtory of Cornwall, gives an account of ſome tin ore abounding with a yellow matter, which was taken by the workmen for mundic: ſome bits of the yellow matter, one of which was a vein as large as a gooſe-quill included in a ſtone about the ſize of a walnut, produced, on being melted, an ounce of pure gold: he mentions ſeveral other pieces of conſiderable bulk, and gives a figure of one, found in 1756, weighing three hundred and ſeventy-ſix grains. It is ſuppoſed to be chiefly the ſtream tin, (that is the tin ore found in detached pieces on the ſides of hills) which contains gold; that all of this ſort contains more or lefs of it ; and that both the gold and tin ore have been brought from elfewhere by torrents of water, and depofited where they are now found like the gold fands of rivers.

Boyle conjectures, that befides the grains of gold which lie detached among fands, there may be many particles fo minute and clofely fixed to the fand, as not to be perceivable by the eye, or feparable by the common methods of wafhing or picking ; that many fmall portions of the metal may be incorporated alfo with the body of the fand, and that by fkilful management they might be extracted. Experiments, he fays, confirmed him in this perfuafion : later experiments have verified it, and fhewn the exiftence of gold in fands to be even more extenfive than he feems to have apprehended. Many of the common fands, particularly the yellow, red, black, and thofe of a black colour inclining to violet, appear to be rich in gold : Becher and Cramer prefume that there is no fand in nature entirely free from it. Hellot relates, that in eleven affays of one kind of fand, made by M. Lieberecht, by a procefs defcribed in the fequel of this fection, the yield of noble metal turned out conftantly from eight hundred and forty to eight hundred and forty-four grains on the quintal or 921600 grains, exclufive of what remained in the fcoriæ, which were ftill found to be rich ; that different parcels of fand, taken up at no great diftance from one another, differed in degree of richnefs, fome having afforded above a thoufand grains, others only three hundred and fifty, and others yielding none by the treatment which had fucceeded fo well for the reft ; and that of the metal thus obtained from fands two thirds are commonly gold, and the reft filver. Yet notwithftanding the great richnefs of thefe fands, no means have hitherto been difcovered of availing ourfelves of the metal they contain, or of extracting it to advantage in the large way. Becher indeed undertook to obtain gold with profit from the common sea sands, and entered into engagements with the states of Holland for establishing a mineral work on this foundation : but though experiments made on little quantities promised very considerable gain, and though one trial in large is likewise said to have proved successful, yet, as he communicated the whole process to the commissioners appointed to examine the affair, and as he has shewn that such a work might be carried on more advantageously in Holland than in other parts of Europe, its never having been prosecuted in Holland affords a strong presumption of its not being sufficiently lucrative. The existence of gold in sands is nevertheless an interesting fact, at least to the philosopher, and further examination may perhaps find means of making it turn to account.

Though gold has been but lately discovered, or expected, in these minerals, in which it is so common and so plentiful, their unpromising appearance having given little encouragement to examine them ; there are others, whose flattering colour has raised great expectations, but which have not been found upon experiment to yield any gold. The yellow pyritæ or marcasites, and other minerals of a golden colour, or containing gold-coloured specks, have by some been regarded as ores or matrices of gold, and accordingly submitted to different operations, as fruitless as expensive : their losing their colour in the fire, or changing it to a yellow, soon discovers that their tinging matter is not gold, but sulphur or a ferrugineous calx. There are indeed pyritæ which contain gold, and in quantity sufficient to deserve notice : Henckel, in the 12th chapter of his *pyritologia*, gives an account of some assays of minerals of this kind brought from the Hungarian mines,

mines, one of which yielded, on the centner or 1600 ounces, half an ounce of noble metal, of which one fifth was gold and the reſt ſilver: from the ſame quantity of another he obtained no leſs than ſixty ounces of ſilver, and eight ounces and a half of gold: but the gold, as he obſerves, is by no means proper to the pyrites, or an eſſential part of its compoſition, having been only caſually intermixed, as it is in ſtones and other minerals in the gold mines.

Many have been deceived alſo by ſome of the talcs: of which there is one ſpecies, naturally of a grey colour, which in a moderately ſtrong fire changes to a gold yellow; and another, naturally of a glittering gold colour, which receives no change from moderate fire: both theſe bodies have a further reſemblance to gold, in imparting a deep yellow tincture to ſtrong aqua regia. By repeated digeſtion in freſh aqua regis, all the colouring matter may be extracted, and the earthy part left white: but the ſolution yields no gold, and is found to be no other than a ſolution of iron. Reaumur obſerves that ſpangles of the yellow talc are frequent in the ſands of ſome rivers, and that they may readily be diſtinguiſhed from gold, which they have often been taken for, by viewing them with a magnifying glaſs; the gold particles found in rivers being conſtantly ſmooth, with the edges rounded, while the talky ones are rugged and ſharp-edged.

II. *Separation of gold from earthy and ſtony bodies by water.*

GOLD intermixed with earthy bodies in ſmall particles or duſt, is ſeparated by waſhing with water, which carries off the lighter earth, and leaves the more ponderous metal behind: the great gravity of gold renders it better adapted to this way of ſeparation than any of the other metals. There are ſundry variations in the manner of conduct-

conducting the procefs, according to the quantity of the matter, the nature of the earthy body, and the conveniency of the place; many of which are minutely defcribed by Agricola in his treatife *de re metallica*: it will be fufficient here to give a general idea of the manner of procedure, in an operation merely mechanical, and whofe fuccefs depends chiefly on manual dexterity acquired by practice.

Where the quantity of matter is fmall, it is laid by a little at a time in a round fhallow difh called a buddle, or in an oblong veffel like a boat, which being gently fhaken backward and forward, in a tub of water, the lighter part of the earth is taken up and wafhed off, leaving with the gold fuch fand or fmall ftones as the mixt contained. By dextroufly repeating the agitation, that the whole may acquire as it were a kind of fluidity, the metalline particles fink to the bottom, and the fand or ftones are thrown up to the top, and may be removed by the hand.

At feveral of the gold mines of the Spanifh Weft Indies, the gold is completely feparated by this fimple operation. According to D' Ulloa's account, in his voyage to thofe parts, the earth, as it comes from the mine, is thrown into a refervoir, a ftream of water conducted on it, the whole ftirred together, and the muddy water let off into another and another refervoir: what the water leaves in the firft refervoir, and what it depofits in the others, is taken up in trays, or buckets with two handles, and agitated in frefh waters, with an uniform circular motion, till the gold is collected at the bottom.

M. de Reaumur, in the French memoirs for the year 1718, gives a particular defcription of the method of wafhing the gold fands of the Rhine and fome other rivers. A board, five feet long, a foot and a half wide, with a ledge at each fide, and at one end, is laid aflope;

 with

with this laſt end on the ground, and the other raiſed a foot and a half: acroſs the board are nailed three pieces of rough cloth, about a foot wide, and at diſtances of a foot; and at the upper end is placed a kind of baſket made of rods. The ſand is ſhovelled into the baſket: water thrown on it waſhes the ſand through, the ſtones remaining: the earth and lighter parts of the ſand are carried down to the bottom of the board, while the particles of gold, and the heavy black and red ſands already mentioned, are detained by the rough cloths, which, when they appear covered, ſo as not to be able to detain more, are taken off and waſhed in a tub of water, then nailed on again, and the proceſs continued till a proper quantity of this richer ſand is obtained. In ſome places, inſtead of cloths, ſkins with the hair or wool on are uſed; and in others, notches are made acroſs the board. The richer ſand thus detained is put into a veſſel ſomewhat like a boat, which is gently ſhaken in water, in the ſame manner as the fan in winnowing corn, till the lighter grains riſe to the top: theſe being carefully poured off with the water, the agitation is repeated ſo long as any grains, of a different colour from the reſt, are found to riſe. No further ſeparation is to be expected by this method, and the gold, of which ſome particles begin now to be diſtinguiſhable by the eye, is extracted from the remaining matter by mercury, as deſcribed in the following article.

Gold bedded in ſtones may frequently be ſeparated from great part of the ſtony matter on the ſame principle, the ſtone being previouſly reduced to powder. In the large way it is beaten in mills, under water, by large wooden ſtampers armed at the bottom with iron, an iron grating being commonly fixed at one ſide of the trough or pit, through which the finer parts are continually

waſhed

washed off by the water. When a little quantity is to be powdered in a mortar, it should likewise be done by blows of the pestle, not by grinding: a blow only flattening the metalline particles, while triture wears and divides them, in part, to such tenuity, as not freely to subside in water. Stones of the hard flinty kind are previously made red hot, and quenched in water; by which means they are rendered more easily pulverable, and at the same time many of the small particles of gold, melting in the fire, unite and form larger masses.

III. *Separation of gold from earths and stones by mercury.*

WHERE the minuteness of the particles of gold, and the weight of the matter with which they are intermixed, renders them inseparable by water, quicksilver is called in aid for imbibing and detaining the gold. The gold sands, freed by water, as in the foregoing article, from as much of the lighter matter, as can be washed off by water without endangering a great loss of the gold, are dried, and a small proportion, less than a hundredth part of their weight, of mercury poured on them: the whole is well kneaded up together, that the mercury may penetrate, as much as possible, into all the interstices between the grains; it imbibes the atoms of gold it meets with, and the sand is afterwards washed off by water.

In the Spanish West Indies, at those mines where the gold is bedded in stones, and requires quicksilver for its separation, the stony matter is reduced to as fine powder as possible, that every atom of the gold may be laid open to the mercury. The powder is soaked for some time in a solution of common salt; the mercury squeezed in through a linen cloth, so as to fall like dew all over the surface; and the mixture being well stirred and kneaded, a gentle heat is applied, by which the activity of the mercury is ſo far increaſed, that the incorporation of the gold with it, which in the cold requires about thirty days, is ſaid by J. Hernandez, in an eſſay on theſe mines, to be effected by this method in five or ſix days.

Alonſo Barba, in the third book of his art of metals, deſcribes another method, which he ſays he has practiſed with great advantage: he puts the powder, with a ſuitable quantity of mercury and water, into a deep copper veſſel fixed in a furnace, and applies a fire ſufficient to keep the water boiling: a ſmall wooden mill aſſiſts the ebullition of the water in giving motion to the earthy powder, which continually riſing and falling down again, is brought into frequent contact with the mercury at the bottom, ſo as to give out its gold to the mercury in as many hours, as the common proceſs without heat requires days.

When the gold is judged to be united with the mercury, the earthy powder is waſhed off by water, ſo as to leave the amalgam clean. Where the mercury has been kneaded up with the powder, a conſiderable part of it is always divided into ſuch minute globules as to be waſhed away along with the earth; an inconvenience which in the other method does not happen or in a far leſs degree.

The gold duſt or filings diſperſed through the ſweepings of the goldſmiths ſhops, are recovered alſo by amalgamation with mercury. Two broad iron bars, rounded at the ends, placed croſswiſe and fixed on an upright axis, are made to turn, by a handle at the top, on an iron plane fitted into the bottom of a tub. The ſweepings being put into the tub with a quantity of mercury and water, the powder, paſſing ſucceſſively under the iron bars, is ground and brought into contact with the quickſilver, which by degrees extracts the gold; while the water, which after a certain time is ſuffered to run off through a ſmall

quill

quill in the ſide of the tub, carries with it the lighter earthy matter: freſh water is ſupplied till all the earth is thus waſhed off. The operation might doubtleſs be expedited by the uſe of heat, as in the above proceſs of Barba.

The gold being by theſe means transferred into the mercury, and the mixture waſhed clean, as much as may be of the mercury is preſſed out through leather, and the remainder forced off by fire. To collect the exhaling mercury, a head and receiver are fitted to the iron pot in which the maſs is expoſed to the fire: Barba adviſes the pot to be lined with a mixture of clay and ſand, to prevent the gold from adhering to or diſſolving a part of the iron in caſe the fire ſhould be raiſed ſo far as to make the gold melt.

It is ſcarcely to be expected, that the greateſt addreſs of the workman can collect, either by water or mercury, the whole of the gold diffuſed through a large quantity of other matter; at leaſt when the mercury is uſed, as it is in the large way, in ſo ſmall a proportion as a hundredth or a two hundredth part of the weight of the earthy powder. Reaumur, after having worked ſome gold ſand with mercury, in the method commonly practiſed by thoſe who waſh the ſands of rivers, obtained, from the remaining ſand, by treating it with a double quantity of mercury, near as much gold as he had done the firſt time.

IV. *Extraction of gold intimately combined in the compoſition of ſands.*

FOR extracting gold from the ferrugineous ſands mentioned in the preceding part of this ſection, the ſand is to be made red hot and quenched in water, and the ignition

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and extinction repeated four times or oftener. The colour changes, from yellow, red, or black, to a reddiſh brown. In the firſt and ſecond heating, the ſand yields a ſlight ſmell, ſomewhat like that of garlick, a mark of its containing arſenic: at the third time, the arſenical ſmell is ſcarcely to be perceived, but on throwing into the crucible a little tallow, or other like inflammable matter, it becomes ſtronger than before: this remarkable circumſtance is by no means peculiar to theſe ſands, for there are ſeveral arſenical minerals which give out little of their arſenic in the fire till ſome inflammable matter is added. The ſand, thus calcined, is mixed with twice its weight of granulated lead, and equal its weight of black flux, the mixture put into a crucible, and covered with ſome ſea ſalt dried over the fire till it has ceaſed to crackle. The crucible is placed in a good blaſt furnace, the fire ſtrongly excited, and the matter ſtirred from time to time with an iron rod: the fire muſt be urged till the ſcoria flows thin as water, which is known by the rod coming out almoſt clean, without the leaſt knob ſticking to the end of it. The crucible is then ſuffered to cool, and broken for getting out its contents: on the top is the common ſalt, in a diſtinct cake; under this, a ſhining black, compact, vitreous ſcoria; and at the bottom, a lump of lead, eaſily ſeparable from the ſcoria. The gold, contained in the ſand, is now transferred into the lead, and may be ſeparated by working off the lead upon a cupel or teſt. Theſe ſands contain alſo ſilver, which here accompanies the gold, and which may be parted, after the cupellation, either by aqua fortis or aqua regia, according as one or the other metal appears to prevail in the mixt. This is the proceſs followed by M. Lieberecht in the aſſays already given an account of.

As the black flux (which confifts of one part of nitre, and two or three of tartar, mixed together, and burnt in a covered veffel to a black alkaline coal) is apparently too expenfive to be employed for any confiderable quantities of the mineral; its place may be fupplied by a mixture of potafh, or other fixt alkaline falts, with powdered charcoal. Four parts of potafh, three of charcoal, and thirty-two of lead, are fufficient for fixteen of the calcined fand. This mixture, as Hello' obferves, requires the fire to be continued longer than the preceding to make the matter equally fluid; but when it is made fo, the yield is found to be in both cafes alike.

The fame end may be obtained alfo, by boiling the calcined fand in melted lead, without any inflammable or faline addition. For the vitreous matter, into which the lead is gradually converted, will diffolve the earth, and the unvitrefied part of the lead will receive and collect the gold; but a much larger quantity of lead is requifite in this than in the other ways.

In all the foregoing methods, though the quantity of gold obtained is confiderable, much ftill remains in the fcoriæ, from want, probably, of a thorough commixture of them with the lead: for whatever degree of fluidity the fcoriæ are brought to, the particles of gold are too minute to fubfide by their own weight, and the lead can collect them only from thofe parts which it comes in contact with. It may therefore be prefumed, that the feparation will be the more complete, as the commixture of the lead is the more perfect. Lead cannot be mixed perfectly with fands but in a vitreous or femivitreous form. By grinding the calcined fand with litharge or other calces of lead, and expofing the mixture to a moderately ftrong fire, they may be intimately united into an uniform glaffy compound; the fand being diffolved by the vitrefied lead, nearly as ſalt is diſſolved by water. On adding to this compound a little powdered charcoal, or barely ſtirring it with an iron rod, the lead revives and falls to the bottom; and as the ſand had thus been in contact with every part of it, the gold will probably be extracted from every part, or at leaſt more effectually than by the other methods. In this way it will be proper to mix ſome alkaline ſalt with the litharge and ſand; partly, to promote the diſſolution of ſuch portion of the ſand as floats on the top of the ponderous metallic preparation; and partly, to continue the fluidity of the ſcoria after the revival of the lead. The crucible may be made of Sturbridge clay, which ſeems to be one of the beſt, of the common materials, for reſiſting glaſs of lead in fuſion. It appears to have been on a proceſs of this kind, that Becher's propoſition to the States of Holland was founded, for extracting gold with profit from common ſands; it is plain from his account of this affair in his *minera arenaria*, that he vitrefied the ſand with glaſs of lead, or litharge, and he expreſsly mentions in one place the precipitation of the lead from the glaſs by iron: he uſed alſo an addition of ſilver, in great proportion, for imbibing the gold, and thus required a vaſt capital for eſtabliſhing a work in large; but where the lead is to be revived, the ſilver is rather detrimental than uſeful; for the gold and ſilver contained in the ſand are imbibed by the lead, and the additional ſilver occaſions an enormous expence of aqua fortis for diſſolving it in order to the ſeparation of the gold. Whether, with this reduction of the expence, of which Becher himſelf ſeems to have had ſome idea, the proceſs might be practicable to advantage, or whether ſome earthy bodies might not be an uſeful auxiliary for promoting the fuſion of the gold ſands, may deſerve further enquiry: one kind of earth is frequently obſerved to bring another into fuſion, though both are of themſelves unfuſible; and the earthy parts of different ores are made fluid in the furnace of the ſmelter by the addition of other earths.

V. *Extraction of gold from the ores of other metals.*

When gold is intimately combined with other metals in their ores, the ore is to be run down in the ſame manner as the ſame kind of ore without gold. The gold commonly melts out with the proper metal of the ore, from which it may be afterwards ſeparated by different proceſſes according to the nature of the metal. There are grounds to believe that moſt metallic bodies, as extracted from their ores, contain generally a portion of gold, though rarely ſufficient to bear the expences of its ſeparation.

Zinc, arſenic, and mercury, are obtained from their ores by a kind of ſublimation: hence if the ores of theſe contain gold, the gold is to be ſought for, not in the metallic ſubſtance ſeparated, but in the remaining matter. There are ſome other caſes alſo, in which the gold, inſtead of accompanying the metal in its fuſion, is thrown off in the ſlag: but the ores and ſlags of this kingdom have been ſo ſeldom examined for gold, that at preſent I can ſay little ſatisfactory on this ſubject.

SECT. XII.

Of the alchemical hiſtory of gold.

SOME of the Greek writers, in the fourth and fifth centuries, ſpeak of an art, as being then known, of tranſmuting the baſer metals into gold; and towards the end of the thirteenth century, when the learning of the eaſt had been brought hither by the Arabians, the ſame pretenſions begun to ſpread through Europe. It has been ſuppoſed that this art, called alchemy, was of Egyptian original; and that, when the ancient Greek philoſophers travelled into Egypt, they brought back ſome of the allegoric language of this Egyptian art ill underſtood, which afterwards paſſed into their mythology. This is all that is known with certainty, or can be admitted with any ſhew of probability, about the origin of an art, whoſe hiſtory and antiquity have been the object of elaborate reſearches, and treated with a profuſion of erudition.

Alchemy was the earlieſt branch of chemiſtry conſidered as a philoſophic ſcience. In the other parts of chemical knowledge, facts preceded reaſoning or ſpeculation; but alchemy was originally ſpeculative. Such of the alchemical writers as are reckoned of moſt authority, as Geber, Hollandus, and others, declare, that we are not to hope for ſucceſs in the practice of this work, without being previouſly well acquainted with the nature, eſſence, and principles of metals; whence they were produced in the mines; whence they receive their increaſe; how and to what ſtate they have a natural diſpoſition to be brought, and would have been brought if it had not been for ſome impediment; and what theſe impediments are.

The alchemiſts ſuppoſed that nature, in all her works aiming at perfection, in producing metals aimed at gold: that the imperfect or baſe metals failed of being gold, either from a redundancy or deficiency of ſome particular element in their compoſition, or for want of ſufficient coction, maturation, or depuration of their principles; and that art could correct or remove theſe impediments, ſo as to complete the work which nature had begun.

They ſuppoſed the general principles of metals to be chiefly two ſubſtances, to which they gave the names of mercury and ſulphur; and that of both theſe there were different

different kinds, particularly of the latter ; which they admitted as many varieties of as there are metals ; and which, in gold, they held to be pure, red, fixt and incombuſtible, but of different qualities in the other metals. In theſe points there is no perfect uniformity among the different alchemical philoſophers, which indeed could not be expected in hypotheſes on ſo abſtruſe a ſubject, where experience had afforded ſo little light : ſome have added a ſaline, ſome an earthy, and others an arſenical principle.

They ſuppoſed that the pure mercurial, ſulphureous, or other principles of which they imagined gold to be compoſed, were contained, ſeparately, in certain other bodies. Theſe principles therefore they endeavoured to collect, and to concoct and incorporate by long digeſtions. In the many volumes written profeſſedly to teach the proceſs at full length, the ſubjects, from which the golden ſeeds are to be obtained, are wrapt in impenetrable obſcurity : thus much is plain, that the ſuppoſed adepts in this myſterious ſcience do not all make choice of the ſame ſubjects, or work upon them in the ſame manner, their practice being probably adapted to their particular hypotheſes.

By thus conjoining the principles of gold, if they could be ſo procured and conjoined, it might be expected that gold would be produced. But the alchemiſts pretend to a product of a higher order, called the elixir, the medicine for metals, the tincture, the philoſophers ſtone ; which, by being projected on a large quantity of any of the inferiour metals in fuſion, ſhould change them into fine gold ; which, being laid on a plate of ſilver, copper, or iron, and moderately heated, ſhould ſink into the metal, and change into gold all the parts it was applied on ; which, on being properly treated with pure gold, ſhould change the gold into a ſubſtance of the ſame nature and virtue with itſelf, ſo as thus to be fuſceptible of perpetual multiplication; and which, by continued coction, ſhould have its power more and more exalted, ſo as to be able to tranſmute greater and greater quantities of the inferiour metals, inſomuch that, according to its different degrees of perfection, one part of it ſhall be ſufficient for ten parts, a hundred parts, a thouſand parts, twenty thouſand parts, two hundred and ſeventy two thouſand three hundred and thirty parts of baſe metal.

If theſe pretenſions were propoſed as matter of ſpeculation only, I believe no one, who has at all conſidered the nature of metals, could heſitate in pronouncing them abſurd: they are inconſiſtent even with the alchemical philoſophy itſelf. But they are endeavoured to be ſupported by arguments of another kind; by hiſtorical relations of the actual tranſmutation of all the common metals, ſtrongly atteſted, not only by the alchemiſts themſelves whoſe teſtimony might be thought ſuſpicious, but likewiſe by perſons ſuppoſed to have been entirely unprejudiced, who had been caſually favoured with ſome quantity of the tranſmuting powder, or who had been witneſſes to its aſtoniſhing operation and to the immenſe riches it had procured.

In regard to theſe narratives I ſhall only remark, that at a time when the tranſmutability of metals was generally believed, the circumſtances of certain princes might render it an advantage to them to be thought to have ſuch an inexhauſtible reſource for wealth: that ſome perſons who, by methods which it was their intereſt to conceal, had acquired ſudden riches, might, in this art, find plauſible means of giving an account for them; that many of the ſuppoſed alchemiſts have been convicted, and perhaps many others guilty, of impoſture; the gold, which they pretended to have made, having

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ſometimes been previouſly concealed in the crucible, or in the materials, or at the end of the rod, with which the matter was ſtirred in fuſion, and ſometimes introduced into the crucible by a confederate, when the furnace was covered, through an aperture communicating with another apartment. So many frauds and juggling artifices are known to have been practiſed on this occaſion, that the evidence of a ſpectator can be of no force; and perhaps thoſe, who were more than ſpectators, were too much intereſted to be admitted as evidences.

I am very far, however, from cenſuring as impoſtors all thoſe who have declared themſelves convinced, from their own experiments, of the tranſmutability of baſe metals into gold. Many experiments have been alledged, in which baſe metals were made to yield ſome portion of gold, and in which gold, treated with certain additions, received an increaſe: though the quantity obtained was rarely ſuch as to bear the charges of the proceſs, it is reckoned ſufficient at leaſt, in a philoſophic view, to demonſtrate the actual tranſmutation, into gold, of a ſubſtance which before was not gold. Moſt of theſe experiments are free from ſuſpicion of any fraudulent deſign; but there are ſtrong reaſons to ſuſpect that the authors have been themſelves deceived by fallacious appearances.

Gold, as we have already ſeen, is now known to be far more frequent in metals and other minerals, than it was formerly ſuppoſed to be; and there is little wonder, if men of warm imaginations, biaſſed by a favourite hypotheſis, have been led to believe that they produced gold when they extracted it from materials in which it was not imagined to præexiſt. We have ſeen alſo, in a foregoing ſection of this eſſay, that the common method of parting ſilver from gold by aqua fortis does not com-

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pletely ſeparate the ſilver; and it has often happened, that when fine gold, melted with ſilver, was ſubmitted to certain operations, and afterwards parted, the portion of ſilver which the aqua fortis left in the gold, has been taken for an augmentation of the gold itſelf. Of this I knew a remarkable inſtance in a proceſs which was ſome years ago referred to my examination, and whoſe ſucceſs was averred to have been ſuch, that it was offered as a very lucrative operation, and a conſiderable price demanded for the communication of it: the gold, after it had paſſed through the tedious proceſs that was to enrich it, and had been parted from the ſilver by weak aqua fortis, according to the directions, weighed indeed notably more than the pure gold employed: but on reducing it to its former purity by ſolution in aqua regis, I found it reduced at the ſame time to its former quantity. It is probable that many of thoſe, who have been moſt ſanguine in their expectations of gain from alchemical operations, had no other foundation than theſe miſunderſtood kinds of experiments; which having once perſuaded them that they could make gold, they might naturally conclude that it could be made in any quantity. I ſhall only further remark on this head, that if a part of the ſubſtance of any metal was by any operation tranſmutable into gold, a part more would be in like manner tranſmutable by a repetition of the operation, and this ſucceſſively, ſo long as any part of the metal remained entire and perfect, or ſo long as it retained the properties which it had at firſt: a proceſs of this kind would be deciſive, but ſuch a proceſs has not yet been made known.

The deſtruction of gold is affirmed by the alchemiſts to be more difficult than its production. This point alſo has been eagerly proſecuted, not only on account of its being intereſting as an object of philoſophy, but on account

count likewiſe of ſome advantages expected to reſult from it, many having perſuaded themſelves that its deſtruction or reſolution would afford the ſure foundation for its artificial production. Divers experiments have been alledged, in which gold is ſaid to have been deſtroyed, or changed into a matter which was no longer gold, or reſolved into diſſimilar principles: but in theſe experiments, as in thoſe of its production, there was probably ſome deception; and many of them, as related by the authors themſelves, are apparently inconcluſive.

Mr. Boyle gives an account of a proceſs, by which he imagines part of the ſubſtance of gold to have been tranſmuted into ſilver. Into rectified butter of antimony, that is a ſolution of the metalic part of antimony in the marine acid, he poured as much ſpirit of nitre as was ſufficient to precipitate the metal, and having diſtilled off all that would come over in a ſmart fire, he returned the liquor on the antimonial powder, and abſtracted it again: of this menſtruum, which is a kind of aqua regia, he had a great opinion, and gave it the name of *menſtruum peracutum*. Some gold was melted with three or four times its weight of copper, the copper extracted by aqua fortis, and the remaining gold powder being brought to its due colour by heat, a large proportion of the menſtruum was poured on it: the gold diſſolved ſlowly and quietly, and there remained at the bottom of the glaſs a conſiderable quantity of white powder. The ſolution of gold being abſtracted, and the gold again reduced to a body and diſſolved a ſecond time, it yielded more of the white powder, but not ſo much as at firſt. On melting theſe powders with borax, he obtained a white metal, which yielded to the hammer, and which, on being diſſolved in aqua fortis, ſhewed itſelf, by the odious bitter-

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neſs it produced, to be true ſilver. He ſays, that even with good aqua regis, he could obtain from the very beſt gold ſome little quantity of ſuch a white powder, but in ſo very ſmall proportion, that he never had enough at once to make him think it worth while to proſecute ſuch trials.

It were to be wiſhed that the ingenuous author had been more careful in aſcertaining the purity of the gold made uſe of in theſe experiments, and noted the exact quantity of ſilver obtained from it. Gold parted from ſilver or copper by aqua fortis, is by no means to be looked upon as being pure: nor is there perhaps any other method, as yet known, of perfectly purifying it from ſilver, than that by which the ſilver was ſeparated in the above experiments; the diſſolution in aqua regia being in effect no other than a purification of the gold. Even aqua regia, when made with an under proportion of marine acid, will not produce a complete ſeparation; this imperfect aqua regia taking up, along with the gold, a little ſilver, ſeparable by a ſecond diſſolution.

Mr. Boyle has given an account alſo of a very extraordinary experiment, under the title of the degradation of gold by an anti-elixir, which was publiſhed in his own life time, and ſince reprinted in 1739. The known character of the author, the earneſt deſire he has ſhewn in all his writings for the diſcovery of truth and the expoſing of falſe pretences, have not only rendered the fact unqueſtionable, but likewiſe induced many to adopt the conſequences which he thought might be drawn from it; and to regard it as a proof of the real alterability of gold, and as ſtrongly favouring the alchemical doctrine of the tranſmutability of metals. I ſhall therefore inſert the account of the experiment in the author's words, and ſubjoin a few remarks; lamenting that it is not in my power to enquire more ſatisfactorily into ſo curious a fact by a repetition of the experiment. The ſubſtance, by which the apparent degradation was produced, was a powder of unknown compoſition, communicated to Mr. Boyle by a ſtranger, and its quantity not ſufficient for more than a ſingle trial. There was ſo very little of it, that he could ſcarce ſee the colour of it, ſave that, as far as could be judged, it was of a darkiſh red : the quantity was eſtimated at an eighth or a tenth part of a grain. The gold had been formerly Engliſh coin, and to be ſure of its goodneſs, he cauſed it to be, by one whom he uſually employed, cupelled with lead, and afterwards quarted with refined ſilver and purged aqua fortis. Two drams of this gold, thus purified, were weighed out, and put into a new crucible firſt carefully nealed, and the gold being brought into fuſion, without addition, he put into the well-melted metal the little parcel of powder with his own hand, continuing the fire about a quarter of an hour, that the powder might have time to diffuſe itſelf every way into the metal : the well-melted gold was then poured out into another crucible, which had been gradually heated to prevent its cracking. But though, from the firſt fuſion of the metal to the pouring out, it had turned in the crucible like ordinary gold, ſave that once, as the aſſiſtant obſerved, it looked for two or three minutes almoſt like an opal : yet when the matter was grown cold, though it appeared on the balance that it had not loſt any thing of its weight ; yet, inſtead of fine gold, there was a lump of metal of a dirty colour, and as it were overcaſt with a thin coat almoſt like half vitrefied litharge : to one ſide of the crucible there ſtuck a little globule of metal, that looked not at all yellowiſh, but like coarſe ſilver ; and the bottom of the crucible was overlaid with a vitrefied ſubſtance, whereof part was

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of a transparent yellow, and the other of a deep brown inclining to red : in this vitrefied ſubſtance there were plainly perceived ſticking at leaſt five or ſix globules that looked more like impure ſilver than pure gold. Having rubbed this odd metal upon a good touchſtone, whereon there was likewiſe rubbed a piece of coined ſilver and a piece of coined gold, the mark left by it on the ſtone was notoriouſly more like that of the ſilver than of the gold. Having knocked the little lump with a hammer, it was found brittle, and flew in ſeveral pieces. Even the inſides of thoſe pieces looked of a baſe dirty colour, like that of braſs or worſe, for the fragments had a far greater reſemblance to bell-metal than either to gold or ſilver. One dram being carefully weighed out, and put on an excellent new and well-nealed cupel, with about half a dozen times its weight of lead ; though it turned very well like good gold, yet it continued in the fire above an hour and a half, which was twice as long as was expected, and yet almoſt to the very laſt the fumes copiouſly aſcended, which ſufficiently argued the operation to have been well carried on ; and when at laſt it was quite ended, the cupel was found very ſmooth and entire, but tinged with a fine purpliſh red ; and, beſides the refined gold, there lay upon the cavity of the cupel ſome dark coloured recrements, which were concluded to have proceeded from the deteriorated metal, not from the lead. But when the gold was put again into the balance, it was found to weigh only about fifty-three grains, and conſequently to have loſt ſeven ; which yet was found to be fully made up by the recrements abovementioned, whoſe weight and fixity, compared with their unpromiſing appearance, did not a little puzzle the ingenious author, eſpecially becauſe he had not enough either of them, or of leiſure, to examine their nature. The ill-looked maſs, before

before it was divided for the cupelling, was weighed in water, and inftead of weighing about nineteen times as much as a bulk of water equal to it, its proportion to that liquor was but that of fifteen and about two thirds to one; fo that its fpecific gravity was lefs by about three and a third than it would if it had been pure gold. From this experiment the author concludes, that an operation very near, if not altogether, as ftrange as that which is called projection, and in the difficulteft points much of the fame nature with it, may be fafely admitted: for the experiment plainly fhews that gold, though confeffedly the moft homogeneous and leaft mutable of metals, may in a very fhort time be exceedingly changed, both as to malleablenefs, colour, homogeneity, and what is more, fpecific gravity; and all this by an inconfiderable proportion of injected powder, not amounting, on the modefteft eftimate, to a nine hundred and fiftieth part of its weight. He adds, that there is a ftill ftranger effect of this admirable powder, which he has not mentioned becaufe he muft not do it.

On this hiftory it may be remarked, 1. That little dependance can be had on the conjecture of the weight of the powder, as it might poffibly not be all diftinguifhed on the paper it was wrapt in, and as different kinds of bodies have different weights under equal volumes. 2. If no miftake was made in weighing the metal after the fufion, the quantity of powder muft have been greater than was imagined; for the lump of metal appeared to weigh as much as the gold employed, exclufive of the vitrefied fubftance which the bottom of the crucible was overlaid with, and of the metallic globules that adhered to it. If thefe globules had been picked out, or feparated by pounding and wafhing the pieces of the crucible, and weighed with the lump, it is fcarcely to be fuppofed that the author, ſo minute in his details, would have omitted ſuch a circumſtance; and beſides, repeated experience has convinced me, that when gold, from any admixture, has contracted a vitreous coat, and any ſmall grains of it ſtick about the crucible by means of this coat, the grains cannot by theſe methods be completely collected. 3. That the gold employed was fine, and that its ſpecific gravity was nineteen, was only ſuppoſed. The author himſelf appears to have ſuſpected its purity, for he ſays that to remove ſcruples on this head he cauſed a dram and a half of it, which had been purpoſely reſerved, to be melted in his aſſiſtant's preſence, and found it fine and well-coloured; but ſurely the colour of the maſs cannot be admitted as a ſufficient criterion of its purity. Indeed it could not have been entirely pure; becauſe, though it had been ſo at firſt, yet the proceſs of parting, however carefully performed, would have left ſome ſilver in it. 4. Admitting the gold to have been perfectly fine, and no error to have happened; it will not follow that the gold was degraded or altered in its nature, or that the experiment gives any countenance to the pretenſions of the alchemiſts. Gold is ſtrongly affected, in many of its properties, by the admixture of very ſmall proportions of certain other bodies: a quantity of tin, leſs even than that which the foregoing powder is ſuppoſed to have amounted to, renders gold brittle. It is plain that at leaſt fifty-three parts in ſixty of the gold in the above experiment were in like manner debaſed only by the coalition of another matter with it, and that this extraneous matter was ſeparable by ſimple cupellation with lead. The hiſtory affords no reaſon to believe that the remainder of the gold might not alſo have been recovered, by ſuitable management, from the ponderous fixt recrement: for gold has frequently been found debaſed and diſguiſed by ſubſtances which

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refifted cupellation, and which have afterwards been feparated by other proceffes. An inftance of this has been already mentioned in the ninth fection, and a more remarkable one is given by Homberg in the memoirs of the French academy for 1693 : a quantity of gold, after cupellation, quartation, fufion with antimony and the difflation of the antimonial metal, and repeated fufions with nitre, continued quite brittle though of a high colour : by treating it again with antimony and lead, and working off the fuperadded metals on a cupel, it loft its colour alfo, and became grey, but by further repetitions of the fufion, both its colour and malleability were at length reftored.

Juncker reports from Borrichius and Ofiander, that on grinding for a length of time, in a glafs mortar, an amalgam of one part of gold and four of mercury, with diftilled water, there feparates daily a black matter, which may be collected by pouring off the water and fuffering it to fettle: that after the triture has been continued for fome weeks, the water yields, on being evaporated, fome granules of a cryftalline falt : that the black powder yields, on fufion, a green glafs; and that the metal is thus refolved or deftroyed. But mercury alone by continued triture or agitation, is changed into a fimilar powder, of which a part abides fixt in a confiderably ftrong fire : the vitrefication probably proceeded from fome particles abraded from the glafs mortar; and the faline matter, the proportion of which is acknowledged to have been very minute, either præexifted in the water or was extracted from the glafs. Borrichius himfelf affords a ftrong prefumtion that the black powder proceeds rather from the mercury than from the gold : after fome days, he obferves, the amalgam grows ftiff, and the feparation more fparing, and therefore frefh mer-

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cury is directed to be added. I have continued the trituration of an amalgam of gold, almoſt inceſſantly, for more than a week, and afterwards recovered the gold entire.

Kunckel imagines, that when glaſs is tinged red by Caſſius's precipitate or other preparations of gold, the particles of the metal are not barely diffuſed through the glaſs, but reſolved into their elementary parts, ſo as no longer to be reducible into gold again. He might indeed fail of recovering the gold; but though no means were known of ſeparating ſo ſmall a propotion of it from ſo large a quantity of vitreous matter, it ſurely could not follow that the gold was deſtroyed.

Some other proceſſes, propoſed for the deſtruction of gold, have been already taken notice of. It has been ſhewn, that the vehement heat, collected in the focus of large burning glaſſes, and the long continued action of a gentle heat, do not, ſo far as can be judged from the facts as yet known, make any real change in it; and that the much boaſted volatilization of gold does certainly not deſtroy it, ſince the volatilized gold may with eaſe be reſtored to its fixity and all its former qualities.

Upon the whole, both the producibility and deſtructibility of gold continue ſtill problems in chemiſtry. I know of no experiment from which the poſſibility of either can be inferred; and to demonſtrate their impoſſibility is beyond the reach of experiments.

But though thoſe, who have laboured the moſt ardently in theſe purſuits, inſtead of acquiring, have generally exhauſted riches, and may on good grounds be preſumed to have miſſed of their principal aim; yet juſtice requires us to add, that their labours have not been altogether uſeleſs, and that many valuable diſcoveries, relative to different ſubjects, have reſulted from their enquiries. It

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is to be regretted, that their affected myſterioufneſs, and peculiar mode of philoſophizing, have rendered their writings ſo forbidding, that many uſeful facts, ſcattered through them, lie ſtill unknown.

S E C T. XIII.

Imitations of gold.

I. *Gold coloured metal.*

FROM the general eſtimation of the colour of gold, which has attracted the notice of the moſt barbarous nations, the communication of the ſame admired colour to metals of low price, for uſes where the other qualities of gold are not required, becomes an important object. The production of a kindred colour, by artificial compoſition, in the common metal braſs, affords a principle for this imitation.

Braſs is prepared by melting copper with the mineral called calamine, from which it receives an increaſe of one third or one half its weight. The matter, which the copper imbibes from the calamine, is found to be zinc, of which that mineral is properly an ore; and accordingly zinc itſelf, melted with copper, communicates a colour of the ſame kind. According to the purity of the zinc and copper, the proportions in which they are mixed, and the intimacy of their union, the compound metal proves more or leſs malleable, and approaches more or leſs to the colour of gold.

Thoſe who have given receits for making a gold coloured metal, differ greatly in the proportion of the two ingredients; ſome directing the zinc to be taken only in a fifth or a ſixth part of the weight of the copper, and others in an equal weight or more. From a ſet of ex-

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periments made to determine this point it appeared, that there is ſome foundation on both ſides; and that, both with the ſmalleſt and the largeſt of theſe quantities of zinc, the metal proves more like gold than with the intermediate proportions.

One part of zinc and three of copper formed a compound of a braſſy yellow colour, but rather brighter than common braſs, and at the ſame time more brittle: when broken, its texture appeared partly fibrous, and partly grained.

On increaſing the quantity of copper to four, five, ſix, eight, and ten times the weight of the zinc, the metal proved more and more tough, of a fine grain without any appearance of fibres, and its yellowneſs more and more mixed with a reddiſh caſt, like that of gold alloyed with copper. The beſt coloured mixture, obtained by an augmentation of the copper, conſiſted of five parts of copper to one of zinc: even this, however, differed greatly in colour from fine gold. A mixture of ten parts of copper and one of zinc looked like gold ſomewhat worſe than ſtandard, and hammered extremely well.

On diminiſhing the proportion of copper, from thrice, to double, equal, and two thirds of that of the zinc, the colour was improved much more than by an augmentation of it, the compounds proved much more brittle, and wholly of a fibrous texture, without any appearance of grains: they broke over ſhort on trying to bend them, and fell in pieces under the hammer. Equal parts of copper and zinc, or a little more zinc than copper, ſeemed to produce the fineſt colour: theſe mixtures, in the maſs, had a near reſemblance to pure gold; though ſtrokes drawn with them on a touchſtone were remarkably paler, looking almoſt white when compared with thoſe of the gold. And indeed all the compoſitions I have examined, whether

whether made by myſelf or others, how nearly ſoever they approached to gold in the maſs, were very different from it on the touchſtone.

The colour of theſe compounds is improved by a ſmall admixture of certain other metallic bodies. Cramer obſerves, that when copper is melted with a fourth or a ſixth of zinc, and a little pure tin; the compound metal, well cleaned and laid in the air for ſome days, acquires on the ſurface the colour of fine gold: this teint, though merely ſuperficial, is not the leſs valuable; for though it ſhould be diſcharged by cleaning, the piece ſoon recovers it again, every freſh ſurface tarniſhing as it were to a like colour. Geoffroy relates, in the French memoirs for the year 1725, that on trying different metals, iron ſeemed to have the beſt effect: equal parts of copper and zinc being brought into fuſion, he threw in ſome iron filings, amounting to an eight part of each of the other metals: the mixt turned out of a beautiful yellow colour, and a fine ſmooth grain, not at all fibrous, as mixtures of copper and zinc in this proportion by themſelves always are, yet very brittle: on repeating the experiment with a fourth more of zinc, the proportions being ten parts of zinc, eight of copper, and one of iron filings, the metal proved of a grain like the former, but more compact, harder, brighter, and in colour ſtill more like gold. He ſays the commixture of the iron with the other ingredients requires a particular management, which I cannot find that he has any where communicated.

It has been ſaid, that the mixtures of zinc and copper may be made tough, by injecting upon them in fuſion a little mercury-ſublimate, as alſo by nitre, ſal ammoniac, borax, and different kinds of inflammable bodies: but theſe additions, as I have often found from experience, and as Pott alſo obſerves in a diſſertation *de zinco*,

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will not anſwer. The great brittleneſs has been generally imputed to the lead, of which the common ſorts of zinc are ſuppoſed to partake in a greater or leſs degree; and hence it has been ſuppoſed neceſſary to previouſly purify the zinc, by cementation and fuſion with ſulphur, which abſorbs and ſcorifies the lead without acting upon the zinc: ſome ſorts of zinc may doubtleſs require a treatment of this kind, but ſuch, as has been uſually brought from the Eaſt Indies, does not ſeem, when prepared in this manner, to give leſs brittleneſs than when unprepared.

It is certain, however, that copper impregnated with zinc, by cementation and fuſion with calamine, proves more malleable, than when melted directly with as much of common zinc itſelf as it imbibes from the calamine; on account, perhaps, of the commixture being in the firſt caſe more equal and perfect. By the proceſs with calamine, copper cannot eaſily be made to receive the full quantity of zinc neceſſary for producing a good gold colour: by combining the two proceſſes together, that is by making the copper firſt into braſs, and then melting it with a ſuitable quantity of zinc, a metal may be obtained of better quality than by either method ſingly. A very ingenious artiſt, who now prepares a gold-coloured metal in great perfection, has a fine kind of braſs made on purpoſe for this uſe. An enquiry into the preparation and improvement of braſs will make a ſeparate article in one of the future numbers of this work.

A good deal of addreſs is requiſite in melting the copper and zinc together; for the heat neceſſary for the fuſion of copper occaſions the zinc to burn and flame, and a conſiderable part of it to be diſſipated, ſo that the remaining copper is defrauded of its due proportion. If the two metals are put into the crucible at firſt, and the fire gradually raiſed, greateſt part of the zinc will be burnt off

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before the copper melts: if the copper be firſt melted by itſelf, and the zinc heated and plunged into it, a ſtrong commotion enſues, though the diſſipation is much leſs conſiderable than in the other caſe, the zinc being quickly imbibed by the melted copper and in ſome meaſure protected and retained by it: if the copper and zinc be brought ſeparately into fuſion, and one poured into the other, an exploſion happens, and great part of the mixture, in my experiment above two thirds of it, is thrown about in drops, to the great danger of the bye-ſtander. The union appeared to ſucceed beſt, and with leaſt loſs of the zinc, when fluxes, containing inflammable matter, were added: I have generally uſed a mixture of black flux and borax; to which may be ſubſtituted a cheaper compoſition of twelve parts of green glaſs in fine powder, ſix parts of potaſh, two of borax, and one of powdered charcoal. The flux is firſt to be brought into fuſion in the crucible, and the copper and zinc dropt into it: aſſoon as theſe appear perfectly melted, they are to be well ſtirred together with an iron rod, and expeditiouſly poured out. The ſame flux ſerves repeatedly for the melting of ſeveral freſh quantities of the metal.

There are many receipts for making a gold coloured metal, from verdegris a preparation of copper, and tutty a preparation or ore of zinc: the difference, above taken notice of, in the effect of zinc itſelf and of its common ore upon copper, induced me to try, whether, in this form of combination alſo, ſome uſeful variation might not happen. One of the beſt of theſe receipts ſeems to be that among Hook's papers publiſhed by Derham; in which eight parts of diſtilled verdegris (that is, verdegris purified by ſolution in diſtilled vinegar and cryſtallization) and four parts of Alexandrian tutty, with two of nitre and one of borax, are directed to be mixed with oil to the conſiſtence

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of pap, then melted in a crucible, and poured into a flat mould first well warmed. The person, who communicated this receipt to Dr. Hooke, says that the metal will not only appear, but work, like coarse gold; that he sold it as dear as silver; and that the king of Poland had a service of it, only mixing fifteen ounces of gold with a hundred of the compound metal. I tried this process with verdegris, which I had myself purified, by dissolving it in distilled vinegar, and evaporating the filtered solution to dryness: a large proportion of the verdegris remained undissolved; and this residuum, on being melted with black flux, yielded a brittle pale coloured metal almost like bell-metal: from whence it might be presumed, that the copper, in the inspissated matter, was rendered purer than ordinary by the separation of this extraneous metal. On melting it with choice tutty, and the other ingredients, the result was a very fine metal, which bore the hammer well; but it was rather a fine brass than a true gold coloured metal; its colour having less resemblance to gold than that of the mixture of equal parts of common copper and zinc already mentioned.

Tutty and calamine contain zinc in a state of calx; and hence, in the use of these, inflammable additions are essentially necessary, for reviving the zinc into its metallic form. Some of the earlier writers direct for this purpose substances of a yellow colour, as turmeric, rhubarb, saffron, aloes, which are still used, as I am informed, by several workmen, who do not seem to have considered, that these kinds of substances can be of service no otherwise than as they furnish an inflammable matter, and that common charcoal answers the same end.

Two ways have been recommended, for giving a gold colour to copper, and at the same time preserving its malleability, without the addition of any zinc, or of

 substances

ſubſtances containing it; the one, as is ſaid, by Homberg (for, though given as from him by ſome late reputable writers, I cannot find it among his papers in the French memoirs) the other by Vigani.

In Homberg's method, the copper is to be amalgamated with pure quickſilver, the amalgam boiled in river water for two hours, the quickſilver diſtilled off in a retort, and again poured back and abſtracted once or twice: the remaining copper, being now fuſed, is ſaid to appear of a beautiful gold colour, and to be more ductile than common copper, ſo as to be well fitted for the finer machines and utenſils. The great difficulty of amalgamating copper by the common methods ſeems to have prevented this proceſs from coming to a fair examination. This difficulty I have ſurmounted in different ways: one of the eaſieſt and moſt expeditious of which was, by diſſolving the copper in aqua fortis, and, when the menſtruum would take up no more, pouring the ſolution into an iron mortar, along with ſix times as much quickſilver as there was of copper, and ſome common ſalt, and then grinding them well together with an iron peſtle: the diſſolved copper is extricated from the acid by the iron, in a very ſubtile form, and falling in this ſtate into the quickſilver, is readily imbibed by it. This amalgam was ground and waſhed with water till it became perfectly bright, and the mercury was then diſtilled off: the remaining copper, melted in a crucible, had, as was indeed expected, no degree of yellowneſs, and appeared exactly of the ſame colour as at firſt. As no ſenſible alteration was thus produced, a repetition of the troubleſome operation was judged unneceſſary.

Vigani's proceſs carries with it ſtrong marks either of error or reſerve; yet from the general character of the author, and the favourable reception he met with in this country, I ſhould not perhaps be held excuſed if I did not take ſome notice of it. Copper is to be melted in a crucible, an equal weight of powdered ſulphur ſprinkled on it, the fuſion continued till the ſulphur is all burnt off, and the metal afterwards flatted into plates. A quantity of orpiment, *auripigmentum*, is to be melted and quenched in vinegar, and the fuſion and extinction repeated twenty-four times. The materials being thus prepared, ſome bean meal is to be placed in the bottom of a crucible, above this nitre and tartar, then ſome auripigmentum, on this ſome of the copper plates with more auripigmentum over them: in this order of ſtratification we are to proceed till the veſſel is full, and then to invert into the mouth another crucible having a hole in its bottom. A moderate heat is to be continued ſo long as any flame or fumes appear, after which the fire is to be raiſed ſo as to bring the matter into fuſion, and continued in this ſtate for an hour. It is not to be expected that this proceſs can afford the ductile gold coloured metal which the author promiſes from it; for orpiment, in virtue of the arſenic of which it largely partakes, tinges copper, not yellow, but white. As Vigani throws a veil over ſome of his preparations, though commonly but a thin one, I have been led to ſuſpect that he has done ſo here; and that by *auripigmentum* he does not mean the orpiment which makes a gold pigment for the painter, but zinc the auripigment for copper. If this explication be right, a yellow metal may doubtleſs be obtained, though the troubleſome method of procedure is not to be recommended. The burning of ſulphur upon the copper, and the repeated extinction of zinc in vinegar, do not appear to be of any advantage; and the gradual augmentation of the fire occaſions always, as already obſerved, a great diſſipation of the zinc.

It has been ſuppoſed by many, that the yellowneſs, reſulting from mixtures of zinc and copper, was no other than a dilution of the coppery red by the whiteneſs of the zinc: if this was the caſe, ſilver would have a like effect, but ſilver is not found to give any yellowneſs to copper. The yellow colour produced from the combination of copper and zinc, is apparently a new quality; as much as the brittleneſs produced from the combination of two malleable metals, gold and tin. It has not been obſerved that any metal, beſides zinc, yields any conſiderable yellowneſs with copper, though tin, in certain proportions, yields a ſlight one; or that any metal beſides copper forms a yellow compound with zinc.

Silver is tarniſhed ſuperficially, by certain vapours, as that of putrefied urine, to a colour ſo like that of gold, that abuſes are ſaid to have been often practiſed on this foundation, particularly in regard to wire and laces: Savary gives an account of ſeveral edicts iſſued in France for preventing theſe frauds. It is obſervable alſo that fine ſilver, on being melted with nitre, acquires frequently a yellow ſpot on the ſurface where the ſalt lay in contact with it; and Stahl affirms that ſilver, by being treated in a certain manner, with certain ſubſtances, of which nitre is the principal, may be tinged throughout of a golden colour: he conceals the proceſs, for fear of giving occaſion to impoſition; though of this there does not appear to be much danger, for he obſerves that the ſilver acquires none of the other diſtinguiſhing characters of gold, and that the adventitious colour is very readily deſtroyed.

II. *Gold coloured pigments.*

In the gilding of wood, ſome pigments, approaching as near as may be to the colour of gold itſelf, are both laid

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under the gold, and uſed alſo for the colouring of depreſſed parts where gold leaf cannot be conveniently applied. The ſubſtance chiefly employed for this purpoſe is yellow ochre; the colour of which may be improved, or brought nearer to the gold teint, by a ſmall addition of vermilion or other red powders.

Of the mineral called auripigmentum or orpiment, ſome ſorts are of a beautiful glittering gold colour. This mineral conſiſts of arſenic and ſulphur, and on being ground with oil for painting, yields an offenſive ſmell, as ſulphur always does when united with oils: this is the principal inconvenience it is accompanied with, and renders its uſe leſs frequent than it would otherwiſe be. Though it is offenſive from the ſulphur, the ſuſpicion of its being poiſonous in virtue of the arſenic appears to be without foundation, for the fetid vapour proceeds wholly from the ſulphur, and even arſenic in ſubſtance, if we may judge from trials made on brutes, has its poiſonous quality ſheathed or deſtroyed by the combination of ſulphur with it.

A beautiful gold coloured preparation, called *aurum moſaicum* or *muſivum*, is obtained from tin. Some fine tin is melted in an iron ladle; and half its quantity of pure quickſilver, previouſly heated in another ladle till it begins to ſmoke, is poured into the melted metal, and the mixture ſtirred with an iron rod: when cold, the matter is found friable, and being reduced into fine powder, it is well mixed with half or a third its weight of ſal ammoniac and the ſame quantity of flowers of ſulphur. With regard to the proportion of theſe ingredients, practical writers differ not a little, and indeed they admit of great latitude, for I have ſucceeded equally with very different proportions: very little of any of them is retained by the tin in the ſubſequent part of the operation. The powder is put into a matras, or round glaſs with a ſhort neck, whch is placed in

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a ſand-bath, and the fire increaſed by degrees, ſo as to keep the ſand at laſt red hot for ſome time. The fire being then ſuffered to decay, and the veſſel broken when cold, a ſaline matter, conſiſting chiefly of ſal ammoniac, is found in its upper part: under this is a dark red maſs, which proves to be cinnabar, or a combination of mercury and ſulphur: at the bottom is the aurum moſaicum, a ſparkling, gold coloured, flaky maſs, weighing about a twelfth part more than the tin employed.

The gold coloured talcs, formerly mentioned, have too much flexibility and elaſticity to be reduced into powder of ſufficient fineneſs for the purpoſes of painting: but there is one imitation of gold, for which powders of much fineneſs are not required, and for which the talcs are better adapted than any other material I know of, on account of their reſiſtance to fire. A kind of glaſs, with gold coloured ſpangles diffuſed through its ſubſtance, has been much admired, and the preparation of it kept a ſecret: this appearance may be communicated by the yellow talcs, by mixing them well with powdered glaſs and bringing the mixture into fuſion.

III. *Gold coloured varniſh or lacker.*

Silver, coated with a tranſparent gold coloured varniſh, is made to reſemble gold ſo exactly, as wholly to ſupply the place of gold in ſome of the works called gilt. The baſis of the varniſh, or what gives adheſiveneſs and gloſſineſs to the colouring matter, is a ſolution of lac made in ſpirit of wine.

Lac or lacca is a ſubſtance collected by certain inſects in the Eaſt Indies: it is found incruſtated on ſticks or branches of trees, in brittle maſſes of a dark red colour, which being reduced into ſmall grains, and freed from part of the colouring matter by infuſion in water, are ſold under the name of ſeed lac. It is in this ſtate that the lac

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is to be uſed for varniſhes: what is called ſhell lac, or the grains formed into plates by melting them in boiling water, does not anſwer ſo well.

The ſpirit muſt be highly rectified, or freed as much as poſſible from any admixture of phlegm or water, for otherwiſe it will not diſſolve the lac. The moſt convenient and expeditious way, of preparing the ſpirit for this intention, is by adding ſome dry potaſh or other fixt alkaline ſalt: the ſalt imbibes, and diſſolves in, the watery part of the ſpirit, and forms therewith a diſtinct fluid at the bottom, from which the ſpirituous part on the top may be poured off. More or leſs of the ſalt will be required according as the ſpirit is more or leſs phlegmatic: if the firſt quantity, after ſtanding for ſome hours and occaſionally ſhaking the veſſel, wholly diſſolves, more muſt be added and the agitation renewed..

The ſpirit being thus dephlegmed, ſome ſeed lac, reduced into fine powder, is added to it, in the proportion of about three ounces to a pint: the veſſel being ſet in a moderate warmth for twenty-four hours and frequently ſhaken, a part of the lac diſſolves; and the ſpirit, now tinged of a reddiſh brown colour, is ſtrained off from the undiſſolved part, and ſet by for a day or two to ſettle. The digeſtion ſhould be performed in a wide mouthed veſſel, covered ſo as to prevent the exhalation of the ſpirit: the undiſſolved lac ſoftens into a viſcous maſs, ſo as ſcarce to be got out through a narrow aperture.

In different portions of the foregoing ſolution, poured off clear after the ſtraining and ſettling, ſome gamboge and annotto are diſſolved ſeparately. Gamboge is a yellow juice, iſſuing from certain trees in the Eaſt Indies, and exſiccated into maſſes by the ſun's heat: Annotto is artificially prepared from the red ſkins of the ſeeds of an American tree, by ſteeping and agitating the ſeeds with water

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till their colouring matter is transferred into the liquor: on boiling the ſtrained liquor, the colouring matter is ſaid to be thrown up to the ſurface in form of ſcum, which is afterwards exſiccated by itſelf, and formed into maſſes, which, as brought to us, are moderately hard and dry, of a brown colour on the outſide, and a dull red within. Both theſe ſubſtances diſſolve very readily in the ſpirit: the gamboge communicates a high yellow colour, and the annotto a deep reddiſh yellow. The ſolution of the gamboge is mixed with about half its quantity of that of the annotto, and trial made of the mixture on ſome ſilver leaf: if the colour inclines too much to the yellow or the red, more of the one or the other liquor is added, till the true golden colour is obtained. There are ſundry other materials, from a due mixture of which a like colour may be produced, as turmeric, ſaffron, dragons-blood, &c.

The ſilver leaf being fixed on the ſubject, in the ſame manner as gold leaf, by the interpoſition of proper glutinous matters; the varniſh is ſpread upon the piece with a bruſh or pencil. The firſt coat being dry, the piece is again and again waſhed over with the varniſh till the colour appears ſufficiently deep.

What is called gilt leather, and many picture frames, have no other than this counterfeit gilding. Waſhing them with a little rectified ſpirit of wine affords a proof of this; the ſpirit diſſolving the varniſh, and leaving the ſilver leaf of its own whiteneſs.

For plain frames, thick tin foil may be uſed inſtead of ſilver. The tin leaf, fixed on the piece with glue, is to be burniſhed, then poliſhed with emery and a fine linen cloth, and afterwards with putty applied in the ſame manner: being then lackered over with the varniſh five or ſix times, it looks very nearly like burniſhed gold.

The ſame varniſh, made with a leſs proportion of the colouring materials, is applied alſo on works of braſs; both for heightening the colour of the metal to a reſemblance with that of gold, and for preſerving it from being tarniſhed or corroded by the air.

Addition to the HISTORY of GOLD.

SINCE the foregoing ſheets went to the preſs, a new manufacture has been ſet on foot in London, for embelliſhing linen with flowers and other ornaments of gold leaf. The linen looks whiter than moſt of the printed linens; the gold is extremely beautiful, and is ſaid to bear waſhing well. I have ſeen a piece, which I was credibly informed had been waſhed three or four times, with only the ſame precautions as are uſed for the finer printed linens, and on which the gold continued entire and of great beauty.

THE Venetians have carried on a large trade, to the Levant, in a kind of brocade called *damaſquète*, which, though it has only about half the quantity of gold or ſilver as that made among us, looks far more beautiful. The flatted wire is neither wound cloſe together on the ſilk threads, nor the threads ſtruck cloſe in the weaving; yet, by paſſing the ſtuff betwixt rolls, the diſpoſition and management of which is kept a ſecret, the tiſſue or flower is made to appear one entire brilliant plate of gold or ſilver. The French miniſtry, ever vigilant for the advancement of arts and commerce, judged this manufacture important enough to deſerve their attention; and accordingly, for contriving the machinery, they engaged the ingenious M. Vaucanſon, known throughout Europe for

for his curious pieces of mechanifm, who, in the memoirs of the academy for the year 1757, lately printed, gives an account of his fuccefs, and of the eftablifhment of fuch a manufacture at Lyons.

The lower roll is made of wood, thirty-two inches in length and fourteen in diameter; the upper one of copper, thirty-fix inches long and eight in diameter: this laft is hollow, and open at one end, for introducing iron heaters. For making the rolls cylindrical, he has a particular kind of lathe, wherein the cutting tool, which the moft dextrous hand could not guide in a ftreight line through fuch a length as thirty-fix inches, is made to flide, by means of a fcrew, on two large fteel rulers, perfectly ftreight, and capable of being moved at pleafure, nearer, and always exactly parallel, to the axis of the roll.

He firft difpofed the rolls nearly as in the common flatting mill. In this difpofition, ten men were fcarcely fufficient for turning them with force enough to duly extend the gilding; and the collars, in which the axes of the rolls turned at each end, wore or gulled fo faft, that the preffure continually diminifhed, infomuch that a piece of ftuff of ten ells had the gilding fenfibly lefs extended on the laft part than on the firft. He endeavoured to obviate this inconvenience by fcrewing the rolls clofer and clofer in proportion as the ftuff paffed through, or as the wearing of the collars occafioned more play between them; but this method produced an imperfection in the ftuff, every turn of the fcrew making a fenfible bar acrofs it. To leffen the attrition, each end of the axes, inftead of a collar, was made to turn between three iron cylinders called friction-wheels: but even this did not anfwer fully, for now another fource of unequal preffure was difcovered. The wooden roll, being compreffible, had its diameter fenfibly diminifhed: it likewife loft its round-

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nefs, fo that the preffure varied in different points of its revolution. On trying different kinds both of European and Indian woods, all the hard ones fplit, the foft ones warped without fplitting, and, of more than twenty rolls, there was not one which continued round for twenty-four hours even without being worked in the machine.

Thefe failures put him upon contriving another method of preffing the rolls together, fo that the force fhould always accommodate itfelf to whatever inequalities might happen. The axis of the copper roll being made to turn between friction wheels as before, that of the wooden one is preffed upwards by a lever at each end furnifhed with a half collar for receiving the end of the axis. Each lever has the end of its fhort arm fupported on the frame of the machine, and the long arm is drawn upwards by an iron rod communicating with the end of the fhort arm of another lever placed horizontally: to the long arm of this laft lever is hung a weight, and the levers are fo proportioned, that a weight of thirty pounds preffes the rolls together with a force equivalent to 17536 pounds, which was found to be the proper force for the fufficient extenfion of the gilding. By this contrivance four men can turn the rolls with more eafe than ten can turn thofe which are kept together by fcrews; and the fame weight acting uniformly in every part, the preffure continues always equal, though the wooden roll fhould even become oval, and though the ftuff be of unequal thicknefs.

A piece of cloth, of about two ells, is fowed to the beginning and end of the ftuff, to keep it out to its width when it enters and parts from the rolls, which could not be done by the hands for fear of burning or bruifing them: as it would take too much time to fow thefe cloths to every fmall piece of an ell or two, a number of thefe is fowed together. The ftuff is rolled upon a cylinder, which

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is placed behind the machine, and its axis preſſed down by ſprings to keep the ſtuff tight as it comes off. Four iron bars, made red hot, are introduced into the copper roll, which in half an hour acquires the proper degree of heat, or nearly ſuch a one as is uſed for the ironing of linen : the wooden roll is then laid in its place, and the machine ſet to work. If more than thirty ells are to be paſſed at once, the wooden roll muſt be changed for another, for it will not bear a longer continuance of the heat without danger of ſplitting, and therefore the manufacturer ſhould be provided with ſeveral of theſe rolls, that when one is removed, another may be ready to ſupply its room : as ſoon as taken off from the machine, it ſhould be wrapt in a cloth and laid in a moiſt place.

The principal inconvenience, attending the uſe of this machine, is, that the heat neceſſary for extending the gilding, though it improves the brightneſs of white and yellow ſilks, is injurious to ſome colours, as crimſon and green. A double preſſure will not ſupply the place of heat; and the only method of preventing this injury, or rendering it as ſlight as poſſible, appeared to be, to paſs the ſtuff through with great celerity.

III. EXPERIMENTS

Of the converſion of Glass Vessels into Porcelain, and for eſtabliſhing the principles of the art.

HAVING many years ago diſtilled ſome wood ſoot, with a ſtrong fire, in a green glaſs retort ſet in ſand, I obſerved great part of the bottom of the retort, after the operation, to be remarkably changed: it was quite opake, of a black colour on the inſide where the ſoot had been in contact with it, and whitiſh on the outſide where it reſted upon the ſand: it had no longer the brittleneſs of glaſs, but broke with difficulty like the better kinds of ſtone ware: its internal ſubſtance was white like porcelain; and not of a glaſſy ſmoothneſs, but of a fine fibrous texture.

This ſingular change, in a body ſupoſed ſo little ſuſceptible of alteration, was attributed to the vapours of the ſoot having penetrated into the ſubſtance of the glaſs: ſundry pieces of the ſame kind of glaſs were therefore intermixed with another quantity of ſoot, in an iron pot, to which was adapted a head with a receiver, and the diſtillation conducted in the uſual manner, till nothing more could be forced out from the ſoot in a ſtrong fire: on examining the pieces of glaſs, ſome, in the middle of the matter, ſeemed ſcarcely at all altered; others, about the ſides and bottom of the pot, were changed in part nearly in the ſame manner as the bottom of the retort had been.

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This change of glafs has doubtlefs happened often, without being attended to. Neumann is the firft writer by whom I find it taken notice of: in diftilling milk in a glafs retort, he obferved that the bottom of the veffel acquired the appearance of porcelain, which he attributes to the fine white earthy matter of the milk forced into the glafs by the heat.

M. de Reaumur was led to the fame difcovery by analogical reafoning, as I have already mentioned in the notes on Neumann's chemical works, where a further account of this affair is promifed. Reaumur, having had large experience of the effects of inflammable and earthy bodies on iron, by baking, in the converfion of forged iron into fteel, and in the foftening of caft iron, applied the fame procefs to common glafs, and thus difcovered the new porcelain, which he calls porcelain by tranfmutation, porcelain by revivification, or porcelain of glafs. The glafs was cemented, or baked, in crucibles, firft with the foot, powdered charcoal, and other fubftances employed in the experiments on iron: it became opake, externally dark-coloured or black, but internally of a fine white colour. Other materials were then made trial of, in hopes that fome one might be found, which fhould occafion the furface to be as white as the internal part: among the fubftances tried in this view, of which he gives no particular account, he judged white fand and plafter-of-paris, or rather a mixture of the two, to anfwer the beft. He directs veffels of common green glafs to be filled and furrounded with this mixture, in large crucibles or cementing pots, fuch as are commonly ufed for the baking of earthen wares; the crucibles to be covered and luted, and fet in a potter's furnace: the fame fire, which bakes the common wares, changes the glafs veffels into veffels of the new porcelain. He obferves, that this porcelain may be be made at a very cheap rate, as the glaſs maker can form veſſels more expeditiouſly than the potter, and as it is happily the very coarſeſt green glaſs that yields the fineſt porcelain : That it is eaſily diſtinguiſhed from all the other ſorts of porcelain by the texture which it exhibits on breaking, as it has nothing of the granulated appearance of the other porcelains and earthen wares, any more than the gloſſy ſmoothneſs of glaſs and enamels, the ſurface of the fracture being compoſed of fine fibres like ſilken threads : That in beauty it is inferiour to the Chineſe, but equal to many ſorts that are held in eſteem ; that in utility, and every eſſential quality of porcelain, it is equal to the beſt, and that in ſome reſpects it is ſuperiour to all that have hitherto been made : That it ſuffers no injury from being ſuddenly heated or cooled, bears a vehement fire without melting or altering its figure, and hence, beſides its uſe for ornamental vaſes, promiſes to make excellent veſſels for the chemiſt.

The character given of this porcelain by Reaumur, and the valuable qualities he aſcribes to it, rendered it an object of more importance than it had appeared at firſt, and engaged me in a further examination of it. That the enquiry might be carried on with ſome regularity, it was divided into five heads. (1.) To trace the gradual progreſs of the change from the ſtate of glaſs to that of perfect porcelain, and to diſcover whether a continuance of the proceſs would be productive of any further changes. (2.) To determine the qualities of this kind of porcelain, and how it differs from other porcelains and from glaſs, in thoſe properties which regard the application of it to common uſes. (3.) To compare the effects of different cementing materials on the ſame glaſs, and (4.) the effects of the ſame materials on different kinds of glaſs. (5.) To aſcertain, as far as might be, the cauſe of the change, or the

the true principle on which it happens. The following is the general result of the experiments I have hitherto made upon these subjects.

SECT. I.

Experiments of the successive changes produced in Green Glass by baking.

IN order to determine the progress of the visible change produced in glass by baking, and the effects of different degrees or a different continuance of the heat; a number of pieces of common quart bottles were surrounded with white sand, in crucibles, which were placed in a wind-furnace, built on purpose for experiments of this kind, consisting of several chambers one over another, with proper apertures in the middle for the ascent of the flame and heated air through each. The crucibles were left open, that some of the pieces might be taken out from time to time, for discovering how the change went on: and that the effects of the process might be seen in its full extent, the fire was slowly raised, and continued for upwards of forty hours.

Such pieces as were taken out before they became red hot, did not appear to have suffered any change, though they had been kept for several hours in a heat very little below ignition. In a low red heat, the change did indeed take place, but exceeding slowly; those which had been exposed for several hours to such a heat being very little altered. In a strong red heat, approaching to whiteness, just not sufficient to make the glass melt, the change went on pretty fast: after an hour's continuance of this degree of heat, the glass had acquired the appearance of porcelain to a considerable thickness; and in two hours longer, the thickest pieces, of the bottoms of the bottles, were found fully changed throughout. In thofe pieces which were flowly affected by a weak heat, and thofe which were more haftily acted upon by a moderately ftrong one, the progrefs of the change itfelf was, for the moft part, nearly in the fame manner.

The green glafs became firft of a bluifh colour on the furface, and in this ftate, when held between the eye and the light, it appeared lefs tranfparent than before, and of a yellowifh hue. After this it was found changed a little way on both fides into a white fubftance, externally ftill bluifh; and as this change advanced further and further within the glafs, the vitreous part in the middle approached more and more to yellow: the white coat was of a fine fibrous texture, and the fibres difpofed, nearly parallel to one another, not longitudinally as might be expected from the direction given to the parts of the glafs in blowing it into veffels, but crofswife to the thicknefs of the piece. By degrees, the glafs became throughout white and fibrous, the external bluifhnefs at the fame time going off, and being fucceeded by a dull whitifh or dun colour: the fibres were for the moft part regularly and uninterruptedly arranged from each fide to the middle, where the fibres from the two fides, meeting together, formed a kind of partition: along this juncture, there were in fome pieces confiderable cavities here and there; others were perfectly folid.

The pieces which were continued in the fire for any confiderable time beyond this period, and thofe which were afterwards returned to it along with frefh fand, fuffered a frefh change, which proceeded, like the firft, from the furface to the center. The fibres became divided or cut into grains at the outer ends, and by degrees they were thus fucceffively divided through their whole length; the whole internal part of the porcelain affuming a granulated

nulated texture, not ill refembling that of the common porcelains.

Thofe which were longer and longer expofed to the fire, received more and more alterations. The grains, at firft fine and of fome degree of gloffinefs, grew larger and duller; and at length, through fundry gradations, lefs remarkable and lefs uniform, what had once been glafs, and afterwards a compact hard porcelain, became a porous friable fubftance, like a mafs of white fand flightly cohering.

During the change of the glafs into a fibrous porcelain, it generally preferved the fmoothnefs of its furface, and the fand freely parted from it: in the fubfequent changes, part of the fand baked together upon the furface, and ftrongly adhered, not to be got off, and not greatly differing from it in appearance; I have fometimes been at a lofs to diftinguifh the matter which had been glafs from the fand that furrounded it. In fome pieces the fandy coat was parted from the internal matter by a number of fine cavities refembling a dotted line: in others, they were clofely applied together.

Such were the general effects of continued cementation in many repetitions of the experiment, though not without variations in fome particulars. Sundry pieces became throughout white, and almoft opake, and fome blue, before they contracted any fibrous coat, which afterwards proceeded in the fame manner as in the others. Some pieces, being broken in different parts after they had been changed to a fibrous ftate, inftead of the uniform tranfverfe difpofition of the fibres, had feveral prominences on the furfaces of the fractures, from which the fibres iffued as rays in all directions. After the fine granulated ftate, which fucceeded to the fibrous on a continuance of the cementation, fome pieces became porous, while in others the grains formed a kind of close plates, and the mass proved very compact. In some, the texture was close and even throughout, without any distinguishable grains, fibres, or plates. Of some of these variations, the probable causes will appear in the following section: others depended perhaps upon the nature of the glass employed.

Notwithstanding these, and other lesser differences, the general appearances, and the gradation of the visible change proportionably to the degree of baking, are so strongly marked, that, from the texture of the porcelain on breaking, we can always judge with certainty of its quality, or of the degree to which it has been baked. Reaumur has also taken notice of something of this kind, finding the porcelain sometimes turn out granulated instead of fibrous: but his experiments do not seem to have been carried far enough to discover the foundation of this difference; to discover, that the different kinds of texture regularly succeed one another from the continued action of one cause, that they are all at the command of the workman, and that they are accompanied with remarkable differences in the intrinsic qualities of the porcelain.

SECT. II.

Experiments of the quality of the substance into which Green Glass is converted by baking.

THE porcelain into which glass is converted by baking, whatever its superficial colour be, is, in its internal substance, always white; and its whiteness is frequently not inferiour to that of the internal part of China ware. Its surface is unhappily the part which is least beautiful. All the thick pieces were quite opake: several thin ones had a degree of transparency, resembling that of China ware. In this respect considerable differences appeared: a very thin

thin coat of fibrous or granulated porcelain upon the glaſs gave opacity; of the pieces of a cloſe ſmooth texture, ſome, tho' pretty thick, were ſemitranſparent, and others, tho' thinner, were opake.

In the fibrous ſtate of the porcelain, it is conſiderably hard; much more ſo than the glaſs it was made from, and than any of the common kinds of porcelain. It freely and plentifully ſtrikes fire with ſteel, which green glaſs does but in a low degree. It cuts common glaſs, as indeed one piece of glaſs in ſome meaſure will another; but neither any of the common kinds of glaſs, nor the file which cuts them, make any mark on the fibrous porcelain. Even when the change is ſcarcely viſible on the ſurface of the glaſs, the external part is found ſenſibly harder to the file than the internal.

It perfectly reſiſts both acid and alkaline liquors, neither permitting them to tranſude through it, nor being at all corroded by them.

It bears viciſſitudes of conſiderable degrees of heat and cold, ſo that veſſels of it may be plunged at once, without any danger of their cracking, from freezing into boiling water. It may likewiſe be ſet on burning coals, with much leſs precaution than any of the porcelains or earthen wares uſed for containing liquids.

In a moderate white heat, it melts, ſo as to be eaſily drawn out into long ſlender ſtrings, which appear ſemitranſparent, and, on breaking, prove not fibrous as before, but of a vitreous ſmoothneſs like white enamel. Some of the melted pieces were conſiderably bright or gloſſy, ſome had no gloſſineſs, and all of them proved ſofter than before the fuſion, ſeeming, though very compact, to be little harder than common green glaſs.

It does not however melt near ſo eaſily as the glaſs itſelf. When the cementation has been continued no longer than till only the external part of the glafs was changed, I have often obferved, that on haftily raifing the fire, the unchanged glafs has melted and run out, leaving a cavity in the middle with a cruft of porcelain on each fide.

When the porcelain has been fo far baked, that the fibrous texture has difappeared, and a coarfe granulated one come in its place, it proves far fofter than before: it now neither ftrikes fire with fteel, nor cuts glafs; but is itfelf cut with eafe both by common glafs and by the file.

With this imperfection, it acquires an advantage of greater refiftance to fire: the longer the cementation was continued, the fufibility feemed always to be more and more diminifhed. A piece of the concave bottom of a common green bottle, which had its fibres only in part changed into grains, ftood the melting of a lump of brafs, of about two ounces, without anywife altering its figure, or fuffering any other apparent change, than that the thin edges were rounded off, and covered in fome parts with a green glazing, which feemed to have exuded from the mafs. Some pieces of the fame cemented glafs being put into a fmall crucible, into which another was inverted and clofely luted, and the whole urged for two hours or more in a fea-coal fire vehemently excited by bellows, the pieces melted together into a very fpongy mafs, of an almoft pearly whitenefs and fome brightnefs, intermixed in different parts with a green glafs, exactly refembling the glafs employed, and which probably was no other than a part of it, that had efcaped unchanged in the cementation, though not diftinguifhable by the eye, till thus fpued out from the lefs fufible porcelain, and collected in its cavities. Pieces which had acquired throughout a fine bright grain, were likewife in an intenfe fire, made to melt or foften into lumps, which generally proved fpongy:

ſpongy: but thoſe, in which a large coarſe grain had ſucceeded to the fine one, could ſcarcely be made to ſoften at all, whether expoſed to the fire in crucibles, or in contact with the burning fuel. Theſe unfuſible pieces, though a continuance of the baking with a moderate heat would have rendered them more and more porous and friable, on being haſtily urged with an intenſe fire became remarkably more compact than they were before; ſome of them ſeemed ſuperiour in ſolidity to any kind of ware I know of.

It may hence be preſumed that the ſmooth texture obſerved in ſeveral pieces after the baking, ſo cloſe and compact that neither grains nor fibres can be diſtinguiſhed, proceeds from their having undergone a greater degree of fire than the others. Several of the pieces, which acquired this appearance in the baking, had in part begun to melt, and others had not: perhaps the former received their compactneſs from an augmentation of the heat, in the earlier period of the cementation, and the latter in the ſubſequent ſtages when their fuſibility had been greatly diminiſhed; and probably the ſemitranſparency of ſome of the compact pieces, and the perfect opacity of others, proceeded from the ſame cauſe. It is plain that the reſiſtance to fire, which Reaumur makes a general property of this kind of porcelain, belongs to it only in certain ſtates; and that the veſſels, which he found to bear the vehement heat of a forge, could not be of the fibrous porcelain he deſcribes, but ſuch as had been baked conſiderably beyond that period.

From the foregoing general reſults of a great number of experiments, a particular detail of which could add little either to the inſtruction or entertainment of the reader, it follows, that this porcelain, though little adapted for ornamental purpoſes, on account of its want of beauty on the outſide, is very well fitted for many kinds of uſeful veſſels.

Green glaſs mortars, or planes for levigation, may be advantageouſly changed into this hard porcelain, greatly exceeding the hardneſs of any kind of marble, and no ill ſubſtitute for agate or porphyry. Mortars and levigating planes of this kind ſeem for ſome purpoſes particularly excellent, as for the grinding of enamels, which, though they ſhould wear off ſome of the matter of the baked glaſs, as well as of marble or alabaſter, yet cannot be ſo much injured by the little they receive from the former, which is analogous to their own compoſition, as by the greater quantity they receive from the latter, which is of very different quality.

Glaſs veſſels, intended for bearing the fire, may, by converting them into porcelain, be made capable of bearing it in a much greater degree, and rendered much leſs liable to crack. As veſſels of this porcelain have in theſe intentions manifeſt advantages above glaſs, they have advantages alſo above all the other porcelains and earthen wares. The unglazed earthen wares permit ſaline liquors to ſoak through them; thoſe which are glazed have their glazing corroded by acids; the compact ſtone wares, and thoſe in general which have clay in their compoſition, as all the common wares neceſſarily have, are corroded and partly diſſolved by certain acids in a boiling ſtate, particularly by the vitriolic: while the porcelain from glaſs is neither affected by theſe cauſes, nor ſo liable to be injured by haſtily expoſing it to the fire. I know of no material, ſo proper, and ſo commodious, for evaporating veſſels, or others, that ſhall be proof againſt all kinds of ſaline liquors.

There are ſome veſſels alſo, which may be figured more perfectly, and with leſs expence, in this kind of porcelain

porcelain than in any other. Long-necked matraſſes for inſtance could ſcarcely at all be formed by the potter, of that equal thickneſs, and internal ſmoothneſs, to which they are expeditiouſly blown by the glaſs-maker.

The above account of the qualities of this porcelain in its different ſtates, points out a caution to be obſerved in the proceſs, eſpecially where mortars are to be changed, or in other caſes where great hardneſs is required; viz. to diſcontinue the baking at the period of the greateſt hardneſs; for otherwiſe the matter ſoon becomes ſoft again, and even ſofter than the glaſs was at firſt. It ſeems to have acquired its full hardneſs as ſoon as it has become white and fibrous; and hence perhaps it may for moſt purpoſes be adviſeable to diſcontinue the operation as ſoon as the glaſs appears covered with a moderately thick white coat. Fragments of the ſame kind of glaſs, put in along with the veſſel to be changed, and occaſionally taken out and broken, will ſerve to inform the operator how the change goes on. Of wide-mouthed veſſels, ſeveral may be placed within one another, with ſand between them. In all caſes, care muſt be taken to apply the heat, as equally as may be, all over the crucible or pot containing the veſſels, that the change may be as uniform as poſſible throughout: no particular contrivances however are neceſſary for this uſe, the ſame caution and the ſame furnace, employed for baking the common fine wares, being ſufficient for the baking of glaſs.

SECT. III.

Experiments of comparing the effects of different kinds of materials on Green Glaſs by baking.

PIECES of green glaſs bottles were ſurrounded with powdered charcoal, ſoot, and ſundry kinds of earthy bodies, in ſeparate crucibles, which were all covered and

 luted,

luted, and placed in a wind-furnace: the fire was gradually raifed, fo as to make the crucibles of a moderately ftrong red heat, and continued in this ftate for fix or feven hours. The fire being then fuffered to decay, and the crucibles taken out and examined, the glafs was found in all to have become porcelain. In the upper chamber, moft remote from the action of the fire, the pieces were in general fibrous, and fome of the thick ones not changed throughout: in the lower chamber, more immediately expofed to the fire, where the matters intermixt with the glafs were the fame as in the upper one, the fibres had in moft of the pieces difappeared, and given place to grains. There did not feem to be any differences, that could be afcribed to the quality of the cementing matters, in the internal colour, hardnefs, texture, or the regular fucceffion of the changes; though, in external appearance, the differences were very confiderable.

All the pieces, which had been furrounded with foot, with charcoal, or with mixtures of the two, were externally of a deep black colour: where fmall proportions of foot or charcoal were mixed with white earths, the porcelain turned out of a brown colour, deeper or lighter, according as the inflammable ingredient was in greater or lefs quantity. Judging that the dark colour, which the foot or charcoal communicate, might be burnt off by fire affifted by the action of the air, I put fome of the black pieces into a crucible, which was placed open in a blaft furnace, and excited the fire, for above an hour, to as great a degree as the porcelain feemed capable of bearing without beginning to melt: the colour refifted this heat, continuing as deep a black as at firft.

The coloured clays, boles, ochres, powdered red bricks, and the fands which burn red, gave likewife different fhades of brown, inclining more or lefs to blackifh, red-

 difh,

difh, or yellowifh: thefe colours alfo refifted the joint action of fire and air, equally with the preceding. The browns and blacks were on fome pieces very gloffy and tolerably beautiful.

Different white earths gave different fhades of whitifh, greyifh, or brownifh; but none of them gave a pure white, nor a whitenefs equal to that of the internal part of the porcelain. It is difficult to diftinguifh precifely the effect of particular earths, in this refpect, from that of the degree of fire or other circumftances in the procefs: for of pieces of the fame bottle, which had been furrounded and baked with the the fame earth, fome turned out manifeftly whiter than others. White fand, calcined flint, and gypfum, feemed in general to give the greateft whitenefs, and tobacco-pipe clay the greateft brightnefs or gloffinefs, though this laft, baking together in a lump upon the porcelain, made the furface in fome parts rough.

In this experiment, and in feveral repetitions of it, the furface of fome of the pieces proved rough like fhagreen, that of fome wrinkled like fhrivelled leather, and of others bliftered or full of blebs. Thefe appearances feem to have depended more upon the fire having been too ftrong or too haftily raifed, fo as to make the glafs foft or ready to melt, than on any particular quality of the materials with which it was furrounded; though it appeared alfo that fome materials difpofe to thefe imperfections more than others. Pieces of one and the fame glafs bottle having been baked, fome with tobacco-pipe clay, and others with quicklime, and with bone afhes, in the fame degree of fire, and for the fame length of time, the porcelain with the clay proved almoft every where fmooth and polifhed as the glafs was at firft, while thofe with the lime and with the bone afh were all over wrinkled.

From the different effects of different materials on the ſurface of the porcelain, I have endeavoured to add ſome embelliſhment to this kind of ware. By covering the outſide of the glaſs veſſel to be changed with powdered charcoal, or with a mixture of powdered charcoal and white ſand, and the inſide with white ſand alone, the porcelain veſſel, reſulting from the cementation, has proved of a deep black or a bright brown colour without, and of a tolerable whiteneſs within. By covering different parts of the glaſs with different powders, as charcoal, white ſand, white clay, lime, and coloured earths, I have obtained, in one piece, variegations, not inelegant, of different ſhades of black, brown, grey and whitiſh, and with gloſſy and wrinkled veins. The above colours, with the bluiſh caſt which the glaſs exhibits before the change is completed, are all that I have obſerved glaſs to receive by the proceſs of baking.

As the action of ſoot and charcoal on iron, in the converſion of iron into ſteel by baking, is promoted, and in ſome reſpects varied, by the admixture of a little ſea ſalt, and of the ſaline aſhes of wood, I made trial of the ſame compoſition for the baking of glaſs; and as the inflammable ingredients in this mixture could not fail to give a black colour to the porcelain, I tried at the ſame time, in another crucible, wood aſhes alone, which had been calcined in a ſtrong fire, to burn out all remains of their inflammable matter, and reduce them to perfect whiteneſs.

The ſteel-making mixture did not anſwer ſo well as the ſoot or charcoal by themſelves: the glaſs did indeed become porcelain, but of a bad quality, all over bliſtered, with many cavities, and ſome of them very large, in the internal part. The wood aſhes, inſtead of changing the glaſs into porcelain, melted and united with it into one ſemivitreous lump.

I tried likewiſe colcothar, or the red calx of iron, which remains from vitriol after the acid has been expelled by fire. Pieces of green glaſs being ſurrounded with this powder, and baked for ſeveral hours in the upper chamber of the wind-furnace, the glaſs and colcothar were all found to have run together into a black maſs, externally rough, internally ſomewhat ſmooth and cavernulous, of conſiderable hardneſs ſo as to ſtrike fire freely with ſteel. It is pretty remarkable, that a metallic ſubſtance ſo refractory in the fire, ſhould be ſo greatly diſpoſed to melt with green glaſs.

SECT. IV.

Experiments of the baking of different ſorts of Glaſs, and of bodies approaching to a vitreous nature.

GLASS conſiſts of earthy or ſtony ſubſtances, or metallic calces, brought into fuſion and tranſparency in a ſtrong fire. Pure unmixed earths cannot be made to vitrefy by any known degree of fire; but frequently one kind of earth is made vitreſcible by mixing with it a certain proportion of a different one, which ſeparately is as unfuſible as the other: thus clay and chalk, though each by itſelf is altogether unfuſible, yet when mixed together in due proportions, melt and form a truly vitreous compound: in ſeveral of the experiments I have been giving an account of, the crucibles were found partly vitrefied, not on the outſide which had been immediately expoſed to the fire, but on the inſide, which had been in contact with earths of a different kind from thoſe of which the crucible was compoſed. The ſeveral ſorts of glaſs in common uſe are prepared however on another principle;

principle; from fand, calcined flint, or pebbles, mixed with certain metallic or faline bodies, by which the earth is brought into fufion more eafily than by the addition of other earths.

Some glaffes of each of thefe kinds were cemented in the fame manner as the green glafs bottles in the preceding experiments; in hopes, that by purfuing the effects of the procefs upon a variety of bodies, though nothing fhould refult of practical utility, the nature of the change, philofophically confidered, might at leaft be illuftrated.

I. *Vitreous bodies compofed of earths, without metallic or faline additions.*

Pieces of crucibles, which from vehemence of fire had melted into a femitranfparent glaffy ftate, were furrounded with bone-afh; which was here made choice of as being the moft indifpofed to vitrefy of all the earthy bodies I know of. As this kind of glaffy matter is very hard of fufion, the crucible containing it was placed in a blaft furnace, and the fire ftrongly excited by the bellows for feveral hours, that the matter might undergo as great a degree of heat as it could bear without melting: the fuel was fea-coal, coaked or charred as for the drying of malt, which I find to be a very convenient fuel where bellows is ufed, being very durable, and giving a ftrong heat, without fmoke. The crucible being grown cold, the pieces were found of their original vitreous appearance, and without any change in their colour or tranfparency. Nor have I obferved that any compofitions of mere earths, whether brought to a perfectly vitreous or only to a femivitreous ftate, received any alteration from this procefs. China ware, which is reckoned a mixture of two different earths femivitrefied, was alfo found to refift it: the glazing of of the ware ſoftened, ſo as that the powder it was ſurrounded with partly adhered, but in other reſpects there was no ſenſible alteration. I tried likewiſe ſome of the more ſimple tranſparent and ſemitranſparent ſtones, as cryſtal and flint; which, by long cementations with different materials, received no other change than the diminution of hardneſs and tranſparency which ſimple heat produces in them.

II. *Metallic Glaſſes.*

PURE glaſs of lead, ſurrounded with ſand, and baked for many hours in a moderate red heat, ſuffered no perceptible alteration, except where ſome of it had melted off and diſſolved a part of the ſand. Common flint-glaſs, in which the flint or ſand that makes its baſis is vitrefied chiefly by an addition of calx of lead, proved alſo unſubduable by cementation: it became rough and browniſh on the outſide, and internally ſomewhat cloudy, but gained nothing of the appearance of porcelain by long continued and repeated bakings.

I cemented likewiſe ſome glaſſes tinged with metallic bodies, as the common blue glaſs tinged with the preparation of cobalt called zaffre, blue and green glaſſes with copper, and the ruby glaſs already mentioned in the tenth ſection of the hiſtory of gold. All of them retained their vitreous appearance, and ſuffered very little change even in their colour: the ruby glaſs grew ſomewhat darker, and one of the copper glaſſes more dull, but the blue glaſs with zaffre did not appear to have received any alteration. The bone aſhes, with which all theſe glaſſes were ſurrounded, adhered to them pretty firmly, probably from the ſurface having been ſoftened or partly melted by the heat: on the zaffre glaſs and the ruby glaſs, the earthy cruſt remained white as at firſt: on all the copper glaſſes it was reddiſh ; on that particularly, which had loſt conſiderably of its beauty in the proceſs, the bone aſh was tinged of a fine fleſh colour. This glaſs had been prepared from twenty-four parts of green glaſs, four of borax, and one of the powder ſeparated by agitation from an amalgam of copper.

III. *Glaſſes prepared with ſaline additions.*

ALL the glaſſes that could be changed into porcelain were ſuch as had been brought to their vitreous ſtate by means of ſaline bodies ; though ſome of this claſs reſiſted the operation, and in thoſe which did become porcelain, there were conſiderable differences, in regard both to the facility of the change, and the quality of the porcelain itſelf.

Green glaſs bottles, compoſed of ſand and the ſaline aſhes of wood, anſwered much the beſt ; and the French bottles better, in point of colour, than the Engliſh. One of our common quart bottles, and a French quart bottle, being ſurrounded with the ſame ſand, and baked in the ſame fire, for the ſame length of time, the porcelain from the French bottle turned out, in ſeveral repetitions of the experiment, manifeſtly the whiteſt, tho' in other reſpects no material difference was obſerved. It is probable that the difference in colour proceeded from the French glaſs being made with a whiter ſand than the Engliſh : it is ſaid that the ſand uſed for green glaſs in France retains its whiteneſs, in great meaſure, after ſtrong calcination ; while that of our glaſs-houſes burns reddiſh.

The vials, in which Hungary water is brought from France, are very difficultly converted into porcelain, and the porcelain they afford is leſs white and leſs compact than that of the common bottles. The vials are much more fuſible than the bottles, probably from their having a larger

larger admixture of ſaline matter: they begin to melt nearly as ſoon as the fire is raiſed high enough to change them; and how carefully ſoever the proceſs is managed, a part of the inſide commonly runs out, and the ſand they are ſurrounded with bakes into a hard cruſt upon the ſurface. The lower portion of one of theſe vials having been cemented with a mixture of ſand and gypſum, a part of it appeared changed throughout into a pretty hard porcelain, a part into a ſubſtance reſembling the mixture baked together, and a part ſeemed ſcarcely changed at all: there were many large cavities, and the glaſs, which had run out from them, coated a part of the mixture with a green glazing. In ſome other trials the change was more equal, but I have never obtained from theſe vials a porcelain ſo uniform, or ſo hard, as from the common bottles.

Glaſs tubes, of a pale green colour, were affected nearly in the ſame manner as the Hungary water vials: they ſeemed to be ſomewhat leſs diſpoſed to melt, and the ſand did not ſo ſtrongly adhere to them: from whence it may be preſumed, that this kind of glaſs has a larger proportion of ſaline matter than the common bottles, but leſs than the Hungary vials.

The common pale green glaſs retorts and receivers did not anſwer well. A piece cut off from the bottom of a retort, and ſeveral circular ſegments of receivers, were placed within one another in a large pot, with ſome bone aſh between and ſurrounding them, and cemented in a wind-furnace for ſeveral hours. They all became browniſh, rough and ſhrivelled on the ſurface, in ſome parts bliſtered, and in ſome extremely thin as if part of the glaſs had melted off. They were ſemitranſparent, nearly in the ſame degree as the finer ſorts of ſtone ware. They eaſily broke, and appeared internally white, not fibrous or granulated, but of a ſmooth glaſſy ſurface.

Common window glaſs appeared to ſuffer the ſame change as the glaſs bottles, becoming opake, and internally both fibrous and granulated according to the continuance of the fire: but it was greatly diſpoſed to bliſter, and part of the glaſs generally melted out.

The finer ſort of glaſs called crown glaſs, and looking-glaſs plates, did not become porcelain at all. In a moderate heat they grew wrinkled and ſhrivelled on the ſurface, and leſs tranſparent than before, but ſtill remained glaſs: on repeating the cementation with a ſtronger heat, they partly melted and mixed with the ſurrounding powder, but did not appear to have ſuffered any other alteration. A glaſs which I had prepared myſelf from calcined flint and pure fixt alkaline ſalt, remained alſo unchanged, in the ſame heat, and ſurrounded with the ſame powders, by which common green bottles had been turned into perfect porcelain. Green glaſs itſelf, melted with an additional quantity of ſalt, amounting to about a ninth part of its weight, and then cemented with ſand, continued likewiſe unchanged.

The foundation of theſe remarkable differences may be preſumed, from this laſt experiment, to depend chiefly on the different quantities of ſalt in the ſeveral ſorts of glaſs. The vitrification of ſand with wood-aſhes is influenced not a little by the action of the two earths on one another; ſo that, though vehement fire reduces the mixture into glaſs, yet the quantity of ſaline matter in the aſhes is much leſs than would be ſufficient for the vitrification of the two earths ſeparately. In the other coarſe ſorts of glaſs, a larger proportion of the aſhes, and conſequently of ſaline matter, is uſed, or ſome alkaline ſalt itſelf is added, to render the maſs more fuſible. In the fine glaſſes, the quantity of ſalt is ſtill larger, the vitrification being effected almoſt wholly by this ingredient.

It

It ſeems to follow, from the whole, that bodies of the glaſſy kind are changeable into porcelain by baking, only in ſo far as their vitreſcent ſtate has been procured by means of ſaline ſubſtances; that thoſe which hold the leaſt ſalt are the moſt eaſily changed, and that the porcelain they afford is the moſt perfect; and that thoſe, in which the proportion of ſalt is large, are very difficultly, if at all, made to undergo this change. Agreeably to theſe remarks, M. de Reaumur obſerves, that the very worſt glaſs makes the beſt porcelain; and ſuggeſts, that in order to the perfection of this kind of ware, it may be neceſſary for the glaſs-maker to acquire a habit of blowing veſſels from more refractory ſorts of glaſs than thoſe which are commonly worked. Perhaps the ſame end might be obtained more advantageouſly on another principle, which the foregoing obſervations point out, *viz.* by forming the glaſs of certain earthy compoſitions more diſpoſed to vitrefy than thoſe commonly employed; ſo that a very little ſalt ſhall be ſufficient for their vitrification in the furnace of the glaſs-houſe, and that the glaſs they afford, inſtead of being more refractory, ſhall be even more fuſible than the common green glaſs.

The different effects of cementation on different kinds of glaſs may perhaps afford ſome light into the cauſe of the change which coarſe glaſs undergoes, and ſome uſeful characters and diſcriminations of different vitreous and ſemivitreous bodies.

S E C T. V.

Obſervations on the cauſe of the changes which green Glaſs undergoes by baking.

THE moſt obvious way of accounting for this extraordinary change is, to ſuppoſe the earthy or other unvitreſcible particles of the matters, with which the glaſs is baked, to be forced into its ſubſtance by the heat: ſuch is the idea that firſt occurred to me on the diſcovery of this change, and ſuch is the idea of Neumann and Reaumur. But ſpecious as this theory appears to be, there are ſome facts which ſeem to overthrow it.

If the change proceeded from the introduction of any extraneous matter into the glaſs, the porcelain would weigh more than the glaſs; as ſteel, prepared from forged iron by cementation, is found to weigh conſiderably more than the iron before the cementation. But pieces of glaſs bottles, baked with ſand till they had become fibrous throughout, and then wiped clean from the ſand, were found, on ſeveral trials, to have received no increaſe of weight.

In ſome of the foregoing experiments in which the glaſs became perfect porcelain, the cementing material was a very coarſe ſand, which had been ſifted from the finer grains for other uſes. Is it not improbable, that the large grains of ſand ſhould be ſubtilized by the heat, and driven every where ſo equally into the ſubſtance of the glaſs, as to produce the remarkable fineneſs, and regularity of texture, of the fibrous porcelain? Charcoal, which gives ſo permanent a blackneſs to the outer ſurface, can ſcarcely be ſuppoſed, when introduced into the internal part, to make it white. Nor could the porcelains, produced with different materials, be ſo exactly alike in their internal ſubſtance, if they proceeded from a coalition of the different bodies with the glaſs.

When green glaſs is heated till ready to melt, and then ſuffered to cool, it frequently contracts bluiſh ſpecks or veins; which induced me to ſuſpect, that the ſame change was there beginning, as happens at the beginning of the baking. In purſuance of this obſervation, I placed ſome necks of quart bottles upright in large crucibles, ſecuring

ſecuring the lower ends in a bed of luting: the crucibles being cloſely covered, and expoſed to the ſame degrees of heat as in the preceding experiments, the glaſs underwent the ſame changes as if it had been ſurrounded with ſand; with only this difference, that the changes happened much more ſlowly; and that the pieces of glaſs having no ſolid matter to ſupport them at the ſides, many of them, made ſoft by the heat, had failed and bent downwards. It ſeems manifeſt from this experiment, that the ſand or other materials are of uſe only for expediting the proceſs, and affording a ſupport to the veſſel; and that they are entirely ineſſential to the porcelain itſelf.

There are other facts which ſeem to ſhew, that the glaſs, inſtead of receiving any new ingredient in its converſion, loſes a part of one of its own, at leaſt in the latter ſtages of the proceſs. In the cementation with ſand, the ſand near the ſurface of the glaſs, as already obſerved in the preceding part of this eſſay, was commonly found to cake together; a preſumption that it had imbibed ſome of the ſaline matter of the glaſs, for ſand of itſelf is never found to cohere by heat. When freſh pieces of glaſs were cemented repeatedly with the ſame ſand, the ſand actually begun to melt, and covered the ſurface of the glaſs, or of the porcelain reſulting from it, to a conſiderable thickneſs, with a ſemivitreous coat, which adhered ſo ſtrongly as not to be ſeparated by a blow. When the baking of one piece of glaſs was long continued, it became friable and porous, the adjacent ſand concreting at the ſame time into a maſs ſcarcely to be dſtinguiſhed from it.

From theſe obſervations I apprehend it may be concluded, that a part of the alkaline ſalt of the glaſs exudes by the heat, and is imbibed by the ſurrounding matters; and that by a long continuance of the baking, ſo much of the alkali is forced out, that there is ſcarcely enough left to make the earthy baſis of the glaſs cohere. Thus glaſs, whoſe production has been commonly ſuppoſed to be the utmoſt limits of the power of fire, has its earth and its ſalt, which one degree of fire had ſo firmly united, almoſt wholly disjoined by another.

If theſe principles be juſt, they afford a ſatisfactory explication of the moſt remarkable phenomena of the proceſs; as of thoſe glaſſes only being convertible into porcelain which are prepared with ſaline matters, of thoſe being eaſieſt changed which have leaſt ſalt, of the ſame changes being producible by cementation with very diſſimilar materials, of the glaſs becoming leſs and leſs fuſible in proportion to the change, of its becoming more and more hard to a certain point, and afterwards more and more brittle.

It has been obſerved above, that glaſs, in its converſion into a fibrous porcelain, did not receive any increaſe of its weight: it muſt be added alſo, that it ſcarcely ſuffered any ſenſible diminution. I do not however apprehend, that this experiment is altogether irreconcilable with thoſe which ſeem to prove the exudation of the alkaline ſalt of the glaſs. The ſtrong marks of the exudation do not appear till after the porcelain has conſiderably paſſed its fibrous ſtate; and then the ſand, concreting inſeparably upon its ſurface, prevents our being able to determine any thing from the weight. Green glaſs has as ſmall a proportion of ſalt, as can be made to vitrefy the earthy matter in the ſtrongeſt fires of the glaſs-houſe: it is probable therefore that the ſeparation of a very minute portion of the ſalt may be ſufficient for producing the firſt degree of change, or rendering the mixt no longer glaſs; the fuſibility of the fibrous porcelain ſeems to be a proof, that the quantity of alkali ſeparated at this period cannot be conſiderable. Perhaps alſo this firſt degree of change may depend in part on an alteration produced, by the heat, in the glaſs itſelf conſidered as a compound, or in the nature of its alkaline ingredient. The remarkable differences, in point of brittleneſs, which happen to glaſs merely from the quick or ſlow manner in which it is cooled, are well known: and as to alkaline ſalts, when expoſed for ſome time to a moderate fire, a part of them is always found to loſe its ſaline nature, and become an earth.

IV. Of the Expansion or Contraction of certain Bodies at the Time of their paffing from a fluid to a folid State.

THE expanfion of bodies by heat, and their contraction by cold, fuppofed to proceed always uniformly by equal augmentations or diminutions of heat, appear to have fundry irregularities; which may deferve to be taken notice of, not only in a philofophical view, but likewife as being productive of fome effects interefting to the workmen.

It has been frequently obferved, that when thermometers prepared with different fluids, as quickfilver, fpirit of wine, water, and oil, have two diftant points of heat marked equally on them all, and the fpaces between divided into an equal number of parts; the heat, which makes the fluid in one expand to any of thefe intermediate points, fhall raife that in another above the correfponding divifion, and in another not fo high. It was probably this irregularity in the expanfion of the fluids, that prevented the agreement of the mercurial and fpirit thermometers which Boerhaave fays he had made for him by Fahrenheit: the different expanfions of different kinds of glafs, to which the ingenious artift has recourfe in order to account for the variation, appears to be infufficient for producing it; fince, if the expanfion of the two tubes be always uniform, or in the fame proportions to one another, the quantity of this expanfion cannot influence the apparent proportional expanfions of the fluids. I have feen a mercurial and fpirit thermometer very nearly correfpond, at different divifions, from the freezing point to the heat of melted wax: the divifions viſions on the mercurial one were all equal, thoſe of the other widened upwards; as if heated ſpirit either expanded more, or heated mercury leſs, by a certain additional heat, than the ſame fluids do by an equal addition of heat made to them in a colder ſtate. Reaumur ſays, that water from freezing to temperate expands only one tenth part as much as ſpirit does, but that from freezing to boiling it expands half as much as ſpirit in the ſame interval. Though the difference in the proportion at different periods of the heat is doubtleſs very conſiderable, I apprehend it does not amount to quite ſo much as this; and that the miſtake aroſe from ſuppoſing the full heat of boiling water to have been communicated to the ſpirit thermometer immerſed in it for a little time; whereas ſpirit cannot bear ſo great a heat as that in which water boils, and conſequently, in this part of the experiment, the ſpirit was leſs heated than the water it was compared with. Theſe variations in the proportional expanſions of different fluids ſeem to have been little conſidered by thoſe who have given compariſons of different thermometers, by reducing the diviſions of one to thoſe of the other from only two correſponding points on each.

A more remarkable exception from the general law of expanſion is obſerved in the freezing of water. Though water ſhrinks more and more, as its warmth diminiſhes, down to the period of its congelation; yet, at the inſtant of its becoming ice, it expands into a larger volume, ſo as to burſt the ſtrongeſt veſſels that have been employed for confining it. The floating of ice in water is a neceſſary conſequence, and a convincing proof, of ice being leſs denſe, or more expanded, than water in its fluid ſtate. M. de Mairan, in a diſſertation on ice, attributes this increaſe of the bulk of the water chiefly to a different arrangement of its parts; the icy ſkin on water being compofed of filaments which are found to be joined conftantly and regularly at an angle of fixty degrees, and which, by this angular difpofition, occupy a greater volume than if they were parallel. He found the augmentation of the volume of water by freezing, in different trials, a fourteenth, an eighteenth, a nineteenth, and when the water was previoufly purged of air, only a twenty-fecond part: that ice, even after its formation, continues to expand by cold; for after water had been frozen to fome thicknefs, the fluid part being let out by a hole in the bottom of the veffel, a continuance of the cold made the ice convex; and a piece of ice, which was at firft only a fourteenth part fpecifically lighter than water, on being expofed fome days to the froft, became a twelfth part lighter. To this caufe he attributes the burfting of ice on ponds.

Wax, refins and animal fats, made fluid by fire, inftead of expanding like watery liquors, fhrink in their return to folidity; for folid pieces of the fame bodies fink to the bottom of the refpective fluids, a proof that thefe bodies are more denfe in their folid than in their fluid ftate. The oils which congeal by cold, as oil olive and the effential oil of anifeeds, appear alfo to fhrink in their congelation. Hence, the different difpofitions of different kinds of trees to be burft by, or to refift, ftrong frofts, are by fome attributed to the juices, which the tree abounds with, being in the one cafe watery, and in the other refinous or oily.

The earthy powders that mingle with water into an uniform pafte, exhibit differences, not lefs ftrongly marked, in the affections of their volume by drying. The contraction of clay in drying is well known, and allowance is made for it by the workmen, in forming models or other works of moift clay where any exactnefs is required in the dimenfions. I tried pure clay, and mixtures of it with different proportions of fand, all beaten up

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with ſo much water, as made them juſt ſoft enough to admit of being formed into long narrow plates: A particular account of theſe experiments will be given hereafter; at preſent it is ſufficient to obſerve, that the plate of pure clay ſhortened in drying one part in eighteen, while a mixture of the clay with twice its weight of ſand, ſhortened but one part in thirty. It is not known that any kind of earth ſhrinks ſo much as clay, and hence the purity of clay may be judged from the degree of its contraction.

Plaſter-of-paris on the contrary, diluted with water into the conſiſtence of a ſoft or thin paſte, quickly ſets or grows firm, and at the inſtant of its ſetting has its bulk increaſed, as appears from the pretty experiment mentioned ſomewhere in Boyle's writings, and which I have often tried: A glaſs veſſel being filled with the fluid mixture and cloſely ſtopt, the glaſs burſts while the mixture ſets, and ſometimes a quantity of water iſſues through the cracks. This expanſion of plaſter-of-paris, in paſſing from a ſoft to a firm ſtate, is one of its valuable properties; rendering it an excellent matter for filling cavities in ſundry works, where other earthy mixtures would ſhrink and leave vacuities, or entirely ſeparate from the adjoining parts. It is probable alſo that this expanſion of the plaſter might be made to contribute not a little to the elegance of the impreſſions which it receives from medals, &c. by properly confining the ſoft matter, that its expanſion may force it into the minuteſt traces of the figure; the expanſion of the matter doing the ſame office as the preſſure by which wax is forced into the cavities of a ſeal.

There are grounds to believe, that differences of the ſame kind obtain in melted metals at the inſtant of their fixing or becoming ſolid; that at this period they do not obſerve the ſame laws as before or after it; and that, while ſome of them contract like oily or reſinous fluids in their congelation, or like clay in drying; others expand, like congealing water, or like plaſter when it ſets.

Mr. Smeaton found, in a ſet of curious pyrometrical experiments, of which an account is given in the 48th volume of the Philoſophical Tranſactions, that from the heat of boiling water to freezing, a rod of zinc ſhrunk near three times as much as one of regulus of antimony; yet, when the two metals were melted, the regulus of antimony ſeemed to ſhrink in fixing conſiderably more than the zinc. This difference is the more remarkable, as among all the metallic bodies that have been tried, regulus of antimony in its ſolid ſtate contracts or expands the leaſt, and zinc the moſt, by equal augmentations or diminutions of heat; whence the excellence of this laſt for metalline thermometers, and other inſtruments whoſe effect depends on their length varying according to the degree of heat.

An elegant phenomenon of the contraction of ſilver in fixing is often obſerved at the end of the proceſs of cupellation. When the ſilver remains fine on the cupel, if the veſſel be drawn forwards from the heat, that it may cool ſomewhat haſtily, the ſurface of the metal ſuddenly fixing and contracting, ſqueezes out ſome of the fluid part within, which iſſues in little jets through different parts of the ſolid cruſt, and ſometimes ſpirts up to a conſiderable height, hardening in the air as it riſes. M. Morel, refiner of the mint at Paris, made ſeveral experiments of this vegetation as it is called, of which an abſtract is given in the French Memoirs for 1727: to cool the metal the more haſtily, he applied a wet cloth to the ſurface, and at the ſame time dipt the bottom of the cupel in cold water, by which means he obtained larger and more numerous jets, variouſly arranged: he obſerves, that the larger

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the quantity of metal, the finer the vegetations are; that a mixture of two parts of lead and one of ſilver gave finer vegetations than pure ſilver; that pure lead had its ſurface perforated too haſtily, and that its jets hardened without riſing high; that copper is not eaſily made to vegetate at all, its ſurface growing ſo hard as to afford more reſiſtance to the fluid underneath than the bottom of the cupel does, which laſt accordingly burſts; and that gold, inſtead of jets which continue fixed at the lower end to the ſurface of the maſs, throws off ſmall round grains, ſometimes to the diſtance of ten inches.

M. de Reaumur, from ſome phenomena in the caſting of iron, ſuſpected that this metal expands in fixing; and accordingly made ſeveral experiments, which are related in a paper in the memoirs of the French Academy for the year 1726, for determining whether iron really expands at this period of its cooling, and whether it is the only metal poſſeſſed of that remarkable property.

He obſerves, that lead, tin, copper and ſilver, caſt into ingots, are always concave or depreſſed on the upper ſurface, which ſeems a mark of their having ſhrunk in fixing. He melted each of theſe metals, ſeparately, in ſmall cylindrical crucibles, which being quite filled with the fluid metals, a plate of iron was paſſed over the ſurface to take off ſuch part as might have riſen above the edges: when grown ſolid, they were all found to have ſunk conſiderably in the veſſels; and on melting them again they were found to fill up the ſpace which they had forſaken in cooling. Having melted pieces of each of theſe metals in ſeparate crucibles, he dropt into them pieces of the reſpective metals unmelted; they all ſunk beneath the ſurface, and ſome fell with a thump on the bottom of the crucible: from whence it is plain, that ſilver, copper, lead and tin, are heavier, or more denſe, in their ſolid than in their fluid ſtate, and conſequently that the melted metals contract in becoming ſolid. In making the laſt of theſe experiments ſome caution is neceſſary, particularly with regard to lead and tin: for if theſe metals are made very hot, the pieces thrown in will melt ſo faſt, that it cannot be judged whether they ſink or ſwim: if not heated ſufficiently, they prove ſo thick, that the exceſs of gravity of the ſolid piece will not be able to overcome the tenacity of the fluid, whence the piece will be ſuſtained on the ſurface, more eſpecially if it is ſmall, and if the ſkin which forms on the fluid has not been previouſly taken off.

On trying the ſame experiments with iron, the event was different. Ingots of iron appeared, he ſays, not hollow on the ſurface, but ſenſibly elevated or convex. Having brought ſome iron into thin fuſion, and carefully cleared the ſurface from groſs matter, he threw in ſolid pieces of caſt iron of different kinds: they all ſwum, like ice on water, and when puſhed down beneath the ſurface, they immediately roſe again; a proof that the ſolid pieces were lighter or more expanded than the fluid, and conſequently that melted iron expands or increaſes its bulk in becoming ſolid. To this property he aſcribes the neatneſs with which caſt iron receives impreſſions from moulds, a neatneſs wondered at by thoſe who work only in copper or other metals: he ſays he has ſeen a hundred and a hundred times, that though iron was poured quite thick into the mould, it nevertheleſs took the figure well, its expanſion forcing it into the ſmalleſt cavities: that he has often ſeen the workmen ſurprized to find, that it was with the utmoſt difficulty they could unſcrew the moulds in which iron had been caſt, while nothing of this kind is ever obſerved to happen in the caſting of other metals: that works of lead, copper, gold, and ſilver, are always found

found lefs than the moulds, but thofe of iron equal to them, or a little bigger.

Having found on trial that folid pieces of iron rofe to the furface of melted iron, and being thus convinced of the truth of Reaumur's principal experiment; I thought I had fufficient foundation to fay, in the foregoing part of this work, page 67, that iron expands in its paffage from a fluid to a folid ftate. Some inftances I had feen of melted iron having clofely applied and fixed itfelf to folid pieces by which it was confined, confirmed me in this opinion, and induced me in page 59, in propofing a method of obviating the common imperfections of the rolls for flatting gold and filver wire, by cafting a hoop of fteel, and after fufficiently forging the hoop, fixing an iron axis within it, to recommend, as the readieft way that occurred for fecuring the axis, pouring melted iron into the fpace between it and the hoop.

An ingenious correfpondent has fince obferved to me, that melted iron does not expand in fetting, and will not fix itfelf to the hoop, but fhrink from it as other metals would do: that though works of caft iron are indeed generally larger than the mould, yet this increafe of bulk does not proceed from the expanfion of the metal itfelf, but from its fluxing and drinking into its furface a confiderable quantity of the fand of which the mould is compofed, which he judges to have been the foundation of Reaumur's miftake: that large iron works caft in open moulds, as forge hammers and anvils, have confiderable hollows on the upper fide: that large works caft in clofe moulds have always a cavity fomewhere in the internal part; that cannon balls cannot be caft without fuch cavities; of which the workmen are fo fenfible, that in order to avoid as much as poffible the inconvenience of the hollow being near the fide, they turn the mould upfide down

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ſoon after the metal has been poured in. It is ſuppoſed, that as caſt iron begins to ſet on the ſurface almoſt immediately on its being poured into the mould, ſo as to become covered with a ſolid ſhell, the cavities muſt proceed from the fluid part within ſhrinking while it becomes ſolid. Several experienced artiſts have alſo aſſured me that the melted iron will ſhrink from the hoop.

I ſhall always take the earlieſt opportunity of acknowledging miſtakes, and my obligations to thoſe who ſhall point them out. With regard to the method of making the rolls, it may be obſerved, that the diſputed property of iron does not affect the eſſential part of the propoſal, which may therefore ſtill deſerve attention, whether iron has or has not that property: for though the particular way, recommended for joining the parts, ſhould not anſwer, the artiſt cannot be at a loſs to find means of ſupplying the defect, or of fixing an iron axis in a ſteel hoop.

To ſatisfy myſelf in regard to the fact, and to diſcover whence any fallacy might have ariſen in the conſequence of an experiment which appeared ſo deciſive, I made ſome further trials.

A rod of iron being placed upright in the middle of a ſteel ring, I melted ſome caſt iron, and poured it into the ſpace between them. When cold, the caſt iron firmly embraced the rod, but parted without difficulty from the ring, though it had received very neat impreſſions from ſome marks on its ſurface.

I melted a quantity of the iron in a large crucible, and thoroughly cleared it from the groſs matter on the ſurface. When in perfect fuſion, I threw into it a ſolid piece of the ſame kind of iron previouſly heated: the piece dropt to the bottom, but immediately roſe up again to the top, as wood does in water: being puſhed down with an iron rod, it roſe again, and continued to float till it melted

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and united with the reſt. I tried different kinds of caſt iron, with the ſame event. Even forged iron, though conſiderably heavier than caſt iron in its ſolid ſtate, was found to be lighter than melted caſt iron; for it floated on the ſurface, and when puſhed to the bottom, it roſe up again, and this repeatedly till it was diſſolved by the melted metal. Had the ſolid pieces barely ſwum on the top, it might have been ſuſpected that they were kept from ſinking only by want of ſufficient fluidity in the melted iron: but their conſtantly riſing up from the bottom, ſeems a proof of their being lighter than the fluid.

It appears therefore that melted iron is really of greater ſpecific gravity, or more denſe, than ſolid iron, and conſequently that in fixing or becoming ſolid, it becomes lighter, or expands into a larger volume; and yet, that when grown cold, it does not preſs againſt, or keep diſtended, the veſſel or cavity it was poured into. Nor do theſe different effects ſeem to be at all repugnant to one another. It is not pretended that iron expands at any other period of its cooling, than in the inſtant of its paſſage from a fluid to a ſolid ſtate: after this time it contracts like the other metals. The internal cavities are agreeable to this account: the outer ſurface firſt expanding and fixing, a vacuity would remain under it if the next did not alſo expand: a vacuity muſt neceſſarily remain at laſt, which can be filled only by the ſubſequent contraction; and its not being filled ſeems to ſhew that the expanſion is greater than the contraction.

To judge in ſome meaſure of the degree of the contraction, I melted ſome caſt iron, and poured it into a long narrow iron ingot mould. The ingot proved in ſome parts convex on the ſurface, and in others a little depreſſed: it was ſhorter than the mould by nearly three parts in three hundred and thirty-two, or one part in a hundred and ten; though it had filled the mould in its fluid ftate, having taken an impreffion from both the ends. The real contraction muft have been fomewhat greater than this; becaufe the mould muft neceffarily have acquired a confiderable heat at the time of the iron's fixing, and confequently in cooling fhrunk along with it.

I have mentioned above that I had feen inftances, in which melted iron applied itfelf firmly to unmelted pieces by which it was confined. The foregoing obfervations occafioned me to recollect the circumftances in which thofe inftances had happened, and indeed naturally point them out. Caft iron fhrinks from an iron or fteel ring, which it filled and diftended at the time of its fixing: but if this ring be previoufly made very hot, it might be prefumed that its fhrinking would keep pace with that of the caft iron, fo that the latter would ftill continue to fill it.

Accordingly I heated the ring to a ftrong red or rather white heat; and placing it on a bed of fand, poured into it the melted iron: when cold, the caft iron filled the ring, and was firmly applied to it, fo as to be in no danger of being feparated or moved by any force that the rolls for flatting gold or filver wire are defigned to undergo; though the juncture was not, perhaps, fufficiently ftrong for refifting fo great force as other rolls muft neceffarily bear in the flatting of larger metalline maffes.

This laft experiment is entirely agreeable to, and feems to confirm, the foregoing. For though the ring or mould be fuppofed heated even to the degree in which caft iron fets; yet, if the melted iron fhrunk in fetting, it would have become lefs than the mould, and continued fo in the fubfequent period of the cooling.

V. Of

V. Of the blowing of Air into Furnaces by a Fall of Water.

THE earlieſt method of animating the large fires of the furnaces for ſmelting ores, appears to have been by expoſing them to the wind. Such was the practice of the Indians of Peru before the arrival of the Spaniards in that country. Alonſo Barba relates, that their furnaces, called guairas, were built on eminences, where the air was freeſt; that they were perforated on all ſides with holes, through which the air was driven in when the wind blew, which was the only time the work could be carried on; that under each hole was made a projection of the ſtone-work on the outſide, and that on theſe projections were laid burning coals, to heat the air before its entrance into the furnace. Some authors ſpeak of ſeveral thouſands of theſe guairas burning at once on the ſides and tops of the hills of Potoſi.

I have been informed, that ſeveral remains of a like rude proceſs are to be ſeen in ſome parts of our own country. The old blomery hearths, as they are called, for the running down of iron ore, are all on the tops of hills; a ſituation which can ſcarcely be ſuppoſed to have been choſen on any other account than for the conveniency of the wind, being, in other reſpects, extremely incommodious.

The gradual ſucceſſion of bellows to this precarious and inſufficient way of ſupplying air, and the gradual improvements made in the ſtructure and manner of working of the bellows, cannot perhaps be traced. It appears, that at ſome of our iron furnaces and others, the bellows were formerly moved by a handle as thoſe of the ſmith's forge, or by the preſſure of the foot upon a treadle, or by other means requiring the ſtrength of men : and that, ſince the force of water has been called in aid to move them, the quantity of ore run down has not only been far greater, but the ſeparation of the metal more complete; inſomuch, that great part of the iron now prepared at ſome conſiderable works, particularly in the county of Glouceſter, is no other than what had been formerly left in the ſlags or cinders for want of ſufficient force of air.

The bellows uſed at our furnaces are compoſed of two boards joined by leather, nearly in the ſame manner as the common bellows. A cheaper kind of bellows, made entirely of woood, was introduced at the furnaces of the Hartz forreſt in Germany, according to Schluter, about the year 1620, and has ſince been received in Sweden and ſome parts of France. It conſiſts of two long boxes, of the ſame figure with the ſmiths bellows, one of which drops over the other, and is of ſuch depth, that when raiſed up on a hinge as high as it is intended to be, it no where comes entirely off; the air enters by a valve as in other bellows, and is forced out by preſſing down the upper box : along the edges of the lower or inner box are placed laths, which ſlide horizontally in grooves, and to which are fitted ſprings capable of preſſing them an inch or two beyond the box, ſo as to form a ledge, of variable width, which always accommodates itſelf to the outer

outer box, and in great meaſure prevents the air from eſcaping between them.

Though the wooden bellows have an advantage above the leather ones of being leſs expenſive and more durable, they have conſiderable defects; for it is ſcarcely poſſible to make the junctures ſo tight as to allow no exit to the compreſſed air, and the friction muſt neceſſarily be very great. Some have therefore had recourſe to water, for doing the office of the under board of the bellows. A bellows on this principle is deſcribed by Mr. Triewald in the Philoſophical Tranſactions, and I have been favoured with deſcriptions and drawings of two ſingular ones, now uſed at ſome of the iron works in this kingdom, one for the finery, the other for a large iron furnace, in which the fuel is coak, and which requires the greateſt force of air of any known kind of furnace. An account of theſe will be given hereafter.

There is another method of applying water, ſo as to produce a ſtrong blaſt, by means more ſimple than any of the foregoing, and at little expence. A ſtream of water, falling through a pipe, in certain circumſtances, carries air down with it; and this air, afterwards diſengaged from the water at the bottom, may be ſo collected, as to have no other vent than a pipe which ſhall carry it to the furnace.

Machines, conſtructed on this foundation, though little known among us, are uſed in different countries, inſtead of bellows, for animating the large furnaces. But their ſtructure and principles of action have hitherto ſo little undergone a ſcientific examination, that thoſe, which have been found to anſwer the beſt, may be preſumed to owe their excellence merely to chance, and that the workmen have often laid the greateſt ſtreſs upon the proportions of parts which are ineſſential. Theſe machines are doubtlefs capable of being much improved, fo as to produce greater effects, with a lefs quantity, and what is of more confequence, with a lefs fall of water : and principles may doubtlefs be difcovered, by which their ftructure may be regulated, and their power afcertained.

The importance of procuring commodious and cheap means of fupplying the vaft quantities of air which the fmelting furnaces require, induced me to examine the feveral accounts that have been publifhed of thefe fimple fubftitutes to bellows; and to make fundry experiments for bringing them nearer to perfection, and for eftablifhing their laws of action.

SECT. I.

Account of the principal machines ufed for blowing air into furnaces by a fall of water.

I. *A fimple pipe.*

THE firft account I have met with of a machine for propelling air into furnaces, by a fall of water carrying down air with it, is of one at the copper or brafs furnaces at Tivoli near Rome, of which a defcription and figure are given in the third number of the Philofophical Tranfactions, and in the *Journal des favans* for the year 1666.

A fquare wooden pipe, of confiderable width, and open at both ends, is placed upright. A ftream of water runs in at the top, and is difcharged at the bottom; and about the middle of the height of the pipe a fmaller horizontal one is inferted, which reaches to the furnace, and is faid to convey to it a ftrong blaft of air.

From fo imperfect a defcription, we can learn little of the nature of the machine, or of the manner in which the blaft is produced. It may be prefumed that the wa-

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ter, running forcibly againſt the ſide of the pipe, as it appears to do in the figure, is in great part daſhed into drops; the intervals between which being filled by air, this air is ſucceſſively puſhed down by the drops which follow, and afterwards eſcapes as ſoon as it meets with a vent. There ſeems, however, to be either ſome inaccuracy in the deſcription, or ſome eſſential part omitted: for in ſuch trials as I have made, when air, thus conveyed into a perpendicular pipe along with running water, was diſcharged by a lateral aperture, part of the water always accompanied it in a ſtream; and more of the water ſeemed to iſſue out in proportion as the quantity of air introduced was the greater.

II. *A pipe with air holes, inſerted into an air veſſel.*

M. Belidor, in his *architecture hydraulique,* gives a more particular deſcription of a water machine uſed in ſome parts of France: he ſays there are four or five forges on the river Iſere, between Romans and Grenoble, which have no other bellows.

The ſtream is divided into two channels, and each diviſion falls into an upright pipe ten or twelve feet high. Near the tops of the pipes are ſeveral holes, made ſloping downwards from the outſide to the inſide: through theſe holes air enters, and is carried down by the water; though the experiments in the following ſection will ſhew, that the quantity of air thus introduced is not ſo great as in the diſpoſitions mentioned hereafter.

The eſſential difference of this inſtrument from the foregoing conſiſts in its having an air veſſel, or reſervoir for the air, at the bottom. An oval wooden tub, near ſeven feet high, and three or four feet wide, is inverted, and its lower edge let into the ground five or ſix inches. The lower ends of the two upright pipes enter into the top of the tub, and under each pipe is a kind of ſmall ſtool which the water falls on. The water loaded with air, daſhing againſt the ſtool with great velocity, rebounds, and its air is diſengaged: a pipe communicating with the top of the tub carries the air to the furnace, while the water runs out at a hole in the lower part; a ſufficient height of water being kept in the tub, above this hole, to prevent any air from eſcaping by it.

III. *A funnel and pipe without air holes, inſerted into an air veſſel.*

M. Mariotte, in his treatiſe *du mouvement des eaux*, gives an account of another contrivance for blowing fire by a fall of water, which Belidor ſays, from the information of a friend who travelled in Italy, is uſed in the Tiburtine mountain near Rome, and near Salan on the lac de Guarde.

A wooden or tin pipe, fourteen or fifteen feet high, and one foot in diameter, has its lower end fixed into an air veſſel or inverted tub, as in the preceding article, from one ſide of which a blaſt-pipe goes tapering to the furnace.

The upper end of the large upright pipe is contracted to an aperture of three or four inches, into which is fitted a funnel, whoſe neck exactly fills it. Into the funnel there falls a ſtream of water, from the height of ten, fifteen, or twenty feet; which we may preſume to be daſhed into drops in its fall, and to puſh down air before it on the ſame principle as in the machine of Tivoli already mentioned.

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This inſtrument promiſes to be more effectual than either of the preceding, though in this country it can be of little uſe, ſo high a fall of water being rarely to be procured, at leaſt in thoſe places where ſmelting furnaces are eſtabliſhed.

IV. *A funnel and pipe with air holes, inſerted into an air veſſel.*

At Lead hills in Scotland.

In N°. 576 of the Philoſophical Tranſactions, in the year 1745, Mr. Stirling deſcribes a machine erected in Scotland, for blowing air into the furnaces in which lead ores are ſmelted; and for conveying freſh air into the works, ſo as to ſave the trouble and expence of the double drifts and ſhafts, and the cutting of communications between them.

A ſtream of water runs into a wooden funnel, ſo as to keep it always nearly full: the height of the funnel is five feet, and the diameter of its throat three inches and a half. The neck of the funnel is inſerted into an upright pipe, whoſe diameter is five inches and an half, and its length fourteen, fifteen, or ſixteen feet: immediately under the throat of the funnel, four air holes are made in the pipe, at equal diſtances round it, about an inch and a half wide, ſloping downwards from the outſide to the inſide.

The lower end of the pipe enters into a wooden tub, cloſe at top, but without a bottom, ſix feet high and five and a half wide, ſunk into a pit dug in the ground, and well rammed about with clay: in the middle of the tub, directly under the pipe, is a flat ſtone about two feet high, for the water to fall upon; and into the top of the tub is fixed a wooden pipe for carrying off the air, com-

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municating at the further end with an iron one which enters the furnace : for regulating the blaſt, a ſmall hole is made in ſome convenient part of the pipe, which is ſtopt with a pin, or opened, according as the blaſt is required more or leſs ſtrong. The hole in the lower part of the tub, by which the waſte water paſſes out, is about five inches ſquare ; and one ſide of the pit, where the water runs off, is a little lower than the ſurface of the ſtone, ſo that the water can never riſe high enough in the tub to cover the ſtone ; though it is ſuppoſed to continue always a conſiderable height above the top of the hole.

Though this machine is ſaid in the Tranſactions to be ſufficient for the ſmelting of harder ore than any in Lead-hills where it was erected, I have been informed by a perſon concerned in thoſe works, that it has ſince been found not to anſwer ſo well as could be wiſhed, and that accordingly it has been laid aſide, and its place ſupplied by the common bellows.

In Dauphiny in France.

THE blowing machines uſed in Dauphiny for the forges and ſmelting furnaces have a great reſemblance in their general ſtructure to the foregoing. They are deſcribed by Swedenborg in the ſecond volume of his *regnum ſubterraneum*, but with little exactneſs : a more accurate deſcription and figures of them, taken from the papers left by Reaumur, are inſerted in the *art des forges & fourneaux á fer*, publiſhed laſt year by the direction of the French academy.

The upright pipe is generally between twenty-five and twenty-ſix feet high : it is compoſed of two pieces of fir, hollowed, and joined together by iron work. Inſtead of a diſtinct reſervoir or funnel on the top, a part

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of the pipe itſelf is hollowed ſo as to perform the ſame office: at the top it is twelve inches and a fifth in diameter (Engliſh meaſure) from thence it grows narrower to the depth of nearly thirty-four inches, where its width is only about three inches and three quarters: immediately below this part, called the choak, its cavity widens to nearly eight inches and a half, and this width it preſerves throughout the reſt of its length. Under the choak are ten air holes, ſix of which are in one horizontal plane, at equal diſtances from one another, and the reſt about three inches and three quarters lower down: all the holes are cylindrical, near two inches in diameter, and cut at ſuch an obliquity, that the orifice of the upper ones is on the inſide of the pipe eight inches, and on the outſide only five inches, below the choak.

The tub or air veſſel, which receives the lower end of the pipe, is five feet and a half, or a little more, in depth, and nearly as much in width: the pipe enters into it about ſeventeen inches: about the middle of its height is a flat ſtone or iron plate, ſupported by croſs bars of wood. The air paſſes off, as already mentioned, through a pipe inſerted into the upper part of the tub, and the water through a hole at the bottom: on the outſide of this hole is fixed a wooden frame, with an upright ſlider, by which the aperture for letting out the water may be occaſionally increaſed or diminiſhed. The blaſt is regulated, and the air ſuffered to eſcape when it is not wanted, by a hole in the blowing pipe, to which is fitted a valve or a ſtopper.

One of theſe machines is ſaid to be ſufficient for the forge or iron finery, and two or three for the furnace in which the iron ore is run down.

In Foix in France.

In the county of Foix, the blowing machines, as deſcribed by Reaumur in the *art des forges* above quoted, are conſiderably different from the foregoing. The pipe is rectangular, and the part above the choak divides into three funnel-ſhaped partitions. On the top is a reſervoir or ciſtern of water; and two of the partitions, cloſe on all ſides, paſs up above the ſurface of the water, for carrying down air, and thus ſupplying the place of the lateral air holes: the water enters into the third partition, which is only the ſpace between the two foregoing, and which has but two ſides, formed by the two oppoſite ſides of the others.

The author makes the principal difference of theſe machines from thoſe of Dauphiny to conſiſt in this diſpoſition of the upper part: but the plate, annexed to his deſcription, ſhews another, which is, perhaps, more material to the effect of the inſtrument. The whole height of the pipe, including that of the water in the reſervoir on the top, is, according to the ſcale, twenty or twenty-one feet, and the choak or narrow throat is almoſt down at the middle of this height; ſo that the water iſſues through the choak with a velocity which it acquires from a preſſure of about ten feet, which is greater than in the machine of Dauphiny in the proportion of about eleven to ſix: the quantity of water ſeems alſo to be much leſs in proportion to the width of the pipe, the great preſſure probably occaſioning it to ſpread, ſo as to fill a larger bore than it could do when falling with leſs velocity.

Two pipes, divided in the ſame manner at the top, are fed by one reſervoir: the lower ends of the pipes enter into one large oblong box, from which the air and water paſs out as in the foregoing machines.

At St. Pierre in Languedoc.

Mr. Barthes, in a curious paper printed in the third volume of the memoirs of the correſpondents of the French academy, gives a minute deſcription, though in ſome parts not ſo clear as could be wiſhed, of a blowing machine at the forge of St. Pierre on the river Obriou, which he looks upon as one of the moſt perfect of the inſtruments of this kind. Its general ſtructure is nearly the ſame with that of Foix, but the height of water above the choak much leſs.

The upright pipe is ſquare, about nine feet high, and ſomewhat more than ſeven inches wide. Into its top are inſerted, at oppoſite ſides, two pyramidal air pipes, widening upwards, and paſſing up obliquely through a baſon of water four feet high. The ſpace included between the pipes, at their lower end, under the baſon, is a kind of hopper, into which the water enters through two apertures in the bottom of the baſon: to each of theſe apertures is fitted a piſton or ſtopper, hung to the end of a lever, by which it is raiſed more or leſs, according as more or leſs water is required. Two of theſe inſtruments are furniſhed with water from one baſon; and the lower ends of both enter into one air veſſel, which is near five feet high, about ſix and a half long, near three and a half wide at one end, and not quite two at the other. The ſtones, for the water to fall upon, are ſomewhat leſs than four inches and a half diſtant from the pipes: the water runs off through two rectangular apertures at the bottom, each about eight inches and a half wide, and near ſix inches high: the pipe which carries off the air, is an inch and a quarter in diameter at the ſmall end where it enters the furnace.

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The obſcure part of the deſcription relates to the hopper, and the apertures by which the water is diſcharged from it into the perpendicular pipe. The hopper ſeems to be divided into two upright partitions; and there are "two horizontal rectangular openings, through which the water runs into the two hoppers, each of them about ſeven inches and a half long, and in width five inches and a half, meaſured on the level of the bottom of the reſervoir, which width is reduced to four and a half at the extremity of the air pipes, where the hopper alſo terminates."

The author obſerves that in this machine, the water, iſſuing from the hopper, is neceſſarily reduced into drops. To ſatisfy himſelf more fully of this particular, he took a tin veſſel, eight inches and a half ſquare and ſix and a half high: in the middle of the bottom he cut a rectangular opening, about an inch and a tenth long, and eight tenths wide: to the two long ſides of the ſlit he ſoldered two tin plates, inclined to one another, and a third acroſs them. Theſe apertures, he ſays, repreſent thoſe of the machine when the ſtoppers are drawn up; and water put into this veſſel came out always, during the whole time of its running, in ſtreams which ſtruck againſt and croſſed one another, and which, after ſpreading, were reduced into drops.

In this illuſtration of the machine, though it ſeems clear, there muſt be ſomething which eſcapes my apprehenſion. Having cut an aperture of the above dimenſions in the bottom of a veſſel, I fitted to each of the longer ſides a plate half the width of the aperture, both of which plates were moveable, and kept at different inclinations by means of the third plate which paſſed acroſs the middle of the two. The veſſel being filled with water, I could not obſerve, as indeed was expected, the leaſt

leaſt croſſing of the ſtreams that run through it: on the contrary greateſt part of the water iſſued in two oppoſite directions, horizontally, from between the ends of the plates.

SECT. II.

Experiments and obſervations for the improvement of the foregoing machines, and for eſtabliſhing their principles of action.

I. *Of the quantity of water they require, and the quantity or force of the air they afford.*

THE quantity of water may be eſtimated with ſufficient exactneſs, from the height of the water in the funnel or baſon on the top, and from the width of the choak or throat of the funnel, through which it is preſſed by the force of a column of that height.

Deſaguliers found, by an experiment often repeated, that the quantity of water running through a ſquare inch hole, twenty-five inches under the ſurface, is five tons and a fifth in an hour, the ton containing two hundred and fifty-two gallons. The quantities diſcharged through equal holes at different depths being as the ſquare roots of the depths, and the quantities through different holes at equal depths being as the areas of the holes; it will appear on calculation, that in the machine at Lead-hills, whoſe funnel is five feet high, and its throat three inches and a half in diameter, the expence of water is ſomewhat more than ſeventy-ſeven tons in an hour, or near three hundred and twenty-four gallons in a minute; and that in the machine of Dauphiny, where the height of water in the funnel is only about half as great, and the bore of the throat a little wider, the quantity of water is about two hundred and ſixty-ſix gallons in a minute. Perhaps the real quantity of water may be ſomewhat leſs than this calculation

calculation gives, as the refiftance of the compreffed air may occafion fome retardation of the motion. Of the other machines, the defcriptions are too imperfect or obfcure for any computation to be made from them.

The water, iffuing from the narrow throat of the funnel with great velocity, is faid to fpread fo as to fill the wider bore of the pipe, and to become frothy from the mixture of air with it. The jet thus enlarged may be conceived as confifting of a multitude of flender ftreams or drops, the intervals between them being occupied by air, which is continually fupplied through the air holes, and pufhed down by the fucceeding drops or ftreams. It has therefore been reckoned, that the volume of air which paffes down the pipe muft be as much greater than that of the water, as the tranfverfe area of the jet, when fpread and reduced to drops in the pipe, is greater than when it paffed through the throat of the funnel. Circles being to one another as the fquares of their diameters, the area of the pipe of the Lead-hills machine will be to that of the funnels throat as eighteen to twelve and a quarter: the volume of air, according to the above principle, being to that of the water in the fame proportion, and the quantity of water nearly 324 gallons in a minute, the quantity of air in a minute fhould be about four hundred feventy-five gallons and a half, or 134000 cubic inches, or feventy-feven cubic feet and a half. In the fame manner, the machine of Dauphiny will be found to yield about 1080 gallons, or upwards of 304000 cubic inches, or 176 cubic feet, of air in a minute: fo that by this way of reckoning, the Dauphiny machine, with near a fourth lefs water than that of Lead-hills, fhould produce more than a double quantity of air.

But tho' this method of computation appears fpecious, it is not perhaps to be much depended on; air, in different

ent circumſtances, occupying very different volumes, in virtue of its great compreſſibility: nor is it certain that the bores of the pipes are ſufficiently filled, ſo as to carry down the full quantity of air. It may be preſumed, that the air, intermingled in the jet, is always in ſome degree compreſſed by the water; ſo that the interſtices between the ſtreams or drops contain more air than equal ſpaces of the atmoſphere. It may be judged however from the above compariſon, that the wider the pipe is, in proportion to the funnel's throat, provided the water running through the throat will ſpread through the whole extent of the bore of the pipe, the more air will be carried down.

Mr. Barthès, the only perſon I know of who has examined theſe machines philoſophically, and endeavoured to improve them, gives a method, in the memoir above-quoted, of comparing the proportional quantities or forces of the air in different blowing machines, on another principle. From conſiderations too abſtracted to be here particularized, he deduces a general rule, that the produce of air will be in all caſes in proportion to the quantity and velocity of the water: ſo that the quantity of water and height of the fall being given in two machines, and the volume or force of the air afforded by one of them being meaſured by experiment, the volume or force of the air in the other may be determined by the rule. Accordingly he made ſeveral experiments of this kind in two machines; meaſuring the force of the air, when the water in the baſon was at different heights, by the weight, which the blaſt acting on the arm of a balance, was capable of raiſing. Taking one of theſe experiments for a ſtandard, he computed by the rule what the reſults of the others ought to have been; but the experiments and calculations agreed ill together. And indeed the rule does not ſeem to be applicable but in circumſtances, which can ſcarcely be expected to occur; for it ſuppoſes the machines to be all perfect, and every drop of the water to have its utmoſt effect, or to carry down with it as much air as it is capable of doing; which cannot be admitted to be the caſe in any of the blowing machines yet conſtructed.

In the *art des forges* are mentioned ſome obſervations of Reaumur of the quantity of air afforded by the wooden bellows. He finds that thoſe uſed at the iron furnaces yield 98280 cubic inches, or upwards of five cubic feet of air at every ſtroke; and, including the two bellows, which act alternately, 240 ſtrokes in a quarter of an hour; which, on a reduction of the French meaſures to the Engliſh, make 1301896 cubic inches, or upwards of 753 cubic feet, in a minute: this quantity exceeds that which the foregoing calculation gives for the machines of Dauphiny above four times, and therefore four of the machines ſhould ſcarcely be able to ſupply the iron furnace with ſo much air as the wooden bellows does; whereas two or three are ſaid to be ſufficient. Again, the bellows of the iron finery and forge was found to give two thouſand fifty-one cubic inches and a third at each ſtroke, and four hundred and twelve ſtrokes in a quarter of an hour; whence the quantity of air in a minute is 458247 cubic inches, or ſomewhat more than 265 cubic feet: this is greater than the calculation of the water machine, in the proportion of about three to two, tho' one of the water machines is found to ſupply the office of the bellows.

It is not to be ſuppoſed, that the quantity of air, which furnaces require, is confined to any ſuch preciſe limits, as that two bellows, from their being found to anſwer ſufficiently for one kind of furnace, or even for one individual furnace, can be concluded to yield quantities of air exactly or nearly equal. The above differences are perhaps as little as can be expected in comparisons of this kind where the effects compared are so indeterminate.

As to the water machines, it is plain, that the quantity of air carried down cannot be greater, than the spaces between the drops or divided streams in the pipe can contain; and that though the air in these spaces must be considered as being compressed to a certain degree, yet it cannot be supposed compressed into two thirds of its natural volume, which would be necessary for making the calculations of the wooden bellows and the blowing machine to agree, because such a condensation would require the weight of a column of water of eleven or twelve feet, or the third part of such a column as is equivalent to the pressure of the atmosphere; whereas in the Dauphiny machine, though the air was pressed down with the full force of the column of water above the choak, the height of this column is less than three feet, and could not condense it more than one twelfth part.

In what manner Reaumur computed the air of the wooden bellows, we have no account: it is probable that he judged, as others have done in the same cases, from their capacity; supposing the whole quantity of air they contained to be delivered at every stroke. If so, we can lay no stress on the computation, for neither the wooden nor the leather bellows deliver their full contents of air; a considerable space remaining full of air when the bellows are closed; and this space containing considerably more air than an equal volume of the atmosphere, on account of the air being condensed in it by the pressure of the bellows. I have been informed by a judicious workman, that the bellows of the iron finery retains commonly a third, and sometimes half of its air; and that when lined with wood, ſo that as little vacant ſpace as poſſible might be left, he found it to blow much ſtronger than before.

The ſtrength of bellows is beſt judged from the force of the blaſt itſelf; and this force may be determined, in the method recommended by Mr. Barthès, already mentioned, by the weight it is capable of raiſing. He found that in the blowing machine of St. Pierre, deſcribed at the end of the preceding ſection, the force of the blaſt iſſuing from a hole of an inch and a third in diameter, raiſed the arm of a balance loaded with a weight of twenty-five ounces and a half. He gives ſome other experiments, of comparing the proportional diminution of its force according to the diminution of the height of the water; which I ſhall here inſert in the original French meaſures, to avoid unneceſſary fractions. The above force of twenty-five ounces and a half is the maximum of this machine, produced by the full quantity of water in the baſon, or a height of forty-eight inches above the choak: with a height of forty-one inches, the weight raiſed was twenty-two ounces; with a height of thirty-two inches, nineteen ounces; with a height of twenty-eight inches and a half, ſeventeen ounces and a quarter; with twenty-four inches and a half, fifteen ounces and a quarter; with nineteen inches, twelve ounces and three eighths; with ſixteen inches and two thirds, ten ounces and a quarter; and with a height of thirteen inches and a half, eight ounces and three quarters.

It may be obſerved, that in ſome of theſe experiments the water muſt have been employed to diſadvantage; and that by increaſing the height of the water much further than the above limits, in the ſame machine, we could not expect to produce proportional augmentations of the force of the blaſt: for if a certain quantity of water, running with a certain velocity through the choak, be ſup-

poſed

pofed to fill the bore of the pipe; a lefs quantity, with a lefs velocity, muft leave a vacancy, which will fuffer part of the air to efcape; and a greater quantity, with a greater velocity, muft have fome part of it fpent ineffectually, for want of fufficient room to fpread. Some experiments mentioned hereafter afford a clear proof of this.

The force of the air may be determined in an eafier and more fimple method, by means of a glafs pipe, open at both ends, with one end fixed in a bafon of water. The bafon may be hung in the upper part of the tub or air-veffel of our water machines, and the glafs pipe let into it through a hole in the top, what fpace may remain between the pipe and the hole being properly clofed: the preffure of the air on the furface of the fluid in the bafon, forces part of it up into the pipe; and this afcent will always be the meafure of the power or denfity of the air. Water is here greatly preferable to the quickfilver ufed in the fame intention on other occafions, as it difcovers fmaller variations in the force; for being fourteen times lefs ponderous than quickfilver, an equal preffure forces it fourteen times higher in the pipe: the whole afcent of quickfilver, by the preffure of the air in bellows, is fo fmall, as frequently not to exceed that part of the pipe which is inferted into the tub. Inftead of a glafs pipe, a copper or iron one may be ufed; and the afcent of the water meafured, either by occafionally dipping a rod in it, or by means of a hollow copper ball, or other floating body, with a ftem ftanding out of the pipe, and a proper weight below to keep it upright. It muft be obferved, that the height of the water in the pipe is to be eftimated from the furface of the water in the bafon: whence the pipe ought to be of fmall bore in proportion to the bafon, that the water may not fall confiderably in the bafon by the lofs of that which rifes in the pipe.

Dr.

Dr. Hales found that a ſmith's bellows raiſed a mercurial gage about an inch, ſo that it would have raiſed a water-gage about fourteen inches. The twenty-five ounces and a half, raiſed in M. Barthès's experiment by the blaſt of the machine of St. Pierre from an aperture of an inch and a quarter bore, Engliſh meaſure, are equivalent to the aſcent of water in the gage pipe forty or forty-one inches. I have been informed, that the pipe by which the air is diſcharged into our iron furnaces is at leaſt of an inch and a half bore; and that the air, with this aperture to paſs off by, ought to be of as great denſity as it can be reduced to by the human breath in a confined ſpace; which is ſuch as to raiſe the water in the gage about fifty inches; in which caſe it is compreſſed into near an eighth part leſs volume than it commonly occupies in the atmoſphere. But the quality of the fuel and other circumſtances occaſion ſuch variations in this reſpect, that no general ſtandard can be laid down. I have been aſſured, that a charcoal fire will be excited as ſtrongly by ſuch a blaſt as raiſes the gage thirty-ſix inches, as a fire of coaked pitcoal will be by one of fifty inches.

II. *Obſervations on the air veſſel.*

THE ſtructure of the air veſſel, or tub at the bottom, is in great meaſure independent of that of the reſt of the inſtrument; the ſame air veſſel ſerving equally for different kinds and ſizes of theſe machines, while the perfection of the other parts conſiſts in their adjuſtment and proportion to one another. The office of this veſſel being only to ſerve as a reſervoir for the air, and to ſuffer the waſte water to paſs off, no great care ſeems to be needful for regulating its dimenſions; and as the ſtone, which is placed in it under the pipe, ſerves only to receive

and

and support the fall of the water, or to occafion the water to be dafhed into fmall particles, that the air may be the more effectually extricated, its diftance from the pipe feems alfo to require no exact adjuftment. There are however fome particulars, in regard to the fize of this veffel, and the difpofition of fome of its parts, which appear to deferve attention.

The gage, mentioned in the preceding article, will be an ufeful addition to it; fhewing at all times by infpection the force of the blaft, and thus enabling the workman to judge whether it is fufficient for the purpofes intended, and giving him notice of any failings or imperfections that may have happened in the machine; as whether any air efcapes through the joints or cracks, or whether the choak or throat of the funnel is obftructed by ftones or other matters brought by the ftream.

All the writers I have met with, who give any account of thefe kinds of blowing machines, feem to fuppofe the water within and without the air veffel to be upon a level. But as the air in the air veffel is fo far compreffed, as to be able to raife the water in the gage to a confiderable height, it muft neceffarily act with equal power on the water below it; and if this water can pafs off freely at the bottom, it muft be depreffed as much as that in the gage pipe is raifed. The water within and without the veffel is exactly in the fame fituation with that in the bafon and pipe of the gage; excepting only that the former receives a continual fupply within, which paffes off as faft on the outfide. The excefs of the height of water on the outfide of the veffel, above that of the water within, appears to be the very power by which the air is compreffed and driven into the furnace.

To be further fatisfied of this depreffion of the water, I ufed, for the air veffel of a fmall machine, a tall glafs, without

without a bottom, ſeven or eight inches of its lower part being immerſed into a tub full of water. As ſoon as the machine began to play and the gage to riſe, the water within the glaſs ſunk lower than that in the tub on the outſide; and the depreſſion of the water and riſing of the gage were, as nearly as could be judged, equal, and kept pace with one another. In a little time the water was forced quite out of the glaſs, and the air following it roſe in bubbles to the top of the tub.

The bottom of the air veſſel ought therefore to be ſunk at leaſt as much below the level where the external water paſſes off, as the gage is expected to riſe; for otherwiſe, before the air is ſufficiently compreſſed to raiſe the gage to the due height, it will force all the water out below, and in part eſcape itſelf by the ſame aperture. Hence the depth of the air veſſel, in any of theſe machines where the water has a free paſſage at the bottom, gives a power which the force of the blaſt in that machine can never be made to exceed: thus at Lead-hills, the water being only of the height of two feet from the bottom of the veſſel to the level of the bank where it runs off, the air can never be compreſſed further, than to be able to ſupport a column of two feet of water, or to raiſe the gage to that height; whereas in the machine of St. Pierre, the compreſſure is about two thirds greater.

The ſinking of the water in the air veſſel may indeed be prevented, by making the aperture at the bottom, through which the water is diſcharged, of ſuch a ſize, that the preſſure of the air may be able to drive through it no more water than is received at the top. But ſuch an adjuſtment would be apparently very difficult; and tho' it ſhould be exactly hit, yet, if the quantity of water received was not always the ſame, it would ſcarcely be poſſible to avoid either a depreſſion or elevation of the water in the air veſſel.

Though the depth of water be ſufficient to reſiſt the preſſure of the air, it will be eaſily conceived, that if there was no ſolid body to ſupport the fall, the great force of the ſtream, falling from ſuch a height, would puſh down or daſh about great part of the water in the bottom, ſo that the air would get at the hole, and in part make its eſcape with the water. It may be preſumed that even the drops of water, rebounding from the ſtone, and falling down again, have a like effect, though in a lower degree: for drops falling through the common atmoſphere into water, carry air with them, which afterwards riſes in bubbles, as may often be obſerved in heavy rains; and it is not to be ſuppoſed, that the drops ſhould not here alſo carry into the water ſome of the compreſſed air, which ſurrounds them and is entangled between them. Though part of the air, which thus paſſes into the water, doubtleſs riſes again in bubbles, as appeared in uſing the glaſs air veſſel above mentioned; yet part may alſo be puſhed ſo low, as to eſcape through the hole, and diſcover itſelf by bubbles in the water on the outſide of the veſſel, which I ſeveral times obſerved before the water was driven entirely out of the glaſs.

Mr. Barthès likewiſe takes notice of air being thus carried down into the water by the drops, or introduced into the cavities which they form in falling. In order to prevent it, he recommends making a partition acroſs the tub, at the level of the ſtone, with only a hole at one ſide, and this in the part moſt remote from the pipe through which the water falls: the rebounding drops are received upon the board, and run off gently through the hole into the water underneath.

The inconvenience may be prevented alſo, as effectually, and with more advantage in other reſpects, by making the air veſſel of a very conſiderable depth below the ſurface of the ſtone: it may be ſunk ſeveral feet into the ground below the level of where the outward water runs off, ſo as to have always a column of water in the veſſel, of any height required, or of a height which ſhall ſecure againſt any air paſſing down to the bottom. This ſtructure would free the workman from any care about increaſing or diminiſhing the aperture, or regulating the height of the water. For if the deep veſſel has an aperture in its lower part, large enough to diſcharge all the water that can fall into it through the pipe in the top, or, for the greater ſecurity, a good deal larger, its magnitude being of no inconvenience; if this veſſel is ſunk in a pit of water up to the level of the ſtone, or to a certain height above it; and if the pit has a drain ſufficient to carry off what more water it may receive: we may be ſure that the water will be always high enough in the veſſel, becauſe the preſſure of the water on the outſide will keep it ſo; and that the preſſure of the air within the veſſel will always keep it below the ſurface of the ſtone.

The air extricated from the water is always moiſt: when let off at a little way above the ſtone, I have often obſerved it to leave drops like dew on any ſolid body oppoſed to it. A ſmall degree of moiſture may perhaps be of no diſadvantage; but ſuch a degree as this muſt doubtleſs be injurious, and render the air of leſs efficacy for animating the fire.

In the water machines of Dauphiny, inclined plates are ſaid to be placed at the entrance of the pipe which carries off the air, to keep back the watery drops. M. Barthès propoſes letting the air off into another veſſel, in which

which ſponges are to be hung for imbibing its moiſture, and in the bottom of which a cock is to be fixed for occaſionally letting off the water that drops from the ſponges. I apprehend the intention may be more effectually anſwered, by making the air veſſel of a conſiderable height above the ſurface of the water: for though the air at the bottom is neceſſarily loaded with moiſture, yet in riſing to the height of four or five feet, ſo much of the water ſeparates and falls down, as to leave the air ſeemingly of ſufficient dryneſs. The veſſel might be made as high as the pipe itſelf: nor would this large ſize be of any inconvenience in regard to the blaſt, for as ſoon as it is filled with air of a certain denſity, the blaſt will continue of the ſame force as from a ſmall veſſel. The joints ſhould be well ſecured to prevent the eſcape of any air through them: the ſtone for receiving the daſh of water, ſhould be placed near as much below the level of where the water runs off, as the gage is expected to riſe; and the pipe ſhould reach as low as within five or ſix inches of the ſtone. It would perhaps be of ſome advantage to have the ſurface of the ſtone a little concave, ſo as to occaſion the watery drops to be rather daſhed backwards towards the ſtream, than thrown upwards through the cavity of the veſſel.

III. *Experiments of air paſſing down through pipes with falling water.*

Water running through a crane.

In the running of water through a ſiphon or common crane, when the ſucking pipe on the long leg of the crane was ſtopt, the water, as it iſſued from the extremity, filled the bore: on opening the ſucking pipe, the column of water appeared leſs than the bore.

 Judging

Judging that the motion of the water muſt be retarded in this laſt circumſtance, I meaſured by a pendulum the times in which equal quantities of water run through the crane in both caſes; and found, in many trials, that the quantity which took the time of a hundred ſwings of the pendulum to run in when the ſucking pipe was open, run in ninety-three, and ſometimes ninety-two, when it was ſtopt.

As theſe differences ſeemed to proceed from air introduced into the water through the lateral pipe; I tried to make this air ſenſible, by raiſing the veſſel which received the water from the crane, and keeping the noſe of the crane immerſed in it. As often as the ſucking pipe was opened, air bubbles aroſe in the water of the receiver, and freſh bubbles ſucceeded while it continued open; but ſo long as it was kept ſtopt, no air bubbles were ſeen.

To collect the air, a caſk without a bottom was ſunk nine or ten inches in a tub of water, and the noſe of the crane inſerted into a hole made in the top of the caſk: into another hole in the top was fitted a ſmall pipe for giving vent to the air; and within the caſk was fixed an inverted mortar for the ſtream to fall on. So long as water was kept running though the crane with the ſucking pipe open, a ſenſible blaſt iſſued from the blowing pipe of the caſk, and a burning coal expoſed to it was excited in the ſame manner as by a common bellows: the ſucking pipe being ſtopt, no blaſt was perceived, nor was any motion produced in the flame of a candle applied to the orifice.

It appears therefore that water, running down through an upright pipe, and filling its bore, admits air to enter through a lateral pipe: that after this admiſſion, the width of the column of water contracts, the introduced

 air

air occupying part of the cavity of the pipe; and that this air paſſes down on the outſide of the water, or in a ſeparate column, not intermixed with it ſo as to render it frothy.

Water deſcending through an oblique pipe with lateral apertures.

I VARIED the foregoing experiment by taking, inſtead of the crane, a leaden pipe, about ten feet long and three quarters of an inch bore. Several holes were made, at intervals, in the length of the pipe, and ſmall tubes fixed into them like the ſucking pipe of the crane. The pipe being laid aſlope, its upper end was turned up perpendicularly, and a funnel fitted to it, which was ſupplied with water by a cock in the bottom of a reſervoir: the other end of the pipe, which the water iſſued from, was inſerted into the air veſſel uſed in the preceding experiment.

The lateral tubes being ſtopt, and the cock ſo turned as to let the water run faſt enough to keep the funnel always full, no air iſſued from the blowing pipe. On opening the tubes, a conſiderable blaſt was perceived; the water paſſed ſlower through the pipe, ſo that the ſame ſtream made the funnel run over; and on pulling out ſome of the tubes, and looking in through the holes, the column of water was very viſibly leſs than the bore of the pipe. The tubes being ſtopt again, the blaſt ceaſed, and the ſtream did no more than keep the funnel full.

A ſmall variation in the circumſtances of this experiment made a very material difference in the effect. The ſupply of water having been diminiſhed, ſo as to riſe only a little way above the throat of the funnel, a pretty ſtrong blaſt iſſued from the blowing pipe though all the lateral tubes were cloſely ſtopt; and when the tubes were open, inſtead of air paſſing in by them, a blaſt paſſed out

out from them, the air veſſel in this caſe yielding none; ſo that here the air muſt have been introduced at the top and paſſed down the funnel, and afterwards eſcaped where it firſt found a vent. To be further ſatisfied in this point, I repeated the experiment with a ſomewhat different apparatus, in the following manner.

Water falling through a funnel.

THE glaſs receiver of an air pump, about two feet high, open at both ends, had its lower end immerſed about ſeven inches in a veſſel of water, and ſupported at a proper diſtance above the bottom for the free paſſage of the water under the edges. A braſs plate being preſſed cloſe on the top, with leather between, a glaſs funnel, about twelve inches deep, and above half an inch diameter in the throat, was fixed into a hole in the plate; and into another hole was fitted a ſmall blowing pipe.

A ſtopper being introduced into the funnel, till the water it was filled with had become perfectly quiet, and then cautiouſly removed, the water run in a ſtream, which falling into that in the receiver, produced air bubbles: but no blaſt iſſued from the pipe; and when the pipe was ſtopt, the water in the receiver did not ſink lower than the level of that in the outer veſſel, whereas, if any air had entered with the water, and been compreſſed in the receiver, it muſt have forced a proportional quantity of the water out below.

The funnel was then ſupplied from a pipe, by which the water was made to daſh againſt one ſide of it. By this means the fluid received a ſpiral motion, and twirling round the funnel, left a large vacuity in the middle, reaching down ſometimes to the funnel's throat. The ſtream, as it run through, was alſo twiſted; a ſenſible blaſt

blaſt iſſued from the air pipe; when the pipe was ſtopt, the water in the receiver was forced lower and lower, and was ſoon driven entirely out, abundance of air bubbles following it into the water in the outer veſſel.

When the funnel was kept entirely full: though the ſtream was directed as before againſt its ſide, there were little marks of any air being carried down. And when the funnel was near empty, the effects were alſo inconſiderable; the vacuity in the middle of the ſpiral circumvolutions of the water ſeeming to reach to the bottom, ſo as to ſuffer the air to eſcape upwards through the hollow column of water.

Water falling from a conſiderable height into a funnel with a pipe.

A LEADEN pipe, ſix feet high and an inch and a half in diameter, was inſerted into an air veſſel, with the water gage already deſcribed. Into the top of the pipe was fixed a tin funnel, whoſe throat fitted cloſe to it; and into the funnel a ſtream of water was let fall, from a reſervoir five feet above, in quantity ſufficient to keep the funnel running over. This apparatus repreſents Mariotte's blowing machine deſcribed in the third article of the preceding ſection.

The water, divided by the fall, puſhed down abundance of air with it: a ſtrong blaſt iſſued from the blowing pipe, and the gage roſe high. On raiſing up the funnel a little, the ſtream that iſſued from it appeared all frothy: as often as the funnel was lifted up, the gage ſunk, the air, which had been driven in by the daſh of water, eſcaping between the funnel and pipe: on letting down the funnel cloſe, the gage immediately roſe again.

Inſtead

Inſtead of a fall of five feet, a ſtream was directed into the funnel from only about half that height. The gage ſtill roſe conſiderably, though not ſo high as before.

It is obſervable, that in the circumſtances of theſe experiments, a twirling motion communicated to the water in the funnel impeded the carrying down of air, the gage always ſinking on the water receiving ſuch a motion; whereas, in thoſe of the preceding article, it ſeemed to be by the twirling of the water that the air was puſhed down.

It appears therefore that there are two ways of making air paſs down with water through a funnel, one by directing the ſtream againſt the ſide of the funnel, the other by letting it fall from a great height: that in the one caſe the air enters between the ſpiral circumvolutions which the water forms in the funnel, and in the other between the drops into which a conſiderable part of it is reduced by the fall; that we cannot avail ourſelves of both ways at once, the one impeding the effect of the other; and that in either caſe the air holes under the throat, ſo neceſſary in other machines, can have no place, as they give a vent to the air brought down from above.

Water falling from a funnel through a pipe with air holes.

The ſix-foot pipe, uſed in the foregoing experiment, continuing fitted into the air veſſel, its upper orifice was widened, that the ſmall end of a funnel-ſhaped copper pipe, of the ſame bore with the preceding funnel, might hang freely in it, without touching the ſides. The funnel-pipe reached up to the reſervoir, and was kept always full, that the water might receive little or no air but at the vacuity between the noſe of the funnel and the leaden pipe.

In

In this ſituation, the quantity of air was much leſs than in the preceding : the water fell through the funnel in a ſtream not at all frothy, and the gage roſe but a little way. I widened the aperture of the leaden pipe, to let in more air, but ſtill the gage continued low.

Into the orifice of the funnel I inſerted a ſmaller pipe, whoſe diameter was one inch, and whoſe area was of conſequence leſs than half of that of the leaden pipe. The blaſt was now ſtrong, and the gage roſe higher than when the water fell from an equal height into the low funnel of the foregoing article. I tried funnels conſiderably ſmaller, and found the gage ſtill to riſe high : but at laſt, with one of a quarter of an inch diameter, it did not riſe at all, and no blaſt could be perceived.

One of the funnels which anſwered beſt being properly fixed, with two or three inches of its neck hanging free within the wider pipe, I made ſeveral variations in the manner of admitting the water and air, with a view to compare the effects of different ways of admiſſion. The funnel being full, and gently ſupplied ſo as to keep the water in it as ſteady as poſſible, the height of the gage was marked : on giving a circular motion to the water, or letting it fall from a height, the gage always ſunk, even a ſlight twirl or daſh ſenſibly affecting its height. The ſpace between the noſe of the funnel and the pipe was ſtopt, ſo that no air could enter but at the top : the funnel being now full, and the water quiet, the gage ſcarcely roſe at all ; on twirling the water, it roſe conſiderably, and when the water fell from a height, it roſe further, though not ſo high as the ſtandard mark.

It appears therefore that there are two general methods in which water may be made to carry down air, one in which it receives the air at the top, and the other through lateral apertures ; and that the circumſtances, which contribute to the effect in one cafe, impede it in the other: That water, being at reft in a funnel, and then fuffered to run through, carries little or no air with it; that when made to twirl round in the funnel, it carries a confiderable quantity; and that when it falls from a height, fo as to be in great part dafhed into drops, it pufhes down confiderably more: That running through a pipe with lateral apertures, perpendicularly or obliquely, it receives air through the apertures, even when its motion is flow; that when the pipe is of equal bore throughout, the quantity of air thus received is not great; but that, when the pipe is contracted to a certain degree in the part where the apertures are, the quantity of air is greater than that introduced through the funnel without air holes: That air brought down from the top of the pipe or funnel prevents the introduction of frefh air through the lateral holes, which in this cafe, inftead of receiving more air, difcharge that already received.

Finding that the two general methods, by which air is made to pafs down with a ftream of water, could not be united in one machine; and that the pipe and funnel, with apertures for the entrance of air about or under the throat of the funnel, have the greateft effect; I proceeded to examine the moft proper form and difpofition of thefe.

IV. *Experiments and obfervations for regulating the ftructure of the funnel and pipe.*

Experiments with funnels and pipes of different heights.

THE water, as already obferved, paffing through the narrow throat of the funnel, is afterwards enlarged into a jet which fills the bore of a wider pipe.

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The quantity of air introduced appears to depend upon the degree of this enlargement, and on the quantity of water that runs through in a given time.

The greater the height of water above the narrow throat, the greater velocity will the jet receive, and the more it will be diſpoſed to ſpread and be enlarged. The length of the pipe does not appear to be of ſo much importance: it ſhould ſeem ſufficient if the pipe is of ſuch length, that the preſſure of water in it may be able to reſiſt the compreſſed air in the air veſſel, and that after part of its power has been ſpent in overcoming that force, it may ſtill have velocity enough left to run down as faſt as it can be ſupplied from the funnel. In order to attain to ſome determinate proportions, the following trials were made.

A leaden pipe, ſeven feet high, and an inch and a half in diameter, being fitted into an air veſſel, as in the foregoing experiments, funnel-ſhaped pipes of different heights were ſupported over it, ſo as that the ſmall end of the funnel might hang freely in the orifice of the leaden pipe, and leave ſpace enough for the entrance of air all round. For the greater ſecurity of the throat being of the ſame area in all the funnels, one and the ſame copper pipe ſerved as a throat for them all: the funnels being formed by inſerting this pipe into larger tapering ones of different heights. The funnels were always kept full, and the water conveyed into them as gently as poſſible, ſo as to produce no daſhing or twirling motion.

A funnel of one foot high had very little effect: the riſing of the gage in the air veſſel was inconſiderable, and the ſtream of air from the blowing pipe was but juſt to be felt: on opening ſome holes made in the upright leaden pipe under the throat of the funnel, the jet of water appeared not ſpread, but rather contracted, and did not fill

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the bore. With funnels of two and three feet, the gage rofe more, and the jet fpread, though it did not appear to fill the pipe, till it had reached about half way down to the bottom. Funnels of five and fix feet produced a ftrong blaft, and kept the gage high, the jet filling the pipe before it had fallen a foot below the throat of the funnel.

On many repetitions and variations of thefe experiments, I have not obferved that the jet fpread fufficiently with lefs than a fall of five feet. With a fall of fixty-four inches, the gage rofe more than five times as much as with one of fixteen inches, though the quantity of water which run in the firft cafe was only double to that in the latter, viz. as the fquare roots of 64 and 16: from whence it is plain that the above differences do not depend entirely on the different quantities of water which run through funnels of different heights, but in great part on its different velocity. Some other experiments feemed to confirm this point: for having ufed fhort funnels fo much wider than the high ones, that the quantity of water difcharged by the former was equal to or greater than that by the latter, the fhort never produced fo ftrong a blaft, or raifed the gage fo far, as the others.

Being fatisfied of the advantage of having the funnel of very confiderable height, I in like manner varied the length of the pipe. Having made a mark at the part where the gage rofe to when the funnel was five feet, and the pipe feven, I added to the pipe about a foot more: the gage fcarcely rofe any further. A foot being cut off from it, the gage fell a little: two feet being cut off, it fell confiderably; and the retrenchment of another foot made the machine of little effect, the gage finking almoft to the bottom, and the blowing pipe yielding but a weak current of air. The pipe, thus reduced to four feet, was tried with a funnel of near eight feet: in this cafe there was no blaft

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at all. But with funnels lefs than its own height, as of two and three feet, it ftill raifed the gage confiderably.

It appears from thefe experiments, that in moft of the machines defcribed in the preceding fection, the lengths of the funnels and pipes are greatly difproportioned to one another, and confequently the water applied to difadvantage. Thofe of Dauphiny in France are particularly faulty in this refpect, the funnel being fcarcely three feet high, and the pipe twenty-five or twenty-fix: with fo fmall a height of water above the choak, I have never been able to make the jet fpread near to fuch a degree as it is faid to do in the machines of Dauphiny, without particular contrivances for that purpofe, which will be mentioned in the fequel of this paper. The Foix machine agrees the beft with my experiments: but as the funnels of the others are undoubtedly much too low, that of this feems to be rather too high. The effect appears to be the greateft, when the funnel is about two thirds of the length of the pipe.

Experiments of the difpofition of the air holes.

In the foregoing experiments, the fimpleft and moft obvious way of admitting air was chofen, by leaving a fpace between the funnel and the pipe. The air pipes of the machines of Foix and Languedoc anfwer the fame end, carrying in the air above the furface of the jet of water. As the other machines have the air holes under the jet, I tried what variations would refult from this circumftance, and from making the apertures at different depths under the throat of the funnel.

Into a pipe of fix feet was fitted a funnel of four feet; and fix inches below the orifice of the funnel, four holes were bored round the pipe, floping down from without inwards: eight inches lower down, I made another row of holes; and

and at like diſtances under theſe, a third and a fourth. To each hole was fitted a ſtopper which exactly cloſed it.

All the holes being ſtopt, the funnel was firſt hung free in the pipe, as in the former trials, and the height to which the water roſe in the gage was marked. The funnel being then let down into the pipe, ſo as exactly to cloſe it, the upper air holes were opened: the gage did not now riſe ſo high as before. The upper air holes being ſtopt, and the ſecond row opened, the gage continued at its laſt height. With the third row open, it roſe rather higher than the firſt mark; and with the fourth it fell the loweſt of all.

The ſeveral entrances for the air were then opened by two and two. With the ſpace between the funnel and pipe, and the upper air holes, open, the gage did not riſe ſo high as with the ſpace only; and with the upper and ſecond row of holes it continued at the ſame height. With the ſecond and third, it roſe conſiderably further, though not up to the firſt mark; and with the third and fourth, it fell a little below the preceding height. In all theſe caſes, where two rows of holes were open, the water manifeſtly did not fill the bore of the pipe at the upper holes; but ſpread ſo as to completely fill it by the time it had reached the lower ones, at which laſt, part of the water ſpirted out and carried ſome of the air with it.

In another pipe of the ſame ſize I made two ſets of air holes, three inches apart, and the uppermoſt of them twelve inches from the orifice of the funnel. With the upper row open, and with both rows open, the gage roſe almoſt equally, being only a little lower in the latter circumſtance than in the former; but with only the lower row open, it ſunk about one half. Theſe being all ſtopt, and another ſet bored oppoſite to the orifice of the funnel, the gage roſe as high as in the firſt caſe.

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Thefe experiments, and feveral others I have made on the fame fubject, are not fo conclufive as could be wifhed. They feem to fhew that it is more eligible, to have the entrances for the air in one horizontal plain, than in two plains above one another ; and either above, or at fome diftance below the jet, than immediately under it : That they ought to be of greater magnitude than in fome of the machines defcribed in the firft fection, particularly in that of Lead-hills, whofe air-holes, taken all together, are not of half the area of the fpace in the pipe which the air has to fill. They ought at leaft to be of an equal, or rather of a double extent, that the air may enter the more freely.

Experiments of the proportional bores of the funnel and pipe.

We have already feen, that unlefs the throat of the funnel is lefs than the pipe, the quantity of air carried down will be inconfiderable; and that by leffening it further than to a certain point, the effect is alfo diminifhed or deftroyed. To hit this precife point is not perhaps poffible ; and the point which is the moft perfect proportion for one height of water, cannot be fo for any other, an increafe of the preffure difpofing the jet to fpread more and fill a larger bore.

It appears from fome experiments already mentioned, that when the whole height of the fall of water is fifteen feet, the height of the pipe ought to be nine feet, and that of the funnel fix. This being as low a fall as thefe kinds of machines have been generally erected for, and as high a one as is generally to be expected in this country, I made feveral trials for adjufting the proportions to thofe heights ; ufing for the funnel a tapering copper pipe, into the lower end of which were occafionally inferted fmaller pipes of different bores.

By trying ſeveral of theſe funnels, we came to certain ſizes, which could not be much increaſed or diminiſhed, without diminiſhing the effect of the machine; but if there is, in this reſpect, any exact ſtandard, our experiments did not diſcover it. There are ſo many circumſtances, as we have already ſeen, which influence the effect, that it is very difficult to judge, when the differences are ſmall, how far they depend on any particular one. When the area of the orifice of the pipe was from four to five times greater than that of the funnel, the differences in the height of the gage were not very conſiderable: the due proportions ſeem to lie within theſe bounds, and perhaps nearer to the latter than to the former; for when the funnel was only about a ſixth part of the area of the pipe, the gage ſtood rather higher than when it was a third part, from whence the proportions ſhould be as one to ſomewhat more than four and a half.

Experiments of dividing the ſtream ſo as to increaſe its effect, and render leſs water ſufficient.

As the effect of theſe kinds of machines depends on the water being ſpread and divided, and the air, which comes in to fill the interſtices between the little ſtreams or drops which compoſe the jet, being puſhed down with velocity by the ſucceeding water; I have endeavoured to divide the ſtream, more effectually than is done in the common machines, and with little or no diminution of its velocity, by varying the form of the aperture of the funnel.

On the orifice of the funnel I fitted a perforated tin plate, like the noſe of a watering pot, but with the holes larger, and of a triangular figure; this figure was choſen on account of its great ſurface, water, paſſing through a triangular aperture, having about a third part more ſurface than

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through a circular one of equal area: ſome more holes were made round the ſides, in ſuch poſitions, that the ſtreams iſſuing from the higher holes, might no where fall upon or coincide with thoſe from the lower ones, but that the water might be uniformly diſperſed through the whole cavity of the pipe. By this diviſion of the water it was made to fill a much larger bore than otherwiſe, and to produce as great an effect as the full quantity of water which the ſame pipe would otherwiſe have required; inſomuch that quantities of water which had little effect in the common way of application, were by this contrivance made to yield a ſtrong blaſt.

This method is accompanied with an inconvenience, which often ſhewed itſelf in the courſe of the experiments, and which muſt be more conſiderable in the continued working of the machine. After it had acted vigorouſly for ſome time, its action frequently abated of a ſudden: the blaſt from the blowing pipe grew weak, and the gage ſunk: ſometimes its force increaſed again in a little while, but for the moſt part it continued to diminiſh more and more. The cauſe was diſcovered to be bits of leaves and other like matters which the water had carried into the funnel, and which had in part ſtopt up the ſmall apertures. The remedy was obvious, letting the water paſs from the reſervoir through a wire ſieve whoſe holes were much finer than thoſe in the noſe of the funnel; and doubtleſs an expedient of the ſame kind would prove effectual for the largeſt machines. It is in all caſes adviſeable to have the water paſs through a grating before it enters the funnel; even the common large apertures being ſometimes choaked up by matters which the ſtream brings along with it. Where ſcantineſs of water, or want of ſo high a fall as is commonly required, perſuade to this contrivance for procuring a more effectual diviſion of it, and for augmenting its power with its ſurface, two or three gratings, or perforated plates, with apertures of different ſizes, will be neceſſary : one with very fine holes, much ſmaller than thoſe of the cullender, that nothing may paſs through the former which can be in danger of ſticking in the latter: another with larger apertures, for detaining weeds, and ſuch other matters as would ſoon obſtruct the finer ſtrainer.

I have tried other methods of procuring this diſperſion of the water, by making the throat of the funnel of different figures; but with little ſucceſs. Whether the throat was made converging or diverging, in greater or leſs degrees, there did not appear to be any material difference in the effect of the machine. I introduced into the funnel a cylindrical core, which was fixed in the middle, by means of pins projecting from it, ſo as to leave a circular aperture all round it; and this core was ſometimes ſolid, and ſometimes a pipe which reached above the funnel and carried down air into the middle of the jet below: but no other difference was obſerved in either caſe than what aroſe from the neceſſary diminution of the quantity of water. It is probable indeed, that by duly proportioning the core to the funnel, and the width of the pipe to the ſheet of water falling round the core, the effect, by this diviſion of the ſtream, would be made greater than an equal quantity of water would produce when falling in one column; though the increaſe, obtainable by this method, did not promiſe to be conſiderable enough to deſerve the troubleſome inveſtigation of the proportions. One trial however, depending partly on this principle, appeared of ſome importance to be made.

As the water machine of St. Pierre is ſaid to have two apertures in the bottom of the funnel, whoſe ſtreams, as they iſſue out, croſs one another and are daſhed into drops, I tried

I tried to anſwer this intention, by uſing for the funnel a wooden trunk, with two of its ſides ſloping downwards ſo as to leave a long narrow aperture between them: in the middle of this aperture, and parallel to the inclined ſides, was placed a wedge of the ſame ſlope with the ſides of the funnel, that the water might paſs out in two ſheets directed towards one another.

The funnel was at top about eight inches ſquare: its width at bottom ſeven inches and eight tenths by one inch and nine tenths. The wedge, dropt into it, entirely ſtopt the lower aperture, and had its thin edge hanging down conſiderably below: ſlips of wood of different thickneſſes faſtened on the wedge occaſionally, two on each ſide, prevented its falling down ſo far, and procured ſpaces of different widths between it and the ſides of the funnel; ſo that the water could be reduced at pleaſure into two ſheets, ſeven inches and eight tenths wide, and from leſs than a quarter of an inch to three quarters of an inch thick; the partition in the middle reaching in all caſes lower down than that which confined them on the ſides, that they might not unite into one upon their diſcharge from the throat. Along the ſloping ſides of the funnel were two air pipes, of the ſame breadth with them, and about an inch and a half wide; ſo that at the bottom there were three oblong rectangular apertures, the middle one, with a wedge in it, for the water, and the two lateral ones for air: the outſides were continued about ſeven inches and a half below theſe apertures, ſo as to form a large cavity for the water to ſpread in.

The funnel, above the throat, was ſomewhat more than three feet high: on the top was fitted a wooden pipe, nearly of the ſame width with it, and four feet eight inches high. The top of this pipe paſſed up through a rectangular ciſtern, nearly 168 inches in length and 96 in width, and

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which confequently contained about fifty feven gallons on every inch in depth. For admitting the water, two holes were made in two oppofite fides of the pipe, about ten inches high, with two fliders fitted to them, for occafionally varying their height and confequently the quantity of water received. On the outfide of each hole was fixed an iron plate, perforated with numerous fmall holes, to keep back fuch matters as might choak up the throat: that the holes might be fufficient to allow water enough to pafs in, the ftrainer was made wider than the aperture in the pipe, and bent to a femi-cylindrical form.

To the bottom of the funnel, enlarged as above mentioned, was fitted a pipe fix feet high, and in width four inches by feven and a half. The lower end of this pipe was inferted into the head of a large cafk without a bottom, which was fet in a tub above three feet deep, with three fupports under the lower edge of the cafk to procure a fpace between it and the bottom of the tub for the water to pafs freely off. About eight inches under the orifice of the pipe, a round board, for the water to fall on, was hung by three cords, which paffed up through the head of the cafk and were fecured by pegs. At one fide, a tin veffel full of water was fupported in the fame manner; and through a faucet, over the middle of this veffel, was inferted a glafs tube thirty four inches long. At the other fide was the blaft pipe, about three quarters of an inch in diameter,

The machine being thus prepared, we proceeded to the trial of it, expecting that the two ftreams, from their floping direction towards one another, would crofs and be dafhed into drops, and carry down abundance of air. But in the effect we were greatly difappointed: the blaft was weak, and the gage rofe to no confiderable height, whether the wedge was dropt down or drawn up, fo as to fuffer the water to pafs in lefs or greater quantity, in thin

thin or in thick ſheets: in continued trials and va-triaions of the apertures for three or four days, the gage was not once obſerved to riſe ſo high as ten inches. A good deal of air indeed eſcaped through the junctures of the pipe and of the air veſſel, but not near enough to make up the expected quantity.

The wedge anſwering ſo ill, it was laid aſide; and in its place was introduced a leaden veſſel, of the ſame ſhape with the funnel's throat, and of ſuch a ſize, as to reſt againſt the ſides of the aperture by its upper edge, and hang ſix or ſeven inches down in the wider part of the pipe: in the ſides and bottom of this veſſel were made ſeveral holes, about two tenths of an inch in diameter. With this alteration I had the pleaſure to find, that though air ruſhed out from the joints even more plentifully than before, yet the blaſt from the blowing pipe was ſtrong, and the water in the gage pipe roſe to the top and run over.

I tried to meaſure the quantity of water neceſſary for producing this effect for a certain time. The reſervoir being filled to the depth of fourteen inches, the gage roſe as before, and continued high for four minutes; after which it begun to ſink faſt, the water in the reſervoir having then become too low to keep the pipe full, though it continued to run for a conſiderable time longer. From the dimenſions of the reſervoir already mentioned it will appear, that if all the water had run out in the four minutes it would have amounted to near two hundred gallons in one minute; but at leaſt a fourth of it remained after that period, ſo that the expence could not exceed a hundred and fifty gallons in a minute. We could not expect any great accuracy in this determination, becauſe as the height of the water continually decreaſed in the reſervoir, its velocity likewiſe decreaſed, ſo that if a due

quantity

quantity run in the laſt minute, a ſuperfluous quantity muſt have run in the firſt.

The leaden cullender being taken out, and the whole throat left vacant for the ſtream, the gage ſtill roſe to the top; but the expence of water was now more than double to what it was before.

Theſe trials, though not carried to ſuch a length as I could have wiſhed, ſatisfied me, and thoſe who aſſiſted at them, that much more air is to be obtained, by dividing the ſtream by means of a cullender, than by any other methods that have been tried; and that with ſuch a machine as is above deſcribed, a ſtream of a hundred and fifty gallons at moſt in a minute is ſufficient to produce a continued blaſt, from a pipe of three quarters of an inch bore, of ſuch ſtrength as to ſupport a column of water of three feet or more.

To afford as much aſſiſtance as poſſible to thoſe who may be deſirous of erecting machines of this kind, I ſhall here collect into one view the moſt material particulars which my experiments have diſcovered with regard to the perfection of their ſtructure, and form from them a deſcription of ſuch a machine as promiſes to be the moſt effectual.

The bottom of the reſervoir of the water ſhould be about fourteen feet above the level of the ground: we need not be very ſolicitous about procuring a greater height, for though a greater would be of ſome advantage, yet this advantage appears to be much leſs conſiderable than has been commonly imagined. In the channel by which the water is conveyed, are to be placed gratings of different ſizes, as already mentioned, and before the aperture a finer grating, which may be either a perforated iron plate or a wire ſieve, to ſerve as ſtrainers for keeping back ſuch matters as would obſtruct the apertures which

which the water is afterwards to paſs through. The ſtream ſhould enter at one ſide, or be ſo managed, that the water in the reſervoir or funnel may not be agitated by it, or put into a ſpiral motion, which our experiments have ſhewn to be very injurious.

In the bottom of the reſervoir is to be made a round hole, for admitting the upper end of what we have hitherto called the funnel, but which may here be more conveniently a cylindrical pipe, of copper or of caſt iron, five or ſix inches in the bore, and ſeven feet long. To the end of this pipe is to be fitted a cullender, about a foot long; with the holes triangular, of half an inch each ſide; and ſix or ſeven ſtrips from top to bottom, at equal diſtances, preſerved without holes, for admitting air to paſs down to the lower ſtreams. All the holes ſhould be directed downwards, that the ſtreams may not be forcibly projected againſt the ſides of the pipe which is to receive them, ſo as to have their velocity too much diminiſhed.

If there are ſix of the perforated ſpaces in the cullender, the number of holes in each may be twenty, ſo that the whole number will be one hundred and twenty. The ſide of each of the triangular holes being half an inch, the area of each will be the eighth part of a ſquare inch, and the ſum of their areas will be fifteen ſquare inches. The quantity of water running through one aperture of ſuch an area, at the depth of ſeven feet and a half under the ſurface, comes out on calculation about ſix hundred and twenty-two gallons in a minute; but the real quantity will doubtleſs be much leſs than this, on account of the great friction of the water in paſſing through a number of ſmall holes, and of the reſiſtance of the air, which increaſes in a very high ratio according to the increaſe of the velocity and enlargement of the ſurface: it is in part to make up for theſe retardations,

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that the pipe is directed to be made ſo high. The ſurface of the water is here above thirteen times greater than if it paſſed all through one circular aperture.

Both the pipe and the cullender ſhould have a flanch or rim round their orifices, and be ſecured to one another by ſcrews paſſing through the rims of both, with a plate of lead between them to make the juncture tight, as commonly practiſed in joining iron pipes for water works. This way of joining them admits the cullender to be taken off and cleaned, when a diminution of the effect of the machine ſhews the holes to be choaked up, which however, it is apprehended, will ſeldom, if ever, happen.

As the holes will permit more water to run through, than may at all times be wanted, it is proper to have ſome contrivance for occaſionally cloſing a part of them. This may be effected by means of a thin copper pipe, open at both ends, as high as the cullender, and of ſuch width as juſt to drop into it. It will be eaſily conceived, that when this regiſter is let entirely down, the lateral holes will be covered, and the water admitted only to thoſe in the bottom; and that by raiſing it further and further, more and more of the lateral holes will be uncovered. The regiſter is to be hung by a wire to a croſs bar over the reſervoir, by which it may be raiſed or lowered; and a ſcale or divided board may be adjuſted againſt the upper part of the wire, for ſhewing the height of the regiſter, or the number of holes cloſed by it.

The moſt commodious and effectual way of admitting air to the water appears to be that of our firſt experiments, viz. hanging the throat of the funnel, in this caſe the cullender, within the wider receiving pipe, for by this means the air is admitted freely and uniformly all round. This laſt pipe ſhould likewiſe be of iron or copper, twelve inches

inches in diameter, and ſpread out at top to the width of ſixteen or eighteen inches, that a large ſpace may be left round the cullender: this ſpace ſhould reach three or four inches above the uppermoſt perforations of the cullender, to prevent any of the water from being daſhed over the top.

A pit is to be ſunk in the ground, not leſs than ſix feet deep. In this is to be placed an air veſſel, made of wood lined with lead, without a bottom, three or four feet in width, and ten or eleven high. The veſſel ſhould be ſupported on feet, of a proper ſtrength, with ſufficient ſpaces between them for the water to paſs freely out: this way is preferable to the common one of placing the lower edge of the veſſel on the bottom of the pit, and cutting an aperture in the ſide, becauſe the height of the aperture is ſo much taken off from that of the veſſel. The reſervoir being fourteen feet above the ground, and the upper pipe and cullender reaching down eight feet, only ſix feet remain below the cullender; ſo that the air veſſel, having ſix feet ſunk in the ground, will reach nearly up to the cullender, and almoſt the whole height of the undermoſt pipe will be included within the veſſel. This pipe may be above nine feet long, three feet or more of it going down into the pit; which three feet are here an entire gain in the height of the fall, for the pipe in the other machines comes at moſt no lower than the level of the ground where the water runs off on the outſide. This height is gained, in virtue of the compreſſed air in the veſſel puſhing down the water below, as already ſhewn in the ſecond article of this ſection: it may be always as great as the height to which the water is intended to riſe in the gage. At the diſtance of five or ſix inches under the orifice of the pipe is to be placed the concave iron plate or ſtone for the water to fall on. In the top of the air veſſel is to be fixed the gage and the blowing pipe.

Such is the general conſtruction of the blowing machine, which promiſes to be particularly uſeful in caſes where water is ſcarce, or where the want of a natural fall renders it neceſſary to raiſe, by very expenſive means, the great quantities requiſite for working the common bellows. It is preſumed, that one of theſe machines will be ſufficient for the iron forge, and for ſundry other purpoſes where the quantity of air is not required to be very great; that it will be leſs expenſive, on account of the durability of its materials, and the ſimplicity of its ſtructure, than any kind of bellows now in uſe; and what is of principal importance, that much leſs water will ſerve for working it. In caſes where one of the machines cannot ſupply air enough, as for the large iron ſmelting furnace, two pipes may be uſed, both fed by one reſervoir, and entering into one air veſſel, as practiſed in ſome of the inſtruments deſcribed in the firſt ſection. The uſing of two pipes appears more eligible than enlarging the bore of one; for air cannot be ſo freely introduced into a large body of water, though divided into ſtreams by the cullender, as into two ſmaller ones of equal quantity.

It may be obſerved, that the blaſt will be ſtronger in a denſe ſtate of the atmoſphere, than when it is more rare or expanded, a greater quantity of air being then introduced nnder an equal volume. If therefore the quantity of water has been adjuſted ſo as to raiſe the gage to a proper height when the air was light, it will frequently happen that the ſame quantity of water ſhall raiſe it higher, and conſequently, if no greater height is required, that a part of the water may be ſaved. As the gage of our machine diſcovers by inſpection theſe variations in its effect, the regiſter affords convenient means of regulating its power, and increaſing or diminiſhing the quantity of water.

VI.

VI. History of Colours.

PART I.

Of Black.

BLACK, a colour in many cafes the moft important, and in its ufe the moft extenfive, of all thofe which art is concerned in preparing or applying, is chofen as the firft article of an experimental hiftory of colours; which will be occafionally continued in the profecution of this undertaking.

The practices of the workmen in one branch of colouring are generally little known to thofe who are employed in another; the feveral methods of applying even one colour, on different kinds of bodies, being the objects of fo many diftinct arts, each of which has its own rules of working, peculiar to itfelf, and eftablifhed by long cuftom.

Of the arts of communicating a black colour to different fubjects, there are fome which have made great advances towards perfection, whilft others remain far more imperfect, in regard not only to the difpatch and facility of the execution, but likewife to the beauty and duration of the colour. Thus woollen and filk are both dyed of a permanent deep black, but with this difference, that what the woollen dyer effects by three or four dippings of the cloth in his dying liquor, the filk dyer fcarcely obtains from twenty or thirty dips; whereas, on the contrary, the dyer of linen and cotton thread, however he prolongs the operation, or repeats the dippings, is unable to communicate to the thread a blacknefs that fhall endure wearing. Thus alfo the printer fixes upon paper an ink which con-

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tinues unaltered for ages, and which is not perhaps capable of being changed by any natural agent that the paper itſelf can reſiſt; while the common writing inks ſoon loſe of their colour both on paper and on parchment, inſomuch that records, of no very long ſtanding, have become almoſt entirely obliterated.

In the preſent hiſtory, I ſhall endeavour to trace, as far as my opportunities of information will enable me, the preparation, production, and communication of black colours, through all the profeſſions in which they are concerned; that the artiſt, confined by his employment to particular views, may be made acquainted with the methods, by which ſimilar effects to thoſe which he produces, or wants to produce, are obtained in other arts, or in arts which in other reſpects differ from his own. Experiments, while they ſerve as a ſure teſt for aſcertaining the reſpective facts, will often contribute at the ſame time to enlarge and render them more extenſive; and likewiſe afford means of diſtinguiſhing, in ſome complex operations, the circumſtances or materials eſſential to ſucceſs, from the ſuperfluous or injurious ones, which ignorance or chance perhaps at firſt introduced, and which prejudice or cuſtom have continued.

By thus examining and comparing the different methods, by which a ſimilar colour is obtained or produced, and by which the ſeveral tinging materials are applied on different ſubjects, I flatter myſelf that many of theſe arts, however disjoined among different ſets of workmen, will be found to have natural and ſtrong connections, ſo that an effective and uſeful commerce may be eſtabliſhed among them; that they will not only tend to illuſtrate, but mutually to improve one another; and that in many caſes the practice of one art may be abridged or facilitated, its imperfections remedied, and its deficiences ſupplied, by

means,

means, which could ſcarcely ever be thought of by a perſon converſant in that art ſingly, but which a general knowledge of the others may be expected to ſuggeſt.

SECT. I.

General obſervations on black colours.

OF black, as of other colours, there are many ſhades or varieties; different bodies, truly and ſimply black, or which have no ſenſible admixture of any of the reſt of the colours, as black velvet, fine black cloth, the feathers of the raven, &c. appearing, when placed together, of teints very ſenſibly different.

2. One and the ſame body alſo aſſumes different degrees of blackneſs, according to the diſpoſition of the ſenſible parts of its ſurface; and in this reſpect, there is not, perhaps, any other colour, which is ſo much affected by an apparent mechaniſm. Thus black velvet, when the pile is raiſed, appears intenſely black, much more ſo than the ſilk it was made from; but on preſſing the pile ſmooth, it looks pale, and, in certain poſitions, ſhews ſomewhat even of a whitiſh caſt.

3. This obſervation is agreeable to the phyſical theory, which aſcribes the blackneſs of bodies to the luminous rays, that fall upon them, being in great part abſorbed, or ſtifled in their pores. When the ſurface is compoſed of a multitude of looſe filaments, or ſmall points, with the extremities turned towards the eye, much of the light is ſtifled in the interſtices between them, and the body appears dark: when the filaments are preſſed cloſe, or the ſurface ſmoothed and poliſhed, more of the light is reflected from it, and the intenſity of the blackneſs is diminiſhed; though the beauty may be improved by the gloſſineſs which reſults from the ſmoothing.

4. There is one cafe however, in which a high polifh may, on the fame principle, produce blacknefs, in bodies otherwife even white. We find that fpecula of white metal or of quickfilvered glafs, which reflect the rays of light to one point or in one direction, look always dark, unlefs when the eye is directly oppofed to the reflected rays.

5. As the abforption of the luminous rays, except in the cafe juft mentioned, makes the phyfical caufe of blacknefs; it is concluded that black bodies receive heat more freely than others. Black marble or tiles, expofed to the fun, become fenfibly hotter than white ones. Black paper is kindled by a burning-glafs much fooner than white, and the difference is ftrongly marked: a burning-glafs, too weak to have any vifible effect at all upon white paper, fhall readily kindle the fame paper rubbed over with ink. Hence black clothes, when wetted, are faid to dry fafter; black habits, and rooms hung with black, to be warmer; black mould to be a hotter foil for vegetables; and garden walls, painted black, to anfwer better for the ripening of wall fruit; than thofe of lighter colours.

6. It is not however to be affirmed that the like differences obtain in the impreffions made by common fire. Black paper, held to the fire, does not feem to be affected fooner, or in a greater degree, than fuch as is white. It may be proper to obferve alfo, that the combuftibility of the paper may be increafed, by impregnating it with fubftances of themfelves not combuftible, and which give no colour to it. This is the foundation of one of the fympathetic inks, as they are called, made of a ftrong folution of fal ammoniac in water, which, though colourlefs when written with on paper, becomes very legible on expofing the paper to the fire; that is, it occafions the parts moiftened with it to fcorch or burn, before the reft of the paper is hurt, to a brown or black. All the falts I have tried

produced

produced this effect in a greater or lefs degree; nitre, alum, tartar, very weakly; fea falt more ftrongly; fixed alcaline falts ftill more fo; fal ammoniac the moft ftrongly of all. Metallic folutions, made in acids, and diluted fo as not to corrode the paper, acted in the fame manner.

7. Befides the fimple blacks, there are a multitude of compound ones, inclining more or lefs to other colours. Thus the painters have blue-blacks, brown-blacks, &c. which may be made by mixing pigments of the refpective colours with fimple black ones, in greater or lefs quantity, according to the fhade required. The dyers alfo have different blacks, and often darken other colours by flightly paffing them through the black dying liquor; but the term brown-black is in this bufinefs unknown, brown and black being here looked upon as oppofite to one another. In effect, the colour called brown-black is no other than that which ill dyed black clothes change to in wearing: no wonder then that it is excluded from the catalogue of the dyers colours.

8. The true or fimple blacks, mixed with white, form different fhades of grey, lighter or darker according as the white or black ingredient prevails in the mixt. The black pigments, fpread thin upon a white ground, have a like effect.

9. Hence the painter, with one true black pigment, can produce on white paper, or on other white bodies, all the fhades of grey and black, from the flighteft difcoloration of the paper, up to a full black: and the dyer produces the fame effect on white wool, filk, or cloth, by continuing the fubjects for a fhorter or longer time in the black bath, or making the bath itfelf weaker or ftronger.

10. Hence alfo the dilution of black pigments with white, or the fpreading of them thin upon a white ground, affords a ready method of judging of the quality or fpecies

of

of the colour; which, if it be a true black, will in this diluted ſtate look of a pure or ſimple grey, but if it has a tendency to any other colour, that colour will now betray itſelf.

11. All the colours, in a very deep or concentrated ſtate, approach to blackneſs. Thus the red liquor prepared by boiling or infuſing madder root in water, and the yellow decoction or infuſion of liquorice root, evaporated in a gentle heat till they become thick, look of a dark black colour, or of a colour approaching to blackneſs; and theſe thick maſſes, drawn out into ſlender ſtrings, or diluted with water, or rubbed on paper, exhibit again the red and yellow colours, which the liquors had at firſt. Nature affords many black objects, whoſe blackneſs depends upon the ſame principle, being truly a concentration of ſome of the other colours. Thus in black cherries, currants, elderberries, &c. what ſeems to be black is no other than an opake deep red: their juce appears black when its ſurface is looked down upon in an opake veſſel, but red when diluted or ſpread thin. The black flint, as it is called, of the iſland of Aſcenſion, held in thin pieces between the eye and the light, appears greeniſh; and one of the deep black ſtones called black agate, viewed in the ſame manner, diſcovers its true colour to be a deep red.

SECT. II.

Native black colours.

THE mineral kingdom affords abundance of bodies uniformly tinctured or variegated with black, or with a deep colour approaching to blackneſs: Such are, the black ſlates, which make an ornamental covering for houſes: the black touchſtone, on which pieces of metals being rubbed leave a mark of their own colour; which ſhews the colour

colour the more perfectly by virtue of its blacknefs, and which thus enables us to judge and compare the colour and finenefs of metallic compofitions, with much more certainty than could be done by viewing them in the mafs: the black flint fo called, which performs the fame office with the touchftone, and being harder than the common touchftones, anfwers better for the hard metals: the common black marbles, ufed for many kinds of ornamental works: the more rare black marble, called *lapis obfidianus* or *opfianus*, which, in virtue of the very high polifh it receives, was made into mirrours by the Greeks and Romans: the black gallinazo ftone, defcribed by D'Ulloa, which anfwered the fame purpofes among the Indians of Peru before the conqueft of that kingdom by the Spaniards: the black jet, and other fubftances of the fame clafs, which are formed into many elegant toys: the plain and variegated black agates, pebbles, cryftals, &c. which are cut by the jeweller. The ftone called tourmalin, remarkable for the fingular phenomena it exhibits in fome electrical experiments, is in its rough ftate of a full black colour, though when polifhed it looks rather of a brown black: I have been informed by a fkilful jeweller that he had feen a black diamond, cut and fet in a ring; though perhaps the examination made of it was not fo rigorous as could be wifhed for determining its being truly of the diamond kind. However this may be, a black tinge in bodies of this clafs is looked upon as an imperfection or foulnefs, although, when the diamond is cut, a black foil placed under it improves its beauty: for the rofe diamonds, the collet, or focket in which the ftone is fet, is fpecked with ivory black in little dots; and for brilliants it is all over blacked.

Among vegetables and animals, blacknefs, though frequent, is lefs diffufed, or of more limited extent. The black colour of the ftalks and feeds of certain plants, that

of

of ſhells, feathers, and hair, and that of the ſkin of the human ſpecies in certain climates, is only a ſuperficial teint. The blackneſs of fruits, as already obſerved, is generally rather a concentration of ſome other colour than a true black. Some woods, particularly the ebony, are tinged throughout with a true blackneſs, on which great part of their value depends, and which art very happily imitates on more common woods. The bony matter which lines the mouth of certain whales has likewiſe frequently a pretty deep black tincture, joined to another quality, elaſticity, on many occaſions more important than its colour.

Among the various ſubſtances which nature has impregnated with a deep and permanent black colour, there are few of which art can avail itſelf for communicating this colour to other bodies. There is not perhaps any inſtance of a black colour being, as the reſt of the colours frequently are, extracted from one body by means of diſſolvents, and thence introduced into another. Nor can the generality of natural blacks be applied in their whole ſubſtance; ſome of theſe bodies being of ſuch a texture, as does not admit of their being reduced into ſufficiently fine powder, for being mixed with a proper cementitious matter, ſo as to be ſpread ſmooth; and others having their colour deſtroyed by the pulverization. Of theſe laſt we ſee an inſtance in the common black ſlates, which may be ſcraped into a white duſt, in which the ſlighteſt ſcratches look white, and which, when drawn along any other black body, as hard as themſelves and not poliſhed, leave a white mark; a property which, while it renders them utterly unfit for any purpoſes in painting or ſtaining, is that on which their uſe depends for occaſional writing, or for making pencils for writing on other ſtones. It is obvious, that for this intention, black ſtones are better adapted than

thoſe

thoſe of any other colour; and that the ſtone ſhould be ſomewhat harder than the pencil, that the marks may proceed chiefly from the pencil, without ſcratching the ſubſtance of the ſtone.

The only native blacks I know of, that have been employed as colouring materials, are the following.

I. *Black chalk.*

THE black chalk or black marking-ſtone of the ſhops, ſo called from its uſe in drawing black lines on paper, is a light earthy ſubſtance, of a pretty deep black colour, moderately firm, in texture ſomewhat flaky like ſlate, not of a rough harſh ſurface like common chalk, but rather ſoft and ſmooth to the touch. It ſtains very freely, and, in virtue of its ſmoothneſs, makes very neat marks. It is eaſily reduced into an impalpable ſoft powder, without any apparent diminution of its blackneſs. In this ſtate, it mixes eaſily with oil into a ſmooth paſte; and being diffuſed through water, it ſlowly ſettles, in a black ſlimy or muddy form; properties which make its uſe very convenient to the painter both in oil and water colours. Entire maſſes of it, laid in water, are alſo by degrees penetrated and diſunited, though much more difficultly than thoſe of white chalk.

It appears, in effect, to be an earth of a quite different nature from common chalk, and ſeems to be rather of the ſlaty bituminous kind. In the fire it becomes white with a reddiſh caſt, and very friable; retaining its flaky ſtructure, and looking much like the white flaky maſſes which ſome ſorts of pitcoal leave in burning. Acid liquors neither diſſolve, nor alter the colour of the black chalk itſelf; nor have they, ſo far as I could obſerve, any ſenſible action upon the white aſhes.

Our colour ſhops are ſaid to be ſupplied with this uſeful earth from Italy and Germany; though ſome parts of England afford ſubſtances, nearly, if not entirely, of the ſame quality, and which are found to be equally ſerviceable, both for marking and as black paints. Such particularly is the black earthy ſubſtance called Killow; ſaid by Dr. Merrett, in his *Pinax rerum Britannicarum*, to be found in Lancaſhire; and by Mr. Da Coſta, in his hiſtory of foſſils, to be plentiful on the ſide, near the top, of Cay-Avon, an high hill in Merionethſhire. The killow has ſomewhat of a bluiſh or purpliſh caſt mixed with its blackneſs, as the black chalk likewiſe has: hence it is named by Merrett blue marking ſtone, *lapis cæruleus killow dictus ducendis lineis idoneus*. There is a harder and ſofter kind of it, *killoia duriuſcula et molliuſcula* of Woodward's method of foſſils.

II. *Pitcoal.*

From the deep gloſſy black colour of ſome of the common ſorts of pitcoal, I was induced to make trial of them as paints: their affinity to oils, in virtue of their bituminous nature, promiſed alſo ſome advantages, in oil painting, above the ſubſtances of a more earthy kind. Several of the finer pieces, levigated into an impalpable powder, were mixed both with oil and with gum water, and applied on paper and on wood. Both mixtures, when laid on thick, appeared of a pretty good black colour, though much inferior to that of the coal at firſt; and the oily one ſeemed to dry ſooner than oil paints generally do. Laid on thin, or in a dilute ſtate, they looked brown, not of the grey colour which reſults from the dilution of a pure black. Pitcoal therefore may be conſidered, not as a true black, but as a brown-black; a colour on many occaſions wanted in painting, and which, as I have been informed by an ingenious

genious artiſt, is often in buſineſs produced with this material.

As different ſorts of pitcoal, and different pieces from one pit, differ much from one another in degree and ſpecies of colour, ſome care ſhould be taken in the choice of them, according to the purpoſe they are intended for. All the ſorts, at leaſt all which I have tried, require long grinding in order to their being reduced into a powder of ſufficient fineneſs.

III. *Black ſands.*

THE black ſands, one of the brighteſt and moſt beautiful of which is found in Virginia, loſe their colour on being ground into powder, and hence cannot be uſed as pigments. There are however caſes, in which they may contribute to the embelliſhment of certain works, by being ſtrewed upon oil paintings for a ſparkling black, in the ſame manner as ſmalt is ſtrewed for blue. In this intention they are uſed on writings, preferably to the white ſands, as they do not weaken the colour of the ink, but coincide with its blackneſs, and give an agreeable luſtre.

IV. *Black-lead.*

THIS mineral is dug in our own country; and is here, as Dr. Woodward obſerves, in the preface to his method of foſſils, more plentiful, and of a better kind, than in any other part of the world. According to Dr. Plott's account, in the Philoſophical Tranſactions, No. 240, it is found only at Keſwych, in Cumberland, and is there called *wadt* or *kellow*, by which laſt name, as we have already taken notice, an earth like the black chalk is diſtinguiſhed in other places.

The colour of black-lead, rather a deep ſhining bluiſh grey than a black, may be ſeen, diluted a little, in the black melting pots when broken or the ſurface ſcraped off, and entire in the genuine ſort of black pencils. It differs not a little in goodneſs, ſome ſorts marking paper freely, and others very difficultly or ſcarce at all. It is ſmooth and as it were unctuous to the touch, and hence is ſometimes uſed inſtead of oil or ſoap, for giving ſlipperineſs to the rubbing parts of machines. Acids neither diſſolve it, nor alter its colour or unctuoſity.

Black-lead has not been found to contain any of the metal from which it receives its name, and its compoſition appears to be of a very ſingular kind. From its known reſiſtence to vehement degrees of fire, whether urged by itſelf in cloſe veſſels, or made with clay into melting-pots and placed among the burning fuel, it ſhould ſeem that it could not partake largely of any volatile ſubſtance; and it has been generally ſuppoſed to conſiſt chiefly of a talky earth. But Mr. Quiſt relates, in a curious paper of experiments on black-lead, publiſhed in the Swediſh tranſactions for 1754, that having expoſed many different ſpecimens of this mineral to a ſtrong heat, on a ſcorifying diſh under a muffle, they all yielded ſulphureous fumes and flowers in great abundance; and that there remained behind, from one ſort, only a fifth part of its weight, and from another no more than a twentieth part, of a yellow or brown calx, which being treated with inflammable fluxes, yielded ſeven tenths its weight of a metallic maſs, which ſeemed to be a mixture of iron and tin. Agreeably to theſe experiments, in an eſſay for a new ſyſtem of mineralogy, publiſhed lately in Sweden, aſcribed to the celebrated Mr. Cronſtedt, and which bears ſtrong marks of great knowledge and experience in the mineral kingdom, black-lead is claſſed among the ſulphureous minerals, and called *ſulphur ſatiated with iron and tin.*

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I could not perſuade myſelf that the minerals, on which the above experiments were made, could be ſuch as are called among us black-lead, till ſome of the fineſt black-lead of our pencil-makers, weighing one hundred and ſixty-eight grains, in three pieces, having been kept of a moderately ſtrong red heat on a ſcorifying diſh for three hours, with the common precaution of covering the veſſel for a time, leſt the matter ſhould crackle, and ſome particles be thrown off from it in ſubſtance; I found it reduced to about an hundred and twenty grains, and all the pieces changed on the outſide to a ſparkling ruſty brown calx, of which a conſiderable part was attracted by a magnetic bar, the internal parts continuing of the ſame appearance as at firſt. Being then broken into ſmaller pieces, and expoſed to a like heat for two hours, it ſuffered the ſame change as before, and was reduced to about ſixty grains. Being further broken, and calcined with a moderate red heat for ten hours, it was diminiſhed to thirty grains; and by a repetition of this operation, to twelve grains, or a fourteenth part of its firſt weight.

The remarkable diſſipation, in theſe experiments, of a ſubſtance which in cloſe veſſels reſiſts intenſe fires, may be ſomewhat illuſtrated by the known property of charcoal, which when excluded from the action of the air, whether by being incloſed in a veſſel, or mixed with clay into a maſs, remains unconſumed and unaltered in the fire. Maſſes of black-lead ſeem to calcine and ſuffer a diſſipation only on the ſurface; the internal part remaining long unchanged, unleſs the maſs be broken, or the calx rubbed off, ſo as that freſh ſurfaces may be expoſed to the air. The common black-lead melting-pots, made of clay and the coarſer kinds of black-lead powdered, like thoſe made of clay and charcoal powder, loſe their external blackneſs with part of their weight, and thus have their ſtaining

quality

quality deſtroyed, by ſtrong fire. Hence furnaces made of theſe pots, as deſcribed at the beginning of this volume, after they have ſuffered ſtrong fire, ceaſe to diſcolour the hands.

Black-lead in fine powder, ſtirred into melted ſulphur, unites with it ſo uniformly, and in ſuch quantity, in virtue perhaps of its own abounding with ſulphur, that though the compound remains fluid enough to be poured into moulds, it looks nearly like the coarſer ſorts of black-lead itſelf. Probably the way which prince Rupert is ſaid to have had, mentioned in the third volume of Dr. Birch's Hiſtory of the Royal Society, of making black-lead run like a metal in a mould, ſo as to ſerve for black-lead again, conſiſted in mixing with it ſulphur or ſulphureous bodies.

On this principle the German black-lead pencils are ſaid to be made; and many of thoſe which are hawked about by certain perſons among us, are prepared in the ſame manner: their melting or ſoftening, when held in a candle, or applied to a red hot iron, and yielding a bluiſh flame, with a ſtrong ſmell like that of burning brimſtone, betrays their compoſition; for black-lead itſelf yields no ſmell or fume, and ſuffers no apparent alteration, in that heat. Pencils made with ſuch additions are of a very bad kind: they are hard, brittle, and do not caſt or make a mark freely either on paper or wood, rather cutting or ſcratching them than leaving a coloured ſtroke.

The true Engliſh pencils (which Vogel in his Mineral Syſtem, and ſome other foreign writers, imagine to be prepared alſo by melting the black-lead with ſome additional ſubſtances, and caſting it into a mould) are formed of black-lead alone, ſawed into ſlips, which are fitted into a groove made in a piece of wood, and another ſlip of wood glued over them: the ſofteſt wood, as cedar, is made choice of, that the pencil may be the eaſier cut; and a

part

part at one end, too ſhort to be conveniently uſed after the reſt has been worn and cut away, is left unfilled with the black-lead, that there may be no waſte of ſo valuable a commodity. Theſe pencils are greatly preferable to the others, though ſeldom ſo perfect as could be wiſhed, being accompanied with ſome degree of the ſame inconveniences, and being very unequal in their quality, on account of different ſorts of the mineral being fraudulently joined together in one pencil, the fore part being commonly pretty good, and the reſt of an inferior kind. Some, to avoid theſe imperfections, take the finer pieces of black-lead itſelf, which they ſaw into ſlips, and fix for uſe in portcrayons: this is doubtleſs the ſureſt way of obtaining black-lead crayons, whoſe goodneſs can be depended on.

V. *Black vegetable Juices.*

THE excellent black varniſh of China and Japan, which has hitherto been but imperfectly imitated in Europe, and which was formerly thought to be an artificial compoſition of reſinous bodies coloured with black pigments, has been diſcovered, by the later travellers in thoſe countries, to be a native juice, exuding from inciſions made in the trunks of certain trees. One of theſe trees, according to the account given of it in Kæmpfer's *Amœnitates exoticæ*, is that whoſe fruit is ſometimes brought to Europe, as a medicinal drug, under the name of anacardium.

The anacardium itſelf, as it comes to us, is remarkable for a black-colouring juice. It is a kind of nut, with a double ſhell, containing, in the ſpace between the outer and the inner ſhell, a fungous ſubſtance filled with a dark-coloured viſcous fluid, which is eaſily forced out, by cutting the nut, and ſqueezing it between the fingers: a little warmth, by liquefying the thick matter, makes it come out more freely; though the quantity obtained, either with or without heat, is not very conſiderable. This juice, rub-

bed

bed on linen or cotton, gives a reddiſh-brown ſtain, which ſoon deepens in the air to a black, and which I have not found to be diſcharged by waſhing, and boiling, with ſoap or alcaline ley. Hence the anacardium is ſaid to be uſed for marking linen and cotton cloths, and to be known all over India by the name of marking nut.

The caſhew nut, called by ſome the anacardium of the Weſt-Indies, and which in ſeveral reſpects has a great reſemblance to the oriental anacardium, differs from it in its colouring quality; the juice lodged between its ſhells being much paler, and giving to linen, cotton, or paper, only a browniſh ſtain, durable indeed, but which does not change at all towards blackneſs.

There are however trees, natives of our own American colonies, which appear to contain juices of the ſame nature with the valuable productions of the Indian. Of this kind are ſeveral, and perhaps the greater number, of the ſpecies of toxicodendron or poiſon-tree. Mr. Cateſby, in his hiſtory of Carolina, deſcribes one, called there the poiſon-aſh, from whoſe trunk flows a liquid, black as ink, and ſuppoſed to be poiſonous: this reputed poiſonous quality, as I have been informed by ſome gentlemen of that country, has hitherto deterred the inhabitants from attempting to collect or make any uſe of it. The abbé Mazéas, in the Philoſophical Tranſactions, vol. 49, for the year 1755, gives an account of three ſorts of the toxicodendron, raiſed in a botanic garden in France, containing in their leaves a milky juice, which in drying became of a deep black, and communicated the ſame colour to the linen it was dropt on: the linen, thus ſtained, was boiled with ſoap, and came out without the leaſt diminution of its colour; nor did ſtrong ley of wood-aſhes make any change in it.

Several of theſe trees have been raiſed in the open ground in England: ſome of them ſtill remain in the

biſhop

biſhop of London's garden at Fulham, after having been long neglected, and ſuffered many ſevere winters: ſee a catalogue of the exotic trees in this garden, by Dr. Watſon, in the Philoſophical Tranſactions, vol. 47, for the years 1751 and 1752. They appear alſo to perfect their colouring juices, in this, nearly as well as in their native climate. The ſpecies called by Mr. Miller the true lac tree, of which I was favoured with a branch by himſelf from Chelſea garden, was found to contain, in its bark, and in the pedicles and ribs of the leaves, a ſomewhat milky juice, which ſoon changed in the air to a reddiſh-brown, and in two or three hours to a deep blackiſh or browniſh-black colour: wherever the bark was cut or wounded, the inciſion became blackiſh; and on ſeveral parts of the leaves the juice had ſpontaneouſly exuded, and ſtained them of the ſame colour. This juice, dropt on linen, gave at firſt little or no colour, looking only like a ſpot of oil; but by degrees the part moiſtened with it darkened in the ſame manner as the juice itſelf. On waſhing and boiling the linen with ſoap, the ſtain not only was not diſcharged, but ſeemed to have its blackneſs rather improved; as if a brown matter, with which the black was manifeſtly debaſed, had been in part waſhed out, ſo as to leave the black more pure.

It were to be wiſhed that ſome attempts were made, for collecting the colouring juices of theſe trees, in ſufficient plenty, for anſwering the important purpoſes to which they promiſe to be applicable. Perhaps alſo means might be found of introducing into ſome parts of the extenſive dominions of Great-Britain, in which all varieties of ſoil and climate are now to be met with, the oriental trees themſelves, to which ſome of the Indian manufactures are ſuppoſed to owe diſtinguiſhed advantages. This there are now ſome grounds to hope for, from the patronage of a ſociety, whoſe encouragement has already ſo greatly promoted the culture of many valuable plants and trees.

As the milky juices of ſome of our common plants turn dark-coloured or blackiſh in drying, I was induced to make trial of ſeveral of them on linen: The milks of wild poppies, garden poppies, dandelion, hawkweed, ſowthiſtle, gave brown or browniſh-red ſtains, which were diſcharged by waſhing with ſoap: the milks of the fig-tree, of lettuces, and of different kinds of ſpurges, gave no colour at all. The colourleſs juice which iſſues from hop-ſtalks when cut, ſtains linen of a pale reddiſh or browniſh-red, extremely durable: I tried to deepen the colour by repeated applications of the juice, but could never make any approach to blackneſs. The juice of ſloes gave likewiſe a pale browniſh ſtain, which, by repeated waſhings with ſoap, and wetting with ſtrong ſolution of alcaline ſalt, was darkened to a deeper brown: on baking the ſloes, their juice turns red, and the red ſtain which it then imparts to linen is, on waſhing with ſoap, changed to a pale bluiſh, which alſo proves durable. The juices both of the raw and baked ſloes were applied repeatedly on the ſame ſpots, in order to deepen the reſpective colours; and the brown or reddiſh-brown ſtain of the raw ſloe, and the blue of the baked, were applied on one another, on principles hereafter explained. In all theſe ways a ſtain was obtained, which when ſlightly waſhed with ſoap, looked of a pretty deep black; but by longer waſhing, much of the colour was diſcharged, and little more was left than a ſingle application of the juice would have produced. The ſloes were tried in different ſtates of maturity, from the begining of ſeptember to the middle of december; and the event was always nearly the ſame. Though theſe experiments, with many others of the ſame kind, proved unſucceſsful in regard to the production of the colour here intended,

ded, they ſerve to point out means, which may be convenient and uſeful on ſome occaſions, of marking linen with a colour, pale indeed, but ſufficiently viſible, which ſoap does not diſcharge.

In the fifth volume of the celebrated Linnæus's *Amœnitates academicæ*, mention is made of a black colour obtained from the berries of two plants, which grow wild in ſome of the northern parts of England, and which I have not hitherto had an opportunity of trying. One is the *actæa ſpicata* or *chriſtophoriana*, herb-chriſtopher or bane-berries; the other *empetrum procumbens* or *erica baccifera nigra*, black-berried heath, crow-berries, or crake-berries. The juice of the bane-berries, boiled with alum, is ſaid to yield a black ink; and the heath-berries, boiled alſo with alum, to dye cloths of a purple-black.

VI. *Cuttle fiſh ink.*

THE cuttle fiſh, ſaid to be pretty common in the Mediterranean, is not wholly a ſtranger to our own ſeas, as appears from its bone found on our ſhores. This bone is hard on one ſide, but ſoft and yielding on the other, ſo as readily to receive pretty neat impreſſions from medals, &c. and afterwards to ſerve as a mould for the caſting of metals, which thus take the figure of the original: the bone is frequently employed likewiſe for poliſhing or cleaning ſilver. Mr. Borlaſe, in his natural hiſtory of Cornwal, ſays that theſe bones, whoſe characters are ſo obvious and ſo ſingular that they cannot be miſtaken, are found frequently on the ſhores of Mounts bay; and likewiſe gives a deſcription of the fiſh itſelf as caught there on the ſands in 1756. Dr. Leigh alſo, in his natural hiſtory of Lancaſhire and Cheſhire, relates that he has ſeen the fiſh ſeveral times on the ſhores of thoſe counties.

This fiſh contains, in a certain diſtinct veſſel, a fluid as black as ink: which it is ſaid to ſhed on being purſued, and thus to conceal itſelf by diſcolouring the water. The particular qualities of this black animal liquor I have had no opportunity of examining myſelf, nor have I been able to obtain any ſatisfactory information concerning them from others. Dr. Leigh, in the place before referred to, ſays he ſaw a letter, which had been written with it ten years before, and which ſtill continued: it were to be wiſhed he had ſpecified more particularly the continuance of the colour, whether in its full deepneſs, or much faded. Some report that the ancients made their ink from it, and others that it is the baſis of the Indian or China ink: both theſe accounts appear however, from ſome experiments and obſervations which will be related in the ſequel of this eſſay, to have little foundation: Pliny, ſpeaking of the inks uſed in his time, after obſerving that the cuttle fiſh is in this reſpect of a wonderful nature, adds expreſſly that ink was not made from it.

SECT. III.

Black produced by Fire.

THE action of fire properly applied, in the burning of animal and vegetable ſubſtances, produces, in the coal and in the ſoot, the two moſt durable and uſeful blacks of the painter and the varniſh-maker. The coal in particular is of extreme permanence, reſiſting the force of time, and all the known agents of nature, except only that of an open fire, which burns it into white aſhes. Some bodies of the metallic kind aſſume alſo, in certain circumſtances, a black colour from fire.

I. *Char-*

I. *Charcoal Blacks.*

Most of the blacks of this clafs, befides their incorruptibility, have the advantage of a full colour, and work freely in all the forms in which powdery pigments are applied; provided they have been carefully prepared, by thoroughly burning the fubject in a clofe veffel, and afterwards grinding the coal into a powder of due finenefs.

Pieces of charcoal are ufed alfo in their entire ftate, for tracing the outlines of drawings, &c. in which intention they have an excellence, that their mark is eafily wiped out. For thefe purpofes, either the finer pieces of common charcoal are picked out and cut to a proper fhape; or the pencils are formed of wood, and afterwards burnt into charcoal, in a crucible, or other like veffel, covered and luted. When the procefs is fkilfully managed, the coal retains exactly the figure of the wood: fome have been fo dextrous as to char an arrow, without altering the form even of the feather.

The artifts commonly make choice of the fmaller branches of the tree, freed from the bark and the pith; and fome particular kinds of wood, as the willow and the vine, they generally prefer to others. To difcover the foundation of this preference, and how far the coals of different vegetables differ from one another as colouring materials, I made the following experiments.

Small branches of the willow, vine, cherry, apple, pear, peach, plum, fig, birch, oak, elder, alder, yew, floe, hazel, fir and pine trees, were thoroughly dried, and inclofed in a mafs of luting, made of clay beaten up with fand and horfe-dung: the mafs, dried flowly and gradually heated to prevent its cracking, was kept red hot about three hours. On carefully breaking it, the pieces were all found well charred; but it could not be obſerved that they differed greatly from one another, either in degree of colour, or in the freedom of their marking upon paper.

This experiment affording little deciſive, I repeated the operation in crucibles, with greater quantities of the materials, that a more exact compariſon might be made of the colour of the coals, by uſing them as paints, both in a concentrated and diluted ſtate. Two crucibles were filled with vine twigs, cut in ſmall bits, freed from the knots, and thoroughly dried: the mouth of one crucible being then fitted into that of the other, the juncture was well ſecured with luting. Small ſmooth branches of moſt of the other kinds of trees above mentioned, were in like manner incloſed, each in two crucibles, and all of them continued about four hours in a ſtrong red heat. Cuttings of white paper, beaten with water into a paſte, ſuch as is called *papier maché*, that they might take up leſs room in the crucibles, and have leſs air lodged in their interſtices, were dried and treated in the ſame manner; but ſome flame appearing to burſt out through a ſmall crack which the vapour had forced in the luting, it was neceſſary to take out theſe crucibles after they had been about ten minutes in a red heat: the paper, nevertheleſs, was perfectly charred.

The ſeveral coals were levigated into fine powder, mixed both with gum water and oil, and applied as paints, both thin and thick, by themſelves, and diluted with different proportions of white. All of them, when laid on thick, appeared of a ſtrong full black; it could not be judged that one was of a finer colour than another. When ſpread thin or diluted, there were indeed ſome ſenſible differences among them, but neither very conſiderable, nor of ſuch a kind as to be eaſily expreſſed or deſcribed: they had all ſomewhat of a bluiſh caſt, but different perſons,

ſons, to whom the compariſons were referred, differed in their judgements of them, and could not fix on any particular coals as being more bluiſh, more truly black, or more beautiful than the reſt.

Inſtead of the ſmall branches, I tried next pieces of different woods, taken from the trunks of the trees. Here alſo the ſeveral coals appeared alike among themſelves, and ſcarcely differed in point of colour from thoſe of the twigs; but they ſeemed in general ſomewhat harder, and did not mark quite ſo freely on paper when uſed as crayons. Suſpecting from hence that the hardneſs of the coal might be proportional to that of the ſubject it was prepared from, I made ſome further trials, which ſeemed to confirm this notion. The coals of the hard woods, box and guaiacum, were very ſenſibly harder than thoſe of the ſoft ones: the ſhells and ſtones of fruits yielded coals ſtill harder, which would ſcarcely make any mark on paper at all; while the coals of the kernels of fruits were quite ſoft and mellow.

It may be judged from theſe experiments, that the preference of one kind of wood to another for making charcoal crayons, does not depend ſo much upon any difference of colour in the coals, as on their ſoftneſs; in which quality perhaps none of our common woods is equal to the willow. Dr. Grew obſerves, in his anatomy of plants, that in this wood the ſoftneſs is equal or alike in all parts; whence the coal, when uſed as a crayon in painting, not only makes the ſtroke light, but every where certain, without diſturbing the even motion of the hand. Deal or fir is likewiſe a very ſoft wood, but of unequal ſoftneſs, ſo that when cut acroſs, it tears, and will never poliſh or work ſmooth, whereas the willow works well in all directions.

Horns,

Horns, and the bones both of fifhes and of land animals, gave coals rather gloffier and deeper coloured than the vegetable coals, and which in general were very hard, fo as difficultly or not at all to ftain paper. It feemed here, as in vegetables, that the hardnefs of the coal depends on that of the fubject matter; for filk, woollen, leather, blood, and the flefhy parts of animals, yielded foft coals. Some of thefe coals differed from others very fenfibly in degree of colour: that of ivory is fuperior to the reft, and is indifputably the fineft of all the charcoal blacks. Indeed we have no black pigments equal in beauty to ivory black, genuinely prepared, but fome care is requifite in the choice of it, what is generally fold under this name being no other than the coal of common bones.

On comparing the vegetable and animal coals together, in their lighter fhades, on paper, the bluifh caft, obferved in all thofe of the vegetable kingdom, was much lefs confpicuous in thofe of the animal, many of which feemed to incline rather to brown than to blue. In the colourfhops a preparation is fold under the name of blue-black, which in this refpect differs from the animal and agrees with the vegetable coals, feeming to have no greater a degree of bluenefs than the coals of the woods and twigs above-mentioned, and even than common charcoal. That this preparation is no other than a vegetable coal, appeared from the following experiment. Laid on a red hot iron, it burnt and glowed like powdered charcoal, and turned into white afhes; which afhes, thrown into oil of vitriol diluted with water, very readily diffolved into a bitterifh liquor, the characteriftic by which the vegetable earth is diftinguifhed. From what particular vegetable matter this blue-black is prepared, experiments cannot difcover; but thofe already mentioned feem fufficient to fhew, that it may be obtained from many, and

that

that the choice of the vegetable ſubject affects rather the ſoftneſs or hardneſs than the colour of the coal.

After examining the different ſubſtances of the vegetable and animal kingdoms, I tried a mineral body, pitcoal; of which ſeveral pieces, of different ſorts, were charred in cloſe crucibles. The charred coals, reduced into fine powder and uſed as paints on paper, ſhewed nothing of the browniſh hue which the unburnt pitcoal had when tried in the ſame manner, all of them inclining to bluiſh, and moſt of them having this caſt in a greater degree than any of the vegetable coals. The blue-black of the ſhops cannot however be of this origin, the aſhes of the charred pitcoal not being diſſoluble by the vitriolic acid, as thoſe of the blue-black were found to be.

II. *Soot blacks.*

The ſoot blacks are in general much ſofter and of a more yielding texture than thoſe of the charcoal kind, and require much leſs grinding for uniting them with oily, watery or ſpirituous liquors, into a ſmooth maſs: of ſome of them a part is diſſolved by water or ſpirit of wine, while none of the charcoal blacks have been found to contain any thing diſſoluble.

This ſoluble matter of ſoot is not however black like the indiſſoluble parts; and in this particular, as well as in the colour of the entire maſs, different ſorts of ſoot differ from one another. Thus the ſoot of pitcoal collected in common chimneys, of itſelf rather greyiſh-black than of a full black, being infuſed ſeparately in rectified ſpirit of wine and in water, tinged the former of a tranſparent reddiſh colour, and the latter of a paler reddiſh; while the deeper black ſoot of wood, both to ſpirit and to water, gave an opake dark brown.

From the watery infufion of wood foot is prepared the brown pigment called biftre, for painting in water colours. According to Mr. Landois, in the French *encyclopedie*, the foot is either boiled in water, or ground with a little urine (water will do as well) into a fmooth pafte, and then diluted with more water: after ftanding for about half an hour, till the groffer fubftance of the foot has fettled, the liquor is poured off into another veffel, and fet by for two or three days, that the finer parts may fall to the bottom, which fine matter is the biftre. That the biftre of our colour fhops has been prepared by a procefs of this kind, and not, as fome have fufpected, by evaporating the infufion of foot to an extract, may be prefumed both from its appearance and its qualities. It is in little maffes, fuch as are obtained in the common way of drying precipitates, or earthy powders that have been ground with water, by dropping them on a chalk ftone. It readily mingles with water, and continues for a time uniformly diffufed through the fluid: a confiderable part was obferved to fettle in an hour or two, a part more flowly, and after ftanding for many weeks a part remained diffolved in the water, fo as to tinge it of a brownifh-yellow colour, like a weak infufion of foot: this tinged liquor paffed through a filter, without any feparation of the colouring matter. In the preparation of the biftre, when the foot liquor has depofited all that will fettle, the fediment, however drained, will neceffarily retain fome of the coloured fluid, which, drying, will leave in it fome of the truly diffoluble parts of the foot; and hence probably proceeds the matter in biftre which we find to continue diffolved in water, the proportion of which is inconfiderable, compared to that which precipitates. Different parcels of biftre differ confiderably in their colour, on account, probably, of the different qualities of the foots which they were made from.

The

The fineſt of the ſoot blacks, and the only one commonly made uſe of as a black pigment, is that called lamp-black, which is brought chiefly from Germany and Sweden. Its preparation is deſcribed in the Swediſh tranſactions for the year 1754, as a proceſs dependent on the making of common reſin: the impure reſinous juice, collected from inciſions made in pines and fir trees, is boiled down, with a little water, and ſtrained, whilſt hot, through a bag: the dregs and pieces of bark, left in the ſtrainer, are burnt in a low oven, from which the ſmoke is conveyed, through a long paſſage, into a ſquare chamber, having an opening in the top, on which is faſtened a large ſack, made of ſleaſy or thin-woven woollen ſtuff: the ſoot, or lamp-black, concretes partly in the chamber, from which it is ſwept out once in two or three days; and partly in the ſack, which is now and then gently ſtruck upon, both for ſhaking down the ſoot, and for clearing the interſtices between the threads, ſo as to procure a ſufficient draught of air through it. Conſiderable quantities of this ſoot are prepared alſo in ſome parts of England, particularly at the turpentine houſes, from the dregs and refuſe parts of the reſinous matters which are there manufactured.

The ſoot ariſing in common chimneys from the more oily or reſinous woods, as the fir and pine, is obſerved to contain more diſſoluble matter than that from other woods: and this diſſoluble matter appears, in the former, to be more of an oily or reſinous nature than in the latter, ſpirit of wine extracting it moſt plentifully from the one, and water from the other. The oilineſs and ſolubility of the ſoot ſeeming therefore to depend on thoſe of the ſubject it is made from, it has been thought that lamp-black muſt poſſeſs theſe qualities in a greater degree than any kind of common ſoot. Nevertheleſs, on examining ſeveral

 parcels

parcels of lamp-black, procured from different ſhops, I could not find that it gave any tincture at all, either to ſpirit or to water.

Suſpecting ſome miſtake or ſophiſtication, or that the lamp-black had been burnt or charred, as it ſometimes is to fit it for ſome particular uſes, I prepared myſelf ſome ſoot from linſeed oil, by hanging a large copper pan over the flame of a lamp, to receive its ſmoke. In this method the more curious artiſts prepare lamp-black for the nicer purpoſes, and from this collection of it from the flame of a lamp, the pigment probably received its name. The ſoot ſo prepared gave no tincture either to water or to ſpirit, any more than the common lamp-black of the ſhops. I tried different kinds of oily and reſinous bodies, with the ſame event: even the ſoots obtained from fiſh oil, and tallow, did not appear to differ from thoſe of the vegetable oils and reſins. They were all of a finer colour than the lamp-black commonly ſold.

Some ſoot was collected in like manner from fir and other woods, by burning ſmall pieces of them ſlowly under a copper pan. All the ſoots were of a deeper black colour than thoſe obtained from the ſame kinds of wood in a common chimney, and very little if at all inferior to thoſe of the oils: they gave only a juſt diſcernible tincture to water and ſpirit, while the ſoots of the chimney imparted a ſtrong deep one to both. The ſoot of mineral bitumens, in this cloſe way of burning, appears to be of the ſame qualities with thoſe of woods, oils, and reſins: in ſome parts of Germany, as I am informed by a worthy foreign correſpondent, great quantities of good lamp-black are prepared from a ſort of pitcoal.

It appears therefore that the differences of ſoots do not depend altogether on the qualities of the ſubjects, but in great meaſure on the manner in which the ſubject is

burnt,

burnt, or the ſoot caught. The ſoots produced in common chimneys, from different kinds of wood, reſinous and not reſinous, dry and green, do not differ near ſo much from one another, as thoſe which are produced from one kind of wood, in a common chimney and in the more confined way of burning above-mentioned.

III. *Black metallic calces.*

THE mineral *cobalt*, roaſted till its arſenical parts are diſſipated, becomes black; and being then melted with inflammable fluxes, yields a regulus, which likewiſe aſſumes a black colour by calcination. The ſame regulus is obtained from the artificial *zaffre*, whoſe baſis is the roaſted cobalt, and which is employed for tinging glaſs blue; as alſo from the deep blue glaſs itſelf, called, when ground, by the painters *ſmalt*, and by the laundreſſes *powder-blue*. The cobalt, more valuable for theſe important products than for the property which occaſions it to be here taken notice of, and which has hitherto been afforded chiefly by Saxony, has of late, by the encouragement of the Society for promoting arts, been diſcovered in our own country: in further ſearches for it, the property here mentioned may be of great aſſiſtance, thoſe minerals, and thoſe only, which calcine black, promiſing to be uſeful cobalts. Calces of iron, whether red, yellow, or of other colours, on being brought into fuſion by the addition of vitreous bodies, give always a black colour to the glaſs if the quantity of iron is conſiderable. From copper alſo a black colour may be produced by fire, and applied to the ſtaining and embelliſhing of certain ſtones, of which an account will be given hereafter towards the end of this hiſtory. I have not obſerved that any of the other metallic bodies are changed black in any circumſtances by ſimple heat.

SECT. IV.

Black produced by mixture.

I. *Black from Iron.*

FROM infufions of certain vegetables, mixed with green vitriol, is produced a deep black liquor, of moft extenfive ufe for dying and ftaining black. To woollen and filk it gives a permanent colour, although from linen, and other vegetable bodies, its blacknefs is difcharged by wafhing.

The fubftances chiefly employed for producing this colour with vitriol, are the excrefcences of the oak tree, called galls; of which there are two principal kinds, one faid to be brought from the Levant, and the other from fome of the fouthern parts of Europe, particularly Sicily and Romania. The former, called by authors Aleppo galls, and in the fhops of our dry-falters blue galls, are generally of a bluifh colour, or of a greyifh or blackifh verging to bluenefs, unequal and warty on the furface, hard to break, and of a clofe compact texture: the others, commonly called white galls, are of a pale brownifh or whitifh colour, fmooth, round, eafily broken, lefs compact, and of a much larger fize. The two forts differ in ftrength, but in other refpects they appear to be of the fame quality. The Aleppo or blue galls are the ftrongeft: two parts of thefe are reckoned by the workmen to be equivalent to three of the white; and fuch comparifons, as I have made of the two, incline me to think, that the difference in their ftrength is rather greater than this proportion.

Thefe excrefcences appear to proceed from the juices of the oak tree iffuing out through fmall wounds made by certain infects; which infects not being found in this climate, no galls are here produced; though other kinds of

excrefcences

excrefcences are frequent on our oaks, occafioned perhaps by infects of another kind. It is not, as might be thought, on any particular fpecies of the oak tree that galls are formed; for Mr. Ray fays, that in his travels abroad, he has feen them on the fame kind of oak with that which is common here.

All the parts of the oak tree feem to contain juices of nearly the fame general virtue with galls; for the leaves, the acorns, and more particularly the bark and wood, ftrike with vitriol a black or a deep colour approaching to blacknefs. There are many other vegetable fubftances which have a like effect in different degrees; as the leaves, fmall branches, and flowery clufters of the fumach tree, balauftine flowers, pomegranate peel, alder bark, biftort root, and thofe in general which are auftere, aftringent, or corrugating to the tafte; infomuch that turning a folution of vitriol black is looked upon as a fure teft of aftringency in vegetables. The power by which they produce this blacknefs, and their aftringency, or that by which they contract an animal fibre, and by which they contribute to the tanning of leather, feem to depend upon one and the fame principle, and to be proportional to one another. Of the other properties of this aftringent and colouring matter, little more is known, than that it is diffolved and extracted from the fubject both by water and fpirit of wine, and that it does not exhale in the evaporation of the liquors by heat.

Green vitriol commonly called copperas, the other ingredient in the black mixture, is a preparation of iron, made at Deptford, Blackwall, Newcaftle, and fome other parts of England, by boiling old iron with an acid liquor which runs from certain pyritæ on being long expofed to the weather. By diffolving iron in the vitriolic acid, and

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cryſtallizing the ſolution, the ſame ſalt is obtained in a purer ſtate.

When a decoction or infuſion of the galls is dropt into a ſolution of the vitriol largely diluted with water, the firſt drops produce bluiſh or purpliſh red clouds, which ſoon mingling with the liquor tinge it uniformly of their own bluiſh or reddiſh colour. It ſeems to be on the quality of the water that this difference in the colour depends. With diſtilled water, or the common ſpring waters, the mixture is always blue. If we previouſly diſſolve in the water the moſt minute quantity of any alcaline ſalt, too ſmall to be diſcoverable by any of the common means by which waters are examined, or if the water is in the leaſt degree putrid, the colour of the mixture proves purple or reddiſh. Rain water, caught as it falls from the clouds, in an open field, in clean glaſs veſſels, gives a blue, but ſuch as is collected from the tops of houſes grows purple with the vitriol and galls; from whence it may be preſumed, that this laſt has contracted a putrid tendency, or received an alcaline impregnation, though ſo ſlight as not to be ſenſible on other ways of trial.

Both the blue and the purple liquors, on adding more of the aſtringent infuſion, deepen to a black, more or leſs intenſe according to the degree of dilution: if the mixture proves of a deep opake blackneſs, it again becomes bluiſh or purpliſh when further diluted. If ſuffered to ſtand in this dilute ſtate for two or three days, the colouring matter ſettles to the bottom in form of a fine black mud, which, by ſlightly ſhaking the veſſel, is diffuſed again through the liquor, and tinges it of its former colour. When the mixture is of a full blackneſs, this ſeparation does not happen, or in a far leſs degree; for though a part of the black matter precipitates in ſtanding, yet ſo much remains diſſolved, that the liquor continues black. This ſuſpenſion

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of the colouring ſubſtance in the black liquid may be attributed in part to the gummy matter of the aſtringent infuſion increaſing the conſiſtence of the watery fluid, for the ſeparation is retarded in the diluted mixture by a ſmall addition of gum arabic; though another principle appears alſo to concur for part of the effect.

If the mixture, either in its black or diluted ſtate, be poured into a filter, the liquor paſſes through coloured, only a part of the black matter remaining on the paper. The filtered liquor, to the eye perfectly homogene, on ſtanding for ſome time becomes turbid and full of fine black flakes: being freed from theſe by a ſecond filtration, it again contracts the ſame appearance, and this repeatedly, till all the colouring parts are ſeparated, and the liquor has become colourleſs. It ſhould ſeem therefore, that there happens a gradual and ſlow concretion of the black corpuſcles, into particles large enough to ſubſide by their own weight, or to be retained on a filter; and that this concretion is greatly influenced by dilution with water. Perhaps it is affected alſo by the action of the air; for having once ſet ſome of the diluted mixture to ſettle in a cloſe ſtopt glaſs, the ſeparation of the black matter was remarkably more ſlow than in the other experiments, in which the veſſel was open.

The colouring matter, thus ſeparated from the liquor, being drained on a filter and dried, appeared of a deep black, which did not ſeem to have ſuffered any change on lying expoſed to the air for upwards of four months. Made red hot, it glowed and burnt, though without flameing, and became a ruſty brown powder, which was readily attracted by a magnetic bar; though in its black ſtate, the magnet had no action on it. The vitriolic acid, diluted with water and digeſted on the black powder, diſſolved greateſt part of it, leaving only a very little quantity of whitiſh matter. Solution of pure fixt alcaline ſalt diſſolved very little of it: the liquor received a reddiſh brown colour, and the powder became blackiſh brown. This reſiduum was attracted by the magnet after being made red hot, though not before: the alcaline tincture, paſſed through a filter, and mixed with ſolution of green vitriol, ſtruck a deep browniſh-black colour, nearly the ſame with that which reſults from mixing with the vitriolic ſolution an alcaline tincture of galls.

From theſe experiments it ſeems to follow, that the colouring matter in the black mixtures is iron, extricated from its acid ſolvent in a highly attenuated or divided ſtate, and combined with a peculiar ſpecies of matter contained in aſtringent vegetables; which matter, after the watery fluid that the compound floats in has been ſeparated, is in part extracted from the iron by alcaline liquors, and may thence be again transferred into freſh diſſolved iron.

The blackneſs is generally attributed to the iron being barely revived from the vitriol in its metallic ſtate; the black matter being ſuppoſed to be of the ſame nature with the impalpable black powder, into which fine iron filings are changed by lying for many months under water. But this black matter differs from that of our mixtures in two very material properties. It is attracted in its black ſtate by the magnet; and when moiſtened and expoſed to the air, it changes ſpeedily into ruſt. The reſiſtance of ours to the magnet and to the air proceeds doubtleſs from the combination of the other matter with the iron; and there appears ſome analogy, in regard to the manner of production, between this black ſubſtance and Pruſſian blue; one being a precipitation and coalition of diſſolved iron with one ſpecies of matter, and the other with another: the principal difference is, that the ſubſtance combined with the iron in the Pruſſian blue defends the metal from the action

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of acids, which that in the black compound is unable to do.

I tried likewife folutions and different foluble preparations of iron, made with the nitrous, marine, and vegetable acids; as alfo an alcaline folution of it, obtained in Stahls method, by dropping into ftrong alcaline ley a folution of the metal made in the nitrous acid. All the preparations, in which the iron was diffolved by an acid, ftruck a black colour with aftringents; but the alcaline folution gave only a reddifh brown. In this refpect alfo the tinging fubftance in our mixtures agrees with that of Pruffian blue.

It has been affirmed, that folutions of iron in the nitrous and marine acids produce no blacknefs with aftringents; and fome trials, formerly made, led me into the fame opinion. On re-examining this matter, the fallacy appeared to lie here; that thofe acids do not very readily fatiate themfelves with the iron, and that any confiderable quantity of redundant acid in the folution prevents the blacknefs. The cafe is the fame with the vitriolic acid alfo; and probably if we had not, in the vitriol itfelf, a faturated combination of this acid with iron, ready prepared for other ufes, the vitriolic folutions would as often have been found to refufe ftriking a black colour, as the nitrous and marine.

After the blacknefs has been produced, the addition of any of thefe acids, and even of the vegetable in fufficient quantity, deftroys it, by rediffolving the ferrugineous matter: hence the ufe of acids or acidulated liquors, for difcharging ftains made by the black mixtures, fuch as that of common ink. Alcalies alfo deftroy the blacknefs, apparently on a different principle, by diffolving the aftringent matter, and precipitating the iron nearly in the fame ochery ftate, as they do from the fimple acid folutions of the metal. After the blacknefs has been difcharged by an alcali, the addition of any acid, in fuch quantity as to fatiate the alcali, reftores it; and after its difcharge by an acid, it is in like manner reftored again by an alcali.

II. *Black from filver.*

Solution of filver in aquafortis, of itfelf colourlefs as water, dropt upon white bone or other like animal fubftances, produces at firft no ftain. In fome time, fooner or later according as the fubject is more or lefs expofed to the fun and air, the part moiftened with the liquid becomes firft of a reddifh or purplifh colour, which by degrees changes into a brown, and at length deepens to a black. Several kinds of ftones and wood receive, from the fame folution, purplifh, reddifh, bluifh, brown, or black ftains.

On what particular combination the colours here depend, has not as yet been explained, nor indeed, fo far as I can find, examined. The following obfervations, which we owe to a paper of Mr. Schulze, in the firft volume of the *acta naturæ curioforum*, though they do not difcover the caufe of the effect, may contribute to its illuftration.

White chalk, moiftened with a folution of filver, and dried in the fhade or by a fire, receives no colour: dried in the fun, or expofed to the fun after it has been otherwife dried, it becomes on the furface of a purplifh black. When the earth is thoroughly moiftened with the folution, if fo much water be added, as will reduce it into a thin pafte, the matter in this ftate alfo becomes coloured in the fun, though in the fhade it acquires no tinge. The colour is produced only in thofe parts on which the fun fhines: a thread applied on the outfide of the glafs, between it and the fun, occafions a correfponding uncoloured vein on the included matter; and hence diftinct characters may

may be exhibited on the maſs, by intercepting a part of the ſuns light by threads or cut paper.

I repeated theſe experiments, and obſerved that the colours produced were nearly the ſame with thoſe which the ſolution of ſilver communicates to bone or ivory, except that they did not deepen to ſo true a black. The colour was entirely ſuperficial; for when the matter, by now and then turning the glaſs in the ſun, had been tinged all over to a reddiſh or browniſh black, it appeared white again when ſhaken and mixed together. By continuing the expoſure for many weeks, and frequently ſhaking the mixture that freſh ſurfaces of it might be ſucceſſively acted upon by the ſun, it became at length coloured, though weakly, throughout. The ſuns rays in december produced the ſame change as in june, and, ſo far as can be recollected, as ſpeedily. The light of candles, and a gentle warmth from common fire, did not ſeem to affect the colour. In a conſiderable heat, greater than that of the ſun in ſummer, the matter became brown, but without acquiring the black colour which the ſun communicates.

I tried alſo ſeveral other earthy bodies, and found that thoſe which diſſolve in acids, the aſhes of vegetables and of bones and horns, ſuffered the ſame changes as chalk and the other mineral calcareous earths. But powdered flint, however moiſtened and drenched with the ſolution, received no colour in half a years expoſure to the ſun. White clay, plaſter-of-paris, and powdered talk remained alſo uncoloured; and even chalk itſelf previouſly ſatiated with the vitriolic acid, ſo as not to be acted upon by the acid in which the ſilver was diſſolved, ſuffered no change.

It ſhould ſeem from theſe experiments, that in order to the production of a black ſtain from ſolution of ſilver, it is neceſſary that the ſubject moiſtened with it be not only expoſed to the ſolar light, but that it contain ſome matter which

which the nitrous acid may diffolve preferably to the filver which it already holds diffolved. This is plainly the cafe in bones, horns, hair, marble, and feveral other bodies which are ftained by the filver folution; though there are alfo fome ftones which are ftained by it, as agate, in which a fubftance foluble by the acid has not yet difcovered itfelf.

It may be obferved, that the production of a dark colour from the action of the fun is not peculiar to folution of filver, or to a combination of this folution with foluble earths. When bifmuth is diffolved in the nitrous acid, and afterwards precipitated by dilution with water, the precipitated powder, exceedingly white, foon becomes dark coloured in the fun, fo as to require great care, in drying and keeping it, to preferve the whitenefs, for which that preparation is valued. Mercurius dulcis, a combination of quickfilver with the marine acid, fuffers a like change. The effect, however, is lefs confiderable here than in the filver liquor; for though both preparations become dark, I have not obferved blacknefs produced in either.

III. *Black from Lead and Sulphur.*

LEAD, a metal which of itfelf makes a blackifh mark on paper, yields colours more approaching to blacknefs in fome of its diffolutions and combinations with other bodies. Solutions of lead made in acids, dropt upon paper or other white fubjects, communicate no ftain; but on being expofed to fulphureous vapours, or wafhed over with alcaline folutions of fulphur, the parts moiftened with the folution of lead become immediately yellow, and foon after of a deep brown or black, according as the liquors were more or lefs faturated with the matters diffolved in them.

The production of this colour has not been applied to any important ufe, being regarded chiefly as a matter of curiofity,

curiofity, as affording the foundation of one of the writings called invifible or fympathetic. For this purpofe, vinegar is ftrongly impregnated with lead, by boiling with litharge, ceruffe, or other calces of the metal; or what amounts to the fame thing, the common preparation called fugar of lead is diffolved in water: folutions of lead in aqua fortis anfwer the fame end, except that, when written with, they are apt to corrode the paper. The fulphureous liquor is commonly prepared by boiling fome orpiment, which is a natural mixture of fulphur and arfenic, in water with quicklime, till the water is ftrongly impregnated with the orpiment: in the room of this preparation may be ufed a faturated folution of common brimftone, made by boiling the brimftone either with quicklime, or in ftrong alcaline ley. Characters written with the lead folution, which when gently dried in the air are not to be diftinguifhed from the reft of the paper, become of a legible deep colour, on paffing over them a pencil dipt in the fulphureous folution. Thofe who amufe themfelves with this experiment, have black characters in the neighbourhood of the invifible ones; which black ones are drawn with burnt cork, or other charcoal blacks, mixed only with water: by the wet pencil, thefe are wafhed off, at the fame time that the others are made to appear.

If any acid be added to the fulphureous folution, a very offenfive fmell arifes; and a folution of fulphur made in ftrong volatile fpirits, prepared with quicklime, exhales a like fmell. This penetrating diffufive vapour, particularly that of the laft of thefe preparations, gives colour to the invifible writing with the lead folution at a confiderable diftance: though the writing be placed in the middle of a quire of paper, or of a pretty thick book, the vapour will foon reach it, and ftain it brown or black. The colour

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is difcharged by acids, and reftored again by the fulphureous vapour or folution.

Calces of lead, melted with fulphur, form a black or blackifh mafs, which proves an ufeful matter for taking cafts from medals, being confiderably more tough than fulphur alone. For this purpofe, equal parts of minium and flowers of fulphur are put in an iron ladle over the fire, till they foften into the confiftence of pap, and are then kindled with a piece of lighted paper, and ftirred for fome time: the veffel being afterwards covered clofe and continued on the fire, the mixture becomes fluid in a few minutes, and is then poured upon the medal previoufly oiled and wiped pretty clean. This procefs, communicated to me by a friend, I have often tried with fatisfaction. The cafts are very neat; the colour, fometimes a pretty deep black, and fometimes a black grey, according to different circumftances in the fufion; they are very durable, and when foiled may be wafhed clean again with fpirit of wine.

There are other metals alfo which produce a black colour with fulphureous bodies. When a folution of filver in aquafortis is added to a folution of fulphur made in alcaline ley, the filver and fulphur unite and precipitate together in the form of a black powder. Quickfilver and fulphur, by being barely rubbed together in a mortar, become black, and hence this mixture, commonly made for medicinal ufes, is called the mineral ethiops. But as thefe kinds of compofitions afford nothing of importance for the art of colouring black, it would be needlefs in this place to confider them more particularly.

IV. *Black from the combination of other colours.*

In the three foregoing articles we have feen blacknefs generated from the action of certain bodies on one another,

other, and, in the preceding ſection, from alterations produced in the bodies themſelves or their component parts. There is another general principle, on which ſome of the moſt common colours are obtained, the combination of two or more differently coloured bodies together, whence reſults a new colour compounded of thoſe of the ingredients: thus green is formed from a mixture of blue and yellow, and purple from blue and red. Theſe compound colours are found to ſucceed, by grinding together coloured earthy powders, by uniting coloured flames or the ſuns beams which have paſſed coloured through glaſſes, by mixing dyed wool, threads, &c. where there can be no ſuſpicion of any intrinſic change made in the ſubjects, or of any action of the ingredients on one another.

Mr. le Blon, in his harmony of colours, forms black on the ſame foundation, by mixing together the three colours called primitive, blue, red, and yellow; and Mr. Caſtel, in his *optique des couleurs*, publiſhed in 1740, ſays that this compound black has an advantage, in painting, above the ſimple ones, of anſwering better for the darkening of other colours. Thus if blue, by the addition of black, is to be darkened into a blue-black, the ſimple blacks, according to him, if uſed in ſufficient quantity to produce the requiſite deepneſs, conceal the blue, while the compound blacks leave it diſtinguiſhable.

Le Blon does not mention the proportions of the three primitive colours neceſſary for producing black. Caſtel directs fifteen parts of blue, five of red, and three of yellow; but takes notice, that theſe proportions are rather ſpeculatively than practically juſt, and that the eye only can be the true judge; our colours being all very imperfect, and our pigments or other bodies, of one denomination of colour, being very unequal in its degree or intenſity. He obſerves that the colours ſhould each be the deepeſt and darkeſt in its kind; and that, inſtead of taking one pigment for each colour, it is better to take as many as can be got; for the greater contraſt there is of heterogeneous and diſcordant drugs, the more true and beautiful, he ſays, will the black be, and the more capable of uniting with all other colours, without ſuppreſſing them, and even without making them tawney.

The trials I have made of mixing different blue, red, and yellow powders, have not ſucceeded ſo far as to afford a perfect black; but I have often obtained from them very dark colours, ſuch as may be called brown-blacks and grey-blacks, ſuch as we commonly ſee in the dark parts of paintings, and ſuch as the charcoal and ſoot blacks appear when diluted a little. The ingredients being each of a dark deep colour is a very neceſſary condition; for bright blues, bright reds, and bright yellows, mixed in ſuch proportions that neither colour prevailed, produced only a grey. In effect, all compoſitions of this kind, phyſically conſidered, can be no other than greys, or of ſome of the intermediate teints between whiteneſs and blackneſs; and theſe greys will be ſo much the lighter or darker, as the component colours of themſelves are bright or dark. Some further experiments of producing a black by compoſition, for the purpoſes of dying and ſtaining, will be mentioned in the ſequel of this eſſay.

SECT. V.

Black paints, varniſhes, &c.

I. *Black paint with oil.*

BLACK oil paint is prepared, by grinding, with a proper quantity of oil, the charcoal or ſoot blacks, or the natural black earths, or pitcoal, till they are united into a ſmooth, uniform, thick compound, which is occa-

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ſionally diluted with more oil, to a due conſiſtence for being worked freely with the bruſh or pencil.

The fineſt black colour is made with ivory-black, ground, before the addition of the oil, into an impalpable powder. The material moſt commonly made uſe of is lamp-black, whoſe colour is for moſt purpoſes of ſufficient deepneſs and beauty. The unctuoſity of lamp-black gives it an advantage above the other pigments, of mixing more eaſily and perfectly with the oil; but from the ſame quality it receives a diſadvantage, of being too ſlow in drying for the diſpatch requiſite in buſineſs. Some deprive it of this imperfection by burning it, that is, by heating it red hot in a cloſe veſſel; but being by this means reduced to the ſtate of coal, it is deprived alſo of its eaſy miſcibility with oil. It may, however, be made to dry as ſpeedily as other oil paints generally do, by a due preparation of the oil; as particularly by ſetting it on fire and boiling it, in the manner hereafter deſcribed, in the tenth article of this ſection, for making printers ink.

The oil, for all paints, requires ſome preparation, to promote its own drying; and the method here recommended appears for this purpoſe both the moſt expeditious and the moſt effectual: The dark colour, which it commonly acquires in the proceſs, and which renders it unfit for the brighter coloured paints, is of no inconvenience to it for blacks. The oil is made conſiderably thick by the boiling, and being in this ſtate well mixed with the black matter, the mixture is diluted for uſe with unboiled oil, to which it communicates a ſufficient degree of the drying quality deſired.

II. *Black paint with water.*

An opake deep black for water colours is made, by grinding ivory-black with gum water; or with the liquid which ſettles from whites of eggs, after they have been beaten up and ſuffered to ſtand a little. Some uſe gum water and the white of eggs together; and report, that a ſmall addition of the latter makes the mixture flow more freely from the pencil, and improves its gloſſineſs.

It may be obſerved, that though ivory-black makes the deepeſt colour, in water as well as in oil painting, yet it is not always, on this account, to be preferred, in either kind, to the other black pigments. A deep jet black colour is ſeldom wanted in painting; and in the lighter ſhades, whether obtained by diluting the black with white bodies, or by applying it thin on a white ground, the particular beauty of ivory-black is in great meaſure loſt: the ſame intentions may be anſwered by pigments of leſs price and more eaſily procurable.

A valuable black for water colours is brought from China and the Eaſt-Indies, ſometimes in large rolls, more commonly in ſmall quadrangular cakes, generally marked with Chineſe characters. By dipping the end of one of the cakes in a little water, and rubbing it about on the bottom or ſides of the veſſel, a part of its ſubſtance is taken up by the water, which may thus be readily tinged to any ſhade of black or grey, from ſuch as will juſt colour paper, to a full black. The compoſition of this Indian ink has not hitherto, ſo far as I can learn, been revealed; and I therefore made ſome experiments with a view to diſcover it.

Though the Indian ink is readily diffuſed through water, it is not truly diſſolved: when the liquid is ſuffered to ſtand for ſome time, the black matter ſettles to the bottom in a muddy form, leaving the water on the top colourleſs; in the ſame manner as the common black pigments ſettle from diluted gum water. The ink, kept moiſt, in warm weather, becomes in a few days putrid, like

like the fluid or ſoft parts of animals; as does likewiſe the clear water, after the black matter has ſettled and been ſeparated from it. The Indian ink appears therefore to contain an animal ſubſtance ſoluble in water; and to conſiſt of a black powder mixed with ſome animal glue. For the greater certainty in regard to this conglutinating ingredient, I boiled one of the China cakes in ſeveral freſh portions of water, that all its ſoluble parts might be extracted, and having filtered the liquors through paper, ſet them to evaporate in a ſtone baſon: they ſmelt like glue, and left a very conſiderable quantity of a tenacious ſubſtance, which could not be perceived to differ in any reſpect from common glue.

Being thus convinced of the compoſition of the maſs, I tried to imitate it, by mixing ſome of the lamp-black, which I had myſelf prepared from oil (ſee page 342) with as much melted glue as gave it ſufficient tenacity for being formed into cakes. The cakes, when dry, anſwered fully as well as the genuine Indian ink, in regard both to the colour, and the freedom and ſmoothneſs of working. Ivory-black and other charcoal blacks, levigated to a great degree of fineneſs, which requires no ſmall pains, had the ſame effect with the lamp-black; but in the ſtate in which ivory-black is commonly ſold, it proved much too gritty, and ſeparated too haſtily from the water.

III. *Compoſition for marking ſheep.*

Great quantities of wool are annually made unſerviceable by the pitch and tar, with which ſheep are marked, and which are commonly not laid on with a ſparing hand, as they conſiderably increaſe the weight of the fleece at a trifling expence. With a view to prevent, as much as poſſible, this great waſte of ſo uſeful a commodity, the ſociety inſtituted in London for the encouragement

ment of arts, manufactures, and commerce, and who continue vigorouſly and judiciouſly to proſecute the important ends of their inſtitution, offered a conſiderable premium for the diſcovery of any cheap compoſition, that might ſupply the place of thoſe hurtful materials; whoſe colour ſhould be ſtrong and laſting, which ſhould bear the weather a proper time, and not damage the wool. Several propoſals for this purpoſe were laid before the ſociety, but none of them have as yet been thought deſerving of the premium. The enquiry having been warmly recommended to me by the late Dr. Hales, as an object of very great importance to the woollen manufactury, I went through a ſet of experiments with this view in the year 1759.

It was hoped, that the ill qualities of tar and pitch might be corrected, by mixing with them ſome ſoap or ſize, which ſhould prevent their too great adheſiveneſs, and render them ſo far diſſoluble in water, as to be diſchargeable from the wool by the means commonly practiſed for cleanſing it; or, in failure of tar and pitch, that ſome compoſition of reſins, oils, or fats might be found, which ſhould be rendred harmleſs to the wool by the ſame correctors, and which ſhould ſerve as ſufficient cements for certain coloured powders, among which black appeared to be the beſt, as being the ſtrongeſt and moſt conſpicuous colour. On theſe principles many trials were made, but with little ſucceſs: for the unctuous and reſinous materials, with the advantage which they received from the ſoap or ſize, of being eaſily waſhed out from the wool, received alſo the diſadvantage of being too ſoon diſcharged by the weather.

It was next conſidered, that as wool has always a natural greaſineſs, which the workmen waſh out with ſtale urine, ſoap, or ley, as deſcribed in the ſequel of this hiſtory;

tory; the common animal fats might probably be difcharged from it by the fame means, fo as not to ftand in need of thofe ingredients, from which the foregoing compofitions had contracted the imperfection of being too eafily difchargeable. Accordingly I melted fome tallow; and ftirred into it fo much charcoal in fine powder, as made it of a full black colour, and of a thick confiftence. This mixture, eafily procurable and at fmall expence, being applied warm with a marking iron on pieces of flannel, quickly fixed or hardened, bore moderate rubbing, refifted the fun and rain, and yet could be wafhed out freely with foap, or ley, or ftale urine. All the good qualities, that can be defired in a compofition for marking fheep, appeared therefore to be united in this fimple preparation.

Though the mixture of tallow and charcoal powder was found fufficiently durable when applied as above upon pieces of flannel; it occurred, that it might neverthelefs, by the repeated attritions to which it is expofed on the body of the animal, be in danger of being rubbed off too foon. If we could add to the compofition a little pitch or tar, we fhould effectually fecure againft any inconveniency of this kind, and it was apprehended that thefe ingredients might here be added with fafety; for being perfectly diffolved by the tallow, it might be prefumed that they would wafh out along with it from the wool. Thus we fee ftains of tar got out from clothes by means of oil, which diffolving the tar, the whole compound is then difcharged by the fame detergents that the oil itfelf would be. I therefore melted fome tallow with an eighth, with a fixth, and with a fourth of its weight of tar, and having thickened the mixtures with charcoal powder, fpread them while hot upon pieces of flannel. None of the compofitions could be difcharged by any rubbing or wafhing with water. By foap they were all wafhed out completely;

completely; that which had the ſmalleſt proportion of tar, eaſily enough; that which had the largeſt proportion, difficultly. If therefore it ſhould be feared, that the tallow will fail in point of durability or adheſiveneſs, which, however, I do not apprehend that it will; it is plain, that as much as can be deſired of this quality may be communicated, without damaging the wool, by a proper addition of the ſubſtances commonly made uſe of. I do not conceive that the nature of the thing can admit of any greater perfection.

There is a material circumſtance in this affair, which does not ſeem to have been ſufficiently conſidered by thoſe who propoſed the enquiry. If we could diſcover, which ſome have fruitleſsly endeavoured to do, a ſtaining compoſition in the nature of a dye, poſſeſſing all the good qualities that have been mentioned; it would ſcarcely be poſſible, as matters ſtand at preſent, to induce the farmers to make uſe of it. They require a ſubſtance that will add weight: and I apprehend it will be no ſmall recommendation to the above compoſition, that in this reſpect, as in all others except its being innocent to the wool, it agrees as nearly as can be expected, with the materials to which they have been long familiarized.

IV. *Compoſition for preſerving wood, &c.*

The great adheſiveneſs, which renders tar unfit as a principal ingredient, and excellent as a ſecondary one, for the purpoſes of the foregoing article, adapts it to another uſe, on ſome occaſions not a little important; the preſerving of ſome kinds of wood on the outſides of certain buildings, the covering of ſheds, paling, &c. as alſo for coating common tiles, in imitation of the black glazed tiles, which are ſold at a much higher price.

Tar

Tar and pitch of themſelves are too ſoft for theſe intentions; even the pitch being liable to be melted off by the heat of the ſun in ſummer, however firm in the cold of winter. Different powdery ſubſtances, as aſhes, ochres and other mineral pigments, have been mixed with them, but without remedying the imperfection ſo effectually as could be wiſhed. In the Swediſh tranſactions for the years 1742 and 1740, two compoſitions are recommended, which are ſaid to be firm, durable, and gloſſy.

One is prepared by melting the tar over a moderate fire, ſo as to make it fluid but not to boil, and ſtirring in as much coal duſt as will render it thick: this mixture, the author ſays, is to be laid on with wooden trowels, in a hot day, as thick or as thin as ſhall be thought proper. The other is prepared by mixing the melted tar with a ſufficient quantity of lamp-black: a little of this mixture is ſpread upon the upper ſide of each tile with a ſtiff, ſhort-haired, painting bruſh: next day, when dry, the tiles are done over with tar alone, and two days after with tar again: this coating being well dried, which in ſummer, according to the author, is generally in eight or ten days, ſome powdered lead ore is ſtrewed over it, and well rubbed in, firſt with a coarſe and afterwards with a fine linen cloth; from this it receives a ſparkling appearance.

I tried both theſe compoſitions, and found them of a good black colour: when the bodies coated with them are held before the fire till the ſurface begins to run, they become gloſſy. They are not however wholly exempt from the inconveniencies complained of in the others. For though the tar was made as thick, both with the coal duſt and lamp-black, as was conſiſtent with its being ſpread ſmooth even in a hot ſun and while warm from the fire, it afterwards ſoftened in the ſun conſiderably;

 though

though the parts, which the ſun did not immediately ſhine upon, proved ſufficiently firm in the hotteſt weather.

By coal duſt, in the firſt compoſition, is meant powdered charcoal. Suſpecting however that pitcoal, in virtue of its bituminous nature, might unite more perfectly with the tar, and be in ſome meaſure diſſolved by it, I made trial of this alſo, chuſing the fineſt coloured pieces, of thoſe kinds which melt in the fire, and grinding them into impalpable powder. The mixture of this powder with the melted tar, made of ſuch conſiſtence as to be freely ſpread while warm with a bruſh, ſeemed to ſoften leſs in the ſuns heat than either of the other two. The durability of theſe compoſitions I cannot yet determine: after having ſtood, without any apparent alteration, one ſummer and winter, they continue expoſed to the weather, for diſcovering what effects longer time and viciſſitudes of ſeaſons may have upon them.

The mixture of tar and lamp-black is found the moſt effectual preſervative for the maſts and yards of ſhips. Such parts of the maſt, as the ſliding up and down of the ſails requires to be only greaſed, and thoſe which are covered with turpentine or reſin mixed with tallow or oil, generally contract large rents, while the parts coated with tar and lamp-black remain perfectly ſound. I have been favoured by a gentleman on board of a veſſel in the Eaſt-Indies, with an account of a violent thunder ſtorm, by which the mainmaſt was greatly damaged, and whoſe effects on the different parts of the maſt were pretty remarkable. All the parts which were greaſed, or covered with turpentine, were burſt in pieces: thoſe above, between, and below the greaſed parts, as alſo the yard arms, the round top or ſcaffolding, &c. coated with tar and lamp-black, remained all unhurt.

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In this place it may be proper to obſerve, that the coating or painting of wood does not in all caſes contribute to its preſervation: unleſs the wood be very thoroughly dry, eſpecially thoſe kinds of wood whoſe juices are not oily or reſinous, the painting, by confining the watery ſap, haſtens the corruption. Several preſſes for a paper manufacture having been made of heart of oak ſeemingly very dry, ſome of them, which with injudicious care had been well painted over, rotted and periſhed in a few years, while the unpainted ones continued for many years perfectly ſound.

V. *Compoſitions for blacking leather.*

In the tanning of leather, it is ſo much impregnated with the aſtringent parts of oak bark, or with that matter which ſtrikes a black colour with green vitriol, that rubbing it over three or four times with a ſolution of the vitriol, or with a ſolution of iron made in vegetable acids, is ſufficient for ſtaining it black. Of this we may be convinced, by dropping a little of the ſolution on the unblacked ſide of common ſhoe leather. This operation is performed by the currier, who, after the colouring, gives a gloſs to the leather with a ſolution of gum-arabic and ſize made in vinegar. Where the previous aſtringent impregnation is inſufficient to give a due colour, and for thoſe ſorts of leather which have not been tanned, ſome galls or other aſtringents are added to the ſolution of iron; and in many caſes, particularly for the finer ſorts of leather, and for renewing the blackneſs, ivory or lamp-black are uſed. A mixture of either of theſe with linſeed oil makes the common oil blacking. For a ſhining blacking, ſmall beer or water are taken inſtead of oil, in the quantity of about a pint to an ounce of the ivory-black, with the addition of half an ounce of brown ſugar and as much gum-arabic. The white of an egg, ſubſtituted to the gum, makes the black more ſhining, but is ſuppoſed to hurt the leather and make it apt to crack. It is obvious, that all theſe kinds of compoſitions admit of many variations: it is ſufficient here to have given a general idea of them.

VI. *Spirit varniſh.*

Black varniſh, for japanning on wood or leather, is prepared by mixing lamp-black or ivory-black with a proper quantity of a ſtrong ſolution of gum lac in ſpirit of wine, ſuch as that deſcribed in the preceeding part of this work, page 224. The lamp-black is commonly preferred to the ivory-black, on account of its uniting better with the fluid, and working ſmoother. The thicker part of the varniſh, which ſettles at the bottom, is uſed with the lamp-black for the firſt coatings, and the mixture applied at different times, in a hot room, one layer after another is dry, till a full body of colour is obtained: after which, the piece is waſhed over in the ſame manner, ſeveral times, with the finer part of the varniſh, juſt tinged with the black, ſo as to make a coating of ſufficient thickneſs to bear poliſhing with tripoli.

VII. *Amber varniſhes for papier maché, &c.*

Papier maché is made of cuttings of white or brown paper, boiled in water, and beaten in a mortar, till they are reduced into a kind of paſte, and then boiled with ſolution of gum-arabic or of ſize, to give tenacity to the paſte, which is afterwards formed into different toys, &c. by preſſing it into oiled moulds. When dry, it is done over with a mixture of ſize and lamp-black, and afterwards varniſhed. The black varniſh for theſe toys (of which the firſt account I have ſeen is in a pamphlet on drawing,

drawing, &c. printed for Mr. Peele in 1732, and ſaid to be taken chiefly from manuſcripts left by Mr. Boyle) is prepared as follows.

Some colophony, or turpentine boiled down till it becomes black and friable, is melted in a glazed earthen veſſel, and thrice as much amber in fine powder ſprinkled in by degrees, with the addition of a little ſpirit or oil of turpentine now and then: when the amber is melted, ſprinkle in the ſame quantity of ſarcocolla, continuing to ſtir them, and to add more ſpirit of turpentine, till the whole becomes fluid: then ſtrain out the clear through a coarſe hair bag, preſſing it gently between hot boards. This varniſh, mixed with ivory-black in fine powder, is applied, in a hot room, on the dried paper paſte; which is then ſet in a gently heated oven, next day in a hotter oven, and the third day in a very hot one, and let ſtand each time till the oven is grown cold. The paſte thus varniſhed is hard, durable, gloſſy, and bears liquors hot or cold.

A more ſimple amber varniſh, of great uſe for many purpoſes, and ſaid to be the baſis of the fine varniſhes which we ſee on coaches, &c. is prepared, by gently melting the amber in a crucible till it becomes black, then reducing it into a powder, which looks brown, and boiling the powder in linſeed oil, or in a mixture of linſeed oil and oil of turpentine. Drying oil is commonly made choice of by the workmen; but it ſeems more eligible here to take the oil unprepared, that the boiling, requiſite for giving it the drying quality, may be employed at the ſame time in making it act upon the amber.

By the previous melting of the amber, its nature is changed, and part of its oily and ſaline matter expelled, as happens in the common diſtillation of it. When the diſtillation is not far protracted, the caput mortuum, or

ſhining

ſhining black maſs which remains in the retort, anſwers as well as the amber melted on purpoſe. Hence ſome of our chemiſts, inſtead of urging the diſtillation to the utmoſt, by which the amber would be reduced to a mere coal, find it more advantageous to diſcontinue the proceſs when the thinner oil and greater part of the ſalt have ariſen, that the remaining maſs may be in great meaſure ſoluble in oils, ſo as to ſupply the common demand of the varniſh makers.

It has generally been thought, that amber will not at all diſſolve in oils, till it has thus ſuffered a degree of decompoſition by fire. Hoffmann relates an experiment, in his *obſervationes phyſico-chemicæ*, which diſcovers the ſolubility of this concrete in its natural ſtate. Powdered amber, with twice its quantity of oil olive, was put in a wide-mouthed glaſs; and a digeſtor, or ſtrong copper veſſel, being filled about one-third with water, the glaſs was placed in it, the cover of the digeſtor ſcrewed down tight, and a moderate fire continued an hour or more: when cold, the amber was found diſſolved into a gelatinous tranſparent maſs.

In Dr. Stockars very curious *ſpecimen inaugurale de ſuccino*, printed at Leyden, in 1760, there are ſundry more important experiments on this ſubject, made by himſelf, conjointly with my worthy correſpondent Mr. Ziegler of Winterthur. They found that by continuing a ſimmering heat twelve hours, and confining the vapour as much as ſtone-ware veſſels would bear without burſting (the danger of which was avoided by making a ſmall notch in the cork ſtoppers) powdered amber diſſolved perfectly in expreſſed oils, in turpentine, and in balſam of copaiba: a ſtrong copper veſſel, with a cover ſcrewed on it, ſeems moſt eligible, and for the greater ſecurity, a valve may be made in the cover, kept down by a ſpring that ſhall give way before

before the confined vapour is of ſufficient force to be in any danger of burſting the veſſel. Though ſuch a heat as converts part of the oil into ſtrong elaſtic vapours, and the forcible compreſſure of the vapour, are expedient for haſtening the diſſolution, they do not appear to be eſſentially neceſſary; for by digeſtion for a week in cloſe ſtopt glaſs veſſels, in which the compreſſure could not be very great, ſolutions equally perfect were obtained.

The ſolution in rape-ſeed oil, and in oil of almonds, was of a fine yellowiſh colour; in linſeed-oil, gold coloured; in oil of poppy-ſeeds, yellowiſh red; in oil olive, of a beautiful red; in oil of nuts, deeper coloured; and in oil of bays, of a purple red. It is obſervable that this laſt oil, which of itſelf, in the greateſt common heat of the atmoſphere, proves of a thick butyraceous conſiſtence, continued fluid when the amber was diſſolved in it. The ſolutions made with turpentine, and with balſam of copaiba, were of a deep red colour, and on cooling hardened into a brittle maſs of the ſame colour. All the ſolutions mingled perfectly with ſpirit of turpentine. Thoſe made with the oils of linſeed, bays, poppy-ſeeds, and nuts, and with balſam of copaiba and turpentine, being diluted with four times their quantity of ſpirit of turpentine, formed hard, tenacious, gloſſy varniſhes, which dried ſufficiently quick, and appeared greatly preferable to thoſe made in the common manner from melted amber.

VIII. *Varniſh for metals.*

Iron ſnuff-boxes, mourning buckles, &c. are coloured black, by making them conſiderably hot, and applying on them in this ſtate a thick mixture of lamp-black, with a certain varniſh called gold-ſize. There is a gold-ſize, formerly mentioned, for gilding, or fixing gold-leaf on wood, &c. The ſize here meant is a compoſition of a different

different kind, confifting of drying oil, turpentine, and the pigment called Naples yellow; which laft ingredient is ufed for giving a high gold colour to the mixture, to fit it for fome of the other purpofes for which it is employed. In the prefent intention, the yellow might doubtlefs be omitted, and the varnifh formed at once by mixing lamp-black with a proper quantity of turpentine and drying oil.

IX. *Sealing-wax.*

Black fealing wax is compofed of gum lac, melted with one half or one third of its weight of ivory-black in fine powder. The inferior fort of lac, called fhell-lac, anfwers as well for this ufe as the fineft. It is cuftomary to mix with it, for the ordinary kinds of fealing wax, a confiderable proportion, as two thirds its weight, of the cheaper refinous bodies, particularly Venice turpentine, by which the beauty of the mafs is here lefs injured than in the red wax, and of which a fmall addition is in all cafes expedient, to prevent the compound from being too brittle. The ingredients being melted and well ftirred together over a moderate fire, the mixture is poured out upon an oiled ftone or iron plate, and rolled, while foft, into fticks, which afterwards receive their gloffinefs by being heated till the furface begins to fhine.

The black figures on the dial-plates of clocks and watches, which look like black enamel, are formed of the finer kind of black fealing wax, which is melted into cavities made in the plate, and afterwards polifhed. Black enamel or ftones are fome times imitated in the fame manner in other works.

X. *Printing*

X. *Printing ink.*

Printing ink differs from the common oil paint, defcribed at the beginning of this fection, only in the preparation of the oil, which muft here have its confiftence and tenacity greatly increafed, and its greafinefs diminifhed, by means of fire. The fame way of preparation, either not carried to fo great a length, or with a fubfequent addition of frefh oil to dilute the mixture, affords, as already obferved, one of the beft drying oils for the black paint.

The oils of linfeed and nuts are made choice of for this ufe : the nut oil is fuppofed to be the beft, and is accordingly preferred for the black ink, though the darker colour which it acquires from the fire makes it lefs fit for the red. It is faid that the other expreffed oils cannot be fufficiently freed from their unctuous quality; whence the ink made with them dries exceeding flowly, is apt to come off and fmear the paper in the beating and preffing which it undergoes in the book-binders hands, or finks into the fubftance of the paper, beyond the mark of the type, and ftains it yellow.

Ten or twelve gallons of the oil are fet over the fire, in an iron pot, capable of holding at leaft half as much more; for the oil fwells up greatly, and its boiling over into the fire would be very dangerous. When it boils, it is kept ftirring with an iron ladle; and if it does not itfelf take flame, it is kindled with a piece of lighted paper or burning wood; for fimple boiling, without the actual accenfion of the oil, does not communicate a fufficient degree of the drying quality required : it feems to be in the more inflammable parts, which are fooneft confumed by the burning, that the injurious fatnefs or greafinefs confifts. The oil is fuffered to burn for half an hour or more, and the flame being then extinguiſhed by covering the veſſel cloſe, the boiling is afterwards continued, with a gentle heat, till the oil appears of a proper conſiſtence: in which ſtate it is called varniſh. It is neceſſary to have two kinds of this varniſh, a more and leſs boiled, or a thicker and a thinner, which are occaſionally mixed together as different purpoſes may require: that which is of a juſt conſiſtence in warm weather proves too thick in cold; and that which anſwers well for large characters, proves in the ſame ſeaſon rather too thin for ſmall ones.

The thickeſt varniſh is of ſuch conſiſtence when cold, that it draws into threads between the fingers nearly like weak glue: this is the mark by which the workmen judge of the due boiling, a little of it being from time to time taken out for this trial, and cooled by dropping it on a tile or other cold body. It is very viſcous and tenacious, like the ſoft reſinous juices or thick turpentines. It is not at all diſſolved, any more than the oil at firſt, by water or ſpirit of wine, but mingles readily enough with freſh oil, and unites with mucilages into a maſs which diſſolves in water into a milky liquor: by boiling with ſtrong alcaline ley it forms a ſoapy compound; whence the types, after an impreſſion, are cleaned from the ink, by waſhing, and rubbing them with a bruſh, in hot ley. The oil emits, during the whole time of the boiling, very offenſive penetrating fumes: when grown cold, it has an acrid diſagreeable taſte, but little ill ſmell. The oil is ſaid to loſe, in being boiled into thick varniſh, from a tenth to an eighth part of its weight, which proportions agree ſufficiently with my trials: common linſeed oil, boiled down to a conſiſtence which appeared ſomewhat too thick, loſt about one ſixth: being further boiled, till it became quite firm when cold, the loſs was near one half. Different

rent oils, and perhaps the ſame oil in different ſtates, differ in this reſpect: fiſh oil, boiled to thickneſs, loſt much more than that of linſeed, the thick matter amounting only to about one fourth of the original weight of the oil.

The workmen are accuſtomed to add, in the preparation of ten or twelve gallons of oil, as ſoon as the burning is over, a pound or two of dry cruſts of bread, and a dozen or two of onions, by which they ſuppoſe the greaſineſs to be more effectually deſtroyed. It may however be queſtioned, whether additions of this kind are of much uſe; for I have prepared the varniſh, ſeemingly of a very good quality, by fire alone.

There is another ſort of additions whoſe effect is more apparent. To give a greater body to the varniſh, and increaſe its drying quality, a proportion of turpentine is thought neceſſary; and with ſome artiſts, litharge has in this intention been a ſecret. It is obſerved, in the French *encyclopedie*, by Mr. le Breton, the printer of that work, that when very old oil is uſed, neither turpentine nor litharge are needful; but that, when the oil is new, ſome turpentine muſt neceſſarily be employed, for without it, the ſmearing of the paper, by the ſpreading or coming off of the ink, cannot be avoided; that it is much more eligible to uſe old oil than to have recourſe to this correction of the new, both turpentine and litharge, particularly the laſt, making the mixture adhere ſo firmly to the types, that it is ſcarce to be got entirely off by the ley, whence the eye of the letter is ſoon clogged up.

When turpentine is uſed, it is firſt boiled by itſelf, untill, on dipping in a piece of paper, it is found to crumble and part from the paper when cold: the oil being then taken from the fire, the turpentine, while ſtill fluid, is poured into it, after which the boiling is repeated, and continued till they are ſufficiently incorporated.

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It is here ſomewhat more difficult to hit the due point of boiling, than when the oil is prepared without addition; the mixture being more apt to grow too thick from continuing the heat too long, and full of little hard grains from not continuing it ſufficiently; which grains are probably undiſſolved particles of the turpentine. The uſe of boiling the turpentine firſt by itſelf is to diſſipate its moiſture or eſſential oil: by the boiling it becomes a reſinous matter, nearly the ſame with common reſin, which poſſibly would anſwer the ſame end.

For making the varniſh into ink, lamp-black is the common material; of which, according to Mr. le Breton, two ounces and a half are ſufficient for ſixteen ounces of the varniſh. They are ground together on a ſtone with a muller, in the ſame manner as oil paints.

The paper, for printing, is moiſtened with water; by which it is made more yielding and pliable, ſo as not only to be leſs apt to be torn by the types in the preſs, but likewiſe to be more cloſely and evenly applied to them, and conſequently to take a neater and more perfect impreſſion. The due moiſture of the paper, and the care and attention of the preſſmen in well working the ink on the types with the balls, are very material points; without which, how excellent ſoever the ink is, the impreſſion will not be beautiful.

The adheſion of printers ink to wetted paper ſeems to ſhew that it is not truly of an oily nature. All expreſſed oils contain probably a gummy or mucilaginous matter; and perhaps the tenacity, conſiſtence, drying quality, and the property of adhering to bodies moiſtened with water, which the oil acquires in the proceſs above deſcribed, may be all owing to ſome of the purer part of the oil being deſtroyed, ſo as to leave the remainder more gummy. When the oil dries, it proves a tough flexible ſubſtance,

ſtance, which has little diſpoſition to unite with freſh oil any more than with water, as if the gummy and oily matter were in ſuch proportions, that one defends the other from the menſtruum that would otherwiſe diſſolve it: eſſential oils on the contrary, being free from gum, harden into a merely reſinous maſs, brittle like other reſins, and which diſſolves, like the oil at firſt, in freſh oil or in ſpirit of wine. The differences obſerved in different expreſſed oils, in regard to the drying quality, may depend on the different quantities of gummy matter; and the difference of old oil from new, on the gum being in the latter more intimately combined, ſo as not to ſeparate in the burning and boiling. When theſe oils are firſt preſſed out from the ſubjects, they abound with mucilage, great part of which is only ſuperficially mixed, ſo as to give a turbidneſs and opacity to the fluid: in keeping, a part of this looſe mucilage is thrown off, and the remainder may be preſumed to become at the ſame time more intimately incorporated with the oil. The repugnance which we obſerve between oil and gum does not in the leaſt invalidate theſe conjectures, any more than the repugnance between oil and water can be an argument againſt the exiſtence of water in oils: indeed we have plain proofs of the coalition of oil with gum, in the analyſis of the pureſt gums, gum arabic, ſenica, tragacanth, from which an actual oil is obtained by diſtillation. The diſtillation of expreſſed oils themſelves ſeems to favour the opinion here propoſed: from all of them there remains in the diſtilling veſſel a large quantity, though from ſome more than from others, of a groſs coaly matter; and there ariſes a fluid oil, which does not dry or grow thick in the air as the oils did at firſt; and which is therefore found to anſwer for certain purpoſes, as in the lapidaries

buſineſs,

bufinefs, for which the thickening of the oils in their natural ftate renders them unfit.

XI. *Rolling-prefs Ink.*

BETWEEN the rolling-prefs printing, and that of the printers prefs ftrictly fo called, there is this effential difference; that in the former the impreffion is received from figures hollowed in a copper plate, but in the latter from prominent types. The damping of the paper is equally neceffary for the rolling-prefs as for the other, in order to foften it, fo that the parts, correfponding to the cavities in the plates, may be forced into them. But the ink is of a fomewhat different quality. For while the printers types require a glutinous or fticky mixture, which fhall adhere upon the prominences of the type, without running into the hollows; the ink for copper-plates muft run into and fill the hollows, efpecially when the plate is warmed, and be fo little glutinous, as to be eafily wiped off clean from the fmooth parts of the plate, or thofe which are to leave the paper white.

The oil, for this ink, muft be boiled, and fet on fire, in the fame manner as for the other, to take off its greafinefs and promote its drying: the boiling is continued more or lefs, according to the different confiftences which different kinds of plates may require, but never fo far as to communicate to the oil the adhefive gluey quality of the printers varnifh. The black matter muft be of the charcoal kind: the lamp-black gives always a degree of toughnefs, but the charcoal blacks, as they do not unite intimately with the oil, divide its texture, and render it lefs gluey. The coal commonly employed for this ufe is brought in powder from Germany, and called German or Frankfort black: this is fofter, and more free from grittinefs,

nefs, than the ivory or other charcoal blacks as ufually prepared among us.

The Frankfort black is fuppofed by fome to be the coal of vine-twigs; by others, that of the kernels of fruits and wine lees burnt together. The coal of vine-twigs, as we have already feen, does not appear to differ, in any great degree, from that of the fmall branches of other kinds of trees; but the kernels of fruits yield a coal confiderably more foft and mellow, eafily crumbling between the fingers into a fine meal. That the Frankfort black is no other than a vegetable coal, appeared from its burning on a red hot iron, like charcoal powder, into white afhes; and from the afhes, like common vegetable afhes, being plentifully diffoluble by the vitriolic acid into a bitterifh liquor, while the afhes of animal fubftances are very fparingly affected by that acid, and form with it a compound of a different kind of tafte.

SECT. VI.

Of the preparation of common writing ink.

COMMON writing ink is prepared from galls, or other aftringent vegetables, and green vitriol, fteeped or boiled in water or other liquors. The ingredients, in different receipts, are fet down in very different proportions: in fome, fix parts of galls are directed to one of vitriol; and in others, three or four parts of vitriol to one of galls: fome order the weight of the liquor to be equal to that of the vitriol and galls together, others fifteen or fixteen times as much.

Moft of the common inks have a capital imperfection, that though at firft of a pretty good colour, yet in length of time they decay, fome fooner and others later, the writing becoming fcarcely legible, or even entirely difappearing;

pearing; of which too many inftances are known to thofe, who have examined records and other writings of any confiderable age. The preparation and improvement of this ufeful fluid, on whofe duration fo much depends, becomes therefore a very important object.

The ingredients being known, it was hoped, that by a proper fet of experiments, the beft ink they are capable of affording, in regard both to the durability and beauty of the colour, could not efcape difcovery. Though length of time be the proper teft of the abfolute duration of inks, it was prefumed that a few years would be fufficient for judging of their comparative durability; and that in this comparifon, fome affiftance might be obtained from expofing the writings for fome months to the fun and weather, by which the influence of time on colours is haftened in a remarkable degree: dyed clothes expofed for a month or two to the fun in fummer, lofe more of their colour, than they do in an age when kept clofe from the air. With thefe views, about fifteen years ago, I engaged in a fet of experiments, of which the general refults are as follow.

I. *Experiments for determining the beft preparation of ink with vitriol and aftringents.*

When common ink, or a black infufion of galls and vitriol, is diluted largely with water, and fuffered to fettle, the black matter, as already obferved, falls to the bottom, and the liquor becomes colourlefs. If fuch a mixture contained more vitriol than the galls could faturate and decompofe, it was judged that the redundant vitriol would remain diffolved in the liquor, and ftrike a black colour with frefh galls; and that on the contrary, if the quantity of galls employed at firft was more than fufficient for the decompofition of the vitriol, the liquor would in like

manner

manner retain the redundant impregnation of the galls, and ſtrike a blackneſs with freſh vitriol; ſo that by trying, till ſuch proportions of the two ſhould be found, as that the liquor, after the precipitation, ſhould produce no blackneſs with a freſh addition of either ingredient, the proportions requiſite for the exact ſaturation might be diſcovered.

Many trials were accordingly made on this principle. When the quantity of galls was ſeveral times greater than that of the vitriol, an addition of more vitriol to the liquor after ſettling produced a freſh blackneſs; and when the vitriol greatly prevailed, an addition of galls had the like effect. But there were ſeveral intermediate mixtures, with proportions conſiderably different from one another, in which no blackneſs could be perceived to ariſe from the addition of one or the other ingredient. By taking a medium between the quantities, in thoſe trials where one or the other did produce a ſenſible colour, it was reckoned that about equal parts of the two were the mean proportions, which could receive no additional blackneſs from a further increaſe of either. In theſe and all the other experiments made with galls, the Aleppo or blue galls were the ſort employed; and care was taken, by boiling or long infuſion, to get out as much of their virtue as can be expected to be done in practice.

Different infuſions of the galls and vitriol, in a more and leſs dilute ſtate, were tried next on paper. Here it was found, that the proportions, which gave the greateſt blackneſs, were not thoſe, whoſe colours were the moſt durable, though in both reſpects there were conſiderable latitudes. Equal parts of the two, the quantities which the foregoing way of trial ſeemed to point out for the beſt, gave an ink of good blackneſs at firſt; but on keeping for a few weeks, and in a few days when expoſed to

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the ſun and open air, the writing changed to a yellowiſh brown. The mixtures, in which the vitriol exceeded the galls, underwent greater and ſpeedier changes; more and more ſo, according as the exceſs of the vitriol was the greater. Thoſe in which the galls exceeded the vitriol were more durable: an infuſion of two parts of galls and one of vitriol did not fade ſo much in two months expoſure, as an infuſion of equal parts of the two did in one month; and three parts of galls to one of the vitriol made an ink which held its colour ſtill better. When the galls were increaſed to five or ſix times the weight of the vitriol, the colour did not prove black enough, though it ſeemed to be rather of more durability than the others.

The writings which had changed to a brown or yellow, I waſhed over with an infuſion of galls. Where the ink had been well loaded with the ingredients, the characters became of a pretty good black; and thoſe, which had been written with more dilute inks, became, though not black, yet ſenſibly more coloured than before, inſomuch that many, which had grown almoſt indiſtinguiſhable, were now ſufficiently legible. How far this infuſion would ſerve for the recovery of decayed writings of great age, I have not had an opportunity of trying; but thus much is clear, that a diſtilled water of galls, recommended for this purpoſe in Caneparius's collection *de atramentis*, cannot anſwer; the aſtringency, or the power of giving blackneſs to iron, reſiding in ſuch parts of the galls as do not riſe in diſtillation.

It ſeems to follow from the above experiments, that the decay of inks is owing chiefly to a deficiency of galls; that the galls are the moſt periſhable ingredient, the quantity, which gives the greateſt blackneſs at firſt, being inſufficient to maintain the colour; that for a durable

ink,

ink, the quantity of galls cannot be much lefs than three times that of the vitriol; and that it cannot be much greater without fomewhat injuring the ink in point of blacknefs.

The proportion of liquid admits of much greater latitude, than that of the vitriol and galls to one another. One ounce of vitriol, three ounces of galls, and a hundred and fifty ounces of water, made an ink, legible indeed, though greatly too pale. With a hundred ounces of water to the fame quantity of galls and vitriol, the colour was ftill too pale. With forty and fifty ounces of water, the ink was of fufficient blacknefs for common ufes: but the fulleft and blackeft colour of all was produced when the quantity of liquor was little more than enough to cover the powders, as fix, eight, or ten ounces. It was expected that thefe fmall quantities of water, diffolving all the vitriol, without being able to fully extract the virtue of the galls, and thus occafioning a deficiency in the quantity of aftringent matter, would have yielded a perifhable ink. Neverthelefs, characters written with thefe mixtures have preferved their colour for fifteen years, continuing ftill fenfibly blacker than where the menftruum was in larger quantity. It appears therefore, that though a large portion of fluid may be tinged by the vitriol and galls of a blacknefs fufficient for many purpofes, the ufing a little quantity is of advantage both to the deepnefs and durability of the colour; perhaps only from the liquor being in this cafe more loaded with the colouring matter of the ingredients, fo that a greater body of colour is accumulated upon the ftroke.

I next tried what alteration would refult from the ufing of different waters or other liquors for the menftruum. Diftilled water, rain water, and hard fpring water, employed in the fame proportions, had, fo far as could be

judged,

judged, the fame effects. White wine produced an ink of a deeper black colour than the waters; and with vinegar, the colour was rather ftill deeper. Proof fpirit extracted only a reddifh brown tinge, and rectified fpirit a paler brown, the vitriol not being diffoluble in thefe liquors. Both the fpirituous tinctures funk and fpread upon the paper, that in rectified fpirit more than the other: hence the addition of fpirit to common ink, directed by fome for preferving it from mouldinefs, or from freezing in winter, occafions generally a precipitation of part of the colour, and makes the ink fink, more or lefs according to the quantity of the fpirit. The coloured juices of fruits, as of privet-berries, mulberries, black-cherries, ufed as menftruums for the galls and vitriol, made the colour rather fuller on firft writing than water did, but it was lefs black, and foon grew dull or rufty in keeping. A decoction of logwood, ufed inftead of water, fenfibly improved both the beauty and the deepnefs of the black, without at all difpofing it to fade.

Inftead of the galls, I tried other ftrong aftringents, as oak bark, alder bark, floe bark, fumach, tormentil root, biftort root, balauftine flowers, pomegranate peel, &c. but could not find one of equal efficacy with galls. Nor did any but the oak bark feem to give the fame fpecies of blacknefs that galls did, moft of the others having more or lefs of a greenifh hue: the oak bark itfelf however, though it came neareft to the galls, made a very bad ink, and though ufed in eight or ten times their quantity, was far from being equal to them in effect. The faw-duft of oak wood, which has lately been found to anfwer for tanning leather, as well as the bark or rather better, and confequently to have no inconfiderable impregnation of true aftringent matter, produced with vitriol a tincture fomewhat different from all the other aftringents I have

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tried: the colour at firſt was an opake deep blue: after the liquor had ſtood for ſome days on a freſh quantity of the wood, it approached more to blackneſs; but ſtill retained a very conſiderable blue tinge. Galls themſelves give indeed a bluiſh colour when the liquor is diluted ſo as to be tranſparent; but in an opake ſtate, ſo far as I have obſerved, they exhibit no blueneſs.

I made trial alſo of the juice of ſloes, which to the taſte is pretty ſtrongly aſtringent, and which, as we have formerly ſeen, page 332, gives of itſelf, to linen, a ſtain of remarkable durability. By mixing the juice, whether of raw or of baked ſloes, with different proportions of ſolution of vitriol, I could not produce the leaſt tendency to blackneſs, the vitriol ſeeming to make little alteration in the colour. Some of the mixtures, however, having been written with on paper, the characters, after ſtanding for ſeveral days expoſed to the air, changed by degrees to a full black, which appeared to be more durable than that of any of the inks made with galls; their colour having ſtood well in the open air from the beginning of november laſt, till the papers were deſtroyed by the weather in the end of february. Writings with good common ink, expoſed along with them as a ſtandard, had faded much.

As all the aſtringent vegetables communicate of themſelves ſome colour to water, galls a browniſh, biſtort root a dark brown, logwood a purpliſh, tormentil root a reddiſh, pomegranate peel a greeniſh yellow, &c. I endeavoured to prepare a compound black from the aſtringents alone, on the principles mentioned at the end of the fourth ſection, page 355; hoping that this additional black in the liquor might coincide with, and heighten, that which the vitriol would produce with the direct aſtringent matter. Accordingly, taking a decoction of galls

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and logwood for the basis, I infused successively in this liquor several different astringents, till at last its colour approached pretty near to blackness. By dissolving in the dark blackish liquor a due quantity of vitriol, I obtained a good ink indeed, but not at all better, so far as could be judged, than if the decoction of galls and logwood only had been used. Perhaps the vitriol, uniting with the properly astringent parts, and thus suppressing some of the component colours of the black infusion, destroyed at once all the blackness which resulted from the combination of the colours.

Instead of the vitriol, or vitriolic solution of iron, I tried saturated solutions of the metal in other acids. With the nitrous and marine acids, the ink was too corrosive, though made as dilute as it could bear to be consistently with a due colour; nor was the colour so true a black as that of the vitriolic ink, the marine acid inclining it to blue, and the nitrous to brownish green. Though the using of vinegar, for dissolving the vitriol, was of advantage to the colour; yet a solution of iron, made in vinegar only, gave a very bad ink. A solution of iron, made by boiling iron filings in water with tartar, and separating the unsatiated tartar by crystallization, &c. produced with galls only a rusty brownish colour. A solution of iron in lemon juice answered better than those in vinegar or tartar, but did not seem to come up to the vitriolic solution.

As the iron of the vitriol, and the astringent matter of the galls, unite together into a new compound, which is the tinging matter of the ink; it may be presumed that the acid, which held the iron dissolved, is extricated, at least in part, and remains loose in the liquor. Suspecting this disengaged acid to be a principal cause of the change of the inks to a rusty colour, I endeavoured to separate it,

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by adding to a black infuſion of vitriol and galls a little quicklime; this earth having the property of imbibing the vitriolic acid, and forming with it a ſelenitic compound, which will not remain diſſolved in the liquor. The ink was far from being anywiſe improved by this addition. A very ſmall quantity of the lime made no ſenſible change in the colour of the liquor; but a larger quantity turned it reddiſh brown, the lime ſeeming to have nearly the ſame effect as alcaline ſalts have. After the writings with theſe mixtures had been expoſed to the ſun and weather about two months, thoſe with the larger proportions of lime could not be read; and thoſe with the ſmalleſt quantities had faded more than the ink by itſelf.

I then endeavoured to ſeparate the acid in another manner. Some good ink was diluted with water, that the colouring matter might ſettle; and the black ſediment was waſhed repeatedly with freſh portions of water, that whatever ſaline matter it contained might be extracted. The black matter thus prepared was mixed with water in which ſome gum arabic had been diſſolved. Writings with this mixture were of great durability: after hanging about four months againſt a ſouth wall, they had contracted no ruſty hue, though they were grown much paler than at firſt, and rather grey than black: perhaps even this change proceeded in part from ſome of the colouring matter being waſhed off by rain. It is the capital imperfection of mixtures of this kind, that after the colouring matter has been ſeparated from the liquor, it cannot be again incorporated with watery fluids near ſo perfectly as it was before in the ink: it can only be diffuſed through the water in a powdery form, as the charcoal powders are, and ſettles from the liquor, and may be waſhed off from paper, almoſt as eaſily.

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The moſt effectual way of preventing any ill effects from this redundant acid ſeems to be by an addition of iron itſelf; part of which, in proportion as the iron of the vitriol is extricated, will be diſſolved in its place, and thus continue both to ſatiate the acid, and ſupply one of the eſſential ingredients of the ink. It ſhould ſeem that in this method, a much leſs proportion of acid, that is, a leſs quantity of vitriol, would ſuffice, than is otherwiſe neceſſary; the ſame acid ſerving to combine with the galls freſh quantities of the iron: and in ſuch caſe, keeping for a length of time, as a year or more, would improve the ink. Of this I have not yet had full experience; but a friend informs me, that he has ſeen writings of more than eighty years ſtanding, which continued of a full black colour, without any tendency to yellow or brown; that the ink was made in the common manner with vitriol and galls, and long kept with pieces of iron in the veſſel. Poſſibly boiling for a little time might anſwer the ſame purpoſe as long keeping; for boiling remarkably promotes the ſeparation of iron from vitriol, and conſequently the action of the acid on freſh iron.

Gum arabic is added to inks, to give a greater conſiſtence to the fluid, and enable it better to keep the colouring matter ſuſpended: it contributes, perhaps, to prevent the black matter from concreting into particles large enough to ſettle by their weight, as well as to prevent or retard their ſettling after they have ſo concreted; for we have ſeen in a foregoing part of this eſſay, that the coalition into ſenſible particles is ſucceſſive, and that before it happens, the black matter is in ſo ſubtile a ſtate, that it may be conſidered as being in actual diſſolution.

The gum appears alſo to be of another advantage, preventing the ink from ſpreading upon the paper, ſo that a greater quantity of the fluid, and conſequently a greater body

body of colour, is collected on each ſtroke. An infuſion of vitriol and galls was mixed with different proportions of common water, and with the ſame proportions of a ſolution of gum arabic in water : all the mixtures with gum water, written with on paper, were at firſt, and ſtill continue, very manifeſtly deeper coloured than thoſe which had been equally diluted with plain water. In an ink which had an over proportion of vitriol, and which, when written with, ſoon loſt its blackneſs and turned to a yellowiſh brown, I diſſolved as much gum as it would bear without becoming too thick to run freely from the pen : the colour was not only deepened, but made greatly more durable; partly perhaps, from the greater quantity of colour in the ſtrokes, and partly from its being in good meaſure defended by the gum from the action of the air.

Gum arabic, gum ſenica, and the plum and cherry tree gums diſſolve in the ink almoſt as eaſily as in pure water. But iſinglaſs, a glue prepared from a kind of fiſh, would not at all mingle with it : when the iſinglaſs was previouſly diſſolved by itſelf in water, and the ſolution poured into an infuſion of the galls only, the fiſh-glue, immediately on mixture, begun to curdle and ſeparate. Solutions of common glue or ſize ſeemed however to mingle uniformly enough with the ink, no ſenſible coagulation or ſeparation enſuing.

Sugar, ſometimes added to inks, is much leſs effectual than gum, either as a coat for defending the colouring matter on the paper, or for preventing its precipitation from the liquor. It even haſtens the precipitation of ſome part of the colour, and is accompanied with another inconvenience, that of making the ink exceeding ſlow of drying. The ſhining hue, which the ſugar communicates, is by no means ſufficient to counterbalance its diſadvantages; and besides, where this quality is desired, an almost equal glossiness may be obtained by means of gum.

I tried likewise to prepare an ink, in which the colouring parts should be secured by a resinous varnish. Here no water could be used, the dissolution of the resin requiring strong spirit of wine; and as this spirit does not dissolve the vitriol of iron, another preparation of the metal became necessary. Iron filings were digested in spirit of salt, with a moderate heat, till the acid would dissolve no more; and the solution being set to evaporate till it became thick, it was in this state diluted with rectified spirit of wine: this preparation is the *tinctura martis in spiritu salis* of the apothecaries. I made a strong tincture of galls in spirit of wine, and dissolved in it as much mastich as it would take up: with this solution poured off clear, I mixed different proportions of the tincture of iron, and obtained bluish-black liquors, of a pretty good blackness when written with, and sufficiently durable, but unfit for the common purposes of ink, on account of their spreading and sinking in the paper, and growing clotty in the pen. Part of the mastich seemed to be precipitated on mixture with the tincture of iron, as resinous bodies generally are with acids; whereas gums dissolve in acids without precipitation.

Instead of the preparation of iron, called green vitriol, some have recommended the blue vitriol of copper, and others the white vitriol of zinc. The white vitriol, though its principal metallic matter be zinc, generally contains also no inconsiderable quantity of iron, and in virtue of this iron it strikes a black with galls. Many blue vitriols also have a mixture of iron with the copper, and in this case they may in like manner strike a black with astringents. To common green vitriol I added different proportions of the pure vitriols both of zinc and copper;

copper: the inks prepared from theſe mixtures were not equal to thoſe made with the green vitriol only. I tried alſo another preparation of copper, verdegris: a ſmall addition of this made the colour of the ink remarkably deeper on firſt writing, but this additional blackneſs did not ſtand, and the colour turned ruſty much ſooner than when no verdegris was uſed. The effect of this ingredient will be further conſidered in the next ſection.

In ſome receipts for ink, the galls are directed not to be powdered, but only bruiſed, or broken into three or four pieces. To ſee if this precaution could be of any advantage, I cut ſome galls into four pieces each, and ſome into bits like large pins heads: another parcel was reduced into pretty fine powder. Equal weights of the three were digeſted for a fortnight, with vitriol and water in equal proportions: the ink from the large pieces was conſiderably paler than the other two, and that from the powdered galls was the deepeſt coloured.

A ſmall wooden caſk, or a ſtone bottle, is commonly choſen for making ink in, and the veſſel is generally kept ſtopt. As air appears to contribute to the deepening of the colour of ink upon paper, the characters not acquiring their full blackneſs till a day or two after writing, it ſeemed probable, that a free admiſſion of air might have a like effect upon the ink in its fluid ſtate, and conſequently that a broad ſhallow open veſſel, and frequent ſtirring, ſo as to expoſe freſh ſurfaces to the air, would contribute to improve the colour, and make the ink flow black from the pen. Accordingly mixtures of galls and vitriol with different proportions of water, were expoſed to the air in flat ſtone-ware diſhes, and ſtirred nine or ten times a day for a month. The liquors wrote blacker than thoſe made from the ſame quantities of the ingredients in cloſe veſſels; but whether the difference

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proceeded only from part of the water having evaporated, ſo that the quantity of liquid was made leſs, or from the inſtrumental efficacy of the air deepening the colour as it does that of ink written with on paper, was not fully apparent from the experiments: probably it depended on both cauſes conjointly.

For obtaining an ink that ſhould write black at once, on many occaſions a very deſirable point, I tried another method, ſimilar to that by which the dyer produces expeditiouſly a deep black on cloth. The dyer firſt boils the aſtringent materials in water for a conſiderable time, and then adds the vitriol and ſlackens the heat, ſo that the liquor may never fully boil after the vitriol is put in. By this way of management, the ink was made to write of a pretty deep colour, much more ſo than thoſe prepared by long continued cold maceration.

It may here be proper to give a caution againſt the uſe of copper veſſels for ink. Mr. Marggraf relates, that when ſolution of pure vitriol of iron is boiled with copper, part of the iron is precipitated in an ochery form, and the liquor becomes ſtrongly impregnated with the copper, which in this diſſolved ſtate, as we have already ſeen, debaſes the colour of ink. I have found that copper is diſſolved alſo by mixtures of vitriol with aſtringents; for having uſed a copper pan in experiments of dying black, related in the following ſection, the liquor, immediately after the addition of the vitriol to the aſtringent decoction, ſhewed plain marks of its having taken up a portion of copper, by giving a coppery ſtain to an iron knife with which it was ſtirred. Mr. Marherr, in an ingenious inaugural diſſertation on the chemical affinities of bodies, printed at Vienna in 1762, gives an obſervation more deciſive of the effects of copper veſſels: when the beſt inks were kept in a copper ink-ſtand, ſo

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much of the copper was diſſolved, that the writings became in a ſhort time as ill-coloured, as if the ink had been of the worſt kind. It is pretty ſingular that the vitriolic acid, in its ſeparation from the iron, ſhould diſſolve a body, on which otherwiſe, in ſo dilute a ſtate, it does not ſeem to have any action. Leaden veſſels are alſo obſerved to be corroded by ink, and debaſe its colour; and probably, except the materials of which ink itſelf is compoſed, all the other bodies, that the vitriolic acid is capable of diſſolving, will be found injurious to ink.

II. *Compoſition of ink, deduced from the experiments.*

The foregoing experiments point out, for the beſt proportions of the ingredients, one part of green vitriol, one of powdered logwood, and three of powdered galls. The beſt menſtuum appears to be vinegar or white wine, though for common uſe water will ſuffice. The quantity of menſtruum admits of great latitude: to make an ink of a full body of colour, it ſhould not exceed a quart, or at moſt three pints, to three ounces of the galls, and one ounce of each of the other two ingredients. The proportion of gum may be varied at diſcretion, according as the ink is wanted to be more or leſs gloſſy or ſhining, or as the nature of the paper may require the fluid to be well gummed to prevent its ſinking: half an ounce to a pint is in moſt caſes ſufficient; though the more gum we can employ, conſiſtently with due freedom of writing, it is probable that the ink will be the more durable.

The ingredients may be all put together at once, in any convenient veſſel, and well ſhaken four or five times a day. In ten or twelve days, and ſooner if ſet in a warm place, the ink will be fit for uſe; though both its colour and durability will be improved by ſtanding longer on the

the undiſſolved ingredients. The ink thus prepared, though it flows pale from the pen, turns to a good black in a day or two after writing.

Or the logwood and galls may be firſt boiled in the liquor for half an hour or more, with the addition of a little more liquor to make up for that which evaporates in the boiling. Strain the decoction while hot, and having put it into the veſſel which the ink is to be kept in, add to it the vitriol and the gum: as ſoon as theſe are diſſolved, the ink may be uſed. By this way of managing the proceſs, we obtain all the advantage of boiling, and the ſeparation of the groſs feculence, without daubing any other veſſels or utenſils than the ink-veſſel itſelf: the ink is expeditiouſly made, and writes of a pretty full colour.

Common pale ink, prepared by cold maceration, may be improved, ſo as to write black at once, by evaporation. It may be ſet in ſuch a heat as will make it viſibly ſteam, not greater; and the heat continued until, on trying the liquor now and then, it is found to be of ſufficient blackneſs. On the ſame principle, when ink is kept in an open ink-ſtand, till it begins to grow ſomewhat thick from the exhalation of part of the watery fluid, it writes as black as can be wiſhed; and when grown too thick to be conveniently written with, it gives blackneſs to a certain quantity of freſh ink. Hence, when we have pale ink to be thus improved, it will be ſufficient, in many caſes, to evaporate to blackneſs only a part of it, and to dilute this occaſionally, as it thickens in the ink-ſtand, with ſome of the reſt, ſtirring them well together after each addition, as the thickened and dilute inks do not very readily unite; if the evaporation was ſuffered to continue till the black matter remained dry, it would ſcarce diſſolve at all in common ink or in water.

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There is another method of giving blacknefs to inks, by the addition of fome of the black pigments formerly mentioned; but the ufe of thefe pigments for writing will make the fubject of another article at the end of this fection.

As the galls and logwood ought to be in pretty fine powder, that their virtue may be more readily and effectually extracted, it is expedient to have the ink feparated from them, as in the fecond of the above proceffes; becaufe otherwife the ink will often be loaded with the finer parts of the powder in fubftance, which being mixed up by fhaking the veffel, remain long fufpended in the liquor. It is proper, however, in order to fecure againft any danger of a deficiency in the aftringent materials, to add to the ink feparated from its feculence, fome galls in coarfe powder freed from the fine duft by a fieve. On the fame principle, an oaken cafk is one of the beft veffels for keeping ink in, this wood having a manifeft aftringency, and anfwering nearly the fame end with the additional galls. Befides the galls, fome pieces of iron may be put into the veffel, as mentioned in page 386.

III. *Of the preparation of the paper for durable writing.*

THE dyers, as we fhall fee hereafter, prepare their cloth for receiving a permanent black colour, by boiling it with galls, that it may be thoroughly penetrated by the aftringent parts of the galls before the vitriol is introduced; fo that wherever the vitriol can reach, it meets with aftringent matter, to unite and produce a black with.

It is obfervable, that writings firft begin to fade or change their colour on the back of the paper, where the larger ftrokes have funk in or are vifible through it; as if part of the irony matter of the vitriol was in a more fubtile or diffolved ftate than the reft, and funk further

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into the paper, on account of its not being fully difengaged from the acid, or fufficiently combined with the aftringent matter of the galls.

Hence it fhould feem probable, that if the paper was impregnated with aftringent matter, the colour of the ink would be more durable; and that therefore a practice fimilar to that of the dyer, would be a valuable addition to the bufinefs of the paper-maker.

To fee how far this notion was well founded, I dipt fome paper in an infufion of galls, and when dry, repeated the dipping a fecond and a third time. On the paper thus prepared, and on fome of the fame paper unprepared, I wrote with different inks; feveral of which, that the effect might be more fenfible, had an over proportion of vitriol. The writings being expofed to the weather, till the beft of the inks on the unprepared paper had faded and changed their colour, thofe on the prepared paper were all found to retain their blacknefs.

It is therefore recommended to the confideration of the paper-makers, whether a particular kind of paper might not be prepared for thofe ufes where the long duration of the writing is of principal importance, by impregnating it with galls, or other aftringents, in fome of the operations which it paffes through before it receives the glazing; as for inftance, by ufing an aftringent infufion, inftead of common water, in the laft operation, when the matter is reduced into a pulp for being formed into fheets. The brownifh hue, which the paper receives from the galling, would not perhaps be any great obftacle to its ufe; and if the propofal fhould be thought worthy of being carried into execution, further enquiries may poffibly difcover means of obviating the imperfection, and communicating aftringency without colour.

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An aſtringent matter might be introduced alſo into parchment and vellum. The common tanned ſkins, as already obſerved, and not only thoſe of the ſofter kind but the firm ſoles of ſhoes, have the very impregnation, which we here propoſe to communicate to the finer ſkins uſed for writing. I ſteeped a thick piece of parchment in water, along with ſome oak bark, for three or four days, and having then preſſed it ſmooth and dried it, I found it as effectually penetrated with the matter which makes ink durable, as the paper in the experiment before mentioned. Even when the ſurface of the parchment was pared off, and the internal part written upon, the characters continued of a good black, while thoſe made with the ſame ink, on unprepared parchment, were changed to a yellowiſh brown.

It may here be obſerved, that an impregnation of paper with one or both of the ingredients of ink, has been ſometimes already practiſed, in a more imperfect manner, and with a view rather to amuſement, than to the anſwering of any uſeful purpoſe. Galls in fine powder being well rubbed into the paper with a hares foot, a ſolution of vitriol, made ſo dilute as to have little or no colour, writes black upon the paper ſo prepared, forming with the galls, in all the parts it touches, an extemporaneous ink upon the ſurface of the paper. If powdered vitriol be firſt rubbed in, the ſame blackneſs is produced by infuſion of galls; and if powdered galls and powdered vitriol be mixed and applied together, both in a very dry ſtate that they may not act upon one another, plain water makes a black writing.

But though practices of this kind ſhould in ſome caſes be convenient; as for making occaſional minutes, in want of ink, with common watery fluids; or for the purpoſe mentioned by Boyle, the keeping of the fingers from being blacked, by uſing colourleſs fluids for writing with; it is plain, that the inks thus produced muſt be in greater danger of fading than thoſe made in the common manner, as the proportions of the ingredients, which form the ink, cannot be aſcertained, and will be different on different parts of the paper. The preparation before recommended depends on a different principle, in regard both to the intention and the means: for here the preparation is only ſuperficial, while there it is diffuſed through the ſubſtance of the paper: the intention here is only the producing of a black colour on the ſurface, by applying a fluid which has no blackneſs, while there the paper is impregnated with the material which is moſt periſhable in ink, in order to continue the blackneſs beyond the period in which that of the ink itſelf would decay.

IV. *Attempts to prepare an ink from more durable materials.*

To introduce into writing the ink whoſe permanence we ſee daily in printed books, appeared ſo deſirable an object, that though there were ſmall hopes of attaining it, its importance ſeemed to deſerve ſome trials.

Printers ink, as we have ſeen in the foregoing ſection, is a thick mixture of lamp black and oil; and ſuch a mixture, though diluted with more oil, is evidently unfit for writing. Inſtead of oil, I mixed both lamp black and ivory black with ſolution of gum arabic, made of ſuch conſiſtence as juſt to flow ſufficiently from the pen. The liquors wrote of a fine black colour, but when dry, part of the colour could be rubbed off, eſpecially in moiſt weather, and a pencil dipt in water waſhed it away entirely.

I tried ſolutions of the animal glues, with the ſame event. Iſinglaſs or fiſh-glue being the moſt difficultly diſſoluble of theſe kinds of bodies, I made a decoction of it

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in water, of ſuch ſtrength, that the liquor concreted into a gelly before it was quite cold: with this gelly, kept fluid by ſufficient heat, I mixed ſome ivory black: characters drawn with this mixture on paper bore rubbing much better than the others, but were diſcharged without much difficulty by a wet pencil.

It was now ſuſpected, that the colour could not be ſufficiently fixed on paper without an oily cement. As oils themſelves are made miſcible with watery fluids by the intervention of gum, I mixed ſome of the ſofter printers varniſh, already deſcribed, with about half its weight of a thick mucilage of gum arabic, working them well together in a mortar, till they united into a ſmooth uniform maſs: this was beaten with lamp black, and ſome water added by little and little, the rubbing being continued, till the mixture was diluted to a due conſiſtence for writing. It wrote freely, and of a full browniſh-black colour: the characters could not be diſcharged by rubing, but water waſhed them out, though not near ſo readily as any of the foregoing. Inſtead of the printers varniſh or boiled oil, I mixed raw linſeed oil in the ſame manner with mucilage and lamp black, and on diluting the mixture with water, obtained an ink not greatly different from the other.

Though theſe oily mixtures anſwered better than thoſe with ſimple gums or glues, it was apprehended that their being diſchargeable by water would render them unfit for the purpoſes intended. The only way of obviating this imperfection appeared to be, by uſing a paper, which ſhould admit the black liquid to ſink a little into its ſubſtance. Accordingly I took ſome of the more ſinking kinds of paper, and common paper made damp as for printing; and had the ſatisfaction to find, that neither the oily nor the ſimple gummy mixtures ſpread upon them ſo much as might have been expected, and that the characters were as fixed as could be desired, for they could not be washed out without rubbing off part of the substance of the paper itself.

All these inks must be now and then stirred or shaken during the time of use, to mix up the black powder, which settles by degrees to the bottom: those with oil must be well shaken also, though not used, once a day, or at least once in three or four days, to keep the oil united with the water and gum; for if once the oil separates, which it is apt to do by standing at rest for some days, it can no longer be mixed with the thin fluid by any agitation. But though this imperfect union of the ingredients renders these inks less fit for general use than those commonly employed, I apprehend there are many occasions, in which these kinds of inconveniences will not be thought to counterbalance the advantage of having writings, which we may be assured will be as lasting as the paper they are written upon. And indeed the inconvenience may be in great measure obviated by using cotton in the ink-stand, which, imbibing the fluid, prevents the separation of the black powder diffused through it.

It has often been remarked, that the inks used in former times were far more durable than those of later years; many modern records being more decayed than the manuscripts of much greater antiquity. Camillo Paderni, in his letters from Herculaneum published in the Philosophical Transactions for the years 1753 and 1754, speaking of the ancient Roman and Greek volumes discovered there, written on the Egyptian papyrus, complains of the paper being so much decayed and rotten, that they have been able to unroll only a few pieces, but makes no complaint of the ink having anywhere faded, all the parts that have been unrolled seeming, from what

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he ſays of them, to be legible enough: in one place he mentions expreſſly the characters being of a very black tincture, exceeding that of the coal to which ſome parts of the paper were reduced. This obſervation occurring to me on reviſing the foregoing experiments, I was induced to look into the Greek and Roman writers, who flouriſhed before the deſtruction of that city, to ſee if any account could be found in them of the ink they made uſe of.

On this enquiry it plainly appeared, that the ancient inks, whoſe great duration we now admire, were no other than ſuch as we have been propoſing in the preſent article. Pliny and Vitruvius expreſſly mention the preparation of ſoot, or what we now call lamp black, and the compoſition of writing ink from lamp black and gum. Dioſcorides is more particular, ſetting down the proportions of the two ingredients, to wit, three ounces of the ſoot to one ounce of gum. It ſeems the mixture was formed into cakes or rolls, which being dried in the ſun, were occaſionally tempered with water, as the cakes of Indian ink are among us for painting. It may be obſerved, that the Indian ink is ſtill the writing as well as the painting ink of the Chineſe. The Chineſe writing indeed is performed in the ſame manner as painting, with a ſtiff hair pencil fixed in the end of a reed: but the Romans uſed a pen, and the inks of this kind are found to anſwer with a pen nearly as well as thoſe now commonly uſed. It might be matter of curioſity at leaſt, and perhaps of utility, for thoſe who have proper opportunities, to enquire more particularly into the preparation of ink in different nations and different ages, and the legibility of the manuſcripts of the reſpective periods.

I have already taken notice, that all the inks, made on the principle we are now ſpeaking of, can be diſcharged by

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waſhing, unleſs the paper admits them to ſink into its ſubſtance. The ancients were not inſenſible of this imperfection, and ſometimes endeavoured to obviate it, according to Pliny, by uſing vinegar, inſtead of water, for tempering the mixture of lamp black and gum. I tried vinegar, and found it to be of ſome advantage, not as giving any improvement to the cement, but by promoting the ſinking of the matter into the paper. As this waſhing out of the ink may be prevented, by uſing a kind of paper eaſy enough to be procured, it is ſcarcely to be conſidered as an imperfection; and indeed, on other kinds of paper, it is an imperfection only ſo far as it may give occaſion to fraud, for none of theſe inks are in danger of being otherwiſe diſcharged than by deſign. The vitriolic inks themſelves, and thoſe of printed books and copper plates, are all diſchargeable; nor can it be expected of the ink maker to render writings ſecure from frauds.

Our experiments and reflections on inks having thus led us back to the practice of the ancients, a further improvement occurred, that of uniting the ancient and modern inks together; or uſing the common vitriolic ink, inſtead of water, for tempering the ancient mixture of gum and lamp black. By this method it ſhould ſeem that the writings would have all the durability of thoſe of former times, with all the advantage that reſults from the vitriolic ink fixing itſelf in the paper. Even where the common vitriolic mixture is depended on for the ink, it may in many caſes be improved by a ſmall addition of the ancient compoſition, or of the common Indian ink which anſwers the ſame purpoſe: when the vitriolic ink is dilute, and flows ſo pale from the pen, that the fine ſtrokes, on firſt writing, are ſcarcely viſible, the addition of a little Indian ink is the readieſt means of giving it the due blackneſs. By this admixture it may be preſumed alſo that the vitriolic ink

ink will be made more durable, the Indian ink in ſome meaſure covering it, and defending it from the action of the air. In all caſes, where Indian ink or other ſimilar compoſitions are employed, cotton ſhould be uſed in the ink-ſtand, as already mentioned, to prevent the ſettling of the black powder.

Though the foregoing enquiries have not attained to the perfection which might be deſired, I flatter myſelf that they will not be found unimportant; that even the unſucceſsful experiments, if they contribute nothing in a philoſophic view, will at leaſt have this uſe, that they will leſſen the labour to others who may engage in the ſame purſuit; that a compoſition of ink has been given, of as black and durable a colour, as there are grounds to believe the materials to be capable of producing; that an improvement has been propoſed in the manufacture of paper, by which the duration of inks will be greatly prolonged; and that means have been pointed out of obtaining, for purpoſes where ſuch duration is required, writings as laſting as the paper itſelf, with fewer inconveniences, than thoſe, which for all occaſions of writing, men acquieſced in for ages without complaint.

SECT. VII.

Of the dying of woollen black.

I. *General obſervations on the black dye.*

THE ingredients from which common writing ink is prepared, green vitriol and aſtringent vegetables, make the baſis of the black dye; the dying of cloth black being no other than the producing of an ink in its pores, or impregnating it with the colouring parts of ink already made. There are, however, ſome variations in the compoſition

poſition of the dying ink if it may be ſo called; mixtures, which prove too periſhable when applied ſuperficially on paper, being of ſufficient durability when introduced into wool or woollen cloth; and mixtures, which make a good black ink on paper, making only a brown in the dyers buſineſs.

2. Cloth is generally ſuppoſed to be weakened by the black dye, more than by any other; on account of the corroſive quality of the vitriol, which is increaſed by the heat made uſe for making it thoroughly penetrate the ſubject: though the vitriol of iron is much leſs corroſive than the ſolutions of the metal made in the nitrous and marine acids, it is reckoned much more ſo than the alum and tartar employed in moſt of the other dyes. The finer the black, the more it is thought to weaken the cloth; inſomuch that ſome writers look upon the beauty of the colour, and its durability or innocence to the cloth, as being incompatible with one another, and hence think it adviſable to abate a little in both points, and to be ſatisfied with a colour of moderate fineneſs that the cloth may be moderately laſting. A German writer on dying, diſtinguiſhed by the approbation of the celebrated Stahl, places this affair in a ſomewhat different light. He obſerves that the vitriol proves corroſive only ſo far as it is not ſaturated with the galls, and that by uſing a proper quantity of galls, it will be mortified, ſo as to be incapable of doing any injury to the cloth: to determine the quantity ſufficient for this complete ſaturation, he directs a decoction of the galls, and a ſolution of the vitriol, to be mixed together in different proportions, and dropt upon white paper, the liquors being made very dilute that their colours may be the better judged of: the proportions, which give the deepeſt black colour, are thoſe which ought to be followed by the dyer, and by which, according to him, the vitriol is made

made harmleſs. The experiments in the foregoing ſection have ſhewn, that about equal parts of galls and vitriol produce the full blackneſs on paper; and our dyers, ſo far as I can find, have generally employed the galls in a proportion not leſs than this, or at leaſt ſupplied their deficiency by a quantity of other aſtringents equivalent in virtue; from whence it ſhould follow, that the common black dye cannot hurt the cloth. In this point I have not myſelf had any fair experience, but am aſſured by a ſkilful and judicious dyer, that black, properly dyed, has by no means the corroſive quality generally attributed to it; and that the rottenneſs or periſhableneſs, often complained of in black cloths, &c. proceeds only from the cloth haveing been damaged before the dying, for black is the dye commonly had recourſe to for damaged and unſaleable pieces, and ſuch as have been ſpoilt in other dyes. Though vitriol, however mortified, be admitted to weaken the cloth, it is pretty clear that black is not the dye which weakens it moſt; for vitriol is uſed for ſome coffee colours, not indeed with quite ſo great a heat but in greater quantity than for the black dye itſelf; and the aquafortis employed in ſcarlets, oranges, and ſome other colours, is certainly more corroſive.

3. For dying black, eſpecially on ſuperfine cloths, it is cuſtomary to give a previous ground of ſome other deep colour; and blue is preferred for this ground, as being one of the moſt innocent dyes in regard to the cloth, and as being of all colours that which has the neareſt affinity to black: common black ink, and the black liquor of the dyer, when diluted largely with ſpring water, appear blue, as if their blackneſs was no other than a concentrated blue. The uſe aſſigned for this blue ground by the writers on dying is, that the cloth, having already a conſiderable body of colour, may require leſs of the blackening

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materials, and consequently be less weakened, than if it was dyed directly from white to black. But there is another more important use of it, the blue being essential to the production of the black dye; for without either a blue ground, or a blue superadded to the vitriol and galls, no other than brown dyes are obtained. There are means, (see hereafter N°. 7.) of introducing this necessary blueness along with the vitriol and astringents; but the colour proves more perishable than when dyed upon a blue ground of indigo or woad.

4. The dyers commonly leave some blue marks at the ends of the cloth, by fixing pieces of lead on them, by which they are secured from the action of the black liquor, to shew that the piece has been regularly dyed on a blue ground, and consequently that the colour may be expected to be durable. This may be discovered, with greater certainty, by steeping a small bit of the black cloth, for a day or two, in water acidulated with a little oil of vitriol; or more expeditiously, by boiling it about a quarter of an hour, in a solution of alum and tartar, made in the proportion of an ounce of each of the salts to a pint of water. Great part of the black matter being destroyed or dissolved by the saline liquors, the cloth will remain of a bluish black colour if it has had a previous blue ground; but if it has been dyed directly from white, it will now look of a muddy reddish brown. The solution of alum and tartar is the essay liquor for black cloths, directed in the new French regulations, which were drawn up from the experiments of Dufay, and published at the end of Hellots *Art de teindre*.

5. Stuffs, whose price will not admit of the blue dye, are said, by the French and German writers, to be grounded with a deep brown, by boiling them with walnut peels, or walnut-tree roots. This practice, as I am

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informed, is never followed by our dyers, who look upon brown as a colour oppoſite to black, and therefore very unfit to ſerve as a ground for it. Whether a brown ground is uſeful or otherwiſe I cannot take upon me abſolutely to determine; but thus much I can affirm, that I have known brown ſtuffs dyed to a black, which was reckoned, by good judges, to look, and to hold its colour in wearing, remarkably well. It ſhould ſeem that any deep colour, which does not hurt the cloth, would be preferable to white; and it may here be proper to obſerve, that all colours whatever receive a black dye, though black will not receive any other; whence black, as already mentioned, is the laſt reſource for cloths that have been damaged or had their colour ſtained or impaired by different accidents.

6. The excellent regulations for the French dyers, drawn up and publiſhed by the order of Mr. Colbert, require the cloth, after it has been blued, to be maddered. In order to fix the colour of madder, the cloth muſt be firſt boiled with alum and tartar; and as theſe ſalts muſt neceſſarily contribute to augment the ill qualities that were ſuppoſed to reſult from the black dye itſelf, and which were endeavoured as much as poſſible to be avoided, it might be thought that the madder was accompanied with ſome conſiderable advantage, ſufficient to counterbalance that inconvenience and the addition which it makes to the expence. It has not been found however, on fair trials, to contribute any thing either to the beauty or duration of the black. Mr. Hellot relates, that haveing dyed a piece of cloth of a deep blue, he maddered one of the halfs, and then dyed both the maddered and unmaddered halfs black in one copper: both turned out of a good black, but the unmaddered, he ſays, was plainly the beſt, the maddered piece having ſomewhat of a rufty

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hue. The beſt way of compariſon is, by placing ſamples of the dyed pieces flat, againſt a full light, that is, with their edges towards the light, and then going back a little, ſo as to look partly down upon them, and partly over the ſurface: this is the way in which the dyers judge of colours. On viewing in this manner ſeveral ſamples of blacks dyed on blue cloth maddered and unmaddered, I could not perceive that they differed greatly from one another, but was convinced, that if the maddered ones are not inferior to the others, they certainly have no advantage above them. In ſome of the old receipts, madder is directed as an ingredient in the black dye itſelf, along with the vitriol and galls; but here it is evidently ſuperfluous, its colour not fixing itſelf in the cloth. Among the reaſons alledged for the uſe of maddering the cloth, there is only one which appears to have any plauſibility, viz. that it prevents the black cloth from ſtaining the ſkin or linen; but all that the madder can do in this reſpect, as Mr. Hellot juſtly obſerves, is, to diſcharge the ſuperfluous blue, and this not in virtue of the madder itſelf, but of the boiling with alum and tartar preparatory to the madder dye. The ſame advantage may be obtained by ſufficiently ſcowering the cloth in the fulling mill after the dye. This is evident from the ſuperfine cloths dyed by our dyers, among whom the injudicious and unfrugal practice of maddering, from ſuch information as I have received, appears to be unknown. They have indeed a colour called madder black, dyed on baize, (a kind of coarſe cloth ſtuff) for Portugal and Spain; but this depends on another principle, as will appear hereafter.

7. Logwood, which as we have ſeen in the foregoing ſection is a very uſeful ingredient in writing ink, is ſtill more ſo in the black dye. Vitriol and galls, in whatever pro-

proportions they are ufed, produce no other than browns of different fhades: I have often been furprifed, that with thefe capital materials of the black dye I never could obtain any true blacknefs in white cloth, and attributed the failure to fome unheeded mifmanagement in the procefs, till I found it to be a known fact among the dyers. Logwood is the material which adds blacknefs to the vitriol and gall brown; and this black dye, though not of the moft durable kind, is the moft common. On blue cloth, a good black may be dyed by vitriol and galls alone; but even here, an addition of logwood contributes not a little to improve the colour.

8. The addition of verdegris, which deepens the colour of the inky liquor, is found alfo to deepen the dye on cloth; and this improved blacknefs, very perifhable in the ink applied on paper, appears in cloth to be more durable, though not entirely fo much as could be wifhed. The effect of the verdegris feems to proceed from its action on the logwood: for with galls, and with green vitriol, feparately, it produced no tendency to blacknefs; but with decoction of logwood it ftruck immediately a deep black, which when diluted appeared of a fine blue. This experiment reconciles two obfervations I have lately met with, one by Mr. Scheffer in the Swedifh Tranfactions, the other by Mr. Hoffmann in a German treatife of œconomical chemiftry, &c. the former of whom relates that logwood with verdegris gives a blue dye, and the latter that it gives a black. Blue is the proper colour of the mixture, and the black is a concentration of the blue. Part of the colouring matter of the mixture concretes very fpeedily into fenfible particles, fo as to look like a black powder diffufed through the liquor: the liquor is found to pafs blue through a filter, and the black matter, which remains on the filter, appears like-

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wiſe merely blue, when ſpread thin on paper, or diluted with white powders.

9. Inſtead of the verdegris, I tried a cheaper preparation of copper, blue vitriol. This had ſomewhat of a like effect, but in a leſs degree: the colour on mixture was leſs black, and the concretion of the colouring parts leſs remarkable: the black or bluiſh-black matter being ſeparated by filtration, the liquor proved not at all blue, but purpliſh or reddiſh, much like a decoction of logwood by itſelf; it ſoon turned to a blue colour when dropt on paper and expoſed to the air, but both the blue and the black were greatly more periſhable than thoſe produced by verdegris.

10. Some have preferred vitriols impregnated with a little copper, as that of Dantzick, to the more purely ferrugineous Engliſh vitriol; not indeed ſuſpecting that the copper would add any thing to the colour, as in the foregoing experiments; but from an opinion of its rendering the vitriol more penetrating or corroſive, ſo as to enable the colouring matter to ſink better into the ſubject. With regard to its adding colour, if the vitriol of copper was even as effectual in this intention as verdegris, which it is very far from being, yet the very ſmall quantity, contained in the vitriols recommended, could be of no material advantage; and as to the penetration, I believe it will be admitted, that vitriol of iron without any copper is penetrating and corroſive rather more than enough. The Dantzick vitriol appears however to have one advantage, not depending on its coppery part, but on the manner of its preparation: greateſt part of the Engliſh vitriol, by haſty cryſtallization, is run into large irregular maſſes, abounding with looſe ochery matter and with watery moiſture, if not with foreign ſubſtances of another kind; while the Dantzick, more ſlowly cryſtallized, is more

pure,

pure, lefs watery and confequently ftronger. The moft perfect vitriol of iron is that which is in the moft folid regular cryftals, of the deepeft green colour; not rufty or yellowifh, from its containing an ochre unfatiated with acid; nor pale, from its being too watery, or holding aluminous or other foreign matter.

11. For producing a black dye on cloth, the cloth is firft impregnated with the aftringent matter, and afterwards paffed through a folution of vitriol mixed alfo with aftringents. If it was firft charged with the vitriolic folution, the colour would not fucceed fo well, and the cloth would be more damaged: if the aftringent and vitriolic liquors were mixed together at firft in one copper, the operation would be prolonged, and feveral repeated dippings would be neceffary for introducing into the fubject a due body of colour. In the dying of great lengths of cloth, where fometimes there is an interval of a quarter of an hour between the paffing of the two ends into the liquor, a little tartar is often added, which does not affect the colour itfelf, but is fuppofed to make the dye take more uniformly, and prevent the cloth from being what the workmen call bloted.

12. If after the cloth has acquired a full black colour, it be again and again paffed through the dying liquor, its colour by no means receives any improvement, but is rather debafed and inclined to brownifh. An overquantity of the ingredients, employed at firft, has a like effect. The lefs quantity of the blackening materials we make ufe of on blue cloth, provided they are fufficient to give full blacknefs, the more durable will the colour be in wearing.

13. The proportions of the ingredients to one another, are regulated on quite other principles than in inks. Equal parts of vitriol and galls feem to be the beft proportions.

portions. If the galls are much increaſed, which it is neceſſary they ſhould be for ink, they make the dye incline to brown; but an increaſe of the vitriol, by which inks are made ſo periſhable, does not appear at all to affect the dye: even the largeſt additions of vitriol, however they may weaken the cloth, do not ſeem to injure the colour.

14. In the dying of black, as of moſt other colours, there are conſiderable variations in the practices of different workmen, which it would be difficult and even uſeleſs to collect. I ſhall here deſcribe two proceſſes, which I have often tried in ſmall, and which appeared to me to be the beſt.

II. *Black with galls, logwood, and vitriol.*

A HUNDRED pounds of woollen cloth, dyed firſt to a deep blue, require, for the black dye, about five pounds of vitriol, five of galls, and thirty of logwood. Theſe, as I am informed by an experienced artiſt, are the quantities generally allowed by our dyers.

The galls, beaten into moderately fine powder and tied up in a bag, are boiled for a little time in a copper of water ſufficient for working the cloth in. The blued cloth, after being ſteeped in river water and drained, that it may be every where thoroughly moiſt, but not ſo as to drip, is in this ſtate put into the boiling decoction of the galls, and kept turning therein for two hours or more, the bag of galls being now and then ſqueezed, that the virtue of this drug may be more effectually extracted and communicated to the cloth.

The logwood, raſped or ſhaved into ſmall chips, or rather ground into powder, is boiled in another copper for ſeveral hours, this wood giving out its colour exceeding difficultly. The logwood liquor is moſt commonly prepared

prepared a confiderable time before it is ufed, its colour being found to improve in keeping.

The logwood decoction being made of a fcalding heat, but not quite boiling, the vitriol is thrown into it, and as foon as this is diffolved, the galled cloth is put in. A boiling heat fhould never be ufed after the addition of the vitriol, not only as it would needlefsly augment the corrofive power of the falt, but likewife as it would injure the beauty of the colour, by haftily extricating part of the ferrugineous matter of the vitriol in an ochery form, before it can come fufficiently in contact with the aftringent fubftance with which the cloth is impregnated. The cloth is inceffantly turned in the liquor that it may receive the colour uniformly, and now and then taken out and aired for a moment, which contributes to fecure the colour, and at the fame time affords an opportunity of judging of its deepnefs.

After about two hours continuance in the dye, the cloth is found to have received a good black, and is then taken out, wafhed with cold water, and paffed through the fulling mill. The fuperfine cloth is three times fulled, with warm folution of foap, which not only difcharges the fuperfluous colour that would otherwife ftain the fkin or linen, but contributes alfo to foften the cloth itfelf by mortifying the acid.

III. *Black dye with verdegris.*

For fome of the fuperfine black cloths, a little verdegris is ufed by our dyers, and this addition appears among the French to be more frequent. Mr. Hellot, after trial of fundry proceffes, gives the following as being the beft, or as that which produces the fineft velvet black on cloth, and which accordingly is followed in the beft dye-houfes in France.

For a hundred pounds of blue cloth; ten pounds of logwood chips, and the ſame quantity of Aleppo galls in powder, are tied up together in a bag, and boiled in a middling copper, with a ſuitable quantity of water, for twelve hours.

One third of this decoction is taken out into another copper, and two pounds of powdered verdegris added to it. In this mixture, kept gently boiling, or rather only ſcalding hot, the cloth is dipt, and turned without ceaſeing, for two hours; after which it is taken out and aired.

Another third of the decoction is laded out into the ſame copper, eight pounds of green vitriol added, and the fire ſlackened about half an hour. The vitriol being now all diſſolved, the cloth is put in and worked for an hour, and then taken out and aired again.

The remaining third of the decoction in the firſt copper is then put to the other two in the ſecond, the bag of galls and logwood being well preſſed out. Fifteen or twenty pounds of ſumach are now added; and as ſoon as the copper begins to boil, two pounds more of vitriol are thrown in, with ſome cold water to ſlacken the heat. The cloth is kept in for an hour, then taken out and aired, dipt a ſecond time, and kept turning for an hour longer.

The cloth, now compleatly dyed, is waſhed in a river, and ſcowered in the fulling mill till the water comes from it colourleſs. It is then paſſed through a copper of weld or woold, prepared as for dying yellow, which is ſuppoſed to ſoften the cloth and confirm the colour.

This proceſs affords a very fine black, but it is too expenſive to be followed by our dyers, the fire, and manual labour of the black dye as here deſcribed amounting to more, as I am informed by a perſon converſant in this buſineſs, than the dyer is paid for the whole dye of the above

above quantity of ſuperfine cloth, including the blue ground. The quantities of vitriol and galls may be diminiſhed, and the time of boiling greatly ſhortened. The paſſing through weld liquor, after ſcowering with ſoap, is entirely unneceſſary; though probably it may be of uſe where the ſcowering is not complied with; not however in virtue of the weld itſelf, but of the alcaline ſalt with which the decoction of it is generally prepared by the dyers, ſo that the weld liquor does no more than ſupply the place of ſoap.

Both in this and the foregoing proceſs, the liquor remains black after the dying of the cloth is finiſhed, and communicates a dilute black, that is a grey colour, to as much freſh cloth as can be conveniently worked in it.

IV. *Method of dying cloth grey.*

The ſimple greys, which are all no other than ſhades of black, are dyed nearly in the ſame manner as the full blacks; only by uſing a leſs proportion of the dying ingredients, or continuing the cloth in the liquor for a ſhorter time.

A decoction of galls and ſolution of vitriol being prepared ſeparately, a little of each of them may be put together at once into a copper of water made ſcalding hot: the liquor becomes black; and cloth, dipt and worked in it, acquires a lighter or deeper grey according to the quantity of the decoction and ſolution employed: By adding more of the liquors with the next parcel of cloth, and thus proceeding ſucceſſively, a ſeries of ſhades may be obtained, from the lighteſt to the darkeſt grey. Or the cloth may be firſt boiled with a proper quantity of galls, and afterwards worked in the ſame liquor, with the addition of more and more vitriol according to the intended depth of colour. The liquor remaining after the dying of full black may be uſed alſo for the dying of greys.

For the quantities of the ingredients, and the time of the cloths continuance in the liquor, no general rule can be given: as they muſt depend upon the degree of colour required, the eye only can be the judge. If the colour happens to be too deep, it may be remedied, in ſome meaſure, by paſſing the cloth through hot water mixed with a little decoction of galls, by which a part of the colour will be carried off. A weak ſolution of alum, tartar, or ſoap, are in this intention much more effectual, but at the ſame time very liable, particularly the two firſt, to exceed in their operation, diſcharging ſo much of the colour, unleſs due care is taken, as to occaſion a neceſſity for re-dying the cloth, which is thus needleſsly weakened by the repeated action of the corroſive liquor. The too great deepneſs of colour may be eaſily prevented, by examining the cloth from time to time, and taking it out as ſoon as it has acquired the due ſhade. It ſhould be immediately waſhed with a large quantity of water, and the very dark ſhades ſhould be ſcowered with ſoap in the ſame manner as the full blacks, to fetch out the ſuperfluous colour, or ſuch as is not fixed in the cloth.

The ſimple greys are dyed from white cloth without any previous ground of blue or other colours. There are alſo a multitude of compound greys and browns, produced from cloth dyed blue, red, yellow, brown, or of colours compounded of theſe, by darkening them with the black dye. The diſtinctions of theſe various ſhades, and the manner of hitting any particular one, practice only can teach.

V. *The dying of wool black.*

THE natural greaſe of wool, of great advantage to it in the warehouſe, as being a ſure preſervative againſt the moth, muſt neceſſarily be removed, before it is attempted to be dyed of any kind of colour: the more perfectly it is cleanſed, the better it will be diſpoſed to receive the dye.

The liquor commonly uſed for the ſcowering of fleece wool is ſaid to be a mixture of ſtale urine with twice or thrice its quantity of water. This mixture being made ſcalding hot, but not boiling, for a boiling heat would felt the wool, or make it run into lumps, ſo much wool, as the copper will conveniently receive, is dipt in it, and turned from time to time with wooden poles, for a quarter of an hour or more: it is then carried in a large baſket into running water, where it is worked by two men, backwards and forwards, one drawing it from under the others pole, till it ceaſes to render the water turbid. The volatile alcaline ſalt, produced in urine by putrefaction, unites with the greaſy matter into a ſoapy compound, which, diſſolving imperfectly in water, continues to give the turbid appearance till it is totally waſhed out. The wool is ſaid to loſe in this proceſs between one fifth and one fourth of its weight.

The wool thus cleanſed is dyed blue, then ſimmered with galls, and the black dye finiſhed with logwood and vitriol; or for a finer black, which however is ſeldom wanted on wool, the above method with verdegris may be followed. The manner of procedure is in all reſpects the ſame with that for dying woollen cloth; and all the obſervations, mentioned under the foregoing articles, are equally applicable here. It is only to be added, that the operations, which wool has to undergo, render the pre-

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venting of harſhneſs of more importance here than in cloth.

VI. *Black dye without galls.*

Of the galls, directed in the foregoing proceſſes, a part is commonly omitted in buſineſs, and ſupplied by cheaper aſtringents, which, being weaker in virtue, are taken in quantity proportionably larger. From the preſent high price of galls I was induced to try whether this expenſive article could not be entirely ſuperſeded. I proceeded exactly according to the French proceſs with verdegris, page 411, only inſtead of the galls taking ſix times as much oak bark, ſuch as the tanners uſe: the cloth, well waſhed with ſoap after the dye, appeared of a black colour, not indeed quite ſo beautiful as that dyed in the ſame manner with galls, yet not a bad one. I tried ſumach alſo, with the ſame event. It appears therefore, that though no effectual ſubſtitute to galls could be found for the purpoſes of making ink, yet cheaper ſubſtances may often be made to ſuffice in the dying buſineſs, where the great conſumption of aſtringent materials renders the reduction of the price of more importance.

In the Swediſh Tranſactions for the year 1753, a fine black is ſaid to be dyed without galls or logwood; the place of both which is ſupplied by a plant common in Sweden, called there *mjœlon* or *mjœlon-ris*, which is gathered in autumn while the leaves continue green, and carefully dried that they may retain their green colour. A hundred pounds of woollen cloth are directed to be boiled with ſixteen pounds of green vitriol and eight pounds of white tartar, for two hours; and the cloth next day to be rinſed out as after the common alum boiling. A hundred and fifty pounds of the dried *mjœlon* cut a little, or a ſomewhat greater quantity if the plant has

has been long kept, are boiled in water for two hours; and the *mjælon* being then taken out, a little madder is put into the liquor. The cloth is put in along with the madder, boiled for an hour and a half or an hour and three quarters, and afterwards rinfed in water. This dye is faid to be ufed chiefly for fine cloth, and to give lefs harfhnefs than the common black.

What the *mjælon* is, we learn from a paper by Linnæus in the fame Tranfactions for the year 1743. He obferves, that about a year before, a leaf called *jackafhapuck* was brought into England from North-America, and mixed with tobacco for fmoaking. Mr. Collinfon favoured him with large fpecimens of it, entitled "the plant Jackafha-"puck which is mixed with tobacco, gathered on "Churchill river in Hudfons bay." This plant, he fays, was eafily known by a Swede, as it grows in Sweden in abundance, on uncultivated gravelly fandy hills. He gives its Swedifh names *mjælon*, *mjælon-ris*, *mjælbærs-ris*; and likewife the latin names under which it is defcribed by different botanic writers, from which it is clear, that the *mjælon* is the fame with the *uva urfi* that has lately come into efteem in Germany for medicinal ufe. Some quantity of the *uva urfi* has been brought from Germany, to be tried as a medicine in this country: the plant is raifed alfo in fome of our botanic gardens, and if the propagation of it fhould be found of any importance, it would doubtlefs thrive on many of our now barren hills.

I have been informed by a foreign correfpondent, that the *uva urfi* is faid to be ufed in England for dying black, and that it is imported for this purpofe from Hudfons bay. I cannot find that this plant, or any other from Hudfons bay, is known among our dyers or dry-falters; but the two foregoing quotations account fufficiently for the report.

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I made trial of the German *uva urſi* both on white and on blue cloth, exactly according to the Swediſh directions; boiling the cloth firſt with vitriol and tartar, and afterwards with a decoction of the *uva urſi:* on the blue cloth I obtained a tolerably good black, but on the white cloth, as with other aſtringents, the colour was only a dark brown. I repeated the experiment without the madder, and with a variation in the order of applying the other ingredients, boiling the cloth firſt in a decoction of the *uva urſi,* and then adding the vitriol and tartar: by this method I obtained, as before, a pretty good black on the blue cloth, but only a brown on the white. I afterwards omitted the tartar alſo, and did not obſerve that the want of it occaſioned any difference in the colour produced. All the ſamples dyed brown with *uva urſi* and vitriol, became black on being paſſed through logwood liquor; but without either logwood or a blue ground, no true blackneſs could be obtained. A dyer, whom I conſulted on this head, made ſome trials for me, on the *uva urſi,* with the ſame event; this plant giving no black dye with vitriol alone, any more than the other aſtringents.

On adding green vitriol to a ſtrong decoction of *uva urſi,* I took notice of a phenomenon which did not happen at all with galls, and which I do not remember to have obſerved, in ſo remarkable a degree, with any of the other ſtrong aſtringents. The liquor, inſtead of the uniform appearance of the common black mixtures of this kind, looked like a black powder diffuſed through water; and being written with on paper, the ſtrokes appeared everywhere unequal and ſpecky, as if made with charcoal powder and water, though they were of a deep and durable black where the colouring matter lay thick. This haſty concretion of the black matter from the liquor, while

while it renders the *uva urfi* entirely unfit for the purpofes of making ink, may poffibly be of fome advantage to it for the black dye; as the largenefs of the colouring particles, which concrete in the pores of the cloth, may render them more fixed, fo that lefs of the colouring matter is wafted in the liquor, and lefs of it can be difcharged from the cloth. To this caufe may perhaps be afcribed a quality of the *uva urfi* dye mentioned by the Swedifh author, that the cloth is cleaner than after the other black dyes, or requires lefs wafhing to free it from the loofe colour.

Among many aftringents I have tried, oak wood came the neareft to the *uva urfi* in this concretion of the colouring matter. A piece of white flannel was boiled firft with oak faw-duft, and afterwards with an addition of vitriol as in the foregoing proceffes. The liquor, as foon as the vitriol was put in, became bluifh-black, though with much lefs bluenefs than the cold infufion of oak-duft and vitriol, page 383: fome of it being poured off into a glafs, it appeared full of powdery matter, which foon fettled to the bottom, leaving the liquor of a pale bluifh. From the blue colour of this mixture it was hoped, that a black dye might be obtained from it without logwood or a blue ground; and in effect the piece of flannel, though it did not acquire a true black, approached more to blacknefs than I remember to have obferved with other aftringents: its colour was a dark grey, without any mixture of blue or brown, like a pure black diluted with a little white. This wood feems therefore to deferve the attention of the dyers: there are grounds to believe that oak faw-duft, or the heart of oak reduced to powder in mills, will be found an aftringent of fufficient efficacy, and fupply with advantage the place of galls: the oak tree doubtlefs contains a matter ſimilar to the galls which are produced from it. Poſſibly by ſome preparation of the oak-duſt, it might be brought nearer to the nature of galls: does not its difference from galls depend on ſome particular juice, more ſoluble than the direct aſtringent matter, and ſeparable by ſlight infuſion in cold water?

VII. *Black dye from a combination of colours.*

In the firſt article of this ſection it has been ſhewn, that the madder dye, required by the French regulations to be applied upon blue cloth as a ground for black, is rather injurious to the colour than of any real advantage. In the experiments which the determination of that point required, a ſomewhat unexpected phenomenon occurred, an account of which was reſerved for this place. A piece of deep blue cloth was boiled in water with alum and tartar, as cuſtomary for preparing cloth to receive the madder dye. The cloth being taken out and ſqueezed a little, ſome powdered madder was boiled in water, in ſuch quantity as to communicate a dark red colour to the liquor. The cloth, ſtill moiſt, was put into this decoction, and a boiling heat continued about half an hour. Being then taken out and waſhed with ſoap, it looked of a very dark colour, ſuch as any perſon would call a black, though not a fine black. Thus we have a kind of black dye, very durable, without any vitriol or other preparation of iron, from a combination of the blue dye with the madder red.

This effect of madder upon blue cloth is well known to the dyers, among whom the colour hence produced is called madder-black. Our black cloths for home conſumption are all dyed with vitriol and aſtringents, either on a ground of woad, which makes the true black, or with an addition of logwood only, in which caſe the

colour

colour being more periſhable is called falſe: but the black baize, which we export to Spain and Portugal, are dyed chiefly of the madder black, a ſpecies of blackneſs which there, it ſeems, is in eſtimation.

If, inſtead of madder, the purer red of cochineal be applied on blue cloth, the colour hence reſulting, is not at all black, but purple. Cochineal, independently of its too great expenſiveneſs for purpoſes of this kind, is too bright a colour to have a place in the compoſition of blackneſs: to change the purple into a colour approaching to black, the addition of other colours is neceſſary, for it is not to be expected that a mixture of ſimple blue and red ſhould produce a black (ſee page 355.) But madder is both a dark and a compound colour, in which an admixture of brown or tawny with the red is very manifeſt. If the madder be ſlightly infuſed in warm water, and afterwards boiled in a freſh quantity of water, the firſt liquor will appear of a pretty good red colour, the other remarkably more dark and browniſh. Hence for dying a good madder red, a boiling heat ſhould be avoided; but for the black dye the madder ought to be well boiled, that the brown as well as the red parts may be extracted.

The madder black might probably be deepened by making it ſtill more compounded, as particularly by the addition of a dark yellow; but any improvement of this kind would be of little advantage to the dyer, who finding the dye already too expenſive, endeavours to imitate it with the cheaper vitriolic black. And indeed, independently of conſiderations of this kind, he is here rather confined to a particular ſhade or ſpecies of colour, which faſhion has brought into eſteem, than ſolicitous about deepening the dye or making it more perfectly black.

SECT. VIII.

Of the dying of ſilk black.

RAW ſilk, in the ſtate in which it is wound off from the cocons, has a harſhneſs which renders it unfit for being ſpun, and for the moſt part a pretty deep yellowiſh or reddiſh-yellow colour, from both which it is cleanſed, by boiling it with ſoap, and afterwards thoroughly waſhing it with ſoft water: when woven, it is again waſhed with ſoap, to free it from the greaſineſs it may have contracted, which would occaſion it to be ſpotted in dying. The ſilk loſes in the boiling generally about a fourth part of its weight: this proportion is aſſigned by the writers on dying, and on enquiry among the workmen, I find it univerſally allowed to be the neareſt calculation. In being dyed black, this loſs is fully made up, the weight of the dyed ſilk being commonly even greater than that of the raw ſilk. There is no dye which adds ſo much to the weight as black: the increaſe is conſiderable in woollen as well as in ſilk, though moſt taken notice of in the latter on account of its great price.

Mr. Macquer obſerves, in his *art de la teinture en ſoie*, publiſhed in 1763, that the fineſt oil ſoap is required for this cleanſing of ſilk; that there is nothing ſaved by uſing the inferior kinds, a proportionably greater quantity of them being neceſſary; that ſome ſorts of ſoap curdle with the matter which they extract from the ſilk, into a ſubſtance almoſt of the conſiſtence of wax; that thoſe, which are made with animal fats, prevent the ſilk from having the proper dryneſs and luſtre, and diſpoſe it to grow reddiſh in keeping; that even the beſt ſoaps are accompanied with ſome imperfections in this reſpect, and that the ſuperiority in luſtre, of the Chineſe ſilks to the

European,

European, is owing to the former being cleanſed without any ſoap. In a French diſſertation on this ſubject, to which a premium was adjudged by the academy of Lyons, in 1761, the ill qualities of ſoap are attributed to its oil, and a ſolution of ſimple alcaline ſalt, made ſo dilute as not to corrode the ſilk itſelf, is recommended in its place: the ſalt of ſoude or bariglia, as being the mildeſt of the alcaline ſalts, is for this purpoſe juſtly preferred to the common more corroſive alcalies. Alcaline ſalts, either in their pure ſtate or made into ſoap with oils, are the only known menſtrua that extract the matter which gives harſhneſs and colour to raw ſilk.

What this matter is, has not been ſufficiently examined. As it is not diſſolved by water, ſpirit of wine, or by acids ſo far diluted as not to deſtroy the ſilk itſelf, Mr. Macquer ſuppoſes it to be either a concrete oily ſubſtance, whoſe oil is of the nature of expreſſed oils; or a compound of oily and gummy matter, ſo proportioned and combined, as to protect one another from the action of their reſpective diſſolvents. Whatever can be ſaid of the compoſition of this matter, may perhaps be ſaid equally of that of ſilk itſelf, which is not an organiſed fibre like wool, but is in its whole ſubſtance a concrete animal juice: naturaliſts obſerve, that on opening the ſilk-worm at a proper ſeaſon, the yellow ſilky juice may be readily diſtinguiſhed, and drawn out into fine flexible filaments. Alcaline ſalts, which when diluted with water, or ſheathed with oil, to a certain degree, are found the proper menſtrua of the harſh and tinging part of raw ſilk, in a purer or leſs dilute ſtate, or by longer boiling, diſſolve alſo the matter on which the tenacity or coheſion of the ſilk depends. Some of the ſpun ſilk called in the ſhops raw ſilk, but which has been boiled with ſoap previous to the ſpinning, and ſuffered the diminution of weight

weight before-mentioned, on being boiled in a ſolution of alcaline ſalt, received a further diminution of two-thirds: another quantity of the ſame ſilk being boiled longer with the alcali, about four-fifths of its weight were taken up by the liquor, which became reddiſh, and the remaining fifth was an incoherent friable maſs, not ill reſembling *papier maché*. It ſhould ſeem from theſe experiments, that even the common proceſs of cleanſing ſilk, in which a fourth of its weight is diſſolved, cannot be entirely innocent, but muſt contribute in ſome degree to diminiſh the ſtrength of the ſilk; and accordingly I find it allowed by the workmen, that a thread of ſilk boiled is not ſo ſtrong as when raw. Some further experiments of the effects of different ſubſtances on raw ſilk are now in hand: if any thing of importance reſults from them, they ſhall be communicated in the appendix to this volume.

Silk is rarely or never dyed of a blue as a preparatory ground for the black dye. The regulations of the French ſilk dyers expreſſly order its being dyed directly from white to black, and this, as I am informed, is the general practice among us, though ſome report that the German ſilk dyers give a brown ground for their black ſilks, by boiling them with the root or bark of the walnut-tree. The only reaſon I have heard aſſigned for the omiſſion of the blue ground on ſilk is, its adding to the expence of a proceſs, which is otherwiſe, as commonly managed, conſiderably more expenſive and troubleſome than the dying of woollen.

Mr. Macquer reckons black a difficult colour to dye on ſilk: and indeed, if all the circumſtances, and materials, of the complex proceſs, which he deſcribes as being followed in many of the good dye-houſes of France, were neceſſary for ſucceeding in the colour, a multitude of

trials

trials muſt undoubtedly have been made, before ſucceſs could have been attained to. But experience has abundantly ſhewn that the caſe is otherwiſe; that the fenugreek ſeed, fleawort ſeed, cummin ſeed, coloquintida, cocculus indus, buckthorn berries, agaric, nitre, ſal ammoniac, ſal gem, litharge, antimony, black-lead, orpiment, corroſive ſublimate, white arſenic, realgar, ſeveral of which are added again and again in different parts of the operation, are entirely ineſſential to the dye, and contribute rather to do harm than good. Mr. Macquer himſelf ſuſpects that ſome of theſe ingredients are unneceſſary; and he has ſubjoined a proceſs followed in the manufacturies of Tours and Gênes, from which we may fairly conclude that they are all ſo; and that a fine black may be dyed on ſilk in as ſimple a method as on wool or woollen cloth, the ſilk requiring only a greater quantity of the ingredients, and a greater number of dippings in the black liquor. The proceſs is as follows.

The ſilk, waſhed with ſoap as above directed, is ſteeped in a decoction of one third its weight of Aleppo or blue galls, or half its weight of the weaker white galls of Sicily and Romania, and afterwards waſhed with water: every twelve ounces are reduced by the cleanſing to nine, which ought to be increaſed by the galling to eleven and not more. The dying liquor, for a hundred pounds of ſilk, is prepared by boiling twenty pounds of galls in a ſufficient quantity of water (about a hundred and twenty ſix gallons) and adding to this decoction, after being ſettled and drawn off from the ſediment, two pounds and a half of Engliſh vitriol, twelve pounds of iron filings, and twenty pounds of the gum of the cherry or plum tree: that the gum may diſſolve the more readily, it is put into a large copper cullender, immerſed in the hot liquor, and ſtirred and worked from time to time with a

wooden

wooden rod till it is all paſſed through. This mixture is kept for ſix or ſeven days or more, a circumſtance ſuppoſed to be neceſſary to its perfection; and being then made as hot as the hand can bear, freſh parcels of the galled ſilk are dipt in it ſucceſſively, and kept in about ten minutes each; and all of them, after being aired, are dipt over again, ſeveral times, with the addition of more vitriol and iron filings, till they have acquired the requiſite blackneſs, after which they are well waſhed in water. It may be obſerved that while five or ſix pounds of galls are ſufficient for a hundred pounds of wool, upwards of fifty pounds of galls are here allowed to the ſame quantity of ſilk; and that logwood, an eſſential ingredient in the black dye on white woollen, is not at all required for ſilk. The quantity of vitriol is not ſpecified.

I tried this proceſs in ſmall, with the exact proportions of each of the articles above ſet down; and by adding more and more of the vitriol, and repeating the dippings thirty times or more, I obtained at laſt a good black. After leſs than half this number of dippings, the ſilk appeared of a beautiful black when taken out of the liquor, but by waſhing it became pale, and in drying it turned always paler. The quantity of vitriol uſed in all was about eight times that preſcribed above to be added at one time, or one fifth of the weight of the ſilk; but the iron filings put in at firſt remaining undiſſolved, it was not thought needful to add any more of this ingredient. I repeated the operation without any iron filings, and could not obſerve that the two blacks differed from one another. I tried it alſo without the gum: there was here a very conſiderable difference in the ſilk as taken out of the dye, that which had been dyed with gum haveing a fine gloſſineſs, which the other wanted: the ſubſequent

ſequent waſhing, however, deſtroyed, as was expected, the gloſſineſs of the gummed ſilk, and reduced them both to the ſame appearance, ſo that the gum ſeemed to be of no manner of advantage: perhaps it is rather of diſſervice than otherwiſe, by thickening the liquor, and making it more difficultly penetrate into the ſilk, in the ſame manner as it renders ink indiſpoſed to ſink into paper. I likewiſe dyed ſome ſilk by the two proceſſes deſcribed in the foregoing ſection for woollen cloth, (page 410 and 411) and obtained by both of them a ruſty black upon white ſilk, and a very good black upon blue: ſo deep a blue as is allowed for the true black on fine woollen cloth, did not appear neceſſary for ſilk; a very ſlight blue ground being here ſufficient to make the black both deep and durable.

It ſhould ſeem therefore that ſilk is not, in any particular manner, more averſe than wool to the receiving of the black dye; and that a good black may be dyed on ſilk, with the ſame materials, in the ſame method, and with the ſame diſpatch, as on wool and woollen cloth; of which a further confirmation will appear at the end of the following ſection. It may be obſerved, that though ſilk takes a ſufficiently good black dye from the method practiſed for fine woollens, yet woollen does not take a black from the proceſs that has been appropriated to ſilk; for ſome pieces of white flannel having been put in along with the white ſilk in one of the trials of the French proceſs above deſcribed, the flannels became only brown, while the ſilk turned out black. Though a black may be dyed on white ſilk without logwood or verdegris, the firſt of which is a neceſſary material for white woollen; yet an addition of both contributes not a little to improve the colour on one as well as on the other.

SECT. IX.

The dying of hats black.

THE Inftructions of Mr. Colbert direct hats to be firft ftrongly galled, by boiling them a long time in a decoction of galls with a little logwood, that the dye may penetrate the better into their fubftance; after which a proper quantity of vitriol and decoction of logwood, with a little verdegris, are added, and the hats continued in this mixture alfo for a confiderable time. They are afterwards to be infufed in a frefh liquor of logwood, galls, vitriol, and verdegris; and where the hats are of great price, or of a hair which difficultly takes the dye, the fame procefs is to be repeated a third time. For obtaining a colour of the utmoft perfection, the hair or wool is ordered to be dyed blue previoufly to its being formed into hats. The prefent practice is more compendious, and affords, as we may daily fee, a very good black. The method of our hatters, as I have been informed, does not differ materially from that of the French, defcribed in the *encyclopedie,* which is as follows.

An hundred pounds of logwood, twelve pounds of gum, and fix pounds of galls, are boiled in a proper quantity of water, for fome hours; after which, about fix pounds of verdegris and ten of green vitriol are added, and the liquor kept juft fimmering, or of a heat a little below boiling. Ten or twelve dozen of hats are immediately put in, each on its block, and kept down by crofs-bars for about an hour and a half: they are then taken out and aired, and the fame number of others put in their room. The two fets of hats are thus dipt and aired alternately, eight times each; the liquor being refrefhed each time

with

with more of the ingredients but in lefs quantity than at firft.

This procefs affords a very good black on woollen and filk ftuffs as well as on hats, as we may fee in the fmall pieces of both kinds which are fometimes dyed by the hatters. The workmen lay great ftrefs upon the verdegris, and affirm that they cannot dye a hat black without it: it were to be wifhed that the ufe of this ingredient was more common in the other branches of the black dye; for the hatters dye, both on filk and woollen, is reckoned a finer black, than what is commonly produced by the woollen or the filk dyer.

SECT. X.

Of the dying of linen and cotton black.

THE black vitriolic dye, though very durable on the fubftances hitherto mentioned, is perifhable on linen and cotton. Pieces of linen and cotton cloth, and fkains of thread, boiled firft with galls, and afterwards infufed and dipt repeatedly in a decoction of logwood with vitriol, received a good black colour; but both the brownifh ftain which the galls communicate, and the blacknefs fuperinduced by the vitriol, were in great meafure difcharged by wafhing with foap; even the rufty colour, which the vitriol of iron gives by itfelf, feeming, in this way of application, to be lefs fixed than if it had been employed without the galls. Steeping the linen for a month, previous to the dye, with galls, and with oak bark, by which method fifhing nets receive from the aftringents a pretty durable ftain, was here of no fervice, the black dye proving equally perifhable.

The dyers of thread follow a procefs fomewhat different from the above. They firft fteep the thread in alum water for ſeveral days; and then dip it repeatedly in the dying liquor, cold, or only lukewarm. The dying liquor conſiſts of the irony and aſtringent matters mixed together; and in the room of, or along with, vitriol, they uſe either filings of iron, or the muddy matter by ſome called ſlipp, found in the troughs of grindſtones where iron tools are ground. The woollen dyers are ſometimes required to dye certain pieces of linen black, and in ſuch caſes they practiſe a method of the ſame kind; ſteeping the piece firſt in alum water for two or three days, and then dying it in their mixed black liquor. By this means the colour is made to hold ſomewhat better; but how periſhable it ſtill is, we may ſee in all black thread.

As the ſtain produced by ſolutions of iron is very fixed on linen and cotton; and as the periſhableneſs of the black dye ſeemed to be owing to the aſtringent matter of the galls not ſufficiently penetrating or uniting with the vegetable fibre, and therefore too eaſily coming off, and carrying the ſuperinduced vitriol with it; I boiled pieces of linen and cotton, firſt in ſolution of vitriol, and afterwards with galls, hoping that the vitriol, fixing itſelf firſt in the cloth, would make the aſtringent matter applied upon it likewiſe fixed. But the event was otherwiſe: the colour did not prove ſo black as when the contrary method of application was followed, and the blackneſs was rather more deſtructible.

The colour of indigo and madder being very durable on linen, it was hoped that a ground of theſe might contribute to fix the black. I therefore made trial of ſundry pieces of red and blue linen, dying them black by the methods already deſcribed. They appeared to have no advantage above thoſe which had been dyed directly from white: the black was as eaſily waſhed out, the blue

pieces

pieces remaining nearly of their original colour, and the red ones a little darker coloured than at firſt.

After many other fruitleſs attempts, with different ſolutions of iron and different intermedia, no probability of ſucceſs appeared to remain, unleſs the vegetable ſubject could be changed as it were in its nature, or impregnated with an animal principle. Accordingly I boiled linen and cotton, previous to the galling, with weak ſolutions of animal glues, but the ſucceſs was no better than before.

In the fourth volume, lately publiſhed, of the Memoirs of the correſpondents of the French Academy of Sciences, M. l'Abbé Mazéas gives a curious diſſertation on the red printed cottons of the Eaſt-Indies; in which he deſcribes a method, practiſed by the Indians, of impregnating their cotton with animal matter in order to its receiving a red ſtain. A ley is made from the aſhes of a certain kind of wood, and with this is mixed ſome ſheeps dung and a quantity of the oil of ſeſamum, in want of which oil, they uſe hogs lard: theſe ingredients ſtirred together, are ſaid to unite into a milky liquid. The cotton is ſteeped in this liquor during the night, and expoſed to the hotteſt ſun during the day for a fortnight. The author above-mentioned ſays he tried this proceſs with the common expreſſed oils, without ſucceſs; but that with hogs lard it ſucceeded perfectly.

On reading the Abbé Mazéas's paper, I immediately ſet about trying, what effect a like preparation would have in regard to the black dye. Here a conſiderable difficulty occurred in making the mixture; for with a ſtrong ley of wood aſhes, or with a ſolution of purified alcaline ſalt, the lard could not be made at all to unite by ſtirring, or even by boiling; the liquor acquired no milkineſs, and the lard floated diſtinct on the ſurface; and

and indeed it was not expected, that a perfect union of this ingredient could be procured without the ufe of the cauftic ley of the foap-boilers prepared with quicklime. The intention, however, being only to obtain a foap made with animal fat, and the common foft foap being fuch a one; I mixed foft foap and fheeps dung well together, three parts of the former to two of the latter, and diluted the mixture with warm water. Some pieces of linen and cotton cloths, and fome fkains of linen thread, were fteeped in this liquid every night, and hung out in the day-time, not indeed in a hot fun, but in all that the month of december laft afforded. The fubjects were then all dyed black, by the fecond of the proceffes defcribed for woollen cloth, page 411; and fome of the fame kind unprepared, were put into the dye along with them. All the pieces being taken out and wafhed, the prepared ones appeared to hold their colour better than the unprepared, though not in fuch a degree as to make the procefs interefting to the workman. From this fhew of fuccefs however, in an unfavourable feafon, the experiment feems worthy of being tried again in more advantageous circumftances.

We have feen in the fecond fection, that linen and cotton are ftained of a lafting black colour by certain vegetable juices; and that thefe juices might probably be obtained in quantity, if not in our own country, yet in certain parts of the Britifh dominions, fome of the trees which afford them being natives of our American fettlements. Till this branch of vegetable curation fhall be eftablifhed, the Britifh artift can receive little benefit from knowing the materials, with which the deep black ftain on the Indian cottons is faid to be fixed.

We have feen alfo, in page 420, that a black colour, or a colour approaching to blacknefs, may be produced

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on woollen cloth, from a combination of two other dyes, viz. by applying a full madder red upon a deep blue ground. Both the blue and the madder red can be fixed upon linen as well as on woollen; and accordingly I tried compounding them on linen in different ways, sometimes applying the red upon the blue, and sometimes the blue upon the red. In ſeveral of theſe experiments the linen, as it came out of the dye, appeared of a good black colour, but on waſhing it, ſo much of the colour was diſcharged, that only a kind of dark purpliſh remained.

Some printed linens and cottons have a durable black ſtain, which, as I am aſſured by a ſkilful and ingenious artiſt, is made with madder and a ſolution of iron. A quantity of iron is put into ſour ſtrong beer; and to promote the diſſolution of the metal, the whole is occaſionally well ſtirred, the liquor at times drawn off, the ruſt beaten off from the iron, and the liquor poured on again: a length of time is required for making the impregnation perfect, the ſolution being reckoned unfit for uſe till it has ſtood at leaſt a twelvemonth. This ſolution ſtains linen yellow, and of different ſhades of buff colour, and is the only known material by which theſe colours can be fixed on linen. The cloth, ſtained deep with the iron liquor, being afterwards boiled with madder, without any other addition, becomes of the dark colour which we ſee on printed linens and cottons, which, if not a perfect black, has a very near reſemblance to it. It is ſubmitted to the conſideration of thoſe whom it may concern, whether this fixt colour would not be preferable, on linen thread, to the periſhable black with which thread has hitherto been dyed. It is probable, that even a better black might thus be dyed on thread, than that which the printer on linen produces: for in this laſt buſineſs, while ſome parts of the linen are ſtained deep with the iron liquor, in order to their being

being made black; others are ſtained paler, with the ſame liquor diluted with water, for making purple; and others, deſigned to be red, are prepared with a ſolution of alum and ſugar of lead: all theſe colours are dyed in one and the ſame copper of madder, with a heat a little below boiling: a boiling heat would give a dark tawney or blackiſh hue to the red, and therefore in this proceſs muſt neceſſarily be avoided; but for the ſame reaſon it would contribute to deepen the black, and therefore ought always to be called in aid where thread, or entire pieces of linen or cotton, are to be dyed of this colour.

SECT. XI.

The ſtaining of Wood, Ivory, Stones, &c. black.

I. *Wood.*

THE ſtaining of wood black, for picture frames, &c. depends on the ſame principle with the black dye in the foregoing ſections. For a deep black, the wood is bruſhed over four or five times with a warm decoction of logwood, and afterwards as often with a decoction of galls, being ſuffered to dry thoroughly between the ſeveral applications of the liquors: thus prepared, it receives a fine deep black colour, from being waſhed over with ſolution of vitriol; in the room of which, ſome uſe a ſolution of iron in vinegar, keeping the vinegar for this purpoſe upon a quantity of the filings of the metal, and pouring off a little as it is wanted. A pretty good black is obtained alſo, more expeditiouſly, by bruſhing over the wood, firſt with the logwood liquor, and afterwards with common ink.

Plumier, in his *Art de tournir*, directs the wood to be previouſly waſhed twice with the ſecond parting water of the

the refiners *(aqua secunda forti separatoria, eau forte seconde)* by which I suppose he means, not aquafortis itself, but the solution of copper in aquafortis remaining after the silver has been precipitated. Washing with aquafortis was found to prevent the production of any black colour on the application of vitriol and astringents, as indeed was expected, this acid liquor destroying the colour of ink already made: a saturated solution of copper in aquafortis appeared to be of no immediate injury, but it appeared also to be of no advantage.

II. *Ivory, bone, horn, &c.*

IVORY, bone, horn, and other solid parts of animals, may be stained black in the same manner as wood. They likewise receive a deep black stain from solution of silver, which should be diluted with water to such a degree, as not sensibly to corrode the subject, and applied two or three times, if necessary, at considerable intervals, the matter being exposed as much as possible to the sun, to hasten the appearance and deepening of the colour: see page 350. Hair also, made perfectly clean, and moistened with the same solution, is changed from a red, grey, or other disagreeable colours, to a brown or deep black: the liquids commonly sold under the name of hair-waters are at bottom no more than solutions of silver, diluted largely with water, with the addition perhaps of other ingredients, which contribute nothing to their efficacy. The solution should be fully saturated with the silver, that there may be no more acid in it than is necessary for holding the metal dissolved; and besides dilution with water, it will be proper to add a little rectified spirit of wine for the further dulcification of the acid. It must be observed, that for diluting the solution, distilled water or pure rain water must always be used; the common spring waters turning it milky, and precipitating a part of the diſſolved ſilver. It is to be obſerved alſo, that if the liquor touches the ſkin, it has the ſame effect thereon as on the matter to be ſtained, changing the part moiſtened with it to an indelible black.

III. *Marble*.

It is difficult to introduce into marble a true black colour. Solution of ſilver ſinks deep into the ſtone, ſometimes an inch or more; but the colour it communicates, at firſt reddiſh or purpliſh, deepens only to a brown. Mr. du Fay, in the Memoirs of the French Academy for the years 1728 and 1732, gives two methods of ſtaining marble of a blue colour, approaching more or leſs to black according to its deepneſs, and not ill reſembling thoſe which are naturally found in ſome marbles: one is with eſſential oil of thyme digeſted in volatile ſpirit of ſal ammoniac, the other with tincture of archel. When the oil of thyme is digeſted with the volatile ſpirit, it becomes firſt yellow, then red, then violet, and at laſt of a deep blue. In ſix weeks digeſtion it had acquired a pale blue, and in this ſtate gave little colour to marble: after ſtanding for ſix months, it was deepened almoſt to a black blue, and being now applied on warm marble, gave the ſtain deſired.

With regard to archel, a tincture of it in water is applied on cold marble, and renewed as it evaporates, till the colour is ſufficiently deep. Though the colour of archel is very periſhable on cloth, yet in marble it appears to be more durable. Mr. du Fay ſays he ſaw pieces of marble ſtained with it, which in two years were not ſenſibly changed. The colour however, though made very deep, is far from being a true black, being rather a dark purpliſh blue.

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The porous marbles, which admit water to ſink into them, I have ſtained of a full black colour with common ink; either by applying on the warm marble an ink already made, or by the alternate application of aſtringent liquors and ſolutions of iron. With the more compact marbles, this did not ſucceed, though they were heated ſo far as to make the liquors boil upon them: in ſome parts the colouring matter ſcarcely penetrated at all; and where it did ſink a little into the ſtone, it was ſo dilute as to appear only purpliſh. The ſpirituous tinctures, deſcribed in page 388, made without the maſtich, ſeemed to penetrate better than the watery infuſions.

On marbles which would not receive the inky matter, I tried the alternate application of ſolutions of lead and of ſulphureous ſolutions, applying ſometimes the one firſt, and ſometimes the other; but could not find that they produced in the ſtone any degree of the black or dark colour which they do on paper. By ſolution of copper, managed as at the end of the following article, and by a ſolution of the metallic part of cobalt in aqua regia, employed in the ſame manner, the moſt compact pieces were ſtained black; though this proceſs requires too great a heat to be practiſed on marble without danger of injuring the ſtone. The colour which ſolutions of gold communicate to marble, in its deep ſhades obtained by repeated applications of the ſolution, approaches very near to black.

IV. *Agate, &c.*

SEVERAL of the hard ſtones, which ſtrike fire with ſteel, receive a dark ſtain inclining to black from ſolution of ſilver. Mr. du Fay relates, in the French Memoirs for 1728, that to chalcedony, this ſolution gave a reddiſh brown colour; to oriental agate, a blacker ſtain; to an agate ſpotted yellow, a purple; to the jade ſtone, a pale brown; to the common emerald, an opake black; to the white parts of the common granite, a violet unequally deep; to ſerpentine ſtone, an olive colour; while the much ſofter ſlates, talks, and amianthus received from it no colour at all. The experiments formerly mentioned, page 350, afford room to ſuſpect, that the ſolution of ſilver ſtains ſtones only in virtue of their containing a calcareous earth, or ſuch an earth as the acid is capable of diſſolving: if this be the caſe, there is little wonder, that ſome of the hard ſtones ſhould be ſtained, and ſome of the ſoft unaffected by it.

Among the hard ſtones that have been tried, the agates ſeem to be thoſe which are acted upon moſt readily: they are thoſe alſo which have ofteneſt been attempted to be ſtained. The ſolution ſhould be made in ſtrong aquafortis or ſpirit of nitre, and fully ſatiated with the metal. The ſtone, after the fluid is applied, ſhould be expoſed to the ſun for two days or more; and if, when dry, it be removed into a moiſt place, and afterwards expoſed again to the ſun, the production of the colour will be the more ſpeedy. After the ſtone has acquired the full colour which the firſt quantity of the ſolution can communicate, it may be moiſtened with more, and this repeated two or three times, by which the colour will be deepened, and made to penetrate further: Mr. du Fay found that an agate about a ſixth part of an inch in thickneſs, by applying the ſolution on both ſides, may be ſtained throughout its whole ſubſtance. The tincture, however, is rarely uniform, on theſe or other ſtones; moſt of them having veins, which, though indiſcernable in the natural ſtone, are in this proceſs made apparent, being more eaſily or more difficultly penetrable than the reſt of the maſs, and ſometimes forming not inelegant varieties in the ſtained ſtone.

Mr.

Mr. du Fay obſerves, that though ſtones may without much difficulty be ſtained by ſolution of ſilver, yet it is ſcarcely poſſible to form very neat deſigns on them, on account of the ſpreading of the liquid; and that this imperfection appears to be the leſs, according as the ſolution is the more ſaturated, ſo as to dry or cryſtallize the more ſpeedily. An eaſy method of obviating this inconvenience is ſuggeſted by the practice of the engraver; for the means, by which he confines the aquafortis on his copper plates to the minuteſt ſtrokes, would doubtleſs anſwer the ſame intention here. The ſurface of the ſtone being coated with a proper tenacious ſubſtance which the acid cannot act upon, as the compoſition called etching wax, which conſiſts of reſinous ſubſtances melted with wax or boiled with oil to a due conſiſtence, and the drawing being made on this ground, ſo that each ſtroke may reach down to the ſtone, it may be preſumed that the ſolution of ſilver, afterwards applied, will nowhere ſpread further than the parts thus laid bare.

The ſtones thus coloured by art differ from the natural in two remarkable properties of the colouring matter. The natural colours reſiſt moderate heat, by which the artificial are in great part deſtroyed. The natural ſtones, ſteeped for ſeveral hours in aquafortis, ſuffer no apparent change; whilſt thoſe, which have been coloured by art, almoſt entirely loſe their colour. It is obſervable that the colour deſtroyed by aquafortis is reſtored again by expoſing the ſtone to the ſun: but that the colour deſtroyed by fire cannot be recovered without a freſh application of the colouring ſolution.

There is another method of ſtaining ſtones, of a colour more truly black than that which the ſolution of ſilver communicates to moſt of them, and with this further difference, that the colour being produced by fire, I have

not

not found that either moderate fire or aquafortis will deſtroy it. Pieces of different ſtones, marbles, pebbles, flint, &c. were waſhed over with a ſaturated ſolution of copper made in aquafortis: when dry they were put into a crucible, and kept for a little time in a fire juſt ſufficient to make the veſſel almoſt red hot. All of them were ſtained, in the parts which had been moiſtened with the ſolution, of a black colour, durable and pretty deep, though it had penetrated only a very little way into the ſubſtance of the ſtones.

When the ſmooth ſurface of an agate, or other ſtones not diſſolvible in aquafortis, is moiſtened with the copper ſolution; if a ſmall iron nail be ſet upright on its head in the middle, the iron abſorbs the acid from the copper, and the copper, now ſeparating from the fluid, ſhoots into fine ramifications like the branches of trees or ſhrubs, generally of a very elegant appearance. If the nail be then removed, and the corroded iron carefully waſhed off by dipping the ſtone in water, the vegetations may be changed by heat to the ſame black colour as the ſimple ſolution of copper in the foregoing experiments, ſo as greatly to reſemble the figures naturally found in certain ſtones, as that called the Mocho ſtone. The colour is not indeed fixed on the ſtone, like that reſulting from the ſolution of copper alone; but a plate of cryſtal laid over it in the manner of a doublet, conceals this imperfection. The only difficulty in this operation conſiſts in the waſhing, in which great dexterity is requiſite, to ſeparate the corroded iron, which would give a ruſty ſtain, without waſhing off or diſordering the fine vegetations of the copper.

SECT.

SECT. XII.

Black glaſs and enamel.

THERE is a ſpecies of blackneſs, as we have formerly ſeen, which reſults, in certain circumſtances, from the ſimple deepneſs or concentration of other colours. Thus many vegetable juices and infuſions, yellow, reddiſh, blue, &c. on being evaporated to the thick conſiſtence of an extract, look black; and theſe black maſſes, when ſpread thin or diluted with water, exhibit again the original colours of the liquors. Something of the ſame kind ſeems to happen in glaſs and enamel. Smalt or zaffre, which in a certain proportion give a blue colour to vitreous bodies, if employed in a larger quantity make them black. Manganeſe, which in a little quantity gives a purpliſh tinge, in a large one gives a black. Preparations of iron, whoſe colour in glaſs, in a dilute ſtate, is ſometimes yellow and ſometimes greeniſh or bluiſh, are always of a dark brown or black when the glaſs is over-doſed with them: hence many of the ferrugineous earths and ſtones melt into a black glaſs, as the coloured clays, ſeveral ſlates, and the ſtone called whynn-ſtone, with which ſome of the ſtreets of London have been lately paved. Black glaſſes or enamels made on this principle have however, like the concentrated vegetable liquids, one imperfection; that though of a deep black colour when in maſſes of any conſiderable thickneſs, yet when ſpread thin they always betray ſome of the original colour, or of the particular hue which they would have if the colouring matter was in leſs quantity. The moſt perfect black is obtained by adding a mixture of two or more of the above darkening materials: inſtead of taking colourleſs glaſs or enamel for the baſis, it will be of advantage to uſe fragments of different

ferent coloured pieces; and compoſitions which have been ſpoilt, in trying to tinge them of other colours, anſwer as well for this purpoſe as any.

The common black glaſs, of which beads are made for necklaces, &c. is coloured, as I am informed, with manganeſe only; hence when powdered it looks of a dirty purple colour. The manganeſe perhaps increaſes the fuſibility of the glaſs, for an ingenious friend obſerves, that in making impreſſions in different kinds of glaſs, he has found this black ſort to be by far the moſt fuſible of any. That there is a ſtrong action between the manganeſe and the glaſs may be preſumed from the great effervescence which happens on melting them together. One part of manganeſe is ſufficient to give a black colour to near twenty of glaſs.

The enamellers require a black more perfect than that which manganeſe alone can produce, and employ, as I am informed by an experienced artiſt, a mixture of manganeſe, zaffre, and ſcales of iron. Theſe ingredients may be mixed together in equal quantities, and one part of the mixture added to fifteen or twenty of the baſis of enamels; which baſis is prepared by calcining a mixture of about equal parts of lead and tin, and melting this calx with equal its quantity of fritt or powdered glaſs.

VII. History of PLATINA.

IN the beginning of the year 1749, there was brought into England, from Jamaica, a quantity of a white metallic ſubſtance in grains, ſcarcely known before to Europe, ſaid to be the produce of the Spaniſh Weſt-Indies, and there called *Platina, Platina di Pinto,* or *del Pinto,* and *Juan blanco.*

The name *Platina* ſeems to be a diminutive of *plata,* ſilver, and conſequently to expreſs the moſt obvious appearance of this body, that of a ſilver-coloured metal in ſmall grains. From its being called platina *of Pinto,* it may be ſuppoſed that Pinto is the name of ſome particular ſpot or diſtrict which affords it: I have not met with this name in any accounts I have ſeen of Spaniſh America, but Mr. Cronſtedt, in an eſſay for a new mineral Syſtem, lately publiſhed in Sweden, ſpeaking of platina in the courſe of his ſyſtem, calls the place it is brought from Rio di Pinto. Its other appellation, *Juan blanco,* aroſe perhaps from ſome frauds which had been practiſed with it, from the difficulty of ſeparating the gold naturally intermingled with it, or from its refractorineſs in the hands of the workman; for as in our own country a duſky coloured mock-ore, that is, a mineral which has the appearance of a metallic ore, but does not in the uſual ways of trial yield any metal, is commonly called *black-jack*; the Spaniards may in like manner have given the name *white jack, white rogue, white mock metal,* to this ſingular metallic body, which though of the true metallic aſpect and weight, and in ſome degree malleable, had eluded all their attempts for ſmelting or running it down.

Mr. Charles Wood, aſſay-maſter in Jamaica, had ſeen ſome platina in that iſland eight or nine years before it was imported here. He ſays it was brought thither from Carthagena; that the Spaniards have a way of caſting it into different kinds of toys; that theſe toys are very common in the Spaniſh Weſt-Indies; that ſome pounds of the metal were bought at Carthagena for leſs than an equal weight of ſilver, and that it was formerly ſold at a much lower price. He gave ſome ſpecimens of it to Dr. Brownrigg, who in 1750 preſented them to the Royal Society.

The ſeeming inconſiſtency between this account and the foregoing, in regard to the fuſibility of platina, was eaſily reconciled by examining Mr. Woods ſpecimens. Some of them were of the true platina in grains, called native or mineral platina, which we have very good grounds to believe the Spaniards have never been able to melt. But there was one of an actual caſt metal, a piece of the pummel of a ſword. A part of this was ſent to me for trial; and I was afterwards favoured with a large piece of an ingot of the ſame kind of metal, by the right honourable the earl of Macclesfield, the late worthy preſident of the Royal Society. This metal was found to melt with great eaſe, and was apparently not true platina, but a compoſition of it with ſome other metallic bodies. As the compound metal has been frequently confounded with the platina itſelf, and called by the ſame name, ſome conſiderable errors have hence ariſen in regard to the properties of the platina, which will be occaſionally taken notice of in the courſe of our experiments. It is ſufficient here to have obſerved, that the caſt metal differs materially from the true platina which makes the object of the preſent hiſtory.

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The platina ſoon engaged the attention both of philoſophers and metallurgiſts, on account of its agreement, in ſome remarkable particulars, with gold. From this relation to gold, it was called by ſome *white gold*. Hence alſo many people were induced to think, that it was at bottom no other than gold, diſguiſed by a coat of ſome extraneous matter; and it was hoped that means might be diſcovered of diveſting it of this coat, and laying bare the gold which it was ſuppoſed to conceal. But the more it was examined, the more did this notion ſeem improbable; and the more grounds were found for believing, that platina is a metal of a peculiar kind, diſtinct in nature from gold, as well as from the other metals, though endowed with ſuch properties, as had hitherto been ſuppoſed to be characteriſtic of gold, or to be poſſeſſed by gold alone; inſomuch that this new metal was reported to have been ſometimes fraudulently mixed with gold, in conſiderable quantity, without being either ſeparable, or diſtinguiſhable, by any of the common methods in which gold is aſſayed or refined.

A full examination of ſuch a body appeared of the utmoſt importance, as regarding not only the diſcovery of the various properties of the platina itſelf, an object ſufficiently intereſting, but likewiſe, what is much more ſo, the preventing the abuſes which it was liable to give occaſion to, and the ſecuring the fineneſs and value of the precious metal; ſo that if the platina ſhould not be rendered an uſeful commodity, it might at leaſt be no longer a dangerous one.

I had begun this examination in the year 1749, but could not then procure enough of the platina for carrying the experiments to ſuch a length as I aimed at; for a metal ſo extraordinary, entirely new, at leaſt to this part of the world, of which only a few general properties were

 known,

known, and thefe but partially and imperfectly, deferved to be fubmitted to all the kinds of operations that are practifed on the other metals, and to all the agents by which other metals are found to be affected. In the beginning of the year 1754, his excellency general Wall, at that time ambaffador from Spain, enabled me to proceed in the experiments, by fending me about an hundred ounces; and I was afterwards favoured with confiderable quantities more by fome other gentlemen. The moft ingenious and experienced chemifts in Europe, as foon as they could obtain any of the new metal, entered into the fame purfuits; and feveral of thefe enquiries have from time to time been made publick.

The firft publication I have feen on this fubject is that of Mr. Wood, in the 44th volume of the Philofophical Tranfactions, for the years 1749 and 1750. To the hiftorical obfervations, of which an abftract has been given above, Mr. Wood fubjoins a few experiments, made partly, as may be prefumed from their event, on the true platina in grains, and partly on the caft metal; one of which experiments, the cupellation of the caft metal with lead, was afterwards repeated, more circumfpectly, by Dr. Brownrigg.

In the 48th volume of the Tranfactions, part 2d, for the year 1754, is inferted an account of the principal experiments which had been then made on the platina by me. They are divided into four papers, which are followed in the next volume by two papers more.

On the publication of the firft four, I was informed that Mr. Scheffer alfo had given an examination of this metal in the *Handlingar* of the Swedifh academy of fciences for the year 1752. Thofe books being difficultly procurable in this country, and written in a language which I did not underftand, it was fome time before I could

could avail myſelf of his enquiries, which I found to be curious and intereſting, and carried, though not ſo far as could be wiſhed, yet much further than could have been expected, conſidering that for his principal experiments he had only a hundred grains of the crude mineral, from which he could pick out but forty grains of the platina to work upon, and that he had no previous notice of its poſſeſſing any remarkable properties, but looked upon it at firſt as being only an iron mineral; he afterwards indeed obtained ſome more, but it was only ſuch another little quantity. Theſe experiments were made by the encouragement of Mr. aſſeſſor Rudenſchœld, who has lately informed me, in a letter from Stockholm, that he brought the platina from Spain in the year 1745, nearly four years before it was known in England. In one of the following volumes of the Swediſh *Handlingar*, there is another paper by the ſame gentleman, containing obſervations on ſome parts of mine, concerning the ſpecific gravities of mixtures of platina with other metallic bodies.

A French tranſlation of all the papers above-mentioned, except the laſt of Mr Scheffers and the two laſt of mine, which had not come to the tranſlators knowledge, was publiſhed at Paris in 1758, under the title of *la platine, l'or blanc,* ou *l'huitieme métal:* to this treatiſe is added an extract of a letter from Venice, relating to what may be called the alchemical hiſtory of platina, not containing any new facts, but ſome reflections drawn from mine.

Profeſſor Marggraf, of the academy of ſciences at Berlin, having obtained a quantity of platina from London, made a large ſet of experiments upon it, repeating and further proſecuting ſeveral of mine, and adding many new ones. Theſe appeared firſt in a French tranſlation, among the *Mémoires* of the Berlin academy for the year 1757, printed in 1759: they have ſince been publiſhed, more

more correctly, in the original German, in the firſt volume of a collection of his chemical writings, the continuation of which is earneſtly wiſhed for.

In the *Mémoires* of the academy of Paris for 1758, printed in 1763, there is a paper on this metal by Mr. Macquer and Mr. Baumé conjointly; who, beſides repeating and varying ſome of my experiments, and drawing from them ſome new conſequences, have expoſed the platina to an agent which the other enquirers have not had opportunities of doing, a large burning concave. Their platina, in quantity a pound, was ſent to them from Madrid.

The foregoing are the only writers I know of, who have treated expreſsly and experimentally on platina. Some others have mentioned it occaſionally, as particularly Mr. Cronſtedt and Mr. Vogel, in their new mineral ſyſtems. The former has in general given a very juſt account of it; but the latter appears to me to be a little miſtaken in ſome points, which will be further taken notice of in their places.

Since the publication of my experiments in the Tranſactions, I have at times been adding others, and endeavouring to aſcertain ſome properties of platina which before had been too ſlightly examined. Nothing now is ſo much wanted, in regard to this extraordinary metal, as a regular hiſtory of what has already been done, or a connected view of the experiments that have been made upon it. Such a hiſtory I ſhall here attempt, quoting every where the authors of ſuch facts as are not taken from my own diaries, and, where any doubts ariſe on comparing the different accounts, making new trials.

SECT. I.

Of the general properties of platina confidered by itfelf, or independent of its difpofition to unite or not unite with other bodies.

I. *Defcription of Platina.*

PLATINA in grains, as brought into England, is of a fhining whitifh colour, fomewhat approaching to that of filver, but lefs white: from this refemblance, which becomes much greater when the platina has paffed through certain operations, it probably, as already taken notice, received its name. Mr. Macquer refembles its colour to that of coarfe iron filings unrufted, but all I have feen was a good deal whiter than any iron filings: this difference from iron is mentioned alfo exprefsly by Mr. Scheffer, for while he had no fufpicion of the platina being a new diftinct metal, he fays it feemed to be iron which by fome accident had been made externally white. Mr. Marggraf calls the colour white inclining a little to that of lead.

The colour of platina is not tarnifhed or altered, fo far as I have obferved, by air or moifture, or by any exhalations that are commonly diffufed through the atmofphere: it refifts vapours which difcolour filver, and appears equally permanent with that of pure gold.

The grains are of various fizes: fome few are as large as linfeed, but moft of them a good deal fmaller. Their figure alfo is various and irregular: fome approach to a triangular, others rather to a circular form: moft of them are flat, none globular, and few of any great convexity: the furface is fmooth, with the edges and angles generally rounded off. On viewing them with a microfcope, the

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ſurface appeared in ſome parts uneven: the prominencies looked bright and poliſhed; the cavities dark coloured and roughiſh, as if they were ſprinkled with a powdery matter. A few of the grains were attracted, though very weakly, by a magnetic bar.

II. *Subſtances mixed with the native platina.*

WITH the grains of platina, above deſcribed, ſeveral heterogeneous matters are intermingled; ſome of which are in ſmall particles or duſt, ſeparable by a fine ſieve; others larger, ſo as to be diſtinguiſhed by the eye and picked out. Theſe ſubſtances, in the different parcels of platina which I examined, were the following.

1. A conſiderable quantity of blackiſh duſt, which appeared to conſiſt of two diſſimilar ſubſtances; a part of it being attracted vigorouſly by a magnetic bar, and a part not attracted at all. The part attracted is of a deep ſparkling black colour, much reſembling the black ſand from Virginia: the reſt is of a browniſh hue, and has ſeveral bright particles intermixed, which appear to be fragments of the grains of platina itſelf. It is probable that the roughneſs and dark colour of the cavities of the grains of platina, and the magnetic quality of ſome of the grains, proceed from ſome portion of theſe extraneous powders adhering in them.

2. Among the larger grains of platina, ſeparated by means of a coarſe ſieve, were obſerved ſundry irregular dark-coloured particles, ſome blackiſh, others with a caſt of browniſh-red, in appearance reſembling fragments of emery or loadſtone. Some of theſe were attracted by the magnet, very weakly, and others not at all. The unmagnetic duſt of the preceding paragraph ſeems to be only ſmaller fragments of this laſt kind of matter.

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3. There were ſome rough yellow particles, very malleable, which appeared to be gold, though not free from a mixture of platina. A further examination of theſe golden particles will be given hereafter. Their quantity differs in different parcels of the mineral: twelve ounces of the richeſt that has come to my hands being diligently picked, with the aſſiſtance of a magnifying glaſs, the grains partly or entirely yellow amounted to about two pennyweights, or one part on a hundred and twenty of the mixt.

4. A few globules of quickſilver containing gold, with ſome particles of platina intermixed and pretty ſtrongly adhering. Mr. Marggraf likewiſe obſerved ſome quickſilver among the platina which he examined, having been induced to look for it with attention, by finding, that when an ounce of platina had been urged with a ſtrong fire in a glaſs retort, a little true running mercury came over into the receiver. The yielding of quickſilver and containing ſome magnetic parts, the former of which is particularly mentioned in the firſt of my papers in the Philoſophical Tranſactions, and the latter not only there, but by all thoſe I know of who have given any experimental account of platina, are ranked by Vogel among the new properties of this mineral diſcovered by Marggraf.

5. Some fine colourleſs tranſparent particles, which were hard to break under the hammer, and were not ſenſibly acted upon by aquafortis. Theſe are probably fragments of the hard kind of ſtone, which frequently inveſts ores in mines, and in which native gold is ofteneſt found lodged, called by the Germans *quartz*, but which has not, that I know of, received any diſtinctive Engliſh name.

6. A very few irregular particles of a jet black colour. Theſe broke very eaſily, and looked like the finer ſorts of

pitcoal: laid on a red hot iron, they emitted a yellowish smoke, and smelt like burning coal.

The foregoing observations afford some room to suspect, that this mineral has not come to us in its native form, but has probably been ground in mills, and worked with quicksilver, in order to extract the particles of gold intermixed with it. But its mineral history will be considered more particularly after we have gone through the history of the experiments, as some points cannot till then be sufficiently understood. It is here only to be well attended to, that all these matters are entirely adventitious to the platina; that their quantities are very variable, and that one or more of them, in some parcels, seem to be altogether wanting, the magnetic or ferrugineous matter being always the most considerable, and possibly the only constant admixture.

III. *Specific Gravity of Platina.*

THE mineral called platina being, as we have before seen, a mixture of very dissimilar matters not uniformly blended, I weighed hydrostatically several different parcels, taking sometimes four or five ounces for one experiment, and in one twelve ounces. In most of the trials, the gravity turned out, to that of water, very nearly as 17 to 1: it was never less than 16,500, nor greater than 17,200. The gravity of platina was examined also by Dr. Pemberton and Mr. Ellicott, who both reported it to be about 17. The late Mr. Sparkes informed me, that a specimen which he made trial of turned out but 16; and Dr. Davies, that he weighed a parcel whose gravity was found to be 17,233.

To come as near as might be to the specific weight of the pure platina, I separated a quantity of the larger grains by a coarse sieve, and endeavoured to cleanse them from the dust that might adhere, by boiling them in aquafortis, mixing them with sal ammoniac and forcing off the salt

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by fire, and afterwards waſhing them with water. The gravity of theſe was found on many trials to be upwards of 18, though the microſcope ſtill diſcovered a portion of blackiſh matter in their cavities. Fahrenheits thermometer ſtanding at the fortieth degree, a quantity of theſe grains which weighed 642 in air, weighed in diſtilled water $606\frac{3}{4}$, whence the ſpecific gravity comes out 18,213. It was doubtleſs the larger and purer grains that Mr. Marggraf examined, when he makes the gravity of platina to that of gold as $18\frac{1}{2}$ to 19.

The remarkable weight of platina appears to have been the principal inducement for believing that it is rich in gold, and is ſtill inſiſted on by many as a proof of its being ſo, agreeably to the general axiom already taken notice of in the hiſtory of gold, which, having long been univerſally received, men cannot eaſily think to be erroneous, that as mercury, among the bodies hitherto known, is the next in weight to gold, all bodies heavier than mercury, whoſe gravity is about 14, muſt therefore neceſſarily partake of gold. Accordingly it has been affirmed that a twentieth, a tenth, and ſome have gone ſo far as to pretend that a fourth part of platina is true gold, the reſt being a ferrugineous matter enveloping the gold.

But if we ſuppoſe platina to contain even this laſt quantity of gold, I apprehend that the ſame difficulty will ſtill remain, and that the axiom will be as effectually overturned as if we ſuppoſe it to contain none. If the matter mixed with the gold in platina is ferrugineous, its ſpecific gravity cannot be admitted to be more than 8, for pure iron itſelf does not come up to that weight. Now if 8 parts of this matter loſe 1 in water, 3,0000 parts will loſe ,3750; and 1,0000 parts of gold, the gravity of this metal being about 19,300, will loſe ,0518; ſo that 4,0000 parts of the compound will loſe ,4268; whence, dividing 4,0000

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by ,4268, we have 9,372 for the gravity of the compound. The gravity of platina ſhould be no more than this, if its compoſition was ſuch as is ſuppoſed; ſo that one part of gold, wrapt up in three of ferrugineous matter, is very far from accounting for the great weight of the mineral. To make the gravity 17, the quantity of gold ought to be 10 parts in 11 of the maſs.

If it be ſuppoſed that the matter mixed with the gold is not iron, but ſomething of a heavier kind, let us inveſtigate what its weight muſt be. If gold be blended with three times its weight of another matter, and the gravity of the mixt be 17; then $4\frac{1}{4}$ parts of gold, and $12\frac{3}{4}$ of the other matter, will together loſe 1 in water: the $4\frac{1}{4}$ or 4,25 of gold loſe ,22 in water, ſo that the 12,75 of the other matter muſt loſe ,78, whence the gravity of this laſt comes out above 16. If platina therefore be ſuppoſed to contain gold becauſe it approaches to gold in ſpecific weight, we muſt ſtill admit that there is a ſubſtance which does the ſame though it contains no gold.

To this way of reaſoning the degraded gold of Mr. Boyle has been objected; which however does not ſeem to me at all to affect the argument. For in Boyles proceſs, of which an account has been already given in the hiſtory of gold, page 206 of this volume, the gravity of the gold, by the mixture of an inconſiderable quantity of foreign matter, was diminiſhed between a fifth and a ſixth part, probably from accidental cavities in the maſs; whereas here, according to the ſuppoſition we have been ſpeaking of, the gravity of the compound, inſtead of being diminiſhed, is increaſed almoſt to double of what it ought to be. There may indeed be ſome variation of gravity from the mixture of two bodies with one another, but of ſuch an increaſe as this I believe it will not be pretended that there is any inſtance. The great weight of platina therefore, inſtead

of

of being a proof of its containing gold, affords rather a preſumption of its being a ponderous body diſtinct from gold.

IV. *Malleability of Platina.*

Some of the purer grains of platina, by gentle ſtrokes of a flat hammer upon a ſmooth anvil, bore to be extended into thin plates, without breaking or cracking about the edges: ſome cracked before they had been much flattened, and diſcovered internally a cloſe granulated texture: others were ſo brittle as to be reduced, without much difficulty, into powder. Even the tougher ones ſoon broke from rude blows in an iron mortar; and they ſeemed all to be more brittle when red hot than when cold.

Mr. Scheffer, in his little quantity of platina, did not take notice that the grains differed in toughneſs: the particles he tried having been of the more malleable kind, he makes platina in general to be as malleable a metal as the beſt iron. Mr. Macquer ſeems alſo to have tried only a ſingle grain: he ſays he took one of the largeſt of the grains, and having beaten it with moderate ſtrokes on a ſteel anvil, he found that it ſuffered itſelf to be flattened into a pretty thin plate, which however cracked upon continuing the beating. But Mr. Marggraf examined ſeveral grains, and obſerved the ſame difference in their malleability as I had done: ſome ſtretched conſiderably; others but a little, breaking from a few blows; whilſt others bore to be extended into pretty thin plates: he takes notice that theſe laſt were moſtly the convex grains.

Upon the whole, as many of the grains are apparently of conſiderable malleability, and as the brittleneſs of the others proceeds doubtleſs from ſome accidental cauſe, we can by no means refuſe platina the title of a malleable metal; though little advantage can reſult from this property, unleſs means ſhould be found of uniting the grains into larger maſſes.

V. *Platina expoſed to the fire in veſſels.*

1. An ounce of platina, containing its uſual admixture of magnetic duſt, was kept for ſome time of a moderate red heat in an iron ladle. The white grains became dark coloured, and almoſt loſt their metallic brightneſs; and the magnet ſeemed no longer to attract any part of the mixt: in other reſpects no alteration was obſerved.

2. Several ounces of platina, freed from the black duſt, and in which no yellow particles could be ſeen, were heated to a ſtrong red heat, and quenched in urine. The platina, as before, loſt its brightneſs: many of the grains looked blackiſh, others of a ruſty or reddiſh brown, and ſome of a high yellow colour; which laſt proved more malleable than platina, and appeared to be in great part gold. Surpriſed at this event, and imagining at firſt, agreeably to the common opinion, that the platina had ſuffered a decompoſition, or been diveſted of its coat, I repeated the ignition and extinction upwards of thirty times, quenching the matter ſometimes in urine, and ſometimes in ſolution of ſal ammoniac and other ſaline liquors: the platina continued ſtill of the dark colour which it had contracted at firſt, and no more golden grains could be perceived. On examining the remainder of the packet of platina, the gold, which the firſt ignition had exhibited, was eaſily accounted for: the particles of gold, naturally intermingled among the platina, were covered with quickſilver, which had doubtleſs been added with a view to extract them; and the quickſilver, evaporating in the fire, had left the gold of its proper aſpect. It is poſſible that others may have been impoſed upon by the like appearances, and thought they had produced gold from the ſubſtance of the platina itſelf, when they had only collected the golden grains, which ought to be looked upon as entirely adventitious.

3. The

3. The platina, difcoloured by the two foregoing experiments, was put into a crucible, which was covered, and kept for half an hour in a pretty ftrong fire, fufficient for the melting of caft iron. The platina loft the ill colour which it had contracted in a weaker heat, and became brighter and whiter than it had been at firft. The grains ftuck together, fo as to come out of the crucible in one lump; but they readily fell afunder again on a flight blow, and did not appear to have at all melted, or altered their fhape.

4. Some of this brightened platina, kept in a moderate red heat for an hour, contracted a dark colour as before; and being afterwards urged haftily with a ftrong fire, it became again bright, almoft like filver. I tried the malleability of feveral of the grains, both when difcoloured and when brightened by fire, and found that in both ftates, as in the crude mineral, fome bore to be confiderably extended, while others cracked or broke from a blow or two of the hammer.

5. I proceeded to try the effect of greater degrees of heat, having fitted up for this purpofe a blaft-furnace or forge with two pair of large bellows. An ounce of platina, in a black-lead crucible, was urged in this furnace with a fea-coal fire, for more than an hour. The heat was fo vehement, that the crucible in great part vitrefied; and the flip of Windfor brick which it was covered with, though defended by a thin coating of Sturbridge clay, as alfo the internal parts of the furnace oppofite to the bellowfes, melted and run down. The grains of platina remained unmelted, being only fuperficially united into a lump of the figure of the bottom of the crucible: their colour was a good deal brighter and more filvery than at firft; and they feemed to cohere more firmly than thofe which had undergone the weaker heat in No. 3.

6. The

6. The foregoing experiment was many times repeated; in different kinds of crucibles, both German and Engliſh; with fires of charcoal, of common ſea-coal, and of ſea-coal coaked or charred. In the moſt intenſe fires I was able to excite, ſuch as neither the beſt of the crucibles, nor the furnace, could long ſupport, the platina did not appear to melt, or ſoften, or alter its figure. I ſometimes indeed obtained a few globular drops, of the ſize of ſmall ſhot, of ſmooth ſurfaces, which broke eaſily on the anvil, and looked internally grey: theſe drops had evidently been melted, but it is probable that they were not pure platina, and that the fuſion was owing to an admixture of the ferruginеous part of the mineral, or of the golden grains: for when the purer picked grains of platina were employed, there was never any appearance of melted particles; and thoſe parcels of the mineral which had once yielded ſome melted drops, could never be made to afford more, though urged with fires at leaſt as vehement as the firſt time. The coheſion of the grains of platina ſeemed to begin in a moderately ſtrong red heat, and to become firmer and firmer as the fire was made more violent, though I never found them cohere ſo much as to reſiſt a ſmall blow of a hammer. The colour, after ſtrong fire, was almoſt always bright and white, except on the ſurface of the maſs, which was often changed to a dark browniſh, with ſometimes a faint yellowiſh tinge: in one experiment, the metal, when violently heated, having been quenched in cold water, the grains which compoſed the internal part of the lump acquired a violet or purple colour.

7. I picked out ſome of the larger and brighter particles of platina, to the weight of about fifty grains, and ſpread them on the bottom of a ſmooth crucible: the veſſel being covered, and kept in a vehement fire, as in the above experiments, for about an hour, the platina cohered but

ſlightly,

ſlightly, and being laid again in the balance, it rather outweighed its former counterpoiſe which had been left in the ſcale. From this experiment, which was two or three times repeated with the ſame event, I concluded, in the firſt paper, publiſhed in the Philoſophical Tranſactions, that platina does not loſe of its weight in the fire: Mr. Marggraf and Mr. Macquer have ſince found, that it not only does not loſe, but really gains weight, and that when the fire is long continued, the gain is very conſiderable.

8. Mr. Marggraf put two ounces of crude platina in a ſcorifying diſh under a muffle, and kept up a ſtrong fire for two hours, ſtirring the platina at times with an iron rod. He obſerved that no fumes aroſe; that when grown cold, the metal looked like ſhavings of lead run together, but blacker and without metallic luſtre; and that its weight was not diminiſhed but increaſed, for it weighed two ounces and ten grains, or one part in ninety-ſix more than it did at firſt.

9. He repeated the experiment with one ounce of platina, in a covered crucible, placed on a proper ſupport, in a melting furnace, which, by means of a long pipe for conveying in the air under the aſh pit, and a long narrow chimney on the top, gives the ſtrongeſt fire of all the furnaces in his elaboratory. The fire being kept up in its greateſt vehemence between three and four hours, the platina was found ſticking together but not melted, and weighed five or nearer ſix grains, that is near one part in eighty, more than at firſt. He takes notice that the grains were pretty eaſily ſeparated by a blow of a hammer; that thoſe in the internal part of the lump were whiter than at firſt, but that they were ſtill in their original form; and that ſome of them bore to be flattened on the anvil.

10. Mr. Macquer put an ounce of platina into a German crucible, and expofed it to a ftrong fire for fifty hours, in a furnace whofe heat, when continued for fuch a time, was capable of melting the mixtures which Mr. Pott fays, in his *lithogeognofia*, yielded him glaffes the moft hard and the leaft fufible. On examining the platina after this trial, he found that it had not melted, and that the grains only ftuck together fo as to form one mafs, which had exactly the figure of the bottom of the crucible, and which had fhrunk from the veffel fo as to come freely out; that all the furface of the mafs was tarnifhed and blackened, and changed to a flate colour, with a diminution of the metallic brilliancy; that the internal part of the crucible, where the platina had touched it, was tinged as if filings of iron had been calcined in it; and that on weighing the platina after the operation, it was found increafed fourteen grains, which amount (the French ounce confifting of five hundred and feventy-fix grains) to about one part in forty-one. The fame platina, fubmitted to another operation fimilar to the foregoing, received a further increafe of two grains, the augmentation in all being fixteen grains, or one part in thirty-fix. There could be no fufpicion, he fays, of any coals or afhes falling in, becaufe the crucible was in a part of the furnace where fuch matters could have no accefs, and becaufe it was alfo clofely covered, though not luted. As the increafe was inconfiderable in the fecond operation, he judges there would have been little or none on a third repetition. We may add, that fince after fifty hours ftrong fire, a further continuance of heat occafioned ftill a very fenfible augmentation of weight, the difference between the refult of this experiment and Mr. Marggrafs, in regard to the quantity of the augmentation, may be eafily accounted for, from the different lengths of time that the fires were continued.

11. It

11. It is well known to the chemifts, that the metals called imperfect, or thofe which calcine in the fire, gain weight in their calcination; a phenomenon not a little aftonifhing, and of which they have not been able to affign any probable caufe, unlefs it be the abforption of air. As platina appears plainly, from many of its properties, not to be one of the imperfect metals, Mr. Macquer very juftly fufpects, that the increafe of weight in the above experiments was owing to the calcination of fome heterogeneous fubftances mixed with the platina. The ferruginous lining which it left in the crucible, and the obfcuration of the colour, feemed to confirm this conjecture, and he further took notice, that after the fecond calcination there were fome grains of a friable matter like fcales of iron, and that the magnetic fand was no longer black and brilliant, but of the fame flate grey colour with the platina. It may here be obferved, that if there was no miftake in Mr. Macquers weights, the quantity of this heterogeneous calcinable matter muft be very confiderable. Of all the experiments I can recollect of the calcination of bodies, there is no one in which the increafe was fo great as that which Mr. Scheffer allows to iron, viz. one third of its weight, as we fhall fee hereafter in the fixth fection of this hiftory: admitting even this augmentation to the calcinable matter in platina, the quantity of this matter, to produce an augmentation of fixteen grains on the ounce, muft be forty-eight grains, or one eleventh part of the platina.

12. The obfervations in the foregoing paragraph account for the difference between my experiments No. 7, and thofe of M. Marggraf and Macquer in No, 8, 9, and 10; mine having been made with the purer grains, and theirs with the entire mineral containing its common mixture of calcinable parts. For further fatisfaction in this point, I

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took 360 grains of the larger and brighter particles picked out from platina, and the ſame quantity of the blackiſh duſt ſeparated from it by a ſieve: the two parcels, in two ſmooth ſcorifying diſhes, were kept under a muffle, in a very ſtrong heat, for five hours; and that both of them might undergo an heat as equal as poſſible, the places of the two diſhes were interchanged about the middle of the proceſs. When cold, the picked platina, weighed with great exactneſs, was found to have gained two grains, or one part in a hundred and eighty; while the duſt was increaſed near nine grains, or one part in forty. It was obſerved that the picked platina had become darker coloured than it was at firſt, but the duſt paler; and that the picked platina cohered very ſlightly, but the duſt was agglutinated into a firm cake not eaſily to be broken between the fingers. It muſt be obſerved that what is here called duſt contains a conſiderable proportion of true platina, divided into particles as fine as thoſe of the impure matter; and conſequently that the quantity of impure matter in the picked platina cannot be judged of from the proportional augmentations which the two parcels received in the fire. But we ſhall here drop an enquiry, which does not ſeem important enough to deſerve the trouble of any further proſecution, eſpecially as we ſhall hereafter find means of attacking theſe calcinable parts more effectually than by ſimple heat.

13. The experiments I had made (No. 5 and 6 of this article) ſeem to prove, that platina cannot be brought into fuſion in the common crucibles, by any heat that the veſſels themſelves can ſupport. Mr. Scheffer concludes alſo from his trials, that to melt it in a crucible is impoſſible, ſince it reſiſts even a ſtronger fire, than that which vitrefies the beſt crucibles made of Waldenburg earth and quartz, which we may ſuppoſe, from this manner of ſpeak-

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ing of them, to be of a very good kind. Neverthelefs, as the melting of platina, if it could be effected, would be a moft important acquifition in regard to its chemical hiftory and mechanic ufes, Mr. Macquer made fome further trials with this view. He expofed platina to the fire of a glafshoufe furnace for five days and five nights, but without perceiving any other alterations than thofe already mentioned: and indeed the glafshoufe fire could not be expected to fubdue this refractory metal, which had already refifted fires much greater than the glafshoufe furnace can produce, and greater than its materials or veffels can fupport.

14. For the laft effort, Mr. Macquer had recourfe to a forge, increafing the activity of the fire by an expedient fimilar to that which we have formerly mentioned in page 26 of the prefent work. The blaft from the bellows was divided into two pipes, which entered the furnace at two oppofite fides; and two other great bellowfes were fo difpofed, that their blafts entered oppofitely at the other two fides. Four ounces of platina, in a Heffian crucible, being placed in the middle of the furnace, the fire was excited by the bellowfes to fuch a degree, that in lefs than an hour and a quarter, all the internal part of the furnace melted and run towards the bottom, forming in the lower part maffes of glafs, which, ftopping up the orifices of the blaft-pipes, made it neceffary to difcontinue the experiment: the crucible, which was all vitrefied, being taken out fome time after, appeared ftill of fo dazzling a whitenefs that the eye could not fupport its luftre: yet notwithftanding this extreme fire which the platina had fuffered, it was no more melted than in the foregoing experiments; except that in the vitrifications, which furrounded the crucible, there were found fome grains, of a filver whitenefs, perfectly round, which appeared to have had

had a very good fuſion, but which, from a ſmall blow of a hammer upon a ſteel anvil, fell into powder. Mr. Macquer appears therefore, in this utmoſt effort, to have produced no other effects than thoſe which I had obtained; and his trials concur with the others in proving, that the beſt of the common furnaces, and melting veſſels, will themſelves melt ſooner than the platina included in them.

VI. *Platina expoſed to the fire in contact with the burning fuel.*

As the power of fire, upon metallic as well as earthy bodies, is remarkably promoted by the immediate contact of the burning fuel, and the impulſe of air upon the ſubject, platina was expoſed to its action in thoſe circumſtances. Mr. Scheffer ſeems to regret that he had not ſome pounds of the metal for a trial of this kind, but the proceſs may be managed in ſuch a manner, that a very little quantity can be made to ſuffice.

A crucible, having a bed of charcoal in it, was laid on its ſide among the fuel, in a good blaſt-furnace, with its mouth towards the noſe of the bellows; and on the charcoal were ſpread four ounces of platina. The fire was vehemently urged for above an hour; during which an intenſe white flame paſſed through the crucible, and iſſued at an aperture made for that purpoſe in the end. Great part of the crucible was vitrefied; but the grains of platina only ſuperficially cohered and became brighter, without ſeeming to have at all ſoftened or altered their ſhape.

The experiment was ſeveral times repeated and varied: common ſalt, whoſe fumes promote the vitrification of the crucibles themſelves, was thrown on the fuel before the mouth of the veſſel, and its fumes ſtrongly impelled upon the platina: the lumps of platina which had undergone the preceding operations, were dropt, before the noſe of the bellows, into violently-excited charcoal and ſea-coal

fires,

fires, ſo ſtrong as almoſt inſtantly to melt off a piece of the end of the forged iron rod with which the fuel was at times ſtirred down. The platina ſtill came out unmelted, and unaltered in its form; except that there were ſometimes a few globular drops like thoſe mentioned in the preceding article.

VII. *Platina expoſed to a burning glaſs.*

After all theſe fruitleſs attempts for the melting of platina, no other reſource remains, for determining its fuſibility or non-fuſibility, than the action of large burning glaſſes or concaves; a trial which I have often regretted that I could not in this country find means of expoſing it to. What has earneſtly been wiſhed for by all thoſe, whom profit, curioſity, or ſcience, have intereſted in theſe kinds of purſuits, Mr. Macquer and Mr. Baumé have endeavoured to ſupply.

They uſed a concave of plate glaſs, well ſilvered, twenty two inches in diameter, and of twenty-eight inches focus. Before they proceeded to try its effects on platina, they expoſed to its action ſeveral other bodies, that ſome judgement might be formed of its force.

Black flint, powdered to prevent its crackling and flying about, and ſecured in a large piece of charcoal, bubbled up, and run into a tranſparent glaſs in leſs than half a minute. Heſſian crucibles, and glaſshouſe pots, vitrefied completely in three or four ſeconds. Forged iron ſmoked, melted, boiled, and changed into a vitreſcent ſcoria, as ſoon as it was expoſed to the focus. The gypſum of Montmartre, when the flat ſides of the plates or leaves, of which it is compoſed, were preſented to the glaſs, did not ſhew the leaſt diſpoſition to melt; but on preſenting a tranſverſe ſection of it, or the edges of the plates, it melted in an inſtant, with a hiſſing noiſe, into a browniſh-yellow

matter.

matter. Calcareous ſtones did not completely melt; but there was detached from them a circle, more compact than the reſt of the maſs, and of the ſize of the focus; the ſeparation of which ſeemed to be occaſioned by the ſhrinking of the matter which had begun to enter into fuſion. The white calx of antimony, commonly called diaphoretic antimony, melted better than the calcareous ſtones, and changed into an opake, pretty gloſſy ſubſtance, like white enamel.

They obſerve that the whiteneſs of the calcareous ſtones and the antimonial calx are of great diſadvantage to their fuſion, by reflecting great part of the ſuns rays, ſo that the ſubject cannot undergo the full activity of the heat thrown upon it by the burning-glaſs: that the caſe is the ſame with metallic bodies, which melt ſo much the more difficultly in the focus, as they are the more white and poliſhed: that this difference is ſo remarkable, that in the focus of the concave whoſe effects we have been ſpeaking of, ſo fuſible a metal as ſilver, when its ſurface was poliſhed, did not melt at all: and that the whiteneſs of platina would doubtleſs in like manner have greatly weakened the action of the concave on it. Meſſ. Macquer and Baumé therefore took the platina which they had before kept five days in a glaſshouſe furnace, and which, while it had concreted into a lump large enough to be held in the focus, had at the ſame time become tarniſhed and browned on the ſurface, ſo as to be in a ſtate the moſt favourable for the experiment. Their account of the experiment itſelf is as follows.

" When the platina begun to feel the activity of the focus, it looked of a dazzling whiteneſs: from time to time there iſſued from it fiery ſparks, and there aroſe a fume, very ſenſible, and even pretty conſiderable: in fine it entered into a true and good fuſion, but it was not till the

the end of a minute and a half that this fuſion took place. We melted it in this manner in five or ſix parts: none of the melted parts however run to the ground, all of them remaining fixed to the piece of platina, probably becauſe they ſet and hardened aſſoon as they were no longer in the center of the focus. Theſe melted parts were diſtinguiſhed from the reſt, by a ſilver brilliancy, and a rounded ſurface, ſhining and poliſhed. We ſtruck the largeſt of theſe melted maſſes upon a ſteel anvil, to examine its ductility: it flattened eaſily, and was reduced into a very thin plate, without breaking or cracking in the leaſt; inſomuch, that it appeared to us infinitely more malleable than the grains of platina are in their natural ſtate, and that we believed it might be extended into as thin plates as gold and ſilver. This platina grew hard and rigid under the ſtrokes of the hammer, as gold, ſilver, and other metals do: this rigidity was eaſily deſtroyed by the method practiſed for gold and ſilver, that is, by heating it to a white heat and letting it cool." Mr. Baumé, in his *manuel de chymie*, printed in 1763, takes notice of another property of the platina thus melted; that it is found to be of a ſpecific weight approaching *(ſemblable)* to that of gold: on this, however, we can lay but little ſtreſs, as he had ſaid before, in ſpeaking of the crude grains of platina, that their ſpecific weight is equal *(égale)* to that of gold.

The above experiment, though not a little curious and intereſting, is by no means entirely ſatisfactory; and it were to be wiſhed that ſome further trials were made, with burning-glaſſes of greater force, for aſcertaining with more preciſion the real fuſion of the platina, and for obtaining ſome quantity of the melted metal, that its ductility, gravity, hardneſs, and other properties, may be more ſatisfactorily examined. Thus much ſeems clear from the experiment, that platina is a great deal more difficult of fusion than flint, and flint a great deal more so than gypsum; and as no means have been found of pushing common fire to such a height, as to produce either in flint or gypsum the least appearance of fusion, without the concurrence of the saline or earthy parts of the fuel, which serve as a flux for those bodies, though not for platina; there appears no room to hope, as the author seems to do towards the end of his memoir, that we shall ever be able to melt platina in great furnaces. It follows also, that the melted drops, which both Mr. Macquer and I obtained in our furnaces, could not be pure platina: for though it is not to be thought that our fires were of equal intensity with that to which the platina was here exposed, our drops had suffered a more perfect fusion, than those parts appear to have done that were melted in the focus of the burning-glass: the drops likewise had nothing of the malleability, which platina melted by the burning-glass is said to possess in so remarkable a degree, but on the contrary fell in powder under the hammer. If the fusion in one case was brought about by the mixture of some foreign metallic matter with the platina, we cannot be certain but in the other also the same cause may have concurred in a less degree; and consequently it is possible that pure platina may require for its fusion a heat still more vehement.

From the experiments related in this section I think it may be concluded, that platina is a silver-coloured metal, of considerable ductility, not fusible by the strongest fires, that can be excited in the furnaces, or sustained by the vessels, of the chemist or the workman; that it approaches to gold in one of the reputedly most discriminating characters of that metal, specific weight; and that it agrees with gold and silver in being fixt and uncalcinable by fire.

SECT.

SECT. II.

Of the action of Acids on Platina.

I. *Platina with the Vitriolic acid.*

SEVERAL parcels of the purer grains of platina were digefted for fome hours in a gentle heat, with the concentrated fpirit called oil of vitriol, and with the fame fpirit diluted with different proportions of water. No folution happened, nor any alteration either in the liquors or the metal.

2. Three ounces of ftrong oil of vitriol were boiled with one ounce of platina, in a tall narrow-necked glafs, for fome hours. The liquor remained nearly of the fame quantity as at firft, and no change could be perceived either in it or in the platina.

3. The glafs being cut off a little above the furface of the liquid, the fire was gradually increafed, till the liquor, which now begun to evaporate freely, had, in five or fix hours, wholly exhaled, and left the platina dry and red hot. The metal, when grown cold, being wafhed with water and afterwards dried, its weight was found to be the fame as at firft, and the furface of the grains fhewed no mark of corrofion. The only alteration obferved was, that many of the grains had become dull coloured and brownifh; an effect which, as we have already feen, fimple heat produces, and which therefore muft not be imputed to the action of the body fuperadded, when a heat fufficient to produce it is employed at the fame time.

It appears therefore, that platina refifts the pure vitriolic acid, which, by one or other of the above methods of application, diffolves or corrodes every other known metallic body except gold.

II. *Platina with the Marine acid.*

1. Weak and ſtrong ſpirits of ſalt being digeſted ſeparately with one third their weight of platina, in a gentle heat, for ſeveral hours, the liquors remained uncoloured, and the platina unaltered. The heat was afterwards increaſed, and the liquors kept ſtrongly boiling till they had totally exhaled, without making any ſenſible change in the platina.

2. When common ſalt is ſtrongly heated, in mixture with certain vitriolic ſubſtances, its acid, forced out by the vitriolic acid, and reſolved into fumes by the heat, corrodes ſome metallic bodies, on which, in its liquid ſtate, it has no action. Two parts of decrepitated or dried ſea ſalt were therefore mixed with three parts of green vitriol calcined to redneſs; three ounces of the mixture preſſed ſmooth into a cementing pot; one ounce of platina ſpread evenly upon the ſurface, and ſome more of the mixture over it; the veſſel cloſely covered and luted, and kept in a moderate red heat for twelve hours. On examining it when grown cold, the ſaline mixture was found to have melted, and formed a ſmooth uniform maſs. The platina, which had ſunk to the bottom, being ſeparated from the mixture by waſhing, appeared to have ſuffered no change, though its weight was a little diminiſhed.

3. The experiment was repeated with a leſs fuſible mixture, called the regal cement, compoſed of one part of common ſalt, one of colcothar, or vitriol ſtrongly calcined, and four of powdered red bricks. An ounce of platina, ſurrounded as above with ſix ounces of this compoſition, and cemented in a cloſe veſſel, with a red heat, for twenty hours, ſuffered no material change, though there was, as before, ſome deficiency in the weight. Many of the grains were diſcoloured; whereas, in the foregoing experiment

periment they were all nearly as bright and white as at firſt, on account, perhaps, of the mixture having melted, ſo as to waſh and cleanſe their ſurfaces.

4. Of the other metallic bodies, gold is the only one which reſiſts the marine acid in the above way of application. As the platina in theſe experiments had no mark of diſſolution, it was preſumed that this metal likewiſe had reſiſted it; and that the deficiency in weight was owing to ſome of the ſmaller grains having been waſhed off along with the ponderous metallic matter of the vitriol. The experiment was therefore varied, by ſubſtituting, to the foregoing mixtures, mercury-ſublimate, a combination of the concentrated marine acid with quickſilver: when this compound is mixed with any one of the common metals, gold excepted, and the mixture expoſed to a proper heat, the quickſilver ſeparates and exhales, while the acid unites with the metal. An ounce of platina was ſpread upon three ounces of powdered ſublimate in a glaſs veſſel, which being ſet in a moderate ſand heat, the ſublimate totally aroſe, leaving the platina of its original weight, and uncorroded, though diſcoloured a little.

5. As the action of ſublimate on bodies depends not only on the acid being capable of corroding them, but on its having a ſtronger affinity to them than it has to the mercury, that is, a diſpoſition to unite with them in preference to the mercury; it is poſſible that there may be bodies, really corroſible by the acid, but which, having leſs affinity to it than mercury has, will of conſequence reſiſt the action of ſublimate. The regal cement was therefore again had recourſe to, but that none of the grains of platina might be in danger of being loſt, twice their weight of gold was melted with them, and the mixture carefully hammered into a thin plate. A piece of the plate, weighing fifty grains, was ſurrounded with

regal

regal cement, the crucible covered and luted, and kept for twenty hours in a red heat. On examining the metal, it was found to retain the whitenefs and brittlenefs, which gold conftantly receives from fo large a proportion of platina, and to have loft in weight about half a grain, or one hundredth part. This lofs proceeded perhaps from alloy in the gold employed, which was above ftandard, but not perfectly fine, or perhaps from the diffolution of fome of the heterogeneous parts of the platina, but by no means from the platina itfelf; for the fame plate, cemented again with frefh mixture for the fame length of time, fuffered no further diminution. If the marine acid was capable of corroding the platina, the corrofion would have continued in the fecond procefs, and inftead of a hundredth part, near a third part would have been eaten out. This experiment therefore determines with certainty the refiftence of platina to the marine fumes; and that the regal cement, fo called from its being fuppofed to purify gold from all heterogeneous metallic bodies, is incapable of feparating platina from it.

6. There are circumftances in which gold itfelf is diffolved by the pure marine acid; as when it has been melted with tin, and the mixture beaten into powder and calcined; or when it has been reduced into the form of a calx by precipitation from other menftrua. Platina calcined with tin, and fome of the precipitates of platina of which an account will be given in the next fection, were digefted in fpirit of falt, with a moderate heat, for feveral hours: the reddifh yellow colour which the menftruum acquired, fhewed that a part of the platina was diffolved, though it feemed to diffolve fomewhat more difficultly, and more fparingly, than gold treated in the fame manner.

III. *Platina with the Nitrous acid.*

1. SPIRIT of nitre diluted with water, proof aquafortis, and the ftrong fmoking nitrous fpirit, were digefted feparately with one third their weight of platina, in a gentle heat, for feveral hours. During the digeftion, fome fmall bubbles were obferved, as if a diffolution was beginning, but the liquors acquired no colour, and the fire being increafed, fo as to keep them boiling till they had totally evaporated, the platina remained unchanged, except only that many of the grains had become difcoloured.

2. Platina was treated likewife with nitrous cements, by proceffes fimilar to thofe in which it had been expofed to the marine fumes. An ounce of pure nitre, and an ounce and a half of green vitriol calcined to rednefs, were ground together, part of the mixture preffed fmooth into a crucible, over which was fpread an ounce of platina, and the reft of the mixture above it. The crucible was covered and luted, and the fire gradually raifed, fo as to make the veffel of a full red heat, in which ftate it was continued for feven or eight hours. Red nitrous fumes iffued copioufly through fome fmall cracks which they had forced in the luting. The crucible being grown cold, the mixture was found not melted or baked together, but loofe and powdery. The platina was of the fame weight and appearance as at firft, except that many of the grains had become, as in the foregoing experiments, dull coloured or brownifh.

IV. *Additional experiments with the foregoing acids, &c. on platina.*

Mr. MARGGRAF has given fome experiments on this head, which having been conducted in a fomewhat different manner from mine, he took notice of fome pheno-

mena

mena which did not occur to me. They were all performed in ſmall glaſs retorts, with receivers adapted to them; and the fire gradually raiſed, ſo as to make the retorts red hot. In this manner he treated platina with eight times its weight of each of the three foregoing acids; with twice its weight of mercury-ſublimate; with twice its weight of ſal ammoniac; and with thrice its weight of the mixture called ſal alembrot, compoſed of one part of mercury-ſublimate and two of ſal ammoniac. The quantity of platina in each experiment was ſixty grains.

With the nitrous and marine acids, he had a white cryſtalline ſublimate in the neck of the retort, which, viewed through a magnifying glaſs, looked like cryſtalline arſenic, but whoſe quantity was too ſmall to be ſubmitted to any further examination. When the marine acid was uſed, there was alſo another ſublimate of a reddiſh colour; and in all caſes, the remaining platina was changed in part to a reddiſh brown. Mercury-ſublimate aroſe uncoloured, and left the platina of a dark greyiſh colour, here and there reddiſh. The ſal alembrot aroſe alſo perfectly white, but was followed by a little yellowiſh matter: the remaining platina was of a bright whiteneſs, almoſt like ſilver. With ſal ammoniac there was a fine yellow ſublimate (erroneouſly called blue in the Berlin memoirs) like that which riſes from a mixture of this ſalt with iron; the remaining platina was rather whiter than at firſt, and after ſome time grew a little moiſt in the air.

Mr. Marggraf expreſsly mentions his uſing in theſe experiments the crude unpicked mineral; whereas in mine only the larger white grains were employed, from which all the heterogeneous parts and ill coloured grains, that could be diſtinguiſhed by a good magnifier, had been carefully picked out. It is pretty certain, that the ſublimates did not proceed from the platina itſelf, but from its ad-

mixtures,

mixtures, the white one poſſibly from the mercurial globules united with the acids, and the yellow from the ferrugineous parts. The author himſelf concludes from the experiments, that the acids have no action on the true platina, but attack in ſome meaſure its ferrugineous matter; and that the marine acid ſeems to have this effect in a greater degree than the other two.

V. *Platina with aqua regia.*

1. Aqua regia, the proper menſtruum of gold, being poured upon platina, begun to act upon it ſlightly in the cold, and by the aſſiſtance of heat ſlowly and difficultly diſſolved it; acquiring at firſt a yellow colour, which deepened by degrees, as the menſtruum became more ſaturated, into a dark, almoſt opake, browniſh red.

2. The experiment was ſeveral times repeated, with different ſorts of aquæ regiæ, made by diſſolving ſea ſalt and ſal ammoniac, ſeparately, in four times their weight of aquafortis, and by abſtracting the nitrous ſpirit in a retort from the ſame proportion of each of the ſalts. All theſe menſtrua diſſolved the platina; and it did not appear to me that one diſſolved it more readily, or in greater quantity than another. Mr. Macquer tried alſo ſeveral aquæ regiæ, compoſed of different proportions of the nitrous and marine acids, and found that a mixture of equal parts of the two ſpirits was one of thoſe which anſwered the beſt.

3. In order to determine the quantity of menſtruum neceſſary for the diſſolution, I prepared an aqua regia by diluting ten ounces and a half of ſtrong ſmoking ſpirit of nitre with eight ounces of water, and abſtracting the mixture from ſix ounces of common ſalt. Five ounces of this aqua regia, which may be reckoned to contain three ounces of very ſtrong acid ſpirit, were poured upon one ounce of

 platina,

platina, in a retort, to which was adapted a recipient. A moderate heat being applied, the menſtruum acted pretty briſkly, and red fumes aroſe in abundance. When about two thirds of the liquor had come over, the action was ſcarcely or not at all ſenſible, though the fire was conſiderably raiſed. The diſtilled liquor, which appeared of a light reddiſh colour, being poured back again into the retort, the diſſolution begun afreſh: the vapour, which now came over, was much paler than the firſt. The cohobation being repeated four times, the diſtilled liquor proved paler and paler every time: at length both the fumes and action ceaſed, though the fire was augmented, and a conſiderable part of the platina remained undiſſolved. The ſolution was therefore poured off, ſome more of the menſtruum added, the diſtillation and cohobation renewed, and theſe proceſſes repeated, till all the platina appeared to be taken up, except a little blackiſh matter which ſeemed to be its impurities. The laſt portions of the menſtruum ſeeming not to be ſufficiently ſaturated, ſome more platina was added; and after the acid had ceaſed to act, the remaining platina was dried and weighed, to ſee how much of it had been diſſolved. It was found, that by this way of application, one ounce of platina was diſſolved by eight ounces and a quarter of the menſtruum; which quantity of the menſtruum, as appears from the manner of its preparation, conſiſted of about four ounces and a half of ſtrong acid ſpirit, diluted with three ounces and three quarters of water; whereas, when the digeſtion was performed in open veſſels, and the fumes ſuffered to eſcape, about fourteen ounces of the above menſtruum, containing nearly eight ounces of ſtrong acid ſpirit, were neceſſary for diſſolving one ounce of platina. Platina appears to require a much greater quantity than gold, and to diſſolve far more difficultly.

4. Marggraf

4. Marggraf uſed an aqua regia compoſed of one part of ſal ammoniac and ſixteen parts of aquafortis; and found that twenty-four ounces of this menſtruum were neceſſary for one ounce of platina. It may be ſuſpected that the quantity of ſal ammoniac was not here ſufficient for enabling all the aquafortis to act on the platina, ſo that the metal was diſſolved only by a part of the menſtruum, the reſt being ſuperfluous aquafortis. The author obſerves, that the ſolution depoſited in the cold ſmall reddiſh cryſtals: yet he diſtilled off one half of it in a retort, and does not take notice of any cryſtallization happening in the concentrated reſiduum; from whence it ſeems to follow, that one half of the liquor was ineſſential to the diſſolution.

5. Macquer made an experiment of the ſame kind, which agrees nearer with mine: of his aqua regia, compoſed of equal parts of the nitrous and marine acids, ſixteen ounces diſſolved, by digeſtion, one ounce of platina; and in my trials, about fourteen ounces were found to ſuffice. Acid ſpirits differ ſo much in their ſtrength, and the diſſolution is ſo much influenced by the vapours being more or leſs confined during the proceſs, as appears from the experiments above related, that an exact agreement in this point is not to be expected.

6. In all the diſſolutions of platina, a portion of blackiſh matter remained at the bottom, whether the platina had or had not been ſeparated from its black duſt. In ſome experiments, where the purer grains of the metal were uſed, the quantity of this indiſſoluble matter amounted to about ſix grains on the ounce, or an eightieth part: where the mineral was taken entire, without any ſeparation of its heterogeneous mixtures, the reſiduum was in one trial above a fortieth, and in another about a thirtieth part. The proportion could not be determined with much exactneſs, the indiſſoluble ſubſtance defending

 from

from the action of the acid ſome minute particles of the metal itſelf.

7. Great part of this reſiduum, as Marggraf obſerves, is attracted by the magnet; its ferrugineous principle being probably bedded in ſandy matter, ſo that the acid could not reach it. As the fineſt grains of the metal leave always more or leſs of an indiſſoluble ſubſtance, it follows that platina is made ſomewhat purer by the diſſolution.

All the experiments related in this ſection concur in eſtabliſhing a ſtrong agreement between platina and gold. There are ſome other metals which diſſolve indeed, and with much more facility, in aqua regia; but to reſiſt either the pure vitriolic acid, or the marine acid, or the nitrous acid, in the circumſtances wherein gold and platina reſiſt them, are properties peculiar to theſe two.

SECT. III.

Experiments on Solution of Platina.

I. *Colour of the Solution, and trials of it for ſtaining.*

SOLUTIONS of platina in aqua regia, when ſaturated with the metal, are of a dark, almoſt opake, brown-red colour; when only ſlightly impregnated, yellow like thoſe of gold. A few drops of the ſaturated liquor tinge a large quantity of water of a fine golden hue. I know of no other metallic body whoſe ſolutions in acids are ſo rich or diffuſive in colour, or tinge ſuch large quantities of watery fluids.

Notwithſtanding this diffuſiveneſs of colour of the liquor itſelf, and its reſemblance when diluted to ſolutions of gold, it is little diſpoſed to communicate any colour to other bodies, and in this reſpect it differs remarkably from gold,

gold. It corrodes the ſkin, making it harſh and rough, but I have not obſerved that it gives any ſtain, not even the yellow one which the menſtruum by itſelf communicates to the ſkin. Ivory, feathers, ſilk, wood, and linen, were dipt in the diluted liquor and expoſed to the ſun, and the dipping and drying repeated three or four times: they all became brown, from the colouring matter of the ſolution having dried upon the ſurface; but water waſhed it off readily, and left them colourleſs as at firſt, except that the ſilk retained a ſlight browniſhneſs after the waſhing. The ſolution dropt upon warm marble, immediately corroded it, but without giving any colour. Dropt into infuſions of cochineal, it did not heighten but deſtroy the red or purpliſh colour, and changed them to a browniſh or blackiſh: ſome of the mixtures applied on paper with a pencil, appeared nearly of the ſame hue with Indian ink in its paler ſhades.

II. *Cryſtallization of Platina.*

Solutions of platina cryſtallize much more eaſily than thoſe of gold. As a conſiderable heat is neceſſary for making the aqua regia ſaturate itſelf with the metal, the ſatiated ſolution generally depoſites, by the time it is grown cold, a browniſh red ſediment, which is no other than a number of minute cryſtals. A quantity of the ſolution having been ſet by in an open glaſs, in warm weather, the ſuperfluous moiſture gradually exhaling left moderately large cryſtals, of a dark almoſt opake red colour, of irregular figures, variouſly joined together, moſt of them in form of leaves, like flowers of benzoin but thicker. Their taſte was nauſeous and ſomewhat ſharp, but not near ſo corroſive as might be expected from the great quantity of nitrous and marine acids combined with the metal. Waſhed with proof ſpirit, they became ſomewhat paler, but ſtill remained

remained of a high colour, refembling that of the deeper chives of faffron. In a moderate heat, they feemed to melt, though only imperfectly, and emitted white fumes fmelling of fpirit of falt; at length they fell into a dufky afh coloured calx, ftaining the tobacco-pipe, in which they were expofed to the fire, of a pale dull reddifh colour.

III. *Volatilization of Platina.*

THIS metal, of itfelf as fixed in the fire as gold, appears to be equally volatilized by the hafty abftraction of an aqua regia made with fal ammoniac. Marggraf put into a glafs retort fix ounces of a folution of platina made in a mixture of fixteen parts of aquafortis and one part of fal ammoniac: having fet the retort in fand, and fitted to it a receiver, he drew off the liquid by a gradual fire, which at laft was increafed, fo as to make the retort red hot and ready to melt. There remained at the bottom a reddifh-brown powder, which being further calcined under a muffle, became more of a brilliant blackifh hue. In the neck of the retort was found a brown-red fublimate, which, on expofure for fome days to the air, run into a red liquor refembling folution of platina. He poured fome of this liquor on a polifhed copper plate, and found that the platina, after fome time, precipitated upon the copper, as it does from its common folutions, covering the copper with a fhining blackifh powder.

IV. *Solution of platina, with vitriolic acid.*

To a folution of platina, diluted with water, I added fome ftrong fpirit, called oil, of vitriol: no precipitation or change of colour enfued, though a large quantity of the acid was at different times dropt in, and the mixture fuffered to ftand for feveral days. But on adding the fame ftrong vitriolic fpirit to an undiluted folution of platina,

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the liquor immediately became turbid, and a dusky coloured matter soon precipitated. The precipitate was not redissolved on the affusion of water; nor was the precipitation prevented by adding water immediately after the acid had been dropt in.

V. *Solution of platina, with volatile alcali.*

The spirits of sal ammoniac, prepared both by quicklime and by fixt alcaline salts, added to solutions of platina diluted with water, precipitated a dark red sparkling powder: but in whatever quantity the spirits were added, the precipitation was not total, a considerable part of the platina remaining dissolved so as to communicate a high yellow colour to the liquor. The red precipitate, dried, and exposed to the fire in an iron ladle, became blackish, without discovering any thing of the fulminating power which precipitates of gold, prepared in the same manner, have in a remarkable degree. On washing some of the precipitate upon a filter, with repeated additions of water, greatest part of it dissolved, only a small quantity of blackish matter remaining on the paper, and the liquor passing through of a deep bright golden colour: a very large quantity of water was tinged of this colour by a small one of the powder.

VI. *Solution of platina, with vegetable fixt alcali.*

Salt of tartar, salt of wormwood, fixt nitre, and the *lixivium saponarium* of the London pharmacopœia, had the same effect on solution of platina as the volatile spirits in the foregoing article, except that the precipitates were of a much duller reddish colour, and less brilliant. The precipitation was equally imperfect; the liquor still continuing of a deep yellow colour, and greatest part of the precipitate being redissolved on the addition of water.

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In the foregoing experiments, the precipitates of platina by volatile alcalies were of a dark kind of red colour and confiderably fparkling, while thofe by the fixt were of a paler dull reddifh with little brilliancy. In the accounts which others have given of thefe precipitations, this difference, in itfelf of fmall importance, is not taken notice of. Scheffer calls the precipitates by both alcalies fimply red; and Marggraf calls them both orange yellow, a term applicable enough to the precipitates which I had obtained with the fixt alcalies, but not to thofe with the volatile. It fhould feem as if there had been fome real differences in the appearances of our refpective products, and I imagined that fuch differences might have arifen from differences in the folutions of platina made ufe of: fome late trials appeared to countenance this fufpicion, for while common folutions of platina yielded precipitates of the red kind, a folution of the cryftals of platina made in water gave only yellow ones.

Macquer accounts for this difference of colour in another manner. He fays the precipitate proves red only when the quantity of alcali is no more than juft fufficient to fatiate the acid; and that the more of the alcaline liquor we add beyond this point, the precipitate proves lefs and lefs red; agreeably to which his coadjutor Baumé fays afterwards more determinately, in his *manuel de chymie*, that with a due quantity of fixt alcali the precipitate is orange yellow, and with an over quantity pale yellow. Mr. Macquer, judging from hence, that the rednefs was owing to a large quantity of acid retained by the platina, digefted fome of the red precipitate in a folution of fixt alcaline falt: the alcaline liquor, abforbing the acid, deftroyed the red colour of the powder, and made it white. It has long been known, that precipitates carry down with them a portion both of the diffolvent and of the body they were precipitated

tated by: the author obſerves that this appears more ſenſible in our precipitate of platina, at leaſt with regard to the diſſolvent, than in moſt others; and that this obſervation diſcovers the cauſe of ſundry ſingular phenomena, which I had remarked in the precipitation of platina, and of which I had not given the theory, as of the red precipitate being ſoluble in water, and of part of the platina remaining ſuſpended whatever quantity of alcali we add in the cold: a detail and explication of theſe phenomena, with others of the ſame nature, he reſerves for another memoir. Some experiments I have made do not very well agree with this theory, but I forbear any further obſervations till the authors memoir appears.

VII. *Solution of platina, with mineral fixt alcali.*

As the two foregoing kinds of alcaline ſalt precipitate platina only in part, there is a third which has not even that effect. The mineral alcali or baſis of ſea ſalt, the method of preparing which will be deſcribed in the following part of this hiſtory, produces no precipitation at all. This remarkable experiment, which we owe to Mr. Marggraf, will be further conſidered hereafter.

VIII. *Solution of platina, with Pruſſian alcali.*

Mr. Marggraf obſerves, that when ſolution of platina is mixed and ſaturated with a lixivium of fixt alcali that has been calcined with blood, it yields a fine blue precipitate, which in certain circumſtances proves as beautiful as the beſt Pruſſian blue, though there falls alſo at the ſame time a little orange coloured matter. On repeating this experiment, the liquors when firſt mixed appeared of a pretty deep blue, but when the precipitate had ſettled, greateſt part of it looked yellow, on account, probably, of the platina I made uſe of containing leſs ferrugineous matter, or the alcaline lixivium being leſs ſatu-rated with the ſubſtance which tinges diſſolved iron blue, than thoſe which Mr. Marggraf employed.

To obtain a ſaturated ſolution of this tinging ſubſtance, which cannot be expected to be done by calcining alcaline ſalts with blood or other like matters, I digeſted ſome common Pruſſian blue both in ſolution of fixt alcaline ſalt, and in volatile ſpirit of ſal ammoniac prepared with quick-lime. Both menſtrua ſoon became yellow; and the irony baſis of the Pruſſian blue, thus freed from its colouring matter, remained in a ruſty form. To both tinctures I added ſome more Pruſſian blue, till they ceaſed to have any action on it. The fixt alcali, along with the tinging ſubſtance, appeared to have taken up ſome of the iron; for it ſtruck a blue colour with good aquafortis, with the acid of ſulphur, and with diſtilled vinegar, in which there were no grounds to ſuſpect any iron to be previouſly con-tained. The volatile tincture appeared free from iron, for in the ſame acid ſpirits it produced no change, though it inſtantly turned them blue when a little iron was firſt diſ-ſolved in them.

This ſaturated ſolution of the tinging ſubſtance was added by degrees to ſolution of platina. The liquor turned at firſt to a deep blue, but on further additions, to a greeniſh yellow. The precipitate was of two kinds, yellowiſh at the bottom, and blue on the top. The whole being ſhaken together and ſet by till next day, a white matter appeared at the bottom, above this a yellow, and on the top a more copious browniſh grey. The liquor was of a deep gold colour.

IX. *Solution of platina, with compound ſalts.*

Solutions of alum, of ſal mirabile, of vitriolated tar-tar, of the fuſible ſalt of urine, made ſeparately in water, and

and ſolution of chalk in aqua fortis, were found by Marggraf to produce no precipitation or apparent change in diluted ſolution of platina.

Sal ammoniac, one of the ingredients to which the menſtruum owed its power of diſſolving the platina at firſt, precipitated great part of it in form of a reddiſh or yellowiſh powder, nearly ſimilar to that thrown down by alcalies. It is obſervable, that though neither ſal ammoniac nor alcalies, ſeparately, occaſioned a complete precipitation, the liquor ſtill remaining of a high colour; yet when one was added to the ſolution remaining after the action of the other, a new precipitate fell, which left the liquor colourleſs.

X. *Solution of platina, with vinous ſpirits.*

As gold is revived from its ſolutions by vinous ſpirits, and made to riſe in yellow films to the ſurface; I mixed a ſolution of platina with a large proportion of highly rectified ſpirit of wine, and expoſed the mixture for many days to the ſun, in a wide-mouthed glaſs ſlightly covered with paper to keep out duſt: there was no appearance of any yellow ſkin, nor was any other alteration perceived, than that the platina had begun to cryſtallize from the evaporation of the fluid.

Suſpecting that though the liquor ſhould really contain gold, yet the platina might ſtrongly retain the gold and prevent its being ſeparated by the ſpirit, I mixed three or four drops of ſolution of gold with two hundred drops of ſolution of platina, and after ſhaking them well together, added ſome rectified ſpirit of wine: the whole being expoſed as above to the ſun, a golden film was in a few days obſerved upon the ſurface.

XI. *Solution of platina, with effential oils.*

A COLOURLESS effential oil of rofemary was poured into about half its quantity of folution of platina, the mixture well fhaken, and fuffered to reft: the oil quickly arofe to the furface without receiving any colour, and the acid underneath remained coloured as at firft.

A compofition of platina and gold, which had been melted together, being diffolved in aqua regia, and the folution treated in the fame manner, the gold was imbibed by the oil, and the platina remained diffolved by the acid: the oil, loaded with the gold, appeared of a fine yellow colour, and on ftanding for a few hours threw off great part of the gold to the fides of the glafs, in bright yellow films, which appeared to have no mixture of platina. Some other diftilled oils were made trial of, with the fame event.

XII. *Solution of platina, with æther.*

THE vitriolic æther or æthereal fpirit of wine, the preparation of which has been defcribed at the end of the eighth fection of the hiftory of gold, was poured into a folution of platina, and into a folution of a compofition of platina and gold. The two vials being immediately ftopt, to prevent the exhalation of the volatile fluid, and lightly fhaken; the æther received no colour from the folution of platina, but became inftantly yellow from that of the platina and gold.

XIII. *Solution of platina, with tin.*

AS a minute proportion of gold contained in acid folutions is difcoverable by their ftriking a purple colour with tin, fome bright plates of pure tin were put into a folution of platina diluted with water. The plates in a little

little time looked of a dark olive colour, and ſoon after were covered over with a reddiſh brown matter. The liquor became at firſt darker coloured, and afterwards, by degrees, as the precipitate fell, nearly colourleſs, without exhibiting the leaſt appearance of a purpliſh or reddiſh hue.

Some platina was digeſted in a quantity of aqua regia ſufficient to diſſolve only about half of it, and the remainder was diſſolved in a freſh portion of the menſtruum. The two ſolutions, treated as above, yielded ſomewhat different phenomena, but no tendency to a purpliſh caſt could be perceived in either. The latter ſolution, which looked yellow from its not being fully ſaturated with the platina, was, when diluted with water, almoſt colourleſs: nevertheleſs, on the addition of tin, it became yellow again, then of a dull red, and at laſt of a dark browniſh red, conſiderably deeper than the other more ſaturated ſolution: on ſtanding for ſome time it grew perfectly clear, depoſiting a paler yellowiſh precipitate.

To determine whether platina was capable of preventing a ſmall proportion of gold from diſcovering itſelf in this way of trial, one drop of a ſolution of gold was let fall into ſome ounces of a diluted ſolution of platina. On adding ſome plates of tin, the liquor became quickly purple.

The foregoing experiments were made with a ſolution of the picked grains of platina. I ſubmitted alſo to the four laſt trials, with tin, æther, eſſential oils, and vinous ſpirits, a ſolution made by digeſting in aqua regia the entire mineral, with its mixture of yellow particles, as it comes to us; which ſolution, in all theſe trials, gave exactly the ſame appearances, as the other ſolution did after it had been firſt mixed with a very little quantity of ſolution of gold, ſtriking a purple colour with tin, communicating a yellow tinge to æther and eſſential oils, and yielding a yellow film with rectified ſpirit of wine.

XIV. *Precipitate*

XIV. *Precipitate of platina expoſed to a burning concave.*

Mr. MACQUER and Mr. Baumé, after examining the action of a burning concave on crude platina, as already mentioned in page 466, expoſed the red precipitate of platina made by alcalies, to the focus of the ſame burning mirrour. " It immediately begun to boil, and diminiſhed conſiderably in volume: there aroſe at the ſame time a very abundant and very thick fume, ſmelling ſtrongly of aqua regia, and which appeared ſo luminous and ſo white in the neighbourhood of the focus, that we could not decide whether it was not a true flame: the precipitate at the ſame time loſt its red colour, to reſume that which is natural to platina, and it now had the appearance of metalline lace. Being continued in the focus, the white fume ſmelling of aqua regia was ſucceeded by another fume or flame leſs copious, whoſe colour inclined to violet. A little time after, there was formed, in the hotteſt part of the focus, a button of ſmooth brilliant matter perfectly melted, and then the vapours ceaſed. Examining this button after it was grown cold, we found it to be a vitreſcent opake matter, of a hyacinth colour on the ſurface, internally blackiſh and pretty compact. We dare not affirm that this was a true vitrification of the platina in virtue of the ſaline matters which were joined to it in the precipitate: the experiment ought to be repeated with pure platina, and with a burning glaſs or concave ſtronger than that we uſed." Indeed as the platina reſumed its metallic aſpect, it ſhould ſeem to have been diſengaged from the ſalts, before the time that the vitrification begun; and perhaps a button of blackiſh vitreous matter, formed in the middle of the focus, may be eaſily enough accounted for from the ferrugineous calx, which the precipitate cannot be ſuppoſed to have been free from: ſee the experiments of the relation of platina

tina to vitreous bodies at the end of the following ſection. The matter on which the powdery precipitate was expoſed to the focus of the burning concave, might alſo have contributed to the vitrification ; what this matter was, the author does not mention.

The experiments of this ſection point out ſome ſtriking differences between platina and gold; not only in the power of producing, when diſſolved, a purple colour with tin, and communicating a like ſtain to different kinds of colourleſs ſubjects, a power for which gold is remarkable, and which platina wants; but likewiſe in properties more importantly characteriſtic, as they afford means of diſtinguiſhing and parting the two metals when blended together. They have ſhewn platina ſeparated in part from its ſolutions, by a ſubſtance which does not at all ſeparate gold, to wit, ſal ammoniac; and gold ſeparated completely by ſubſtances which do not at all ſeparate platina, viz. the mineral alcali, vinous ſpirits, eſſential oils and æther. It appears likewiſe from theſe experiments, that beſides the black duſt which remains behind in the diſſolution of platina, the part diſſolved is not pure platina; for the blue colour produced by the Pruſſian alcali amounts to a proof that the ſolution contains iron.

S E C T. IV.

Platina expoſed to ſtrong fires, with ſaline, inflammable, ſulphureous, vitreous and earthy bodies.

HAVING ſeen the effects of the purer acids on platina, and the general properties of its ſolutions, we ſhall proceed to apply to it what are commonly called *fluxes* and *dry menſtrua*, that is, ſubſtances which either barely promote the fuſion of metals without corroding them, or which corrode and unite with them, when properly

perly heated, nearly on the ſame principle as humid menſtrua diſſolve them.

I. *Platina with Borax.*

HALF an ounce of platina was dropt into an ounce of melted borax, and urged with an intenſe fire for an hour. The platina appeared to have ſuffered no alteration, but the borax was changed to a dark blackiſh colour, probably from its having diſſolved and vitrified ſome of the ferrugineous duſt. The whole was returned to the fire, which was kept up ſtrong for a conſiderable time longer, till the borax had ſunk through the crucible : it left the grains of platina of a bright white colour, ſlightly cohering but unaltered in form.

II. *Platina with Alcali.*

I TREATED platina in the ſame manner both with the common fixt alcaline ſalts well purified, and with the cauſtic alcali prepared by evaporating ſoapboilers ley, but could not perceive that either of them had any other effect than contributing to brighten its colour. Mr. Marggraf mixed a dram of platina with half an ounce of ſalt of tartar, and gave them a vehement fire, in a cloſe luted crucible, for two hours. When cold, he found a hard mixt, of a yellowiſh green colour, in which the platina was diſperſed. The whole being ſeparated, as much as poſſible, from pieces of the crucible, by ſcraping and waſhing, the water above the matter was next day found like gelly: the platina was whiter than uſual, almoſt of the whiteneſs of ſilver, but of its wonted figure. The gelatinous conſiſtence which the water acquired in this and ſome of the following experiments, is probably not owing to the platina, but to ſome of the earth of the crucible diſſolved by the ſaline matter.

III. *Platina with Nitre.*

Nitre, which reduces all the known metallic bodies, except gold, ſilver and quickſilver, into a calx, was mixed with equal its weight of platina, the mixture thrown into a red hot crucible, and the fire kept up for about a quarter of an hour. No deflagration happened; and the platina, freed from the ſalt by repeated waſhing with water, appeared to have ſuffered no other change than having its colour darkened, an effect which the ſimple heat would have produced in it. The nitre was nevertheleſs in great part alcalized.

Four ounces of platina and eight ounces of the pureſt nitre were put into a crucible, the crucible covered with a larger one inverted over it, and kept in ſtrong cementation, in a wind furnace, for three days and three nights without intermiſſion. The matter being now boiled in water to ſeparate the ſalt, the platina looked ruſty coloured, and had loſt almoſt half its weight: the ſaline liquor, on being filtered, left a browniſh powder ſomewhat more than equivalent to this diminution, and being afterwards evaporated to dryneſs, yielded a ſmall quantity of a greeniſh cauſtic alcali. The ſame platina was cemented thrice more with the ſame quantities of freſh nitre, and the fire continued for three days and three nights every time. In the two firſt repetitions, a ſmaller quantity of a paler powder ſeparated, and the remaining metal in good meaſure loſt the ruſty hue which it had contracted before. After the laſt cementation, the little quantity of metal which remained had much the ſame appearance as the platina at firſt: on waſhing it, there was ſcarcely any further ſeparation of powdery matter, but the nitre was ſtill alcalized. The platina was then mixed with ſal ammoniac, and the ſalt ſublimed in a Florence flaſk: the ſalt aroſe

 uncoloured,

uncoloured, and left the metal white and bright. The powders ſeparated in the cementation were treated in the ſame manner, and the ſublimation repeated thirty times with freſh quantities of the ſalt: in the firſt ſublimations, ferrugineous yellow flowers aroſe, but at laſt the ſalt received no tinge, and the powder remained of a greyiſh colour.

Mr. Marggraf gives an account of an experiment of the ſame kind, in which he takes notice of ſome phenomena, which either did not occur, or were not attended to, in mine. He threw into a red hot crucible four ounces of nitre, and one ounce, or four hundred and eighty grains, of platina: no detonation happened, but a conſiderable fume aroſe. The fire being continued, with care to prevent the falling in of any piece of coal, the matter, after ſome time, begun to ſwell up, and a portion of it being taken out looked greeniſh: it afterwards turned to a deep olive green, and grew conſiderably tough and thick: after ſome hours of ſtrong fire, it proved as thick as pap. The thick matter was taken out while hot with an iron ſpatula: it was of a deep olive-green colour. As much as poſſible of what adhered to the crucible was collected, and ſet to digeſt with the other in diſtilled water: next day the whole was as thick as gelly. Being then diluted with more water, ſtirred about, and ſuffered to ſettle, the liquid was poured off, and this repeated till all the lighter parts were waſhed over: this light matter, ſeparated from the ſaline liquor by filtration, well waſhed on the filter with hot water, and dried, weighed two hundred and twenty-five grains: it was of a dark grey colour, and by ſtrong calcination under a muffle became black like pitch. The more ponderous part was ground in a glaſs mortar, by which ſome more became fine enough to be waſhed over: this was of a clear brown colour, and amounted to thirty grains. The platina

tina weighed three hundred and ten grains, and consequently had lost above a third: it still resembled crude platina, and retained its lustre; the brownish rusty coat, with which mine appeared covered after the first cementations, having probably been here rubbed off in the grinding. The nitre was totally decomposed, and had acquired all the characters of alcalicity. The crucible and its support were tinged almost throughout of an amethyst colour, as usually happens in the calcination of manganese with nitre.

The platina was treated in the same manner with three ounces of fresh nitre. The crucible and its support were still tinged of a fine amethyst colour, the nitre was totally alcalized, and all other circumstances happened as in the first operation, except that the lighter parts, first washed off, weighed only sixty grains: by calcination they became, as before, of a pitchy blackness: the remaining powdery matter was of a clear grey, and weighed forty five grains: the platina, still bright, weighed two hundred and fifteen grains, or less than half of its first weight.

The operation was repeated with three ounces more of nitre. The crucible and its support were now less strongly tinged. The first washings gave two grains of a light powder, in appearance much resembling the Eckertsberg blue earth; and by rubbing the rest of the platina in water, there were obtained forty grains of a light powder of a grey-brown colour. The platina lost in this operation but five grains; and so inconsiderable a diminution giving little hopes of any further effect from a repetition of the process, the experiment was here dropt.

It had been affirmed, that platina is a compound of gold and some other matter, so intimately combined together, as not to be separable without other methods of procedure than are commonly practised or known. An adept, in the pretended art of this higher metallurgic analysis, boaſted of having deſtroyed the heterogene matter, ſo as to leave the gold pure, by long continued and repeated cementations with nitre. To remove all ſcruples on this head, I permitted him to make the experiment of which I have above given a ſhort account, and of which I have ventured to inſert only ſuch particulars as came under my own obſervation. The experiment, with which that of Mr. Marggraf, ſo far as it goes, ſufficiently correſponds, was deciſive. It ſhewed much the greateſt part of the platina changed to a powder, and the remaining platina as remote from the nature of gold as it was at firſt. I tried it both by acids, and by cupellation with lead, a proceſs of which an account will be given hereafter, and found it to preſerve its own diſcriminating characters, without any marks of gold, though it appeared to be purer than platina in its common ſtate. I tried alſo, by the ſame methods, the powders which had been ſeparated in the cementations, after the reiterated ſublimations of ſal ammoniac from them; and found theſe likewiſe to be no other than platina, not reduced to a calx, but barely divided.

It may be preſumed that the action of the nitre was not directly upon the platina itſelf, but on the irony matter, adhering to the ſurfaces of the grains, or more intimately blended in their ſubſtance; which irony particles being changed to a calx, the platina intermixed became divided along with them into a powdery ſtate. This ſuppoſition accounts ſatisfactorily for the principal phenomena of the proceſs; as the ſeparation of the powder being plentiful in the firſt cementation, and more and more ſparing in the following ones; the firſt powder being of a deep colour, and the others paler, as if the iron prevailed in the firſt, and the platina in the others; the powders yielding yellow ferrugineous flowers with ſal ammoniac, while the platina that remained entire gave no colour to the ſalt.

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In regard to the pretenſions to the obtaining of gold by this proceſs, it is not perhaps unreaſonable to ſuppoſe, that the remarkable ſeparation of powdery matter in the cementation, and the appearance of ſome golden grains which had been naturally intermingled among thoſe of the platina, led men of warm imaginations to anticipate the further effect of the proceſs, and to make the aſſertion which the above experiments overturn.

IV. *Platina with common ſalt.*

An ounce of common ſalt, dried, was kept in fuſion with a dram of platina, in a cloſe crucible, for an hour and a half. The ſalt appeared yellowiſh, and on breaking the maſs, there were found in the middle of it ſome red cryſtalline grains. The platina was all at the bottom of the crucible, and preſerved its figure, having ſuffered no change, except being made very white. The experiment was repeated with what is called regenerated common ſalt, and the phenomena were exactly the ſame. Both theſe experiments are from Marggraf.

V. *Platina with vitriolic ſalts.*

Marggraf mixed a dram of platina with ſome pure Glaubers *ſal mirabile,* and kept the mixture in a ſtrong fire for two hours: the ſalt ſunk through the crucible, and left the platina of a dark grey colour: on waſhing the platina with water, and rubbing it in a glaſs mortar, there ſeparated a little light matter of a bright blackiſh colour, and what remained was platina unchanged. A dram of platina, and an ounce of vitriolated tartar, were treated in the ſame manner: the ſalt melted and became reddiſh; the platina ſuffered no change, except that it looked ſomewhat more grey.

VI. *Platina with the eſſential ſalts of urine.*

From putrefied urine inſpiſſated to the conſiſtence of a ſyrup, is obtained by cryſtallization a ſingular ſaline concrete, called the fuſible or eſſential ſalt of urine, or microcoſmic ſalt, containing the acid of phoſphorus united with a volatile alcali. This ſalt, expoſed to the fire, parts with its alcali, and aſſumes a glaſſy appearance; in which ſtate, all the common metals, gold not excepted, are ſaid to be corroded by it in fuſion. A hundred and eighty grains of this ſalt were mixed with thirty grains of platina, and urged in a crucible with a ſtrong fire for two hours: the platina was found unchanged at the bottom, covered with the ſalt, which likewiſe appeared little altered. Sixty grains of this ſalt, the ſame quantity of calcined borax, and thirty grains of platina, were treated in the ſame manner: there was a vitreous ſcoria, ſomewhat opake, of a yellowiſh green colour: the ſalts and lighter parts being ſeparated by waſhing, the dried platina appeared of its natural form, but whiter than at firſt.

After the cryſtallization of the foregoing ſalt from urine, there cryſtallizes another, not containing the phoſphorine acid, and whoſe compoſition is as yet unknown. Three drams of this ſalt and half a dram of platina being urged with a ſtrong fire in a cloſe crucible, the ſalt run all through the crucible, and the platina, after rubbing in a mortar and waſhing with water, appeared in its original form, being only ſomewhat whiter than before. A dram of the ſalt, a dram of calcined borax, and a dram of platina, treated in the ſame manner, gave a green-yellowiſh, dark-chryſolite-coloured vitreous maſs, under which lay the platina unaltered, except that as in the former caſe it was whiter than at firſt. All theſe experiments are from Marggraf.

VII. *Platina*

VII. *Platina with phoſphorine acid.*

WHEN the phoſphorus of urine is ſet on fire under a glaſs bell, nearly in the ſame manner in which ſulphur has been uſually burnt for obtaining its acid, it yields ſpongy flowers, in appearance much like thoſe of zinc; and both the flowers, and what matter remains on the glaſs diſh which the phoſporus was placed upon, imbibe moiſture from the air and run into a thick acid liquor, which expoſed to the fire leaves a dry matter that melts into a glaſſy form. Mr. Marggraf mixed ſixty grains of platina with twice as much of this acid liquor, and put them into a retort, whoſe juncture with the receiver was only cloſed with paper. The watery moiſture being drawn off by a gradual fire, the retort was ſet, while hot, upon burning coals, till it begun to melt; after which, being taken from the fire, a flaſh like lightening filled both the retort and receiver, and a violent exploſion followed. The author very ingeniouſly, and with great probability, attributes this effect to a regenerated phoſphorus, to which the iron mixed with the platina had contributed the inflammable principle; the action of which phoſphorus could then only take place, when the abatement of the heat ſuffered air to paſs in through the ill-cloſed juncture. The pieces of glaſs being collected, the bottom of the retort appeared covered with a white ſaline matter, which being ſcraped off, the platina was found under it unchanged. It is evident that the platina itſelf neither was, nor was ſuppoſed by the author to be, anywiſe concerned in producing the fulguration; though Vogel makes this fulguration one of the *new properties of platina* diſcovered by Marggraf.

VIII. *Platina*

VIII. *Platina with black flux, &c.*

The black flux commonly employed by the chemifts for the fufion of metallic minerals and calces, compofed of one part of nitre and two of tartar mixed together and burnt in a covered veffel to an alcaline coal, was kept in fufion above an hour, in a clofe crucible, with one fourth its weight of platina. Compofitions of wood-foot, charcoal powder, common falt, and wood afhes, directed by M. de Reaumur for changing forged iron into fteel, were mixed with platina, and cemented feveral hours, in clofe crucibles, both with moderate degrees of heat, and with fires ftrongly excited. In all thefe trials I could not obferve that the metal fuffered any change, except that its colour was darkened.

IX. *Platina with fulphur.*

An ounce of platina was fpread upon twice its weight of fulphur, with which fome powdered charcoal had been previoufly mixed, to prevent its becoming fluid in the fire, fo as to fuffer the platina to fubfide. The crucible, having another crucible, with a hole in the bottom, inverted into its mouth, was kept in a cementing furnace for fome hours: being then taken out, it was found that the fulphur had entirely exhaled; and that the platina, feparated by wafhing from the charcoal powder, had the fame weight and appearance as at firft, except that its colour was changed to a blackifh: by rubbing it in a glafs mortar with a little alcaline falt and water, the blacknefs was deftroyed, and its original brightnefs reftored. I varied the experiment, by ftrongly heating the platina in a crucible by itfelf, and repeatedly throwing upon it pieces of fulphur: it ftill remained unaltered, the fulphur feeming to have no more action on this metal than on gold.

X. *Platina*

X. *Platina with ſulphurated alcali.*

As fixed alcaline ſalts enable ſulphur to diſſolve gold in fuſion, I expoſed platina to the fire with a mixture of equal parts of ſulphur and fixt alcali, called *hepar ſulphuris*, or liver of ſulphur. After a conſiderable heat had been continued for ſome time, and the matter now and then ſtirred with a clean tobacco pipe, the crucible was taken out, and the mixture digeſted in water. Among the matter that remained undiſſolved, only a few particles of platina could be diſtinguiſhed; and the examination having been carried no further when my papers were given in to the royal ſociety in 1754, it was judged that the platina had been diſſolved by the ſulphurated alcali, as moſt of the other metals are. The experiment however ſeeming on a reviſal not ſufficiently ſatisfactory, I was going to repeat it with more attention, when Mr. Marggrafs memoir came to my hands, in which I find it repeated alſo by him.

Mr. Marggraf firſt mixed two ounces of pure ſalt of tartar, one ounce of ſulphur, and half an ounce of platina; and ſet the crucible, with another inverted and luted on it, in a forge. After the fire had been vehemently excited for three hours, the Heſſian crucible and its ſupport, with part of the bricks of the forge, were found melted together, and on ſome fragments was ſeen platina, in form of little ſilver leaves, but not well cohering. The exceſs of heat having rendered this operation fruitleſs, it was neceſſary to make another trial.

Half an ounce of platina, half an ounce of flowers of ſulphur, and an ounce of pure ſalt of tartar, in a crucible carefully luted as before, were urged in a ſtrong fire for two hours. On opening the crucible, the matter appeared to have melted, looked yellowiſh on the outſide, and when

 broken,

broken, ſhewed here and there ſome reddiſh cryſtals: it was leafy, like the mineral called by the Germans *eiſenrahm*. Some hot water was poured on it, and more water added ſo long as the liquor received any tinge. The filtered *lixivium* was of a yellow-green colour like the common ſolution of hepar ſulphuris. On waſhing off the lighter parts of the undiſſolved matter, the remainder looked exactly like the *eiſenrahm*, being in form of broad flakes, and ſoft to the touch: it was alſo lighter than platina, and had not the leaſt reſemblance to it.

He mixed forty grains of this matter with an ounce of nitre, and threw the mixture by degrees into a red hot crucible: ſcarcely any detonation happened. The fire being kept up for an hour, with care to prevent the falling in of any pieces of coal, there was obtained a grey maſs inclining to greeniſh, which being ſet to digeſt in diſtilled water, the fluid became preſently like gelly. By diluting and waſhing the matter, he recovered, without alteration, the platina which he had believed to be deſtroyed.

This experiment appearing ſtill indeciſive, I made ſome further trials. I mixed four ounces of flowers of ſulphur with the ſame quantity of pure fixt alcaline ſalt, and threw the mixture by little and little into a red hot crucible, covering the crucible after each injection. The mixture being in perfect fuſion, an ounce of platina, which had been previouſly expoſed to a ſtrong fire by itſelf till the grains were united into a lump, was dropt in, and a moderate heat continued for three or four hours. The lump of platina was quickly divided, though the metal did not remain ſuſpended in the ſulphureous mixture, but ſubſided, at leaſt in great part, to the bottom, from whence it was every now and then ſtirred and taken up with the bole of a tobacco pipe. The crucible at length cracked and was greatly corroded. The matter being boiled in about a

quart

quart of diſtilled water, the filtered liquor was of a dark reddiſh colour: the remainder, boiled in freſh quantities of water, gave an olive-green tincture. The boiling being repeated, and the matter rubbed in a mortar, till it gave no more tinge to the water, the part which remained at laſt undiſſolved was a dark-coloured powder, which had nothing of the appearance of platina, but was found to be no other than platina divided. This platina was treated in the ſame manner with freſh hepar, three or four times: the crucibles always failed and were much corroded, and the platina was reduced into a powder ſo ſubtile, that it could not be ſeparated by waſhing from the parts of the crucibles which were pounded with it.

I tried alſo a hepar made in Stahls manner, by melting vitriolated tartar with powdered charcoal. This mixture melted very eaſily, without any addition of the alcaline ſalt or common ſalt, which are generally thought neceſſary for promoting the fuſion: for though vitriolated tartar is very hard of fuſion by itſelf, yet here, its vitriolic acid uniting with the inflammable part of the charcoal into ſulphur, the matter becomes a compound of ſulphur and alcali, and melts as eaſily as the hepar made directly from thoſe ingredients. Platina, treated with this hepar, ſuffered the ſame change as from the other. The crucibles were equally corroded: the watery ſolutions of the maſs were partly reddiſh, and partly of an olive-green colour: the grains of platina, previouſly agglutinated into a lump by ſtrong fire, were diſunited, and in great part divided into a powdery form.

It appears therefore that platina is divided by hepar ſulphuris in fuſion, nearly in the ſame manner as by long cementation with nitre: it remains to examine whether any part of it was truly diſſolved, ſo as to be taken up by the water along with the ſulphureous alcaline mixture. I filtered

tered the liquors twice through double papers, and then added by degrees ſpirit of ſalt to neutralize the alcali: at firſt a browniſh precipitate fell, and afterwards a white one like the common precipitated ſulphur. A little of the brown precipitate was heated in a ſmall ſcorifying diſh, and ſome nitre added to burn off the ſulphur more effectually: there remained on the diſh ſeveral bright particles like platina, ſprinkled all over its ſurface. The reſt of the precipitate being burnt in like manner, I added ſome pure lead, to collect the diſperſed particles of the platina, and afterwards worked off the lead in a cupel: it left a rough brittle bead, exactly like thoſe obtained in cupelling crude platina with lead, of which an account will be given hereafter in the ſeventh ſection. It ſeems to follow from theſe experiments, that hepar ſulphuris really diſſolves platina, though very difficultly, and very ſparingly.

XI. *Platina with earthy bodies.*

CERTAIN earthy bodies are found to promote the fuſion, not only of ſome metallic minerals, but in ſome inſtances, of the purer metals alſo: thus forged iron, which could not be made to melt in a crucible without addition, was brought into fuſion by ſurrounding it with gypſum or plaſter-of-paris, a fact which we owe the diſcovery of to Mr. de Reaumur. To ſee if platina would be anywiſe affected by ſubſtances of this kind, I intermixed an ounce of it with gypſum, and urged it with a ſtrong fire in a blaſt furnace for two hours: the Heſſian crucible was corroded in many parts to the thinneſs of paper, and here and there quite through, the matter of the crucible and the gypſum having in ſome meaſure vitrified together; but the platina remained unmelted, and unaltered.

Quicklime, and calcined flint, were likewiſe made trial of in the ſame manner, but no change was produced by them in the platina.

XII. *Platina with vitreous bodies.*

1. Half an ounce of a precipitate thrown down from ſolution of platina by tin, was ground in an iron mortar, with eight times its weight of common flint glaſs, and the mixture put into a crucible, which was covered and luted, and placed in a wind furnace. The fire was gradually raiſed, and kept up extremely ſtrong for about ten hours: the crucible being then taken out and broken, the matter proved of a dark blackiſh colour, untranſparent, friable, interſperſed with a bright whitiſh ſubſtance apparently metallic. It is probable that this metallic matter was the platina, and that the glaſs owed its opacity and dark colour, not to this metal, but to tin in the precipitate, or ſome particles of iron worn off from the mortar, or other accidental cauſes.

2. I ground in a glaſs mortar a quarter of an ounce of a precipitate of platina made by alcaline ſalt, with twelve times its weight of powdered flint glaſs, and committed the mixture to the ſame fire as the foregoing. The reſult was a compact cloudy glaſs, pretty tranſparent in thin pieces, covered in part with a thin whitiſh coat. Towards the upper part, and all round the ſides, were obſerved ſeveral particles of metal, which appeared to the eye like bright platina, and proved hard to the point of a knife. In this, as in the foregoing experiment, the glaſs ſeems to have received nothing from the platina, the change being no other than what flint glaſs is found to undergo from a ſlight introduction of inflammable matter.

3. Mr. Marggraf gives an account of three experiments of the mixture of platina with vitreous bodies. Five drams of pure ſalt of tartar, twelve drams of clean ſand calcined and waſhed, one dram of calcined borax, two of nitre, and two of crude platina, were mixed together, and

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kept in a vehement fire, in a cloſe crucible, for ſeveral hours. The reſult was a vitreous, ſomewhat opal-like maſs, inclining to a ſea green: the platina, no otherwiſe altered than in being made whiter, was diſperſed partly on the ſurface of the glaſs, and partly about the ſides, and ſurrounded with a diſtinct vitreous matter of a deep hyacinth colour.

4. He tried alſo the powder ſeparated from platina by cementation with nitre, as deſcribed in page 492. Six grains of this powder were mixed with a hundred and eighty grains of white ſand, and ninety grains of ſalt of tartar. The mixture, melted with a vehement fire in a cloſe crucible, proved a porous, greyiſh, untranſparent glaſs.

5. He prepared a precipitate from platina and tin together, and tried to vitrefy this mixt. A poliſhed plate of tin being digeſted in ſolution of platina, part of the platina precipitated upon the tin in form of a blackiſh red powder, and the tin, in ſome days, was quite corroded: the liquor, of a dark coffee colour inclining to black, being put into a filter, run through blackiſh. This compound ſolution of platina and tin was precipitated with ſalt of tartar: the liquor now paſſed the filter colourleſs, and the matter which remained on the paper, being well waſhed with hot water and dried, was a black ſubſtance, almoſt reſembling, in its fracture, broken pitch or fine pit-coal. Forty grains of this ſubſtance, ſixty of calcined borax, a hundred and twenty of purified nitre, two hundred and forty of pure ſalt of tartar, and four hundred and eighty of powdered flint, were well mixed together, and melted in a very ſtrong fire. They yielded a greyiſh glaſs, in which no metallic grains could be found: a thin piece of the glaſs, laid upon the nail and held up to the ſun, inclined to an amethyſt colour.

It

It does not appear from these experiments, that any part of the platina was truly vitrified. We may rather conclude, that the disappearance of the platina in the two last experiments was owing to its being diffused through the mass in a state of powder too subtile to be distinguished: the colour of the glass cannot be ascribed to the platina, since No. 3. afforded colours more considerable, though the grains of platina remained unaltered.

6. In my experiments, No. 1 and 2, particularly in the latter, the platina, though it had been attenuated by solution and precipitation before its mixture with the vitrescible ingredients, separated from the glass in fusion, and was collected into very sensible particles, some of which were of considerable magnitude. In an experiment of Mr. Macquers, this effect was still more strongly marked. The red precipitate of platina made by alcalies was mixed on a porphyry stone with a flux composed of one dram of calcined borax, one dram of creme of tartar, and two drams of a white glass, which he had himself prepared from six parts of white sand and eight parts of borax: the proportion of the precipitate of platina to this flux he does not specify. The mixture was urged with the fire of a forge, animated by several bellowses, for thirty-five minutes, and the matter being then in good quiet fusion, it was suffered to cool. The upper part of the mass was a blackish glass: at the bottom of the crucible was found a well collected lump of platina, pretty brilliant and smooth on the surface, weighing ninety-six grains. This lump had all the appearance of a metal that had received a very good fusion: nevertheless, on trying to extend it under the hammer, it broke in two pieces, and shewed an oval chamber or cavity in the middle: the fracture resembled that of large-grained brittle iron: in hardness it was nearly equal to forged iron, for it scratched deeply gold, silver, copper, and even iron

itself.

itſelf. The texture, brittleneſs, and cavity in the lump ſhewing that the platina, though it had approached conſiderably towards fuſion, had not melted perfectly, the author propoſes to repeat the operation with a degree of fire ſtill ſtronger.

It muſt be obſerved on this experiment, that in the precipitate made uſe of, the platina cannot be ſuppoſed to have been pure from other metals. Solutions of platina plainly contain iron, as appears from their ſtriking a blue colour with the Pruſſian alcali: either fixt or volatile alcalies precipitate this iron along with the platina; and as part of the platina remains diſſolved, the precipitate may contain a greater proportion of iron than the grains of platina itſelf did. Though the iron is in a ſtate of calx, diſſoluble by the glaſs, and not miſcible with metallic bodies in their perfect ſtate; yet a ſlight introduction of inflammable matter is ſufficient to revive it, calces of iron ſeeming to be eaſier of revival than thoſe of any other metal. The black colour of the glaſs was owing doubtleſs to the iron; nor would it be ſurpriſing, if preparations of platina ſhould on further trials be found to tinge glaſs of all the colours that iron can communicate. If the platina really melted, the fuſion may be aſcribed to a mixture of the ſame metal: but moſt probably the appearance of fuſion was no other, than a conglutination of the impalpable atoms into which the platina had been divided, ſimilar to what we find to happen when the crude mineral is urged with a ſtrong fire.

From the experiments related in this ſection it appears, that platina is not only of itſelf refractory in the fire; but obſtinately reſiſts the additions, and managements, by which every other known metallic body is corroded, diſſolved, or changed to a vitreous ſtate. If, as the chemiſts teach, metals are the more perfect, in proportion as they are the more permanent and the leſs ſuſceptible of changes, platina is of all known metals the moſt perfect.

SECT. V.

Of the mixture of platina with metals.

THE advantages which this new metal receives from its permanence and untarniſhing whiteneſs, and from its reſiſtence to liquids by which moſt of the other metals are corroded or diſſolved; are in great meaſure rendered ineffectual, by its wanting the fuſibility, which might enable the workman to form it into veſſels or utenſils. We have little foundation to expect any uſes of this kind, from ſo refractory a body, unleſs in combination with other metals; ſome of which may, perhaps, either have their own qualities improved by the admixture of certain proportions of it, or ſerve as intermediums for uniting the parts of the platina, without much injuring it in regard to thoſe properties in which its excellence conſiſts. Theſe hopes contributed to animate me in the proſecution of a laborious ſet of experiments, which however, independently of ſuch conſiderations, could not fail of affording intereſting phenomena. I regret that throughout this ſection, I have little more than my own trials to relate: Marggraf and Macquer have not entered into this enquiry, and Scheffer could proceed in it but a little way for want of platina to work upon. From the united labours of ſuch hands, diſcoveries of more importance may reſult.

As platina is to be diſſolved by the melted metals, we ſhall apply to it the ſeveral metallic bodies nearly in the order of the facility with which they become themſelves fluid in the fire; beginning with the ſingular one which we find naturally in a ſtate of fuſion.

I. *Platina with Quickſilver.*

ONE ounce of platina and ſix ounces of pure quickſilver were rubbed together, with a little common ſalt and water and a few drops of ſpirit of ſalt, in an iron mortar. After the grinding had been continued about ſix hours, the grains of platina appeared coated with the quickſilver, ſo as to cohere together into a kind of imperfect amalgam. The fluid quickſilver being poured off, I evaporated part of it in an iron ladle: it left a conſiderable quantity of a dark-coloured powder, intermingled with ſhining particles. A part of the quickſilver was paſſed through a linen cloth, and a part was ſtrained through thin leather: both theſe left alſo on evaporation a like powder, the quantity of which was pretty conſiderable from the portion which had been ſtrained through the linen, but very ſmall from that which had paſſed through the leather.

Mr. Scheffer alſo tried the amalgamation of platina with mercury, and reports that it did not ſucceed, though the grinding was continued, with the addition of a little aqua regia, at leaſt twice as long, as is requiſite for the amalgamation of iron filings with mercury when ſolution of green vitriol is added. It appears from the above experiment, that great part of the platina, even after long grinding, remains ſtill in entire grains, not diſſolved or combined with the mercury into ſuch a maſs as is called an amalgam: but the adheſion of the mercury to the ſurface ſhews an affinity between the two, or a diſpoſition to unite; and the powder left upon evaporating the ſtrained quickſilver is a proof that ſome part of the platina was truly diſſolved. I repeated the experiment ſeveral times, and always found that a part of the platina was diſſolved by the mercury, and that the undiſſolved grains were coated with it.

II. *Platina*

II. *Platina with Bismuth.*

A MIXTURE of black flux and common ſalt being brought into fuſion in a crucible, equal parts of platina and biſmuth were dropt in, and urged with a quick fire ſtrongly excited by bellows. The two metals appeared to have melted together in a few minutes; and the crucible being then taken out of the fire and cooled, the metallic lump at the bottom, freed from the flux, was found to weigh nearly as much as the ingredients did at firſt, the loſs being only about one part in a hundred and twenty. On breaking it, no grain of platina could be ſeen, this metal ſeeming to be all diſſolved and blended with the biſmuth.

The experiment was repeated in a wind furnace, but in this gradual heat the two metals did not well unite; nor was the union here perfect till the biſmuth was increaſed to about thrice the weight of the platina. By larger quantities of biſmuth, the platina was very eaſily diſſolved in the wind furnace as well as in the blaſt furnace; but in all caſes a part of it ſubſided if the mixture was ſuffered to cool ſlowly.

I melted platina with different proportions of biſmuth, as far as twenty-four parts of the latter to one of the former. All the compoſitions proved, like the biſmuth itſelf, extremely brittle: one was not remarkably more or leſs ſo than another. To the file, they were ſcarcely harder than pure biſmuth. On breaking them, the ſurface of the fracture appeared for the moſt part compoſed of ſtriæ and narrow plates ranged tranſverſely: with the larger proportions of biſmuth, the ſtriæ and plates were coarſe and irregular; with the ſmaller proportions, finer; and when the two metals were in equal quantity, they could ſcarce be diſtinguiſhed at all. When the maſſes were newly broken, they looked bright and ſparkling; except the compoſitions with a large proportion of platina, which were of a dull greyiſh colour, without any brightneſs. In the air they all tarniſhed in a remarkable manner, changing to a yellowiſh, a purpliſh or bluiſh, and at length to a purpliſh black: every one of them has ſuffered theſe changes, though ſome more ſlowly than others.

III. *Platina with Tin.*

1. EQUAL parts of platina and pure tin were dropt into a mixture of black flux and common ſalt in ſtrong fuſion, and urged with a quick fire in a good blaſt furnace. After a few minutes, the two metals appeared perfectly melted; and being inſtantly poured out, they run freely along a narrow mould, forming a ſmooth ingot, nearly of the ſame weight with the platina and tin employed. The compound proved extremely brittle, breaking eaſily from a fall. When broken, it appeared of a cloſe and ſmooth, though uneven, ſurface, and of a dull dark colour. By the file, or a knife, it was readily ſcraped into a blackiſh duſt.

2. One part of platina and two of tin, covered with black flux, borax, and common ſalt, were melted in a wind furnace: the platina appeared perfectly taken up by the tin, ſoon after the fire had been raiſed to a light white heat. The ingot was found deficient in weight about one ninetieth part. It greatly reſembled the foregoing, being only a little leſs brittle, and of a ſomewhat lighter colour.

3. One ounce of platina and four of tin, covered with black flux and common ſalt, and urged with a quick fire, melted together, with ſcarcely any loſs. This compound ſtretched a little under gentle ſtrokes of a flat hammer, but was by no means tough. It broke in pieces from a rude blow, and was readily ſcraped into duſt by a knife. The broken ſurface was rough, and of a granulated texture.

4. One

4. One ounce of platina and eight of tin, dropt into a fluid mixture of black flux and common ſalt, united, without loſs, into a pretty tough compound; which bore to be conſiderably flattened under the hammer without breaking, cut ſmooth with a thin chiſel, and ſhaved with a knife. Broken, it appeared of a ſparkling, dark coloured, coarſe grained texture.

5. One part of platina and twelve of tin, treated in the ſame manner, formed a mixture tolerably ductile; but ſtill of a dull dark hue, and a rough coarſe grain, though leſs ſo than the preceding.

6. A mixture of one part of platina and twenty-four of tin, ſtretched under the hammer almoſt as eaſily as tin itſelf, but broke much ſooner on bending. The colour was whiter, and the grain finer and evener, than thoſe of the preceding compoſitions, though in both reſpects it fell conſiderably ſhort of pure tin.

7. Several of theſe compoſitions, covered with black flux which had been previouſly melted by itſelf, till it ceaſed to boil up, were expoſed, in crucibles cloſely luted, to a ſtrong fire in a wind furnace, which was ſteadily kept up for eight hours. When taken out, they were all found to have ſuffered ſome diminution of weight, amounting to about one fortieth part of the tin. In their appearance and quality, there did not ſeem to be any alteration, except that the grain was a little finer, and the texture rather more uniform.

The foregoing mixtures ſeem to include a ſufficient latitude, in the proportions of the two metals, for diſcovering their general effects on one another. We may infer from them, that within this latitude, platina diminiſhes the malleability of tin, renders its texture coarſer, and debaſes its colour, more or leſs according as the platina is in greater or leſs proportion; and that, when the platina

amounts

amounts to about one third of the tin or upwards, the malleability, which both metals ſeparately poſſeſs, is deſtroyed by their combination with one another. The difference in the colours of theſe compoſitions was not ſo conſpicuous on the touchſtone, as when the fractures of the ingots were examined; although, on cloſe inſpection, the marks on the ſtone alſo appeared all of a darker colour than thoſe of pure tin, and the more ſo as the proportion of platina prevailed in the mixt. Kept in a cloſe room, in pill-boxes, they all tarniſhed in the fracture to a yellowiſh hue; but pieces which were ground and poliſhed have in ten years ſuffered little change, except only the mixture of equal parts of platina and tin, which is grown conſiderably dull and yellow.

It is obſervable, that though tin is a metal very readily deſtructible by fire, yet in moſt of the foregoing fuſions there was ſcarcely any loſs of weight. This may be attributed in part to the admixture of the platina preventing the ſcorification of the tin; and in part to the flux made uſe of, and the celerity and ſhort continuance of the heat. No. 2 and 7, where the heat was ſlowly raiſed and long continued, were the only ones in which the loſs was at all conſiderable.

IV. *Platina with Lead.*

1. Equal parts of platina and lead were injected into a mixture of black flux and common ſalt previouſly melted together, and the fire raiſed haſtily by bellows. A much ſtronger heat was requiſite than for the fuſion of platina with an equal quantity of tin, and the loſs was conſiderably greater, amounting to about one ſixty-fourth part of the metallic mixture. The metal yielded difficultly to the file, broke from a moderate blow, and appeared, on the fracture, of a cloſe texture, an uneven ſurface, and rough jagged edges. The colour was very dark, with a faint purpliſh caſt.

2. One part of platina and two of lead, covered with black flux and borax, and expoſed to a gradual fire in a wind-furnace, did not come into due fuſion till the fire had been raiſed to a ſtrong white heat. From the long continuance of the fire in this experiment, the loſs was great, amounting to nearly one twenty-fourth part of the mixture. The ingot proved hard and brittle like the preceding, but the texture ſtriated, and the ſtriæ diſpoſed tranſverſely.

3. One ounce of platina and three of lead, treated in the ſame manner, required ſtill a very ſtrong fire for their perfect fuſion, and loſt about one twenty-ſixth. The metal broke leſs eaſily than either of the preceding, and in ſome meaſure ſtretched under the hammer. Its colour was ſomewhat darker, and inclined more to purpliſh.

4. One part of platina and four of lead being covered with black flux and common ſalt, and committed to a wind furnace, the platina ſtill did not appear perfectly taken up till the fire had been raiſed to a conſiderably ſtrong white heat: the loſs was about one fortieth. The ſame proportions of the two metals, dropt into a fluid mixture of the flux and ſalt previouſly brought to the above degree of heat, quickly melted, and loſt only one part in a hundred and ſixty. The ingot was much tougher than the preceding, filed well, and cut tolerably ſmooth with a knife. On breaking, the upper part appeared compoſed of bright plates; the lower, of dark purpliſh grains.

5. One part of platina and eight of lead united eaſily in a quick fire, and loſt little or nothing. The metal worked, and looked, like very bad lead. On breaking it, the texture appeared partly compoſed of tranſverſe fibres, and partly of grains; its colour was dull and purpliſh.

6. One part of platina and twelve of lead united without loſs into a compound very little different from the preceding.

preceding. Its texture was finer, and composed chiefly of transverse fibres, with very few grains.

7. A mixture of one part of platina and twenty-four of lead proved not very much harder than lead of a middling quality. The colour was still somewhat purplish, and the texture fibrous; but the fibres were remarkably finer than when the platina was in greater proportion.

8. The four first of the foregoing compositions, when newly polished, appeared of a dark iron colour, which quickly tarnished to a brownish yellow, a deep purplish, and at length to a blackish. The three last, cut with a chisel, looked of a leaden hue, which tarnished but little; though the fractures, and outer surfaces, of all the seven have changed nearly to a like purplish black.

9. Upon returning these compounds to the fire a second time, it was constantly observed, after they had come into perfect fusion, that if the heat was slackened a little, great part of the platina subsided: that nevertheless, the lead decanted off even in a heat below ignition, retained so much of the platina, as rendered it of a fine fibrous texture and purplish colour.

10. The several mixtures, covered with black flux, and kept in strong fusion, in crucibles closely luted, for eight hours, suffered a diminution in weight, amounting, in most of them, to about one thirtieth part of the lead. On breaking them, those with a large proportion of platina appeared of a leafy, and those with a smaller of a fine fibrous texture, which seemed in general to be characteristics of the perfect union of the platina and lead. They all looked whiter and brighter than at first, but tarnished sooner in the air. One mixture in particular, of four ounces of platina and twelve of lead, broke into large, white, shining, talk-like flakes; which, on exposure to the air, changed in a very little time, in less than an hour, to a reddish,

a purple,

a purple, and a deep blue, and at length turned ſlowly to a dark purpliſh black colour.

The relations of platina to tin and lead appear therefore to be very different. Though a ſmall proportion of it is taken up and kept ſuſpended by lead in a very gentle heat; a large proportion is not near ſo readily diſſolved as by tin, and, when united by a ſtrong heat, ſubſides in great part upon the abatement of the heat. A little quantity ſtiffens and hardens lead more than it does tin, but a large one does not near ſo much diminiſh its malleability: a mixture of equal parts of platina and lead, though it has nothing of the ductility which each of the metals has ſeparately, is much leſs brittle than the mixture of equal parts of platina and tin. But the moſt remarkable phenomena in the mixtures with lead are the leafy or fibrous texture, and a purpliſh or bluiſh colour or a diſpoſition to acquire theſe colours ſpeedily in the air, and the black to which they at length change. Biſmuth, as we have already ſeen, exhibits with platina nearly the ſame appearances, though in a ſomewhat lower degree; and as none of the other metallic bodies I have tried was found to affect, or be affected by, platina in this manner, theſe experiments may be added to thoſe of Mr. Geoffroy, in one of the late volumes of the memoirs of the French academy, for eſtabliſhing an analogy between biſmuth and lead.

V. *Platina with Arſenic.*

White arſenic is a volatile metallic calx, reducible to its metallic form by expoſing it to a moderate fire with inflammable additions. A mixture of white arſenic and fixed alcaline ſalt, of each one ounce, with two ounces of powdered charcoal, was preſſed ſmooth into a crucible, and one ounce of platina ſpread above it: the crucible was cloſely covered and luted, and kept for twelve hours in a

 moderate

moderate cementing heat, which towards the end was increaſed to a conſiderable degree. On ſeparating the platina from the mixture by waſhing, many of its grains appeared divided, and its weight was ſomewhat increaſed. Being afterwards expoſed haſtily to a very intenſe fire, it did not melt, but emitted arſenical fumes, and after theſe had ceaſed, the platina was found to weigh juſt one ounce as at firſt.

This experiment ſeeming to ſhew that platina and arſenic have ſome diſpoſition to unite, I was preparing to proſecute it, to ſee if more arſenic could be combined with the platina ſo as to bring it into fuſion, when Mr. Scheffers papers came into my hands, in which I find a remarkable experiment on this point. Mr. Marggraf likewiſe has ſince tried platina with arſenic, in a manner not greatly different from that above mentioned.

Mr. Marggraf mixed one dram of platina with two drams of white arſenic, and expoſed the mixture to the fire in a glaſs retort: the arſenic roſe uncoloured, and left the platina white and undiminiſhed in weight. The proceſs was repeated with the ſame quantity of freſh arſenic, and the fire augmented to as great a degree as the coated retort could bear: the arſenic ſtill roſe white, but the grains of platina were now become black, though they ſtill continued malleable, and weighed as much as at firſt. A dram of platina, two drams of arſenic, and one dram of ſulphur, being well mixed together and treated in the ſame manner; the arſenic and ſulphur ſubliming together formed, as they uſually do when united in theſe proportions, a red compound; the platina becoming blackiſh, and weighing two grains, or one thirtieth part, more than at firſt. It ſeems therefore that in this way of managing the proceſs, the arſenic has leſs effect on the platina than in my experiment above mentioned.

Mr.

Mr. Scheffer proceeded in a different manner. The platina was firft ftrongly heated in a crucible by itfelf, and a little arfenic being then thrown upon it, they immediately melted together. He obferves, that platina melts with arfenic as eafily as copper and iron do when they are blended with arfenic; that there is no occafion for any flux; that one part of white arfenic is fufficient for four and twenty parts of the platina; and that the platina thus melted with arfenic is quite brittle, and breaks grey like arfenicated filver.

On repeating this experiment it appeared, that though the judicious author is by no means chargeable with any miftake, yet the little quantity of platina, he had to allow for the trial, made it impoffible for him to difcover the limitations, with which this ftrong action of arfenic on platina ought to be underftood. When only a few grains of platina are ufed, there is all the appearance of true fufion, but on taking larger quantities we frequently find the fufion to be only fuperficial and imperfect. An ounce of platina was ftrongly heated in a crucible, and pieces of white arfenic repeatedly thrown upon it, the arfenic amounting in all to near as much as the platina: fome of the grains melted into round drops: the greater part cohered into a mafs, differing from thofe, into which platina itfelf is formed by fire, in the furface being fmooth and uniform, and the grains in the internal part more firmly coherent. I treated another ounce of platina in the fame manner, and with the fame event: the mafs was of a fmooth furface, as if it had been perfectly melted, but its internal part was compofed of grains of platina in their ufual form. I put both maffes into a crucible, with frefh arfenic mixed with powdered charcoal, and urged them with a ftrong fire for half an hour: they run into one lump, of the figure of the bottom of the crucible, exter-

 nally

nally ſmooth, and of a bright white colour like quick-ſilver, very brittle, internally greyiſh, of a ſpongy texture, with ſome few of the grains of platina left entire in the middle: the crucible was lined with a black glaſs, probably a vitrification of the ferrugineous part of the platina; and ſeveral ſhining metalline globules adhered to the vitreous matter. The lump was again dropt into a ſtrongly heated crucible, with more arſenic and charcoal powder, and the fire excited by the bellows for another half hour: it melted as before, into a cavernulous maſs, in which no grains of platina could now be ſeen. It was again treated in the ſame manner with freſh arſenic, and tried to be poured out; but though the fire was made very intenſe, the metal would not run from the crucible. Being then urged in a quick fire without addition, it concreted into a lump of the ſame appearance as before: but a piece of this lump, dropt again into a crucible intenſely heated, did not ſeem to ſoften or ſuffer any alteration of its figure. The reſt of the lump was incloſed between two ſmall pieces of charcoal, a cavity being made in each piece for receiving it: the charcoal was coated over with luting, and, when thoroughly dried, dropt in among the fuel before the noſe of the bellows: the metal did not alter its figure, nor was its weight diminiſhed. I took half an ounce of the metal, and arſenicated it again in the ſame manner as at firſt, adding at different times more and more arſenic: it run into a lump as before, but I could not, by any increaſe of the fire, or by any addition of arſenic, make it thin enough to flow from the crucible. I took half an ounce more of platina, and having combined with it as much arſenic as I could by repeated injections, I reduced the maſs into groſs powder, mixed it with black flux and ſome freſh arſenic, and urged it with a quick fire in a covered crucible: the metal run into a

ſpongy

ſpongy lump, which retained particles of the flux here and there in its cavities, a mark that it had not flowed thin.

It appears upon the whole, that platina does melt with arſenic, but leſs perfectly than with other metals; and that it would be very difficult, if not impoſſible, to bring it, on this foundation, to ſufficient fuſion for being poured into a mould. All the arſenicated pieces are very brittle, internally of a greyiſh colour, and a looſe granulated texture. It is obſervable that though arſenic ſoon changes in the air to a blackiſh hue, and when mixed with other metals diſpoſes moſt of them to change in like manner, the arſenicated platina, after lying in a dry room for ſeven or eight years, continues nearly of the ſame appearance as at firſt.

VI. *Platina with Zinc.*

For uniting zinc with platina, I firſt tried the method in which zinc is commonly united with copper, and by which the zinc is at the ſame time purified from ſuch other metallic bodies as are frequently blended with it; viz. expoſing the platina to the fumes, extricated by fire and inflammable additions, from calamine, one of the purer ores of zinc. But that theſe fumes might act the more effectually on the platina, a little variation was made in the common manner of diſpoſing the materials.

Four ounces of calamine in fine powder were mixed with two ounces of powdered charcoal. Having often obſerved that calamine, with this proportion of charcoal, acquires a kind of fluidity in the fire, ſo that the platina would be apt to ſink through it to the bottom; I made the powder into a maſs with a little thin tempered clay, and preſſed it into the bottom of a crucible: above this maſs, the crucible was lined all round with luting to a conſiderable thickneſs, ſo as to leave only a ſmall paſſage in the middle for the fumes of the zinc to iſſue out; in

which

which paſſage, when the luting was thoroughly dried, an ounce of platina was placed. The crucible was covered and ſet in a wind furnace, and a pretty ſtrong fire kept up for ſix hours. Being then taken out, ſome flowers of zinc were found adhering to the cover, greateſt part of the platina was melted into ſmall bright globules, and ſuch grains, as retained their figure, appeared froſted over with minute globular protuberances, as if they had juſt begun to melt. Its weight was increaſed above a third part, ſo that it had imbibed about as much of the zinc as copper does in the common proceſs of making braſs.

Finding the fumes of zinc to act ſo powerfully on platina, I next tried zinc in its common metallic form. Upon an ounce of platina, covered with borax, and heated in a blaſt furnace to a ſtrong white heat, I threw an equal quantity of zinc. A violent deflagration aroſe, and the platina ſeemed to be almoſt inſtantly diſſolved. The metal, being immediately poured out, run freely into the mould, and was found to have loſt near half an ounce in weight; ſo that the quantity of zinc, which had ſufficed to keep the platina in good fuſion, was very little more than one half of the platina.

I made ſeveral further trials of the ſame kind, with different proportions of the two metals, both in a quick fire in a blaſt furnace, and in one more gradually raiſed in a wind furnace: the zinc always proved a ſtrong menſtruum for the platina, though much of the zinc was diſſipated by the heat requiſite for rendering the mixture ſufficiently fluid. One ounce of platina and four ounces of zinc being melted together in the blaſt furnace, as in the above experiment, the loſs was an ounce and a half, ſo that there remained with the platina about two ounces of the zinc. This compound was dropt upon another ounce of platina, ſtrongly heated as before with borax: the metal,

poured

poured out, run clean from the crucible, and weighed juſt two ounces and a half, ſo that the platina was here kept in fuſion by one fourth its quantity of zinc. This mixture was put into the ſame crucible, with the ſame borax: it ſtill deflagrated, melted, and on being poured into an iron ingot-mould, which had been newly ſmoked over the flame of a torch but not heated, the fluid metal was thrown about with violence in ſmall drops: this probably happened, not from any particular qualities of the metal, but from ſome moiſture in the mould.

Compoſitions of platina with different proportions of zinc differed little in appearance from zinc itſelf; except that where the quantity of platina was large, they were of a cloſer texture and duller hue, with rather more of a bluiſh caſt. Kept for ten years in a dry room, they do not ſeem to have tarniſhed or changed their colour. They were much harder to the file than zinc itſelf, and fell in pieces under the hammer; without at all ſtretching, as pure zinc does in a conſiderable degree. One twentieth of platina deſtroyed the malleability of zinc, and one fourth of zinc deſtroyed the malleability of platina: within this compaſs, we have no degree of ductility to expect from any mixture of the two.

VII. *Platina with Regulus of Antimony.*

EQUAL parts of platina and regulus of antimony were dropt into a fluid mixture of black flux and common ſalt, and the fire ſtrongly excited by the bellows. They melted perfectly together, and run freely into the mould. The compound looked of a much duller colour than the regulus at firſt, and, when broken, ſhewed a cloſe and uniform, though uneven ſurface: it proved conſiderably harder to the file, but not remarkably more or leſs brittle under the hammer.

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One part of platina and twenty of regulus of antimony being treated in the ſame manner, the compound looked brighter, and of a leafy texture, little different from that of the pure regulus.

The two metals were melted together in ſeveral of the intermediate proportions, but no other differences were obſerved than thoſe abovementioned; the mixtures with a large proportion of platina being of a dull colour and cloſe texture, and thoſe with a ſmall one bright and leafy. All of them continue untarniſhed.

Though the platina and regulus ſeemed to unite very well together, yet in ſlow cooling, part of the platina was apt to ſubſide. Six ounces of platina and twenty-four of regulus of antimony having been melted together with a quick fire, and poured into a mould, the compound appeared uniform throughout. Being melted again, kept in ſteady fuſion for five or ſix hours, and ſuffered to cool gradually in the furnace; the upper part of the maſs was bright, and of a large leafy texture, much like the regulus at firſt; the bottom was much duller and of a cloſer texture, and contained apparently a much larger proportion of the platina.

VIII. *Platina with Silver.*

1. Twenty grains of platina, and the ſame quantity of pure ſilver which I had revived from luna cornea, were covered with borax, and urged with a vehement fire in a blaſt furnace. They melted difficultly together, and did not prove fluid enough to run freely along the mould. The metal weighed thirty-nine grains, and on the ſides of the crucible were ſeen ſeveral ſmall particles, amounting, as nearly as could be judged, to about a grain more, ſo that there appeared to be no loſs of weight. The compound was hard to the file, and broke from a rude blow, though by gentle ſtrokes

ſtrokes it bore to be conſiderably flattened. Internally it appeared of a much duller and darker colour than ſilver, and of a much coarſer grained texture.

2. One part of platina and two of ſilver, covered with nitre and common ſalt, did not flow thin till the fire was raiſed to a ſtrong white heat, and, when poured out, left many ſmall particles adhering about the ſides of the crucible. The metal proved leſs brittle than the foregoing, and not ſo hard to the file: its texture was finer grained, and the colour whiter.

3. One part of platina and three of ſilver required alſo a very ſtrong fire for their perfect fuſion, and many particles of the metal were thrown up almoſt to the top of the crucible, as if the action of the ſilver upon the platina had been accompanied with a kind of ebullition or exploſion. The compound was hard and brittle, though leſs ſo than the preceding: by repeated nealing, it bore to be hammered, or flatted between ſteel rolls, into thin plates.

4. One part of platina and ſeven of ſilver melted together pretty eaſily, but a part of the metal was thrown up about the crucible as before. The compound hammered tolerably well, proved much harder than ſilver, and not ſo white, nor of ſo fine a grain.

5. In the foregoing experiments, the quantity of platina was from ten to twenty grains. I tried ſixty grains of platina with four times, eight times, twelve times, twenty times, and thirty times as much fine ſilver. One of theſe mixtures was treated without any flux, another was covered with borax, another dropt into borax previouſly brought into fuſion, another into melted black flux, and the laſt into melted common ſalt: the fire was ſtrongly excited by the bellows, and all the mixtures ſuffered to cool in the crucibles. With theſe larger quantities of the two metals, the phenomenon above taken notice of was

more remarkable: Numerous metallic globules appeared all over the infides of the crucibles, and many on the covers alfo: the differences in regard to the fluxes, and in the proportions of the two metals, feemed to make no material difference in this refpect. Some of the mixtures were melted over again, in frefh crucibles, feveral times: the metal fparkled up in the fame manner every time. On pouring them into moulds, unlefs the heat was very intenfe, a confiderable part remained behind, the filver feeming to quit the platina on an abatement of the heat. When the heat was fo ftrong that the whole run fluid into the mould, great part of the platina feparated and fell to the bottom in cooling, unlefs when the mould was very broad, fo that the compound begun to fix almoft immediately, without allowing time for the platina to fubfide.

6. I likewife melted filver with different proportions of a precipitate of platina obtained by adding mercury to a folution of platina in aqua regia. Here alfo the event was the fame: the metal fputtered up in extremely minute grains, which feemed as it were to penetrate the crucible.

7. There appears upon the whole a ftrong repugnance between platina and filver. Mr. Scheffer takes notice alfo of the difficulty of uniting thefe two, though the fparkling up of the metal, which was not confiderable in my experiments when the quantities were fmall, does not feem to have been perceived at all in his. He obferves that platina melts more difficultly with filver than with lead or copper; that three parts of filver are neceffary for making one part of platina melt by a blow pipe; and that the mixture retains the whitenefs which both metals poffefs, but proves hard and brittle. In all my mixtures with large proportions of platina, the colour was greatly inferior to that of filver: befides being very dull, they had fomewhat of a yellowifh caft; and this yellowifhnefs continued fenfible

even

even when the ſilver amounted to twenty times the weight of the platina; but one part of platina with thirty of ſilver made a mixture as white as the ſilver itſelf. None of them ſeem to have tarniſhed or changed their colour in keeping.

IX. *Platina with Gold.*

THE near and remarkable relation betwixt platina and gold in many properties hitherto ſuppoſed to belong to gold alone, their as manifeſt diſagreement in others, and the reports of gold having been debaſed by the admixture of conſiderable quantities of platina, induced me to examine more particularly the effects of theſe two metals in combination with different proportions of one another. The proportions were adjuſted according to the carat weights, as explained in the ſeventh ſection of the hiſtory of gold, the fineneſs of gold being uſually expreſſed in carats and their ſubdiviſions. The abſolute weight of what in theſe experiments is called a carat, was four grains.

1. Twelve carats of fine gold, and the ſame quantity of the purer grains of platina, were urged in a blaſt furnace for near an hour, with a fire ſo ſtrong, that the ſlip of Windſor brick with which the crucible was covered, though it had been dipt in thin tempered Sturbridge clay, begun to melt. Upon breaking the veſſel, the metal was found in one ſmooth lump or bead, which being nealed by the flame of a lamp, and boiled in alum water (the liquor commonly uſed by the workmen for cleanſing or brightening maſſes of gold and ſilver) appeared, both in the maſs and upon the touchſtone, of a pale bell-metal colour, without any reſemblance to gold. It bore ſeveral ſtrokes, and ſtretched conſiderably under the hammer, before it began to crack about the edges. On viewing the fracture with a magnifying glaſs, the gold and platina ap-

 peared

peared unequally mixed, and ſeveral ſmall particles of the latter were ſeen diſtinct: nor was the mixture entirely uniform after it had been again and again returned to the fire, and ſuffered many hours of ſtrong fuſion.

2. Eighteen carats of gold and ſix of platina were melted together as the foregoing, in an intenſe fire continued about an hour. The bead, nealed and boiled, was leſs pale coloured than the former, but had nothing of the colour of gold. It forged tolerably well, like coarſe gold. To the naked eye it appeared uniform; but a good magnifying glaſs diſcovered, in this as well as in the other, ſome inequality of mixture, notwithſtanding the fuſion was two or three times repeated, with as great a degree of heat as we could eaſily excite by the bellows.

3. Twenty carats of gold and four of platina were kept in ſtrong fuſion above an hour and a half. Theſe united into an equal maſs, in which no granule of platina or diſſimilarity of parts could be diſtinguiſhed. The colour was ſtill ſo dull and pale, that the compound could ſcarcely be judged by the eye to contain any gold. It hammered well into a pretty thin plate, but we could not draw it into wire of any conſiderable fineneſs.

4. Twenty-two carats of gold were melted in the ſame manner with two carats of platina, the ſame proportion that ſtandard gold contains of alloy. The mixture was uniform, and had a good deal of a golden colour, but with a particular dull dark hue, by which the eye could at once diſtinguiſh it, not only from fine gold, but from all the common ſorts of alloyed gold. It worked well, was forged into a thin plate without cracking, and drawn into moderately fine wire.

5. Twenty-two carats and a half of gold and one and a half of platina, or fifteen parts of the former to one of the latter, melted into an uniform maſs, which after the uſual

nealing

nealing and boiling, proved ſomewhat tougher than the preceding, and of a better colour.

6. Twenty-three carats of gold were melted with one of platina, which is nearly half the proportion that ſtandard gold contains of alloy. The compound worked extremely well; but was diſtinguiſhable from fine or ſtandard gold by ſome degree of the ill colour of the two foregoing, which it retained after repeated forgings, fuſions and boilings.

7. Twenty-three carats and one fourth of gold, and three fourths of a carat of platina, or thirty-one parts of the former to one of the latter, formed an equal mixture, very malleable, ductile like the three foregoing while hot as well as cold, but not altogether free from their particular ill colour.

8. A mixture of twenty-three carats and a half of gold with half a carat, or one forty-ſeventh its weight of platina, was very ſoft and flexible, of a good colour, without any thing of the diſagreeable caſt by which all the foregoing were readily diſtinguiſhable by the eye from any kind of alloyed gold I have ſeen.

9. A mixture of twenty-three carats and three fourths of gold with one fourth of a carat, or one ninety-fifth its weight of platina, could not be diſtinguiſhed, by the eye or the hammer, from the fine gold itſelf.

10. In all the above proceſſes, even where the quantity of platina was very ſmall, the fuſion was performed with a vehement fire, that the platina might be the more perfectly diſſolved, and equally diffuſed through the gold. This appeared to be a very neceſſary precaution. Having once melted gold with one fourth its weight of platina, the button appeared not much paler than ſtandard gold with ſilver alloy, but on a ſecond fuſion it loſt its yellowneſs, and looked not much unlike bell metal. The gold

colour

colour appeared to have been only ſuperficial, from an imperfect mixture; moſt of the platina having been concealed in the internal part of the maſs, and covered as it were with a golden coat.

11. In ſome circumſtances I have ſeen the gold, after it had been thoroughly mixed with the platina, ſpued out again in part to the ſurface. The foregoing bell-metal coloured mixture, after repeated fuſions with and without additions, and in different degrees of heat, became once yellow on the ſurface. On cupelling mixtures of platina and gold with lead, I have oftener than once ſeen the remaining button covered with a golden ſkin, and all the internal part grey.

12. In melting the platina and gold together, a little borax was always uſed as a flux; with an addition of nitre, which ſomewhat heightens the colour of gold, or at leaſt prevents the borax from making it pale. Pieces of ſome of the mixtures were remelted, with borax alone, with nitre alone, with common ſalt, with fixt alcaline ſalt, and with powdered charcoal: thoſe with borax ſeemed to be the paleſt, and thoſe with charcoal powder the beſt coloured, though the differences were very inconſiderable.

13. As a ſmall portion of copper ſomewhat heightens the colour of pale gold, I melted platina with eight times its weight of ſtandard gold made with copper alloy; that is, three parts of platina with twenty-two parts of fine gold and two of copper. The fuſion was performed, as in the preceding experiments, with a ſtrong fire, in a cloſe crucible, but without any flux, and continued about an hour. The metal appeared covered with a black ſcurf, and had loſt about a two-hundredth part of its weight. It was much duller coloured, much harder under the hammer, and cracked ſooner about the edges, than mixtures of fine gold with conſiderably larger quantities of platina. By

repeated

repeated fuſion and frequent nealing, it became a little ſofter and tougher, ſo as to be drawn into pretty fine wire; but the colour was ſtill exceeding dull, more reſembling that of very bad copper than of gold.

It appears from theſe experiments, that platina diminiſhes the malleability of gold much leſs than it does that of the other malleable metals; and infinitely leſs than lead, tin, iron, and the brittle metals do that of gold: that in conſiderable proportions it debaſes the colour of gold far more than the uſual alloy, communicating a peculiar and remarkable ill colour; and that it both hardens, and debaſes the colour of ſtandard gold, with copper alloy, much more than fine gold: that in ſmall proportions, as one forty-ſeventh and downwards, it does not ſenſibly injure either the colour or malleability of gold; and conſequently, that large proportions of platina mixed with gold are diſcoverable at ſight, but that ſmall proportions, if perfectly united with the gold, will not betray themſelves either to the eye or in the workmans hands.

X. *Platina with Copper:*

1. Equal parts of platina and copper, expoſed, without addition, to a ſtrong fire haſtily excited by bellows, ſoon became fluid, but not thin; and loſt about one ſixty-fourth. The metal proved extremely hard to the file, broke difficultly on the anvil, flew aſunder upon endeavouring to cut it with a chiſel, and appeared internally of a coarſe grained texture and white colour.

2. One ounce of platina and two of copper, urged with a quick fire in a blaſt furnace, without addition, flowed ſufficiently thin, and ſcarcely ſuffered any loſs. The metal was ſtill very hard, and ſtretched but little under the hammer. It looked darker coloured than the foregoing, with a ſlight reddiſh caſt.

3. One

3. One ounce of platina and four of copper, treated in the ſame manner, united without loſs into a pretty tough compound, which bore to be conſiderably flattened, cut with a chiſel, and bent almoſt double before it cracked. Internally it looked of a fine texture, and of a very pale copper colour.

4. A mixture of one ounce of platina and five of copper ſtretched ſomewhat more eaſily under the hammer than the preceding, and appeared of a redder colour.

5. Upon increaſing the copper to eight times the quantity of the platina, the compound proved ſufficiently tough, broke difficultly, and hammered well. It was much harder than copper, and of a paler colour.

6. A mixture of one part of platina and twelve of copper was ſomewhat more eaſily extended under the hammer than the preceding, and proved ſofter to the file. It ſtuck a little in the teeth of the file, which the compoſitions with a greater proportion of platina did not.

7. A mixture of one part of platina and twenty-five of copper was ſtill ſomewhat paler coloured than pure copper, and conſiderably harder and ſtiffer, though very malleable. On increaſing the copper a little further, the mixture continued ſomewhat harder than the copper by itſelf, and appeared of a fine roſe colour.

8. In the foregoing fuſions, though in general no flux was made uſe of, there was ſcarcely any loſs of weight, except in No. 1, where the large proportion of platina required the fire to be raiſed to a violent degree. This ſeems owing in great meaſure to the platina preventing the ſcorification of the copper: for on melting pure copper, a great number of times, both with and without fluxes, there was conſtantly ſome loſs.

9. The mixtures with large proportions of platina are difficultly extended under the hammer when cold, and

when

when red hot they fly in pieces: they bear a good poliſh, and do not ſeem at all tarniſhed in keeping ten years; of the mixture of equal quantities in particular, the poliſhed part continues very brilliant. No.7. has tarniſhed a little, but ſeemingly not ſo much as pure copper.

Platina appears therefore from theſe experiments to harden copper, to dilute its colour, and diminiſh its diſpoſition to tarniſh; in ſmall proportions, to improve its hardneſs, without much injuring either the colour or malleability; and in larger proportions, to injure the malleability leſs than it does that of any of the other ductile metals, except gold and perhaps ſilver. Platina and copper ſeem to form valuable compoſitions, of which I doubt not but the workman may avail himſelf.

In a letter from Spain to a perſon in London, a tranſlation of which has been communicated to me, there is an account of an experiment on platina and copper, which, though imperfectly related, may deſerve to be mentioned here. The author firſt tried platina with an equal weight of ſilver, and found them to melt together . . . . he afterwards melted it with copper, which united perfectly well; but whether it was the platina itſelf, or the mixture with ſilver, that was melted with the copper, is not clear from the words, though it ſeems to have been the former. The mixture with copper, " on trying to hammer it, flew about like glaſs; but having melted it over again with a ſtronger fire for ſome time, and thrown in a little ſaltpetre, mercury-ſublimate, and other corroſives, it became malleable, and was then made into rings, which were worn for a good while without ſoiling the fingers, and preſerved always the ſame colour and luſtre as thoſe called in Spaniſh *tombagos*, which conſiſt of two parts of copper and one of gold."

A mixture of equal parts of platina and copper (No. 1. of the above experiments) was tried by Mr. Scheffer, who reports, that they melted as eaſily as copper by itſelf; and that the mixture proved tolerably malleable, as mixtures of gold with a like quantity of copper: in both theſe points, the little quantity he could allow for the experiment may be ſuppoſed to have occaſioned ſome deception. He adds, that when this compound is urged by a ſtrong blaſt impelled upon the ſurface, as in the purification of copper before the bellows, it throws out ſparkles like iron in welding, and that theſe ſparkles are found in form of round grains, which partake of both the metals; a phenomenon which gold does not exhibit with copper. After this operation, he found the mixture leſs malleable than before, like copper over-refined.

XI. *Platina with Copper and Zinc.*

1. EQUAL parts of platina and braſs, covered with borax and expoſed to a quick fire in a blaſt furnace, melted perfectly together, and ſuffered very little loſs. The mixt was of a greyiſh white colour, filed hard like bell-metal, broke from a blow of the hammer without ſtretching or receiving any impreſſion, and flew aſunder upon endeavouring to cut it with a chiſel. Internally, it appeared of an uniform fine grain, a cloſe texture, and a darker colour than on the outſide. It bore a very fine poliſh, which in ten years does not appear to have at all tarniſhed.

2. One part of platina and two of braſs, melted together in a ſlow fire, loſt about one thirty-ſixth. The ingot was of a duller colour than the foregoing, with a faint yellowiſh caſt. It filed ſofter, and broke leſs readily from the chiſel, but cracked and fell in pieces under the hammer. It received a good poliſh, and continues untarniſhed.

3. One

3. One part of platina and four of brafs, covered as before with borax, and expofed to a quick fire, melted together without lofs. This compound proved yellower than the preceding, and fofter to the file; it bore to be cut fome depth with a chifel before it broke, and received fome impreffion from the hammer, ftretching a little, but foon cracking in various directions.

4. Upon increafing the brafs to fix times the weight of the platina, the compound appeared yellower, though ftill very pale. It proved fofter to the file; and ftretched more under the hammer, and received a deeper impreffion from the chifel, before it broke.

5. A mixture of one part of platina and twelve of brafs was confiderably paler, and much harder, than brafs. It broke under the chifel; and cracked, before it had extended much, under the hammer. Both this and the two preceding compofitions bore a tolerably good polifh, and have not tarnifhed fo much as brafs by itfelf; though in both refpects they fall fhort of No. 1 and 2.

XII. *Platina with Copper and Tin.*

1. Fifty parts of platina, feventeen of copper, and fix of tin, covered with borax, became fluid in a ftrong fire, and fuffered very little lofs. The ingot proved confiderably hard, fo as fcarce to be touched by the file; and very brittle, breaking from a moderate blow, of a rough furface, and dull bell-metal colour. It bore a good polifh, and continues untarnifhed.

2. Platina and copper of each one ounce, and four ounces of tin, melted perfectly together, with little or no lofs. This compound filed freely and eafily, and bore to be cut with a knife, but broke readily on the anvil; the fracture was of an irregular furface, and a dull whitifh colour. Polifhed, it looked like polifhed iron: the fracture

 foon

ſoon tarniſhed to a yellowiſh hue; the poliſhed part grew dull but retained its colour.

3. A mixture of platina and copper of each one part, and eight of tin, proved ſofter than the foregoing, and flattened a little under the hammer. Broken, it ſhewed a very irregular ſurface, compoſed of a great number of bright white plates. It did not poliſh well. The fracture ſoon tarniſhed; the poliſhed part retained its colour.

XIII. *Platina with Iron.*

1. Half an ounce of platina and an ounce of iron wire were placed on a bed of gypſum in a Heſſian crucible, and covered and ſurrounded with more gypſum: after being urged in a blaſt furnace with two pair of bellows for about an hour, the crucible was in great part vitrefied, and a large hole made in its ſide, by which moſt of the metal had run out. The experiment was four or five times repeated, but a perfect union of the platina and iron could not be obtained, the crucible being corroded and vitrefied by the gypſum before the iron flowed thin enough to diſſolve the platina. It was obſervable that the iron, thus melted, proved very malleable; though ſome have thought that forged iron, brought into fuſion, is of the ſame nature with common caſt iron.

2. Caſt iron and platina, of each three ounces, expoſed without addition to a ſtrong fire, united into a thick fluid, which, on adding an ounce more of the iron, flowed pretty thin. The black lead crucible having become too ſoft from the great heat, to admit of being lifted with the tongs, the metal was ſuffered to cool in it. On breaking it, the metal was found in one lump, not convex, but of a very concave ſurface: its weight was about one ſixteenth leſs than that of the platina and iron employed. It proved exceſſively hard, ſo as not to be touched by the file, and yet

yet ſo tough, as not to be broken by repeated blows of a ſledge hammer, from which it received ſome impreſſion. Heated red, it broke eaſily, and looked internally of an uniform texture, not compoſed of bright plates as the iron was at firſt, but of very dark coloured grains which had no metallic luſtre.

3. One ounce of platina being thrown upon four ounces of caſt iron beginning to melt, and the fire kept up ſtrong, the whole came quickly into fuſion. The compound, like the foregoing, was extremely hard, and ſeemed to ſtretch a little under the ſledge hammer, without breaking. The texture was grained, as before, but the colour ſomewhat leſs dark.

4. One part of platina and twelve of iron melted without difficulty, and with little or no loſs. This mixture alſo was much harder than the iron at firſt, and received ſome impreſſion from the hammer. Like the others, it could not be broken while cold without extreme violence, but proved very brittle when heated red.

5. All the foregoing compoſitions received a good poliſh. The firſt, in keeping ten years, has ſuffered no ſenſible change; the ſecond has ſome ſmall ſpecks of tarniſh, and the third is tarniſhed ſomewhat more, but not ſo much as a piece of the iron itſelf.

6. About an ounce of a compoſition of one part of platina and four of iron was ſurrounded, in a crucible, with Reaumurs ſteel-making mixture, compoſed of eight parts of wood ſoot, four parts of wood aſhes, four of charcoal powder, and three of common ſalt: the crucible was covered and cloſely luted, and kept in a ſtrong red heat for twelve hours. The metal gained an increaſe of about one thirty-ninth of its weight, yielded to the file more eaſily than at firſt, ſeemed to receive no additional hardneſs on being ignited and quenched in water, and did not appear to have

acquired

acquired any of the qualities by which ſteel is diſtinguiſhed from iron.

7. A piece broken off from the ſame ingot, weighing about three quarters of an ounce, was treated in the ſame manner with the powder for ſoftening caſt iron, viz. bone aſh with a ſmall mixture of charcoal powder. The metal was found increaſed in weight about one thirty-fourth: it was leſs hard to the file than at firſt, but harder than the part which had been cemented with the ſteel-making mixture.

It may be proper to obſerve, that caſt iron is by no means a pure or ſimple metallic body, like thoſe whoſe relations to platina have been examined in the foregoing articles. It ſeems generally to contain mineral ſulphur, to which perhaps its brittleneſs is chiefly owing, and which is ſeparated in the proceſs by which the iron is made malleable. As platina appears incapable of contracting any union with pure ſulphur, I have ſuſpected, that while the platina and caſt iron unite together, ſome of the ſulphureous matter is thrown out and conſumed, and that the degree of toughneſs, obſerved in the compounds, may proceed in part from this cauſe; but experiments have not yet been carried to a ſufficient length to enable us to enter ſatisfactorily into diſquiſitions of this kind.

If however the caſt iron ſhould be as effectually purified by the platina, as it is even at the finery in the iron works, yet the toughneſs of the mixtures would ſtill be pretty remarkable, conſidering how much platina, when its proportion is large, is diſpoſed to diminiſh this quality in all the other metals. Perhaps platina, for certain purpoſes, may prove a valuable addition to this moſt uſeful metal; a metal to which the workmen cannot communicate the hardneſs which is often required, without communicating at the ſame time brittleneſs and intractability.

XIV. *Platina*

XIV. *Platina with metallic glaſſes.*

Mr. Marggraf, after having ſatisfied himſelf that platina perfectly reſiſts the common unmetallic fluxes of the vitreous and ſaline kind, as related in the fourth ſection of this hiſtory, proceeded to try if the more active glaſs of lead would ſerve as a flux for it.

A glaſs of lead, prepared from four parts of the fineſt minium and one part of pure flint, was reduced into powder and paſſed through a fine ſieve, to ſeparate any metallic grains that might remain in it. Eight ounces of the powder were mixed with one ounce and a half, or 720 grains, of platina, and the mixture urged with a ſtrong fire, in a cloſe luted crucible, for two hours: a white or greyiſh brittle regulus was obtained, covered with a yellowiſh ſcoria. The regulus was remelted with more of the ſame glaſs of lead, and kept again two hours in fuſion: it looked as before, had a like yellow ſcoria, and weighed 606 grains, or about a ſixth part leſs than the platina employed. Kept in fuſion two hours in a cloſe crucible, it loſt ſix grains, or about a hundredth part. It was then beaten in pieces in an iron mortar, and mixed with an ounce of common green glaſs in fine powder: the mixture being kept melted for three hours in a covered crucible, the ſcoria proved turbid, inclining to greeniſh, and in ſome parts to bluiſh; the metal had loſt thirty grains, or about a twentieth; it filed well, looked very white in the marks of the file, had ſome toughneſs, and did not very eaſily break under the hammer. It was again expoſed to a ſtrong fire for two hours in a cloſe crucible, with half an ounce of calcined borax: the borax run through the crucible, but the metal did not perfectly melt, only baking into a maſs, of an unequal rough ſurface, porous, eaſy to break, in the fracture of a grey and white colour intermixed, in

weight

weight 540 grains, ſo that it had loſt above a twentieth part more. It was further treated with half an ounce of calcined borax, the ſame quantity of powdered white flints, and an ounce of ſalt of tartar: the mixture being urged for two hours in a cloſe crucible, with a vehement fire, the ſcoriæ were of a topaz inclining ſomewhat to a chryſolith colour; the metal of a fine white colour, ſpongy, rough on the ſurface, in weight 450 grains, ſo that it had loſt in this fuſion one ſixth part, and weighed now three eighths leſs than the platina at firſt.

It may be preſumed, that the metal obtained in this experiment was no other than a mixture of part of the platina with ſome lead revived from the glaſs. Though the author took care, by covering and luting the crucible, to guard againſt the falling in of any inflammable matter that might revive the lead, yet ſuch a matter might have happened to be introduced in the pounding and ſifting of the glaſs; and independently of any accident of this kind, there was, perhaps, in the platina itſelf, a power ſufficient for producing the effect. Common platina, ſuch as Marggraf employed, plainly contains iron; and on barely ſtirring glaſs of lead in fuſion with an iron rod, part of the lead is revived. I mixed ſome of the purer grains of platina both with glaſs of lead and with glaſs of antimony, and expoſed both mixtures to a fire as ſtrong as I could excite: the platina ſhewed no diſpoſition to melt, the grains remaining of their uſual appearance. Vogel ſeems therefore to have ill underſtood Marggrafs experiments, when he concludes from them that platina yields a white regulus with glaſs of lead.

Mr. Marggraf gives alſo another experiment of the fuſion of platina, with an arſenicated glaſs of lead. A glaſs was prepared by melting together eight ounces of minium, two of flints, and one of white arſenic. Six

ounces

ounces of this glafs in fine powder were mixed with one ounce of platina, and the mixture melted in a clofe crucible for two hours. A brilliant regulus was obtained, greyifh on the fracture, but when filed pretty white, weighing twenty-eight grains, or about one feventeenth, more than the platina: the fcoria was of a dark brown colour.

Here the increafe of weight is a full proof that the fufion of the platina was owing to its having imbibed either lead or arfenic from the glafs: in the brilliancy of the furface, and the grey colour of the internal part, Mr. Marggrafs metal agreed with our maffes of arfenicated platina already defcribed; and probably the ufing of arfenic in a ftate of vitrification with fubftances which ferve to detain it in the fire, may be the moft effectual means of combining this volatile metallic body with platina.

XV. *General obfervations on the mixtures of platina with other metals.*

1. It appears from the foregoing experiments, that platina, unfufible by itfelf in the ftrongeft fires of our furnaces, and proof againft the moft active unmetallic fluxes, melts with, or is diffolved by, every one of the common metallic bodies: That the different metals diffolve it with different degrees of force, and this not in proportion to the degree of their own fufibility: That there are remarkable differences in its relation to different metals, in regard to the change which it produces in the quality of the metal; that it hardens, and diminifhes the malleability of, all the malleable metals, but feems to communicate fome degree of toughnefs to one which of itfelf has none, viz. caft iron; that it diminifhes the malleability of tin more, and of gold lefs, than of the other metals; that in certain quantities, it debafes the colour of all the metals, communicating to

ſome its own whiteneſs, as to copper, and producing with others a new colour, as with biſmuth, lead, and gold; that it preſerves copper and iron from tarniſhing or ruſting in the air, but occaſions lead and biſmuth to tarniſh in a remarkable manner.

2. Though platina, when its quantity is not very large, becomes fluid with moſt of the metals in a moderate fire, a ſtrong one ſeems to be always requiſite for its perfect and total ſolution. Compoſitions of copper, of ſilver, and of lead, with one third their weight of platina, which had flowed thin enough to run freely into the mould, and appeared to the eye perfectly mixed; on being digeſted in aquafortis till the menſtruum ceaſed to act, left ſeveral ſmall grains of platina in their original form. Upon viewing theſe with a microſcope, ſome appeared to have ſuffered no alteration: others ſhewed a multitude of ſmall, bright, globular protuberances, as if they had juſt begun to melt.

3. Mixtures of copper, ſilver, and lead with ſmaller proportions of platina, which had been kept in ſtrong fuſion for ſome hours that the platina might be wholly incorporated, were digeſted and boiled in freſh portions of aquafortis, till the platina was left by itſelf in fine powder, free from any thing that aquafortis could extract. Theſe powders were expoſed to very vehement fires, without addition, with the addition of borax, with alcaline ſalts, and with flint glaſs: they proved as unfuſible as the platina at firſt, neither melting, nor communicating any colour to the ſalts or glaſs. It appears therefore that the platina is only ſimply diſſolved by the metals in fuſion, and does not by their means become truly fuſible itſelf.

4. As platina unites with ſeveral metals into compounds of new qualities, ſuch as the ingredients neither poſſeſs ſeparately, nor can be conceived, on any known mechanical

nical principles, to produce by their ſimple junction; and as ſuch new properties ſeem to be in no metallic mixture more conſpicuous than in thoſe which platina affords; it follows, that the diſſolution of platina by metals is by no means a ſuperficial mixture, but as perfect and intimate a coalition as we have grounds to believe that of any one metal to be with any other.

SECT. VI.

Of the ſpecific gravities of mixtures of platina with different metals.

AMONG the experiments communicated to the Royal Society by Mr. Wood, there is a remarkable one of the ſpecific gravity of a mixture of equal parts of platina and gold. The gravity of the heavieſt platina he examined was to that of water as 15 to 1; and the gravity of gold, as we have ſeen in the hiſtory of that metal, is about $19\frac{3}{10}$. If 15,0 parts of platina loſe one on being immerſed in water, and 19,3 parts of gold loſe 1; then, if the two metals be mixed in equal quantities, 34,3 parts of the compound ſhould loſe 2; whence, dividing 34,3 by 2, we have 17,150 for the gravity of the compound. Such ought the gravity to be, if the two metals were joined ſuperficially, and each preſerved its own proper volume; but when melted together, the ſpecific weight of the maſs is ſaid to have been conſiderably greater, amounting to no leſs than 19. If this be the caſe, 19 parts of the melted maſs muſt occupy no more ſpace than $17\frac{15}{100}$ did before the fuſion; ſo that near a fourth part of one metal is received into the pores of the other, without increaſing the bulk of the maſs. It may be ſuſpected, that the ſubſtance which Mr. Wood weighed by itſelf under the name of platina was the lighter caſt metal mentioned at the begining of this hiſtory, and that what he melted with gold was the true platina; in which caſe, the gravity of platina being ſuppoſed 17, the increaſe of gravity on mixture comes out about a twentieth part, ſo that about a tenth part of the platina has its bulk loſt in the maſs.

To ſatisfy myſelf in this point, I weighed hydroſtatically the mixture, already mentioned, of equal parts of platina and gold. The ſpecific gravity of the gold was 19,285: the platina was the larger grains, whoſe gravity, as we have ſeen in the firſt ſection, was at leaſt 17. The compound weighed in air 13605, and loſt in water 750, whence its gravity was 18,140: the gravity by calculation comes out 18,071; ſo that though the platinas gravity had been no more than 17, the increaſe of gravity from the mixture was not very conſiderable. As a little loſs had happened in the fuſion of this mixture, and as the ſpecific weight of the platina employed was not certainly known, I made two freſh ones, with pieces cut off from the ſame maſs of gold, and ſome of the largeſt grains of platina, whoſe gravity was nearly 18. One of theſe mixtures, weighing 5129, loſt in water 276; and the other, weighing 6415, loſt 345; whence the ſpecific gravity of the former turns out 18,583, and that of the latter 18,594, which come as near to one another as can well be expected in experiments of this kind: the gravity by calculation is 18,622; ſo that both mixtures were a little ſpecifically lighter, or expanded into a larger volume, than if the metals had been weighed ſeparately, or joined by ſimple appoſition of parts. As theſe experiments were made with a good deal of care, it may be preſumed that in thoſe, where there ſeemed to be a great increaſe of gravity, or contraction of volume, either ſome error happened in the weighing, or the platina had not been all taken up by the gold in the fuſion.

I weighed

I weighed alſo hydroſtatically the other mixtures of platina and gold, and ſundry mixtures of it with different proportions of the other metals. Such maſſes as could bear the hammer, were gently hammered a little, with care not to make them crack; for the pure metals themſelves, after fuſion, are ſeldom found to come up to their true ſpecific weight, till brought to greater ſolidity under the hammer. The ſurface was filed ſmooth, where any cavities or irregularities were likely to retain air; and moſt of them were kept immerſed in water for an hour or more, that the air might be more effectually extricated, and the water more cloſely applied to them. The effect of this precaution was manifeſt in ſome trials purpoſely made: when the metal, hanging in water from the end of the beam, had been cleared from all viſible air bubbles, and exactly counterpoiſed; on ſtanding for an hour or two, it ſenſibly, and ſometimes very conſiderably preponderated. The water was in ſome of the trials melted ſnow, and in others diſtilled water, which were both found to be of the ſame ſpecific weight. The temperature of the air was from the 50th to the 60th degree of Fahrenheits thermometer.

The balance, made uſe of in theſe experiments, was of great ſenſibility, but not exactly equibrachial: and here it may be proper to obſerve, that though the writers on balances require, and are very ſolicitous about procuring, a perfect equality of the arms; yet as this equality is exceeding difficult, if not impoſſible, to be obtained, ſo neither does it appear anywiſe neceſſary to the accuracy of the inſtrument. If ten equal ſmall weights, put into one ſcale, are counterpoiſed by a weight in the other; and if the ten weights be then removed, and a bit of ſilver or braſs plate put in their room; it is evident, that when this plate ſhall be made equiponderant to the counterpoiſe, it

will

will be exactly equal in weight to the ten, how unequal ſoever the arms of the balance may be; and conſequently, that any unequal-armed balance may, on this principle, have a ſet of weights adjuſted to it, which being uſed always in one ſcale, the inſtrument ſhall be of the ſame accuracy as if the arms were moſt exactly equal. The beſt way of procuring equal ſmall weights is, by cutting off equal lengths of the fineſt ſilver wire: the ſilver thread, kept equally ſtretched by a heavy body at the end, may be coiled cloſe round a thicker piece of braſs wire, and all the coils cut through at once by a ſharp inſtrument applied lengthwiſe. Silver wire is drawn to ſuch fineneſs, and of ſo uniform thickneſs, that weights, thus made by menſuration, are of greater nicety than it is poſſible for any balance to weigh. A piece of the wire, whoſe length is very ſenſible and much further diviſible, ſhall not have weight enough to give any ſenſible motion to the tendereſt balance. Theſe ſmall pieces, or ſuch as will but juſt move the balance when empty, and which conſequently will not move it at all when loaded, I have found to be a very uſeful appendage to the adjuſted ſeries of weights. Though a balance appears exactly in equilibrio, yet one ſide may really preponderate, by any quantity of force, leſs than that which is ſufficient to overcome the friction on the center: as leſs additional force will ſerve to depreſs this ſide than the other, one of the ſmall weights, tried firſt in one and then in the other ſcale, will enable us to judge whether the equipoiſe is exact, or on which ſide the preponderation lies.

The reſults of theſe experiments were publiſhed in the Philoſophical Tranſactions, together with the gravities of the ſeveral mixtures deduced from calculation; from which it appeared that the experimental gravities were almoſt always leſs than the computed. But an error in

thoſe

thoſe calculations has made the computed gravities in general too great: for though the ingredients in each mixture were proportioned to one another by weight, the calculations were inadvertently made as if they had been taken by volume. The diſcovery of this miſtake I owe to Mr. Scheffer, who gives a paper on this ſubject in the Swediſh tranſactions for the year 1757.

The computed gravities being rectified, there appears to obtain, in ſeveral of the mixtures, ſome degree of what the above experiments ſhew not to obtain in thoſe with an equal quantity of gold; the compounds being of greater gravity, or more contracted in volume, than the two metals conſidered ſeparately.

This exceſs of the experimental gravities above the computed is attributed by Mr. Scheffer to the gravity of the platina being greater than that which I had aſſigned to it. He imagines, that particles of air, adhering in the cavities of the rugged grains, had occaſioned them, when weighed in water, to occupy a larger ſpace than that of their own proper bulk; and that, when the platina was melted into a maſs with other metals, it then diſcovered its true gravity. On this foundation he endeavours to deduce, from the ſpecific weights of the mixtures, that of the platina itſelf; one of the moſt important points, as he obſerves, in its philoſophic hiſtory, that I had left undiſcovered. Though I failed, on account of the above inadvertence, of attaining to its true weight, my experiments, he thinks, lead to it; and from thoſe experiments he concludes, that it is certainly more ponderous than pure gold.

This point ſeems to require ſome further examination: for ſuch a concluſion is not to be received without the ſtrongeſt proofs; and if the principle of induction is not perfectly juſt, it may give riſe to fallacies of worſe conſequence than an error in the gravity of platina.

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I have therefore computed the gravities anew, together with the gravity which each mixture gives for the platina. The firſt column, in each of the following tables, contains the proportions of the two metals in the ſeveral mixtures, the loſs ſuſtained in fuſion, where there was any, being deducted: as platina itſelf ſuffers no diminution in the fire, it is from the quantity of deſtructible metal mixed with it that this deduction is made. The ſecond column contains the ſpecific gravities of the mixtures as found by experiment, and the third their gravities by calculation ſuppoſing the platinas gravity to be 17: in the fourth is ſhewn the difference between the experimental and computed gravities, with the marks + or -- according as the former is greater or leſs than the latter. The laſt column gives the gravity of platina deduced on Mr. Scheffers principle from each of the mixtures.

GOLD	Specific Gravity By Expér.	Specific Gravity By Calcul.	Difference	Platinas Gravity reſulting
	19,285			
Platina 1, Gold 2 - -	18,378	18,458	,080 --	16,797
Platina 1, Gold 3 - -	18,613	18,658	,035 --	16,852
Platina 1, Gold 5 - -	18,812	18,862	,050 --	16,759
Platina 1, Gold 11 - -	18,835	19,071	,236 --	14,988
Platina 1, Gold 15 - -	18,918	19,124	,206 --	14,723
Platina 1, Gold 23 - -	19,089	19,177	,188 --	15,481
Platina 1, Gold 31 - -	19,128	19,204	,076 --	15,273
Platina 1, Gold 47 - -	19,262	19,231	,031 +	18,711
Platina 1, Gold 95 - -	19,273	19,258	,015 +	18,214

As the experiments with gold had not come to Mr. Scheffers hands when he wrote his paper, he was in hopes, that when ſuch experiments ſhould be made, they would give platinas gravity with certainty; gold being free

free from ſome of the cauſes of error which attend the other metals. It appears however from the foregoing account, that of twelve mixtures of platina and gold, there was not one ſo heavy as the gold itſelf, whereas on Mr. Scheffers principle they ought all to have been heavier. It is plain therefore that either platina is not ſo heavy as gold, or that the principle of induction does not obtain in the mixtures of gold and platina.

From the two laſt mixtures, the gravity of platina comes out between 18 and 19; but on theſe no dependence can be had, the difference between the experimental and computed gravities being ſo inconſiderable, that it may be attributed to the unavoidable imperfections of the inſtruments uſed for the weighing; for an error of leſs than a thirty-thouſandth part of the weight makes a difference of ,012 in the ſpecific gravity of the mixture, and of 1,000 in that of the platina deduced from it. The caſe is the ſame in the mixtures with other metals where the platina is in ſmall proportion.

The other compoſitions give the platinas gravity leſs than 17; and as the platina is found by itſelf to be 17 or more, it ſeems to follow, that there muſt neceſſarily be a diminution of gravity produced by the union of the two metals with one another. A phenomenon obſerved in the fuſion appeared to confirm this. Moſt metallic bodies, made fluid by fire, ſhrink and aſſume a concave ſurface in their return to ſolidity: pure gold ſhrinks perhaps rather more than any of the others. But mixtures of gold and platina, where the platina was in conſiderable proportion, were obſerved to ſhrink little; ſome of them even expanded and became convex. Of this expanſion or dilatation of volume, a decreaſe of ſpecific gravity is the neceſſary conſequence.

As the pureſt grains of crude platina have ſome admixture of heterogeneous matter, it is poſſible that this matter may prevent the intimate union of the platina and gold, and thus occaſion the two metals, when blended together, to occupy a larger volume than naturally belongs to them. I therefore melted gold with platina that had paſſed through ſome of the operations hereafter deſcribed, and which may be preſumed to have been thereby purified from moſt of its heterogeneous parts.

One of the neateſt beads of platina cupelled with lead, (article vi. No. 5, of the following ſection) was melted with equal its weight of gold in a ſtrong fire, and continued in fuſion about an hour: the maſs proved ſpongy and very light. I remelted it ſeveral times, with the moſt vehement fires I could excite; and in order to ſeparate as much as poſſible of the lead, to which its ſpongineſs ſeemed owing, I beat it in pieces, and boiled it in aquafortis, and repeatedly injected corroſive ſublimate upon it during the fuſion. The maſs nevertheleſs ſtill turned out cavernulous, and brittle, and ſpecifically lighter than either the gold or the bead of platina were by themſelves.

Platina diſſolved in aqua regia was precipitated by mercury, and the precipitate boiled in aquafortis and well waſhed with hot water. Twenty-ſix grains of this preparation were melted with four times as much gold: the platina ſeeming to be imperfectly mixed, the fuſion was three or four times repeated, and the quantity of gold increaſed to about eight times that of the platina. This mixture proved as ponderous as the gold itſelf, or rather more ſo: it weighed in air 16802, and in water 15934, whence its gravity was 19.357. It was examined by ſome other gentlemen as well as myſelf, who all agreed in its being remarkably heavy: Dr. Pemberton, with a very exact balance, found the weight in air 229.735 grains, and

in

in water 217.885, from which numbers the ſpecific gravity comes out 19.387.

LEAD	Specific Gravity By Exper.	Specific Gravity By Calcul.	Difference	Platinas Gravity reſulting
	11,386			
Platina 1, Lead 0,97	14,029	13,679	,350+	18,105
Platina 1, Lead 1,92	12,925	12,838	,087+	17,459
Platina 1, Lead 3,97	12,404	12,196	,308+	19,242
Platina 1, Lead 8 -	11,947	11,819	,128+	19,732
Platina 1, Lead 12 -	11,774	11,682	,092+	19,923
Platina 1, Lead 24 -	11,575	11,538	,037+	19,238

From this table it appears that the gravity of lead is affected by crude platina in a different manner from that of gold; the mixtures with gold being ſuch, as if the crude grains were of leſs gravity than 17, but thoſe with lead as if they were of greater; ſo that in one or the other caſe, or in both, an alteration of volume muſt neceſſarily be produced by the action of the two metals on one another.

SILVER	Specific Gravity By Exper.	Specific Gravity By Calcul.	Difference
	10,980		
Platina 1, Silver 1 - -	13,535	13,342	,193+
Platina 1, Silver 2 - -	12,452	12,449	,003+
Platina 1, Silver 3 - -	11,790	12,046	,256 --
Platina 1, Silver 7 - -	10,867	11,488	,621 --

Here we ſee the effects of the ebullition and diſperſion of the ſilver taken notice of in the hiſtory of the fuſion of platina with this metal. The laſt mixture is lighter even than ſilver itſelf, a proof that the metal is rarefied or made cavernulous by the action of the platina: the greater gravity of the two firſt mixtures was probably owing to a part of the ſilver having been thrown off in the fuſion, and the platina not perfectly diffolved by the reft. I took all poffible precautions for preparing a fet of mixtures of thefe two metals on purpofe for this examination, but they always fputtered up fo much about the crucible, that no dependence could be had upon the proportions of the two in the remaining mafs.

COPPER	Specific Gravity By Exper.	By Calcul.	Difference	Platinas Gravity refulting
	8,830			
Platina 1, Copper 0,969	11,400	11,869	,469 --	
Platina 1, Copper 2 - -	10,410	10,514	,104 --	
Platina 1, Copper 4 - -	9,908	9,768	,140+	19,364
Platina 1, Copper 5 - -	9,693	9,598	,095+	18,970
Platina 1, Copper 8 - -	9,300	9,328	,028 --	
Platina 1, Copper 12 - -	9,251	9,168	,083+	21,607
Platina 1, Copper 25 - -	8,970	8,996	,026 --	

Mr. Scheffer remarks that copper of itfelf can never be caft clofe; that when melted with a weak heat, it proves fo incompact as not to bear the hammer; and that when melted in a ftrong heat, with the addition of inflammable matter, in order to render it malleable, it proves cavernulous on the outfide. The irregularity in the above fet of experiments feems to fhew that fomething of the fame kind happens in the mixtures of copper and platina; fince four mixtures out of the feven were lighter than they ought to have been, and this not from any uniform action of the two metals on one another, but apparently from accidental porofity. I melted fome of the mixtures a fecond time, and found their gravities confiderably altered: that of 11,400 was increafed to 11,693; and that of 9,251 was diminifhed to 8,985. Little therefore can be concluded from thefe mixtures, in regard either to the gravity of the platina, or its effect in varying the gravity of copper.

IRON

IRON	Specific Gravity By Exp.	By Calc.	Difference	Platinas Gravity resulting
	7,100			
Platina 1, Iron 1,295	9,917	9,511	,406+	20,403
Platina 1, Iron 3,333	8,700	8,202	,498+	34,963
Platina 1, Iron 5,150	8,202	7,842	,360+	40,951
Platina 1, Iron 10 - -	7,862	7,496	,366+	
Platina 1, Iron 12 - -	7,800	7,432	,368+	

The compoſitions with ſilver have afforded a proof of the diminution of gravity from mixture, or of the maſs being dilated, from the action of the ingredients upon one another, into a larger volume than they occupied ſeparately: The above compoſitions with iron ſeem to be as ſtriking inſtances of a contrary effect: the gravity of the two laſt of them is ſuch, as no ſubſtance, however ponderous, could poſſibly produce by the ſimple appoſition of its own parts to thoſe of the iron; for it appears in the calculation, that the platina and iron together occupy leſs volume than even the iron by itſelf.

Mr. Scheffer very ingeniouſly accounts for this remarkable phenomenon from a ſingular property of iron. When metals are deprived by calcination of their phlogiſton or inflammable principle, their abſolute weight is increaſed: iron, by complete calcination, receives an augmentation of one third of its weight. Caſt iron has this particularity, that it can bear a conſiderable diſſipation of its phlogiſton, without calcining, or without loſing its metallic form; and in proportion to this diſſipation its abſolute weight is increaſed. Now, as the above ponderous mixtures were melted without any inflammable addition, he thinks a part of the phlogiſton of the iron muſt neceſſarily have been burnt out in the fuſion, and the metal of conſequence acquired an additional weight; but that, as no increaſe was

obſerved

observed on weighing it, a part of the iron, equal to the acquired weight, muſt have been ſcorified and loſt, and conſequently the volume of the metal diminiſhed; ſo that there remained with the platina as great a weight of iron as at firſt under a leſs volume.

To ſatisfy myſelf whether the increaſe of ſpecific gravity, or diminution of volume, was owing wholly to this cauſe, I made another mixture. But as caſt iron is a very impure metal, I took a piece of a bar of the beſt forged iron, and cemented it with a mixture of wood ſoot and powdered charcoal, till it had imbibed ſo much of the inflammable matter as to become ſteel; repeating the cementation, with a freſh mixture, till the ſteel melted. The metal in this ſtate was very brittle, ſo as without much difficulty to be reduced into powder. A portion of this powder was mixed with charcoal powder, and melted again: 7000 grains of the ſteel powder, and 1000 grains of platina, were likewiſe mixed with charcoal powder and melted in a cloſe crucible. The ſpecific gravity of the forged iron was 7,795; which by the introduction of phlogiſton in the firſt cementation was diminiſhed to 7,618. By the repeated cementation and fuſion, the gravity was diminiſhed to very little more than 7. Of the powdered ſteel melted with the charcoal powder, the gravity was 7,032, very nearly the ſame as before this laſt fuſion. Of the powdered ſteel and platina melted with charcoal powder, the gravity was 7,760, which ſtill exceeds the computed gravity, though not in ſo great a degree as that of the mixtures with as large proportions of caſt iron. The melted mixture weighed 30 grains leſs than the two ingredients before the fuſion, on account, perhaps, of ſome ſmall grains of the metal remaining diſperſed among the charcoal powder. Though this loſs be ſuppoſed to have been of the ſteel only, yet, as there will remain

main 697 parts of ſteel with 100 of platina, and as 7,76 parts of the mixt loſe 1 in water, the gravity of the platina comes out on calculation no leſs than 27,813.

It appears therefore that iron is very variable in its ſpecific weight, in the different circumſtances of being melted or forged, and impregnated more or leſs with phlogiſton; but that probably ſome other cauſe alſo concurs in varying the gravity of mixtures of it with platina. This cauſe may perhaps be found in a remarkable property of iron, which the experiments related in the former part of this work (page 261) ſeem to have eſtabliſhed. Melted iron, in the inſtant of its becoming ſolid, is dilated into a larger volume, and one of the marks of this dilatation is the convexity of its ſurface in circumſtances wherein that of other metals is depreſſed. Platina ſeems to deſtroy this power in iron. In the firſt mixture I made of caſt iron and platina, the ſurface was as much hollowed as that of any metallic maſs I remember to have ſeen, nor was this phenomenon omitted in the account of the experiments printed in the Tranſactions. If then fluid iron expands in fixing, and the admixture of platina occaſions it to contract, or to expand leſs, we need not wonder at the increaſe of gravity in the hydroſtatical experiments.

	Specific Gravity			
	By Exper.	By Calcul.	Difference	Platinas Gravity reſulting
TIN	7,180			
Platina 1, Tin 0,984	10,827	10,129	,698+	21,649
Platina 1, Tin 1,966	8,972	8,920	,052+	17,619
Platina 1, Tin 4 - -	7,794	8,117	,323 --	
Platina 1, Tin 8 - -	7,705	7,672	,033+	18,613
Platina 1, Tin 12 - -	7,613	7,513	,100+	26,745
Platina 1, Tin 24 - -	7,471	7,349	,122+	27,368

The

The firſt of theſe mixtures with tin is that from which Mr. Scheffer endeavours to obtain the true gravity of platina, and from this it comes out 21,649. He obſerves that tin is not variable, as iron is, in its gravity, or quantity of phlogiſton, ſo long as it preſerves its metallic form; and hence concludes, that when platina and tin are melted together, the exceſs of the ſpecific weight of the mixture above that of the tin, muſt give the true ſpecific weight of the platina. As the experiment on equal parts of tin and platina, makes the gravity of platina, on this principle, above 21, he ſeems to think that all the mixtures, whoſe gravity was found ſuch as to make platinas gravity leſs than this, muſt have been porous, and are therefore to be diſregarded in the preſent enquiry. He remarks, from the whole, that though the ſpecific weights of fluids may be determined accurately enough by hydroſtatical experiments, we cannot be ſo certain about that of ſolids, on account of cavities, incompactneſs, and air bubbles adhering; that the experiments on the foregoing mixtures afford a proof of this, mixtures of platina with one and the ſame metal being ſometimes heavier, and ſometimes lighter, than they ought to be by calculation; and that the ſame thing happens alſo in the pure unmixed metals, according as they are caſt in a weaker or ſtronger heat.

The gravities of metals are doubtleſs influenced not a little by circumſtances of this kind; and it muſt be added, that in the mixtures with platina, there is another cauſe of variation, which has not yet been attended to. When platina is melted with other metals in any conſiderable proportion, a part of the platina, unleſs the mixture is cooled haſtily, is apt to ſeparate before the fluid ſets, ſo that unleſs the whole maſs be weighed in the hydroſtatic balance, which was not the caſe in ſome of the foregoing experiments, we cannot be ſure but the part weighed may have

have more or lefs than its due proportion of platina. In the mixtures with fome metals, as lead, this unequal diftribution, or feparation of the platina, is very vifible; and it may be prefumed to happen in a greater or lefs degree in the mixtures with all the metals, though it cannot always be diftinguifhed by the eye. Compofitions of platina with zinc, tin, and copper, by all which the platina feems to be uniformly enough diffolved, were poured into narrow cylindrical moulds: the cylinders being broken in two, the lower half of each was found to be of confiderably greater gravity than the upper.

Thus much however the experiments demonftrate, that in fome inftances, in the mixtures with filver at leaft, there is a true diminution of gravity, from the action of the ingredients upon one another: and if they do not demonftrate, they render it extremely probable, that in fome cafes, particularly in the mixtures with iron, there is a true increafe of gravity. If an increafe or diminution happen in the mixtures with one metal, we cannot be certain but they may happen alfo in thofe with another; and confequently the fpecific gravity of platina cannot be inferred with certainty, or even with probability, from that of any mixture of it with any metal.

Of a variation of gravity produced by mixture, there are fome remarkable inftances in the other metals alfo. Copper, whofe fpecific gravity was 8,830, was melted with half its weight of tin whofe gravity was 7,180: there was a little lofs in the fufion, which we need not here regard, for the mixture was fpecifically heavier than the heavieft of the metals by itfelf, its gravity being 8,898: both the mixture, and a piece of the copper, were examined by fome other gentlemen, who all reported the mixture to be the heavieft, although, as is ufual in trials of this kind, there were fome differences in the numbers: if, from the

 gravity

gravity of this mixture, we were to compute that of the tin employed in it, we ſhould make it above a fourth part greater than it really is.

Mr. Hooke made an experiment of the ſame kind, before the Royal Society, on a mixture of tin and ſilver. The gravity of the tin was about 7, and that of the ſilver 10,666: of equal parts of the two metals melted together, the gravity was 10,812. By applying Mr. Scheffers principle to this mixture, if ſilver was a metal of unknown gravity, we ſhould conclude, that its gravity muſt be upwards of 23. Several other experiments of the gravities of metallic mixtures are given in Dr. Birch's hiſtory of the Royal Society; but the reader muſt obſerve, that the computed gravities are no where to be relied on, Mr. Hooke having fallen into the ſame miſtake, in regard to the calculations, as I had done in the tables publiſhed in the Philoſophical Tranſactions.

Dr. Brandt, in the Swediſh acts for 1744, where we likewiſe find an inadvertence of the ſame kind in the method of calculation, gives three experiments on mixtures of lead and tin; in two of which there is ſuch an increaſe of gravity, as would make the ſpecific weight of lead above 13, and in the third a more remarkable one: 531 grains of fine tin loſt in water $75\frac{1}{2}$, ſo that 100 parts loſt 14,218: 531 grains of a mixture of 87 parts fine tin and 3 parts lead, loſt in water $72\frac{1}{2}$, ſo that 100 parts of this mixture loſt 13,653: the quantity of tin in it ought to have loſt more, or to have occupied a greater ſpace in the water, than the whole mixt did; ſo that the lead and tin, by their mixture, were contracted into leſs volume than that of the tin by itſelf.

It appears therefore that the gravity of a metal can never be with any certainty deduced from that of its mixture with another metal, as a dilatation or contraction of the volume may reſult from their action on one another. It follows

follows alſo, that when two metals of known gravities are melted together, their proportions cannot be found from the gravity of the compound, without a previous hydroſtatic examination of known mixtures of them in different proportions; that conſequently the celebrated propoſition of Archimedes is of more limited uſe than it has generally been ſuppoſed; and that the table which Mr. Scheffer has been at the pains to calculate, in the Swediſh acts for 1755, for determining the quantities of lead and tin in any given mixtures of the two, by a ſtatical examination of them, without compariſon with ſtandard mixtures, is little to be depended on.

As the variations of gravity ariſing from the mixture of metals have been aſcribed to cauſes which do not obtain in fluids; it may be proper to obſerve, that the ſame thing often happens in fluids themſelves; and here the effect is perhaps ſtill more conſpicuous and more ſtrongly marked. One meaſure of water, and one meaſure of rectified ſpirit of wine, mixed together, fall very ſenſibly ſhort of two meaſures; a proof that their volume is diminiſhed, or their weight, under an equal volume, increaſed by the mixture. Mr. Hooke found, that twenty-one meaſures of water, and three meaſures of oil of vitriol, mixed together, made only twenty-three meaſures, ſo that one twenty-fourth part of the bulk was loſt.

SECT. VII.

Of the effect of fire and air on mixtures of platina with certain metals.

I. *Calcination of Tin with platina.*

AS gold and tin, melted together, and kept in a heat ſufficient for calcining the tin, are ſaid by Dr. Brandt, in the Swediſh tranſactions, to affect one another in a pretty remarkable manner; the gold to become diſſoluble in the pure marine acid, which gold by itſelf reſiſts; and the tin to become eaſily vitreſcible, though otherwiſe it can ſcarce be vitrefied at all; I treated platina and tin in the ſame manner.

Two parts of the picked grains of platina and three parts of tin were melted together, the mixture reduced into powder in a clean iron mortar, and a hundred and ſixty grains of the powder ſet in a cupel, under a muffle, in ſuch a heat as is employed for the cupellation of ſilver. The cupel being taken out, the matter appeared of a dark purpliſh colour, and part of it ſtuck together into a lump. It was then put into an unglazed porcelain ſaucer, ſet again under the muffle, and ſtirred every now and then for two hours: here and there ſome grains appeared glowing, like bits of burning coal; a phenomenon which tin uſually exhibits in its calcination. The powder, when cold, looked of a mixed greyiſh-reddiſh colour, the red prevailing: it weighed thirteen grains more than at firſt, ſo that it had gained an increaſe of about one twelfth, excluſive of part of it which had ſtuck both to the cupel and to the roughiſh ſurface of the unglazed ſaucer.

A part of the calx was urged in a covered crucible, with a ſtrong fire in a blaſt furnace, above an hour. It did not in the leaſt melt, and baked together but very ſlightly: its colour was darkened almoſt to a black. Both the red and the black calces, digeſted in ſpirit of ſalt, gave pretty deep yellow tinctures, like diluted ſolutions of platina in aqua regia; whereas neither the grains of platina, nor the tin calcined by itſelf, give any colour to the acid.

II. *Separation of Mercury from platina.*

Some quickſilver, which by long trituration with platina had diſſolved a part of the metal, was put into an iron

ladle,

ladle, and expoſed to a moderate fire. The mercury evaporated freely, and left the platina behind, in form of a dark coloured powder intermingled with ſome ſmall bright ſhining particles. It may be preſumed that the platina, by this diſſolution in quickſilver, is purified from great part of its iron, a metal which quickſilver has little diſpoſition to unite with.

III. *Separation of Arſenic from platina.*

Pieces of platina, which had been melted with arſenic, were urged with a very ſtrong fire in an open crucible. Arſenical fumes, diſtinguiſhable by their garlic ſmell, aroſe in abundance for ſome time: at length the fumes entirely ceaſed, and the platina remained in a ſpongy maſs. On this maſs I injected a freſh quantity of arſenic, ſo as to bring it into fuſion, and having then haſtily excited the fire till the fumes ceaſed, found the matter again ſpongy, and nearly of the ſame weight as after the firſt operation. This was repeated three or four times, with the ſame event. It did not appear that the arſenic carried off with it any part of the platina, as it does of all the other metals, gold itſelf not excepted: but a portion of the arſenic ſeemed to be retained by the platina even in ſtrong fires. Though the maſs was pretty compact when ſo far ſatiated with the arſenic as to be in ſome meaſure fuſible, it always became ſpongy when ſo much of the arſenic had been diſſipated as to leave the platina unfuſible. All theſe maſſes were ſpecifically lighter than the platina at firſt, the gravity of the heavieſt of them being only about 16,800.

IV. *Separation of Regulus of antimony from platina.*

A mixture of platina and regulus of antimony was melted in a ſtrong fire, in a ſhallow wide crucible, and the noſe of a bellows directed obliquely upon the ſurface of the fluid.

fluid. The matter continued to flow, and to fume copiously, for some hours: at length it became consistent in an intense white heat, and scarcely emitted any more fumes though strongly blown on. The mass, when grown cold, broke easily, appeared very porous, blebby, of a dull grey colour, and weighed considerably more than the quantity of platina employed. Its specific gravity was only about 15.

This experiment was several times repeated, and the event was always the same; the platina not only resisting, as gold does, the volatilizing power of the antimonial regulus, but likewise defending a part of it from the action of the fire and air, and refusing to melt after a certain quantity had been dissipated.

I likewise treated platina with crude antimony. Four ounces of antimony and two ounces of platina, kept for some time in a fire pretty strongly excited by bellows, appeared melted only in part: four ounces more of antimony being added, and the fire renewed, a reguline matter was found partly at the bottom and sides of the crucible, and partly intermingled among black spongy scoriæ: the whole was returned to the fire with black flux and common salt: it now melted sufficiently thin, and the regulus perfectly separated. This regulus did not differ in appearance from mixtures of regulus of antimony and platina melted together, and exhibited the same phenomena also on trying to blow off the antimonial part.

Mr. Scheffer likewise tried platina with antimony, and the result of his experiments was the same as of mine. He observes that as platina resists sulphur equally with gold; it cannot be scorified by the sulphureous part of antimony, and therefore remains, as gold does, in the regulus; but that the regulus cannot be blown entirely off from it, as it is from gold, on account of the platina not continuing fluid.

V. *Separation of Zinc from platina.*

A MIXTURE of platina and zinc, expofed haftily to a ftrong fire, deflagrated and appeared in violent agitation. This continued but a little time: the matter quickly became folid, and could no longer be made to flow, or the zinc, of which a confiderable quantity ftill remained in it, to flame. The mafs was very brittle, dull coloured, fpongy, and, like the two foregoing, fpecifically lighter than the crude platina.

VI. *Cupellation of platina with Lead.*

1. A MIXTURE of platina and lead was cupelled under a muffle in an affay furnace. For fome time the procefs went on well; the lead fmoking moderately, and changing into fcoriæ, which were thrown off to the fides and abforbed by the cupel. In proportion as the lead worked off, the matter required a ftronger fire to keep it fluid; and at length, collecting itfelf into a dull flat lump, it could no longer be made to flow in the greateft degree of heat which the furnace was capable of giving. The lump broke eafily under the hammer, appeared of a dull grey colour both internally and externally, and of a porous texture. It weighed near one fifth part more than the quantity of platina employed.

2. This experiment was many times repeated and varied. I endeavoured to fcorify the lead in affay crucibles, by intenfe fires in a blaft furnace; to work it off on bone-afh preffed into the bottoms of crucibles; and to blow it off on tefts before the nofe of a bellows. The event was ftill the fame; the platina not only refifting the power of lead, which in thefe operations deftroys or fcorifies every other known metallic body except gold and filver, but likewife retaining, and preventing the fcorification of, a part of the lead itfelf.

3. In the hiſtory of the fuſion of platina with lead it has been obſerved, that lead depoſites, in a gentle heat, great part of the platina which had been united with it in a ſtrong one. As the part which remains ſuſpended in the lead, might be ſuſpected to differ from that which ſubſides, a quantity of lead was decanted from freſh parcels of platina in a heat below ignition, and both the decanted metal and the reſiduums ſubmitted to cupellation ſeparately. The event was the ſame in all; the metal becoming conſiſtent after the lead had been worked off to a certain point, and refuſing further ſcorification.

4. Mixtures of platina and lead, which had been cupelled in an aſſay furnace as long as they could be kept fluid, were expoſed to ſtronger fires in a blaſt furnace, by themſelves, with powdered charcoal, with black flux, with borax, with nitre, and with common ſalt. None of them perfectly melted, or ſuffered any conſiderable alteration; they only became ſomewhat more porous, probably from the exudation of ſome of the lead and a partial liquefaction or ſoftening of the maſs. The immediate contact of burning fuel, agitated by bellows, made ſome of theſe mixtures flow after they had refuſed to melt in crucibles acted on by intenſe fires: the beads by this means became ſomewhat neater and more compact, but very little of the lead was ſeparated.

5. The cupelled beads were in general brittle, breaking eaſily under the hammer, without ſtretching in any conſiderable degree. They were of a grey colour both on the upper ſurface and in the fracture, but pretty bright and white on the lower ſurface, and when ground or filed: they had nothing of the purpliſh hue, which the mixtures of platina and lead (page 515) had in ſo remarkable a degree; nor does their colour appear anywiſe altered after keeping for ten years in the ſame circumſtances in which

thoſe

thofe mixtures were kept. On weighing them hydroftatically, the more fpongy ones were found nearly as ponderous as the crude platina. Among the more compact, the gravity of one turned out 19,083, that of another 19,136, and of a third 19,240. It is probable that thefe remarkable gravities proceeded partly from the platina having been purified in the procefs from its lighter heterogeneous admixtures, and partly from an increafe of gravity occafioned by the coalition of the platina with the lead. The laft of thefe mixtures, whofe gravity was 19,240, is that which was melted with equal its weight of gold, as mentioned in page 548.

6. A mixture of one part of platina and three of gold was cupelled with lead in an affay furnace. The matter worked well for a confiderable time: at length it collected itfelf into a bright hemifpherical lump, which by degrees became flatter, dull coloured, and rough. The button, on being weighed, was found to retain about a twelfth part of lead.

7. The experiment being repeated with a mixture of one part of platina and fix of gold, fome part of the lead appeared ftill to be retained. The bead proved rounder and brighter than the foregoing, and of a good golden colour on the outfide; but it broke eafily under the hammer, and appeared internally greyifh: fome of the fragments hung together by the outward golden coat.

8. Mixtures of platina and filver, fubmitted to the common procefs of cupellation, retained likewife a little of the lead. Thefe, in becoming confiftent, formed not hemifpherical beads, but flat maffes, very rough and brittle, and of a dull grey colour both externally and internally.

9. The cupellation of platina with lead was one of the experiments made by Mr. Wood, and communicated to the Royal Society in the year 1750; but the platina being

then very imperfectly known, ſome deception happened in this point. Mr. Wood relates, that platina having been melted in an aſſay furnace on a teſt with lead, and therewith expoſed to a great fire for three hours, till all the lead was wrought off, the platina was afterwards found remaining at the bottom of the teſt, without having ſuffered any alteration or diminution by this operation. Dr. Brownrigg, ſurprized at this reſiſtence of platina to lead, repeated the experiment. He melted twenty-ſix grains of platina upon a cupel, with ſixteen times its weight of pure lead, which he had himſelf revived from litharge: the lead being ſcorified, there remained in the cupel a button of platina weighing twenty-one grains, ſo that the platina loſt in this operation near a fifth part of its weight. From this experiment he conjectured, and not without probability conſidering the little that was then known of the properties of this new metal, that a part of the platina was ſcorified by the lead; that the whole might have been ſcorified by repetitions of the proceſs; and that conſequently gold and ſilver may be purified from platina, by cupellation with larger quantities of lead than are commonly employed. What the author has modeſtly propoſed only as a conjecture, to be confirmed or refuted by further trials, has by ſome been taken for a certainty: in a letter preſented to the Royal Society ſoon after, the proceſs is ſpoken of as a method diſcovered by Dr. Brownrigg, for ſeparating platina from gold and ſilver. It is plain that this experiment muſt have been made, and the author has lately informed me that it was, with the caſt metal mentioned at the beginning of this hiſtory, which was then ſuppoſed to be true platina, and does loſe of its weight in the common proceſs of cupellation.

10. Mr. Scheffer tried the cupellation of the grains of platina with lead, and the event was exactly the ſame as in my

my experiments. The bead was dark coloured and rugged at top, white underneath, and retained a portion of the lead amounting to two or three parts in a hundred. He obſerves that the lead cannot, by common fire, be worked off clean from this metal, as it is from gold and ſilver, on account of the platina not continuing fluid after the lead has been ſeparated to a certain point; and judges that a ſufficient heat for the complete ſeparation of the two metals is not to be obtained by any other means than by large burning glaſſes.

11. I have already obſerved, page 494, that platina divided by cementation with nitre, and afterwards purified by repeated ſublimations of ſal ammoniac, appeared nowiſe different in cupellation from the common grains. Mr. Marggraf made trial of platina attenuated by ſolution and precipitation. The orange coloured precipitate thrown down by fixt alcali from ſolution of platina in aqua regia, being well waſhed with hot water and ignited under a muffle, became browniſh: nine parts of this matter were melted with an ounce of pure granulated lead, and the mixture expoſed to the fire in a ſcorifying diſh till a conſiderable part of the lead was ſcorified: the remainder worked in a cupel, left a rough bead, of a whitiſh grey colour, very brittle, perfectly like that obtained in the cupellation of crude platina: its weight was one grain. The experiment was repeated with a precipitate made with volatile alcali, and the event was the ſame. He tried alſo the powder which remained on diſtilling a ſolution of platina to dryneſs: this powder, calcined under a muffle, acquired a ſhining blackiſh colour, in which ſtate thirty grains of it were mixed with twenty times as much granulated lead, and the mixture worked as above, firſt on a ſcorifying diſh and afterwards in a cupel: the ſcoriæ were of a black-brown colour: the cupelled bead was brittle and of

a grey-white colour like the others, and weighed forty-two grains, or two fifths more than the platina employed. This was treated in the ſame manner with the ſame quantity of freſh lead: the ſcoriæ were of the ſame colour, and the bead ſtill weighed juſt forty-two grains.

12. The ſame author gives an account of another operation, in which platina and ſilver were combined together, the mixture melted with lead, the lead ſcorified, the ſilver ſeparated by aquafortis, and the remaining platina again cupelled. He took thirty grains of crude platina, and thrice as much of the combination of ſilver with marine acid, called *luna cornea*. The mixture being expoſed to as great a heat as a glaſs retort would bear, no liquid paſſed into the receiver, but a little white matter ſublimed into the lower part of the neck of the retort, as commonly happens when luna cornea is expoſed to ſuch a heat by itſelf. The mixt run clean together into a dark yellow hyacinth coloured maſs, and appeared well united: the glaſs was ſtained of a dark yellow. The mixt was pounded, along with pieces of the glaſs, which could not eaſily be ſeparated, in a clean iron mortar, the powder mixed with two ounces and a half of granulated lead, and melted in a crucible with a ſtrong fire: the ſcoria was greeniſh. The metal, worked on a cupel, drove well, as in the common ſilver aſſay, till towards the end of the proceſs, at which time it came aſunder, grew flat and rough, and looked like ſilver ſprung on the cupel by being too haſtily cooled, but without the leaſt metallic brightneſs on the ſurface: it was very brittle under the hammer, but bore to be filed, and the mark of the file looked white: it weighed a hundred and ten grains. It was cupelled with an ounce more of lead, and the product was the ſame as before, with the loſs of ſeven grains in weight. This laſt bead was beaten in pieces, mixed with ſix drams of pure nitre, and melted

with

with a ſtrong fire: the metal was of a ſilver whiteneſs, and weighed ſeventy grains: the ſcoria was cauſtic, liver coloured, and when liquefied in the air looked greeniſh. The regulus was melted again, with half an ounce of the pureſt nitre and a dram of borax: the ſcoria proved cloudy, inclining to yellow underneath and to greeniſh above: the regulus was of a fine white, and weighed ſtill ſeventy grains; it had ſomething particular in its appearance on the ſurface and about the ſides, reſembling the radiated cobalt; it ſtretched pretty well under the hammer, and bore to be flatted into a thin plate, but was harder than fine ſilver. A part of this plate was digeſted in purified aquafortis: the menſtruum became firſt of a high graſs-green colour; afterwards, in a boiling heat, the plate grew black, and the ſolution browniſh. The ſilver being at length diſſolved, there remained at the bottom a black ponderous matter like calx of gold. This was thoroughly waſhed with hot diſtilled water, then dried, and made red hot, but it received no gold colour. It was mixed with granulated lead, and the mixture worked firſt on a ſcorifying diſh, and then on a cupel: there remained a convex bead, without metallic luſtre, which ſprung under the hammer, and reſembled the other beads obtained by cupelling platina with lead.

13. It appears upon the whole, that Marggrafs trials for working off lead clean from platina, ſucceeded no better than Scheffers and mine, ſo much of the lead being always retained as to make the metal very brittle, whereas platina by itſelf, whether in its crude ſtate of grains or when melted by a burning-glaſs, is of conſiderable malleability. Macquer and Baumé made another effort: they were "deſirous of ſeeing, whether a heat of a good deal longer continuance would not produce that, which one *coup de feu*, perhaps more ſtrong but of ſhorter duration,

had

had been unable to produce. They put upon a cupel of a proper ſize one ounce of platina and two ounces of lead, and having placed the cupel in a furnace like that of Mr. Pott for the vitrification of earthy bodies, they raiſed the fire by degrees, and kept it up without intermiſſion for fifty hours, in ſuch manner, that during the laſt twenty-four hours it continued in its full violence. The cupel being then taken out, they found that the platina, inſtead of being in a round brilliant button as gold and ſilver are after cupellation, was extended and flattened on the cupel: its upper ſurface was tarniſhed, dark coloured and wrinkled, from whence it was judged at firſt that the operation had ſucceeded no better than thoſe we have been ſpeaking of: the platina parted eaſily from the cupel, which was become very hard, of a yellowiſh white colour, ſemitranſparent, and ſtruck fire freely with ſteel. But upon exactly weighing the platina, they found, that inſtead of receiving an augmentation of weight from ſome of the lead remaining undeſtroyed, it had loſt one ſixteenth of its weight: its lower ſurface was white and ſilvery: finally it was not eager, but bore very well to be extended under the hammer: they diſſolved a part of this cupelled platina in aqua regia, and this diſſolution did not ſhew any veſtige of lead."

As Mr. Macquer appears to have employed in this experiment the platina ſuch as he received it, containing a large admixture of ferrugineous and other foreign matters undoubtedly deſtructible in the proceſs; it is obvious that it might have retained a very conſiderable proportion of the lead, notwithſtanding the diminution in weight. Nor can aqua regia be looked upon as an infallible teſt of its having been pure from lead; for this menſtruum, in certain circumſtances, will diſſolve lead as well as platina. But whatever might be in this, the event of the experiment, in regard to the malleability of the cupelled maſs, appeared

too

too interesting to be passed over, in this history, without being verified by further trials.

14. Having at hand a wind furnace, formed of a mixture of Sturbridge clay and powdered glass-house pots, secured by iron hoops on the outside, about two feet high from the grate to the top of the dome, fourteen inches wide in the middle and ten inches at the grate, with a chimney of nearly half the diameter of the grate and fourteen feet high; I first made trial of this furnace, and found its effect to be such, that there was no occasion to have recourse to any other. I fitted into it a muffle, in the manner described by the ingenious author in a memoir on the vitrefication of clay with chalk, formed of the same composition with the furnace, two inches high, three inches wide, of such length as to reach across the furnace, supported at the height of five inches above the grate by a brick of fire-standing clay, which was cut sloping downwards so as to cover as little as possible of the grate.

15. A large cupel having been kept red hot in the muffle about an hour; two ounces of lead were put in, and one ounce of the picked grains of platina dropt into the melted lead. The fire being raised with coaked pitcoal to its greatest vehemence, the whole internal part of the muffle appeared of a dazzling brightness, and the cupel could not be distinguished, till cold air was suffered to pass through by keeping the door open for some time, which was done frequently, to promote the scorification or dissipation of the lead. In this state the heat was continued, untill, in five or six hours, penetrated by the vitrescent cinder of the coal, the muffle begun to fail: all its back part, and some of the internal part of the furnace, melted, forming partly irregular vitreous lumps, and partly running down through the grate in large drops of black hard glass. The cupel was hard, yellowish white, and semi-

transparent,

tranſparent, like Macquers. The platina was in a flat cake, coated with the ſemivitrified matter of the cupel and glaſſy drops from the muffle, ſo that nothing could be judged from the weight: it broke pretty eaſily under the hammer, and did not ſeem to differ from that of former cupellations.

16. What was here wanting in the continuance, I endeavoured to ſupply by a repetition of the fire. The platina, pounded and waſhed, was placed under a freſh muffle, on a ſcorifying diſh; and the heat kept up in its full violence, chiefly with wood and charcoal, for fourteen hours. Greateſt part of the platina ſtuck ſo firmly to the diſh, in virtue of part of the lead which had exuded and vitrefied, as not to be got off without pounding the veſſel. Where the platina on the diſh was ſtruck with a hammer, or rubbed with a ſteel burniſher, it ſtretched, and acquired a continuous ſurface like ſilver or tin leaf. After the powder had been paſſed through a fine ſieve, and waſhed, on beating it again ſome broad flat grains appeared, which ſtretched eaſily under the hammer, and on being ſqueezed with a pair of plyers, bent almoſt double: one of theſe bore to be opened, and bent again in ſeveral directions, without cracking. This powder, whoſe particles appeared ſo ductile and flexible, I tried to reunite into a maſs, by urging it with a vehement fire, in a covered crucible, for four hours: it cohered into a button, of the form of the crucible, not at all ſticking to the veſſel, and free from diſcolourment: the button broke from a blow or two of a hammer, but not very eaſily, filed tolerably ſmooth, and burniſhed like fine ſilver.

17. I cupelled four parcels of platina, with thrice their quantity of lead, till they would no longer continue fluid in a good aſſay furnace; and repeated the cupellation on freſh cupels, with the ſame quantity of lead, a ſecond and

a third

a third time. The firft cupels were tinged of a deep rufty colour, probably from the irony matter in the platina; the others only yellowifh, as from lead alone. The plates of metal, after the firft cupellation, were dull coloured and ftuck to the cupels; after the others, they were brighter and did not ftick. The four plates, weighing 3031 grains, kept for twelve hours on a fcorifying difh, in as ftrong a fire as could be excited in the affay furnace, became whiter, and loft 218 grains: the white difh was covered all over with a yellow glazing. The plates, which had fuffered no appearance of fufion, and which ftill proved brittle though much lefs fo than before, were broken into fmaller pieces, and fet on four cupels, under a muffle, in the wind-furnace above defcribed: during eight hours vehement fire, the two cupels in the fore part of the muffle, which was lefs hot than the back part, were obferved, as often as the door was kept open for a little while, to fmoke confiderably; but all the air that could pafs into the muffle, did not fo far diminifh the dazzling heat, as that any fumes could be diftinguifhed in the back part. The arch and further end of the muffle were found all over glazed by the fumes; the cupels friable and unftained; the metal of a filver whitenefs, and diminifhed 105 grains. The pieces in the front cupels were ftill brittle; thofe in the further ones bore to be flattened confiderably under the hammer, and feemed nearly as foft as alloyed filver.

18. I made many other cupellations of the fame kind; of which, as no other remarkable phenomena occurred than have been already mentioned, it would be unneceffary to give a particular detail. They agree in eftablifhing an important fact, that though in the common procefs of cupellation, even when performed with ftronger fires than the cupelling furnace can give, and continued fome hours beyond the time in which the fixing of the

metal ſeems to ſhew that the fire has produced its full effect, platina has been always found to retain ſo much of the lead as to break under the hammer; yet by continuing theſe vehement fires for twenty hours or more, ſo much of this retained lead is ſeparated, as to leave the platina malleable. Much of the lead was forced out after the metal had become ſolid, as appears in the experiment, No. 17, in which the quantity expelled from the cupelled plates, without their having anywiſe ſoftened or altered their figure, amounted to above a tenth part of their weight. The thinner the metalline plates, the ſooner and more effectually were they freed from the lead, and rendered malleable: in one cupellation, a part of the metal having run into the form of a fine wire, this wire, after ſix hours ſtrong heat, proved ſo flexible, as to bear bending backwards and forwards ſeveral times without breaking, while a thick piece of the ſame maſs, after eighteen hours longer continuance of the fire, was ſtill brittle: when a ſmall quantity of platina, worked in a cupel of a proportionate ſize, had, from the ſhape of the veſſel, formed a pretty thick maſs, which was the caſe in moſt of the firſt cupellations (No. 1 to 8 of this article) a vehement fire, of much longer continuance than that of Macquers experiment, was inſufficient for rendering the maſs malleable; but when beaten into powder and ſpread thin, a fire not extremely vehement, continued ten or twelve hours, made the particles of the powder ſo ductile, that they ſtretched under the peſtle into fine plates like fragments of ſilver leaf: the powder thus flatted was remarkably ſoft or unctuous to the touch, like talk; and being rubbed on paper, ſtuck to it, ſo as not to be eaſily bruſhed off, making it look like what is called ſilver paper. It was therefore a happy circumſtance in Macquers experiment, and indeed eſſential to its ſucceſs, that he uſed a conſiderable quantity of of platina ſo as to form a thin plate on the bottom of a large cupel. Much of the lead exudes at firſt in a vitreous form, and glazes or ſtains the diſh or cupel on which the plate is expoſed to the fire; but towards the end it ſeems to be forced out only in fume, no viſible mark remaining on the veſſel: in one experiment, the metal loſt about a twenty-fifth part of its weight, after it had ceaſed to give any tinge to the cupel.

19. It may be proper to obſerve, that in moſt of the cupellations of platina with lead, eſpecially where the quantity of the mixt was conſiderable, and a pretty ſtrong fire made uſe of, the cupelled plates appeared of a regular and ſingular figure on the ſurface, ſuch as no other metal or metallic mixture I know of aſſumes in fixing. In the middle was a broad flat-bottomed depreſſion, with a lip or margin round it, like a common table plate; and the lip was froſted as it were with regular tranſverſe rows of prominent dots. The ſmooth parts were in general ſoft or ſlippery to the touch.

VII. *Cupellation of platina with Biſmuth.*

Mixtures of platina with biſmuth were ſubmitted to the common proceſſes of cupellation under a muffle, ſcorification in aſſay crucibles, and teſting before the noſe of a bellows. The general event was nearly the ſame as when platina and lead were treated in the ſame manner: the mixtures, which at firſt flowed eaſily, became leſs and leſs fuſible in proportion as the biſmuth was driven off, and at length could not be kept fluid in an intenſe fire, though they appeared, on weighing, to retain a conſiderable quantity of the biſmuth. Nor could biſmuth, any more than lead, be worked off clean, by the common proceſs of cupellation, from mixtures of platina with ſix times its weight of either gold or ſilver.

 When

When one parcel of platina was cupelled with three or four fresh quantities of bismuth, the first cupels were always tinged of a blackish rusty hue, the next paler, and the third for the most part only of the orange yellow colour which bismuth itself communicates, and which is considerably deeper than the stain imparted by lead.

In many of the cupellations, the surface of the metal was found covered with a leafy substance like deep coloured litharge; and sometimes, under the cupelled plate, there was a large quantity of rough spongy greenish matter, adhering in many parts strongly to the platina, running into cavities in its bottom, and in some places lying as it were between plates or flakes of the metal. It appeared that bismuth, in cupellation with platina, does not diffuse or spread itself so thin, or sink so deep into the cupel, as lead does; but loads the parts which it touches, in such a manner, as to be prevented from extending further, and to be collected there in its semivitrified state; sometimes lying in large quantity on the cupel, though a considerable part of the cupel at bottom was not tinged with it. This does not seem to happen when bismuth is worked off alone, and therefore probably proceeds from this metal being a less powerful menstruum than lead for the ferrugineous and other foreign matters blended with platina. Many of the cupellations however went on well, without any appearances of this kind, and yielded brittle plates, sometimes dull coloured and sometimes bright, according as less or more of the bismuth was worked off, of uneven surfaces, with large protuberances irregularly and sometimes elegantly disposed. Some of the minutes of these experiments having been lost, I cannot recollect whether it was with large, or with small proportions of bismuth, that the process succeeded best.

From

From the effect of a long continuance of ſtrong fire on mixtures of platina and lead in the preceding article, I was induced to ſubmit to the ſame treatment mixtures of it with biſmuth, a metal which promiſed to be eaſier ſeparated than lead, as being itſelf much more eaſily diſſipated by fire.

Some of the cupelled plates of the foregoing operations were kept for ſix hours, on four cupels under a muffle, in as ſtrong a heat as could be raiſed in a good aſſay furnace. Of one of the plates a part had melted, and ſpread in fine ſilver-like leaves over the edge of the cupel: of all of them the thin edges bore to be hammered pretty well, and bent conſiderably before they cracked: the cupels were ſtained of a pale orange yellow. The plates being then urged for ſix hours longer on freſh cupels, in the wind furnace before mentioned, they all proved of a bright ſilver colour, and hammered well in the thinner parts, but ſtill continued brittle in the thick ones: the cupels were very ſlightly tinged.

From the experiments related in this ſection it appears, that platina perfectly reſiſts the deſtructive power of lead and biſmuth, which, with the concurrent action of fire and air, reduce all the other known metallic bodies, except gold and ſilver, into a calx or ſcoria: that it reſiſts antimony, by which ſilver as well as the baſe metals are ſcorified, and which has always been eſteemed the ſevereſt teſt of gold: that it is not ſenſibly volatilized by arſenic, which in ſtrong haſty fires carries off a portion of gold itſelf: that in degrees of heat conſiderably ſtronger and of longer continuance than have hitherto been employed for theſe kinds of operations, the platina preſerves a part of thoſe deſtructible metallic bodies themſelves, retaining ſo much of them as to be rendered brittle; but that by further continuance of vehement fire, thoſe bodies, at leaſt lead

and

and bifmuth, may be wholly or almoft wholly diffipated, fo as to leave the platina in a mafs, as malleable as the fineft grains were feparately, and perhaps more fo, in virtue of their being purified in the operation from their irony or other foreign matters, as gold and filver are by the like means from all the bafe metals.

How far this diffipation of lead or bifmuth may be practicable in the large way, or on maffes of confiderable thicknefs, cannot be abfolutely determined from the experiments hitherto made, for as yet, with me at leaft, the procefs has fucceeded only on thin pieces of the metal. Mr. Macquer feems to make no doubt that platina may on this foundation be rendered manageable by the workman in large, fo as "to furnifh us with burning concaves, fpecula for telefcopes, an infinity of veffels and utenfils for chemical and culinary ufes, and almoft all the works of the lockfmith." He obferves that platina would for thefe purpofes be an excellent material, "as its vivid and brilliant polifh is never tarnifhed by any kind of ruft, and as it not only refifts the action of air, water, fire, acids, and the voracious metals, as well as the pureft gold does, but joins to thefe admirable qualities a property ftill more precious, which is wanting to gold, viz. the force and hardnefs of iron." In my experiments, the cupelled plates, both with lead and bifmuth, were confiderably harder than fine gold or filver, but fofter than iron: the hardnefs here attributed to them appears to be inferred from the experiment on precipitate of platina related in page 505.

SECT.

SECT. VIII.

Of the Affinities of platina.

IN this ſection it is propoſed to give an account of ſuch experiments as have been made relative to the comparative affinities of platina and other metals, to one another, and to ſaline diſſolvents; the ſeparation of platina from one metal by the intervention of another, or of one metal from another by the intervention of platina; the ſeparation of platina by other metals, or of other metals by platina, from their ſolutions in acids. For the greater diſtinctneſs, the reſults of the ſeveral experiments are expreſſed in the reſpective titles, after the ſame manner as in the common tables of affinity. The body placed uppermoſt is always to be underſtood to have a greater affinity to that which is immediately under it, than to the third or lowermoſt; inſomuch that if the firſt and third be combined together, the middle one, properly applied as mentioned in the experiment, will break their union, and throwing out the third body, join itſelf to the firſt, though the ſeparation is not always complete. Where no ſuch affinity, or ſeparation, appears in the experiment, the ſeveral bodies are placed in a continued line.

I. *Mercury:*
Platina:
Lead.

ONE part of platina and about four of lead were melted perfectly together, and after the heat had ſomewhat abated, the fluid was poured gently, in a ſmall ſtream, into three times its quantity of quickſilver heated ſo as to fume. On ſtirring them with an iron rod, a blackiſh powder was immediately thrown to the ſurface, which appeared to be

chiefly

chiefly platina. On grinding them together in an iron mortar, a frefh powder gradually feparated, which, being occafionally wafhed off, in appearance greatly refembled the foregoing, but was found, on proper trials, to participate more largely of mercury and lead than of platina. The amalgam was of a very dull colour, and on being expofed to the fire in an iron ladle, fwelled and leaped about, though the heat was fcarcely fufficient to make any of the quickfilver evaporate. I therefore had the grinding continued, in a kind of mill, compofed of a thin iron plate, cut into the form of a crofs, and made to turn in an iron mortar: the plate was bent up nearly to the fhape of the bottom of the mortar, and between two of the ends was fixed a piece of wood, the other two ftanding loofe, and accommodating themfelves to the mortar in virtue of their elafticity: the piece of wood received the end of an upright fpindle, which being fecured by crofs pieces to keep it in the middle of the mortar, and a fmall weight, fometimes greater and fometimes lefs, placed on the top, a wheel and pulley procured a rapid motion with little labour. After conftant agitation in this machine, with water occafionally renewed, for feven or eight days, the amalgam looked bright and uniform, and fuffered the quickfilver to exhale freely. The mercury being all evaporated, there remained a dark grey powder, which proved upon examination to be platina with a very little lead. For a part of the powder being digefted in aquafortis, a fmall portion of it diffolved, and the folution appeared to be no other than a folution of lead: the undiffolved part, now of a dark purplifh colour, was moftly taken up by aqua regia, to which it communicated, not indeed the common hue of folutions of platina, but a kind of dull olive colour: plates of tin, however, quickly difcovered that the matter diffolved was platina, by occafioning a pre-

cipitate

cipitate of the ſame appearance with that which tin throws down from common ſolutions of platina. The reſt of the powder was cupelled with lead: it left a rough, flatted, bright maſs, which would no longer melt, and which exactly reſembled thoſe obtained in cupelling crude platina with lead.

Mercury is ſuppoſed to have a greater affinity to lead than to any other metallic body, gold and ſilver excepted. In this experiment it ſhewed a greater affinity to platina than to lead, ſince it retained much of the platina, after the lead, which was at firſt in much larger proportion, had been almoſt all thrown out.

II. *Mercury:*
Gold:
Platina.

A MIXTURE of one part of platina and two of gold, which proved very white and brittle, was well nealed, and cautiouſly flatted into thin plates, which were thrown red hot into boiling quickſilver. On grinding and waſhing with water, a powder ſeparated, copiouſly at firſt, and by degrees more ſparingly. After the proceſs had been continued about twenty-four hours, there was no further ſeparation, except of a little blackiſh matter into which a part of the mercury itſelf is always changed in theſe kinds of operations. The amalgam, which looked bright, was put into a crucible, and the quickſilver being evaporated by moderate heat, there remained a ſpongy maſs, of a high colour, which being melted and caſt into an ingot, proved very ſoft and malleable, and not diſtinguiſhable by the eye from the pure gold made uſe of. How far this proceſs is applicable to the ſeparation of platina from gold in the way of buſineſs, will be conſidered in the following ſection. It is ſufficient here to have eſtabliſhed the greater affinity

 of

of mercury, to gold than platina, and to platina than lead.

III. *Platina:*
Lead:
Iron.

ONE ounce of a mixture of iron and platina, and two ounces of lead, were covered with black flux, and urged with a pretty ſtrong fire, but which did not prove ſufficient for the fuſion of the platina and iron: the lead being poured off into a cylindrical mould, the lower part of the cylinder looked of a duller hue than the lead was at firſt, and proved ſpecifically heavier, in the proportion of 11,598 to 11,386. The lumps of iron and platina were mixed with the lead a ſecond time, and expoſed to a ſtrong fire till the whole came into perfect fuſion: on cooling the crucible too haſtily in water, the fluid matter exploded and threw off the cover, and the lead was found reduced into ſmall filaments, filling the crucible, which before was not one fourth part full. The iron regulus at the bottom was in a round, ſmooth, very hard lump, and ſeemed to retain a conſiderable portion of the platina. The lead, melted into a maſs with a little reſin, appeared, from its ſpecific gravity, and more manifeſtly on cupellation, to have imbibed more of the platina than the iron retained.

Caſt iron being dropt into a melted mixture of platina and lead covered with black flux, and the fire kept up ſtrong till the iron melted, moſt of the platina appeared to be retained by the lead, and very little if any of it to be taken up by the iron. It was judged at firſt that this did not happen from the platina having leſs affinity to iron than to lead, but from its not having come ſufficiently in contact with the iron; for we have elſewhere ſeen that great part of the platina ſinks to the bottom even of the lead, and the iron floats on the ſurface of the lead.

A mixture

A mixture of platina and iron was melted with thrice its weight of lead upon a cupel, and a ſtrong fire kept up till greateſt part of the lead was worked off. The remaining maſs was rugged and cavernulous: in its cavities, and at the bottom, was a very conſiderable quantity of a dark blackiſh powder with ſomewhat of a purpliſh caſt, which was attracted, though not vigorouſly, by a magnetic bar.

This experiment ſeems deciſive of the greater affinity of platina to lead than to iron; as it ſhews iron, which had been previouſly well combined with platina, thrown out again in its metallic form by lead. It may therefore be preſumed, that the abſorption of part of the platina from iron by lead in the firſt experiment, proceeded from this ſuperior affinity of the platina to the lead, and not, as was at firſt ſuſpected, from its having an equal affinity to them both.

IV. *Aqua regia:*
Zinc:
Platina.

Platina, digeſted in a ſaturated ſolution of zinc made in aqua regia, did not appear in the leaſt corroded; but zinc, put into a ſaturated ſolution of platina, ſoon begun to diſſolve, and to precipitate the platina. The precipitate was of a browniſh black colour: the liquor, after the zinc ceaſed to be acted on, continued yellow, a mark that the precipitation by zinc was not total, any more than by the unmetallic precipitants in ſection iii. Marggraf found, that when ſolution of zinc in aquafortis was mixed with ſolution of platina, an orange-red or brick-coloured precipitate fell, the liquor continuing yellow as in the other caſe.

V. *Aqua regia:*
Iron:
Platina.

A SATURATED ſolution of iron in aqua regia did not ſenſibly act on platina: a ſaturated ſolution of platina readily corroded iron, the platina precipitating. A good quantity of yellow ochery powder ſettled at the bottom, and the undiſſolved part of the iron appeared incruſtated with a dark coloured matter: it could not be judged from the colour whether the precipitation was complete, the ſolutions of platina and of iron having a great reſemblance in colour.

VI. *Platina:*
Aqua regia and ſolution of iron-vitriol:
Gold.

SOLUTION of iron in the vitriolic acid, or a ſolution of the common green vitriol of iron made in water, which totally precipitate gold from aqua regia, made no change in ſolution of platina. A mixture of platina and gold, which had been melted together and kept in fuſion for ſome hours, being diſſolved in aqua regia, and the vitriolic ſolution added, the gold was precipitated and the platina remained diſſolved. Solutions of iron in the nitrous and marine acids did not precipitate either platina or gold.

VII. *Aqua regia:*
Copper:
Platina.

PLATINA, put into a ſolution of copper in aqua regia, was not ſenſibly acted on: plates of copper, put into ſolution of platina, begun quickly to diſſolve, and to precipitate the platina. The precipitate was of a dark greyiſh colour,

colour, and was found on trial to have a confiderable quantity of the copper blended with it: the liquor was of a more dufky green than folutions of pure copper, probably from its retaining fome of the platina. Solutions of copper in the vegetable, nitrous, marine and vitriolic acids, mixed feparately with folution of platina, produced no precipitation or turbidnefs: Marggraf indeed found, that with the folution in the nitrous acid, a reddifh orange coloured powder was depofited after long ftanding, but in this precipitation the copper folution probably had no fhare, for the folution of platina by itfelf, as he obferves, yields, in time, a like precipitate.

VIII. *Aqua regia:*
Tin:
Platina.

We have feen in the third fection that plates of pure tin precipitate platina, and that they do not produce with it the red or purple colour which they do with folutions of gold, but a dark brownifh or olive: it muft here be added, for eftablifhing the affinity more fully, that when platina is digefted in a folution of tin made in aqua regia, no precipitation of the tin, or corrofion of the platina enfues. The precipitation by tin is not total, any more than by the metals hitherto mentioned, but it may perhaps be queftioned whether the matter which remains diffolved, and which gives colour to the liquor, be true platina, or the ferruginous fubftance that was blended with it, fince in a former experiment, page 487, after the more foluble parts of the mineral had been extracted by aqua regia, the remainder, diffolved in frefh aqua regia, appeared to be completely precipitated by tin, the liquor proving perfectly colourlefs. Solution of tin, mixed with common folution of platina, feemed to have nearly the fame effect as tin in fubftance:

a dark

a dark reddiſh orange coloured powder precipitated, a part of the platina or its iron remaining diſſolved, ſo as to give a high colour to the menſtruum.

IX. *Aqua regia: Mercury: Platina.*

Mercury, which is ſaid to precipitate from aqua regia no one of the common metallic bodies except gold, being put into a diluted ſolution of platina, ſeemed to be in a little time corroded, and did not run freely: ſoon after, it appeared covered with a greyiſh powdery matter, which at firſt was apprehended to be a precipitate of the platina, but was found afterwards to be only a part of the mercury corroded: upon applying a moderate heat, the whole of the quickſilver, the quantity of which was very conſiderable, was diſſolved, without any precipitation of the platina. This ſolution of the two metals, being evaporated a little ſo as to diſpoſe it to ſhoot, yielded cryſtals not at all like thoſe of platina, but in form of needles, externally of a yellowiſh hue: the cryſtals, ſlightly waſhed with proof ſpirit, became colourleſs: expoſed to the fire, they emitted copious white fumes, with a hiſſing or crackling noiſe, and left a very ſmall quantity of a reddiſh powder, giving a dull red ſtain to the tobacco pipe which ſerved for the veſſel: the cryſtals laid on marble, and heated almoſt, if not quite, to a red heat, ſcarcely gave it any tinge or injured its poliſh. It appears from this experiment, that aqua regia, ſaturated with platina, is capable of diſſolving a conſiderable quantity of mercury, and that in cryſtallization great part of the mercury ſhoots before the platina.

To another quantity of ſolution of platina I added more quickſilver than it was capable of taking up. The platina now gradually fell down among the undiſſolved mercury, in in form of a dark brownifh powder, leaving the liquor very little coloured. Platina therefore agrees with gold in having lefs affinity to aqua regia than mercury has, though it differs in its affinity to the mercury, gold in this precipitation uniting with the mercury into an amalgam, while platina remains in a diftinct powder. This obfervation accounts for a phenomenon obferved by Marggraf in the following experiment.

Half an ounce of quickfilver, and an ounce of folution of platina being fhaken together, the mercury run fluggifh, and foon after a quantity of yellowifh white powder fettled at the bottom. The folution being fet to digeft, it appeared next day fomewhat greenifh. The digeftion was continued a day longer, and the mixture diluted with water; the clear liquor being decanted off, the matter at the bottom was thoroughly edulcorated, and the yellowifh white powder wafhed off from the mercury and dried. The uncorroded mercury was not of the nature of an amalgam, but run pretty freely: being diftilled in a retort, it left a metalline grain behind, fo fmall, that its appearance could not well be diftinguifhed without a microfcope, which fhewed it yellow. The white powder, fet to fublime in another little retort, yielded a fublimate of a reddifh yellow colour in the lower part, and whiter above: there remained a little grey matter, which being preffed looked like an amalgam. It is remarkable that the mercury had here borne a very ftrong fire, by which the whole belly of the retort had been melted, though without any hole being made in it.

It is probable that the little yellow grain, left upon diftilling the uncorroded mercury, was a particle of gold which the platina had contained; and that, agreeably to the foregoing remark, platina and gold, diffolved together in aqua regia, may be parted on this principle, the gold being

being imbibed by the mercury, while the platina is precipitated in powder, which may be ſeparated from the amalgam by waſhing.

Solution of mercury in aquafortis rendered ſolution of platina inſtantly turbid, and precipitated a greyiſh brown powder. Solution of mercury-ſublimate in water, poured into ſolution of platina, precipitated a red matter, with numerous bright ſparkling particles, the liquor continuing yellow: the precipitate bore waſhing with water, without loſing its red colour.

X. *Aqua regia:*
Nickel:
Platina.

Marggraf relates, that a piece of pure regulus of cobalt, or *cobald-ſpeiſe*, from the ſmalt works at Schneeberg in Saxony, after being repeatedly melted with glaſs till all its blue-colouring matter was extracted, was readily attacked by ſolution of platina: the regulus loſt its brightneſs, and became black, a yellowiſh powder precipitated, and the liquor looked greeniſh.

The ſubſtance by which the platina was here precipitated, and which communicated a green colour to the liquor, I apprehend to have been the metallic body called nickel, diſcovered and deſcribed by Mr. Cronſtedt, in the Swediſh tranſactions for the years 1751 and 1754, one of whoſe characters is to diſſolve green in aqua regia, whereas the regulus of cobalt, ſtrictly ſo called, gives a reddiſh ſolution. Mr. Cronſtedt obſerves, that cobalt generally contains, beſides its proper regulus, or the metal which gives a blue glaſs, a quantity both of nickel and of biſmuth: that the *ſpeiſe*, or metal which ſeparates to the bottom of the melting-pot in making the blue glaſs, generally conſiſts of all the three metals; the cobalt-regulus and biſmuth, which of themſelves are averſe to any union with

one

one another, being rendered miſcible by the intervention of nickel: that when this mixture is again melted with glaſs, the cobalt-regulus vitrefies firſt; the nickel, more difficultly calcinable or vitreſcible, preſerving its metallic form to the laſt. It may be preſumed therefore that the operations, which Marggrafs metal paſſed through, ſeparated the true cobalt-regulus, and left only the nickel.

XI. *Platina, Gold, and Aqua regia.*

INTO a ſaturated ſolution of platina made in aqua regia, Mr. Marggraf put a plate of fine gold, and digeſted the whole in a moderate warmth for ſome days: the gold was not in the leaſt acted upon, and there was no precipitation of the platina, except that a little dark orange coloured cryſtalline powder ſettled to the bottom, which the ſolution of platina would have depoſited by itſelf. The purer grains of platina were treated in the ſame manner with a ſaturated ſolution of gold, and with the ſame event, the acid ſhewing no diſpoſition to quit either of theſe metals in order to attack the other, ſo that its affinity ſeems to be equal to both. I melted the two metals together, and digeſted the compound in aqua regia: the menſtruum diſſolved them both, but the gold moſt readily; for the firſt portion of the liquor having been inſufficient to diſſolve the whole of the maſs, and the reſt being digeſted in freſh aqua regia, the firſt ſolution was found to have the greateſt proportion of gold, and the other of platina. When the quantity of gold was ſuch, as to give any thing of a gold colour to the mixture, the acid ſoon made the plates white, by eating out the gold firſt. I likewiſe mixed together ſolutions of the two metals, and did not obſerve any turbidneſs or precipitation to enſue, though Mr. Marggraf found, in his repetition of this experiment, a reddiſh orange coloured precipitate: in this reſpect variations may happen from the nature of the aquæ regiæ made ufe of, as from an over-proportion of fal ammoniac in the aqua regia in which the gold is diffolved, for fal ammoniac, as we have formerly feen, is of itfelf fufficient to precipitate a part of the platina. Though I could not perceive any feparation on mixing the two folutions, yet on diluting the mixture with water, and fuffering it to ftand for fome days, a bright gold coloured pellicle was thrown up to the furface: that this, however, was owing to the action of the platina, I will not affirm; for I have feen a like feparation from diluted folutions of gold alone. Another mixture of folutions of gold and platina was evaporated a little, fo as to difpofe it to fhoot: it yielded firft fine red cryftals, which feemed to contain chiefly gold, with very little platina; and afterwards deep faffron coloured cryftals, in which the platina apparently prevailed.

XII. *Platina, Silver, and Acids.*

Platina, digefted in a folution of filver made in aquafortis, was not at all acted upon, as indeed might have been expected, the platina not being foluble in the acid itfelf by this treatment. A plate of filver, digefted in folution of platina, was ftrongly attacked: a white calx fettled upon the filver, and incrufted it all over, and the plate was fo corroded as to become friable between the fingers, the liquor ftill continuing of a gold yellow colour. This experiment is from Marggraf: it feems to fhew, that filver abforbs the marine acid from folution of platina, and that the platina remains diffolved in the nitrous acid, for if any of the platina had precipitated we may prefume that the calx would not have been white. He found, however, that when the filver was previoufly diffolved, either in the nitrous or vitriolic acids, it then occafioned a precipitation of the platina, for on mixing thefe folutions with folution of platina, a yellow precipitate fell.

XIII. *Platina, Lead, and Acids.*

THIN plates of lead put into folution of platina are foon corroded, and white cryftals form at the bottom with a blackifh matter intermixed, the liquor continuing yellow: the cryftals diffolve in water, leaving the blackifh powder, which appears to be platina. Marggraf, from whom this experiment is taken, tried alfo folutions of lead, made both in aquafortis and in diftilled wine vinegar, and relates that on mixing thefe folutions with folution of platina, no precipitation enfued; a phenomenon not a little remarkable, as folutions of lead, made in either of the above menftrua, are in general precipitated by aqua regia or liquors containing the marine acid. If there was no error or deception in thefe experiments, it might be concluded from them, that the marine acid has a greater affinity to platina than it has to lead; but with me the event was otherwife. A folution of lead in aquafortis, and a folution in diftilled water of cryftallized faccharum faturni which I had prepared myfelf, being dropt into feparate portions of folution of platina, the firft drops produced no apparent change, but on continuing to add more of the lead folutions, both mixtures grew turbid and milky, and depofited quickly very copious white precipitates, the liquors continuing yellow like diluted folutions of platina. I repeated the experiment three or four times with different folutions of platina, and the appearances were always the fame.

XIV. *Platina, Regulus of antimony, and Aqua regia.*

MARGGRAF found, that a piece of pure regulus of antimony, digefted in folution of platina, was attacked by the acid. A good deal of white powder fettled at the bottom, which was doubtlefs for the moft part fome of the regulus corroded: the reft of the regulus was reduced into fmall

 brilliant

brilliant parts, and appeared to be intermixed with precipitated platina: the liquor continued yellow.

XV. *Platina, Bismuth, and Acids.*

The author above-mentioned relates, that on digesting bismuth in solution of platina, the effect was nearly the same as with regulus of antimony, the bismuth appearing corroded, a white powder settling at the bottom, and the liquor continuing yellow: and that solution of bismuth in aquafortis being mixed with solution of platina, no precipitation happened.

The experiments in the five last articles of this section are too obscure and ambiguous for points of such importance as the affinities of bodies to be established on them; but those of the first ten seem to be sufficiently clear and decisive. It may be observed, that in some of these affinities platina agrees with gold, as in being precipitated from aqua regia by zinc, iron, copper, tin, and quicksilver; but that in others, it differs so essentially from gold, that when the two metals are intimately combined together by long fusion, they may still be parted from one another in virtue of this contrariety in their affinities to particular bodies, platina being rejected by quicksilver while gold is retained, and gold being rejected by aqua regis, when vitriolic solutions of iron are added, while platina is retained.

SECT. IX.

Of distinguishing and purifying Gold mixed with Platina.

We have now finished a laborious examination of the properties of this new metal and its relations to other bodies. One of the most important advantages, that were expected to result from this enquiry, considered in a commercial view, was the preserving of the fineness and value

value of gold; or preventing it from being fraudulently debafed, by the admixture of a body, endowed with fo many of what have been univerfally reckoned the moft peculiar and inimitable characters of the precious metal. This advantage has been obtained in the moft ample manner that could be wifhed for; the experiments having pointed out different means, by which fmall proportions of platina mixed with gold, or fmall proportions of gold mixed with platina, may be eafily diftinguifhed, and by which the two metals, however blended together, may be eafily parted from one another, either in the way of affay, or of bufinefs in large. The principal of thefe means it will here be proper to collect together from the different parts of the hiftory, and to confider them more particularly, in regard to their ufe and application in practice.

I. *Amalgamation with Quickfilver.*

In an experiment related in the laft fection, page 579, a mixture of platina and gold being united with mercury, and the amalgam ground with water for a confiderable time, the platina was gradually thrown out, and the gold retained by the quickfilver.

This procefs, fimple and convenient in the execution, is accompanied with fome uncertainties in regard to its effect, which render it of lefs general ufe than it may at firft promife to be. Repetitions of the experiment have fhewn, that though the feparation fucceeds in fome cafes, it does not perfectly in all: that if there is any particle of the platina not fully diffolved by the gold, which will generally happen unlefs the quantity of gold is three or four times greater than that of the platina and the mixture is melted with an intenfe fire, this part will be retained in the amalgam, not diffolved by the mercury, not comminuted by the peftle, and too ponderous to be wafhed off in

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its grofs form. Various mixtures of platina and gold were treated in the manner above defcribed; and the gold, recovered from the amalgams, was fubmitted to further examinations. Where the proportion of platina was large at firft, the microfcope almoft always difcovered fome grains of it remaining with the fpongy mafs of gold after the evaporation of the mercury; and even when the gold had been melted, and made fluid enough to be poured into a mould, I have fometimes feen diftinct grains of platina on the fracture of the ingot. Where the proportion of platina had been fmall, the recovered gold was frequently, but not conftantly, found to be pure.

It appears therefore, that though mercury has a greater affinity to gold than to platina, and though platina, on this principle, is capable of being feparated from gold; yet the procefs is too vague and precarious to be applicable in the way of affay, as we can have no mark of the precife time for difcontinuing it, and as we can never be certain, without making another affay, whether the whole of the platina is feparated or not. As a preparatory operation, where the quantities of platina and gold to be parted are large, it is neverthelefs of good ufe; as greateft part of the platina may by this means be wafhed over with little trouble, and the gold brought into a lefs compafs, fo as to be commodioufly fubmitted to a further purification by the means hereafter pointed out.

This procefs may be confidered as anfwering the fame purpofe, in regard to mixtures of gold and platina, as that of ftamping and wafhing does in metallic ores, which could not be reduced to pure metal in the furnace to advantage, without the previous feparation of great part of their earthy or ftony matter by water. To enfure fuccefs, the mixt, if brittle enough to be pulverable, fhould be reduced into very fine powder, in ftamping mills, or in an iron mortar:

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the pulverifation may be facilitated by means of heat, both the grains of platina itfelf, and mixtures of them with other metals, being confiderably more brittle when hot than when cold. Or what is ftill better and eafier, the mixt may be melted with a fuitable quantity of lead, and this compound fubmitted to the trituration with mercury and water. If there is any truth in the report, that certain gold mines are neglected, on account of their intractablenefs from platina contained in them, this laft procefs may turn out a very important and advantageous one.

II. *Precipitation by vegetable fixt Alcalies.*

As gold is totally precipitated by fixt alcaline falts, but platina only in part, and as a minute portion of platina remaining diffolved tinges a furprizingly large quantity of the fluid of a yellow colour; it was prefumed that a fmall admixture of platina with gold might by this means be readily difcovered. A few drops of a folution of platina were therefore mixed with above a hundred times the quantity of a folution of gold, and a pure fixt alcaline falt gradually added fo long as it occafioned any effervefcence or precipitation. The remaining liquor was ftill fo yellow, that it was judged the platina would have difcovered itfelf, though its proportion had been lefs than one thoufandth part of that of the gold. It may be obferved, that though it is cuftomary to dilute metallic folutions pretty largely with water in order to their precipitation, yet here, as we want only to fee whether any colour remains in the liquor after the precipitate has fettled, the lefs dilute the liquor is, the lefs quantity of colouring matter we fhall be able to diftinguifh.

It has been objected to the above experiment, that though the platina is difcoverable when thus mingled fu-

perficially

perficially with the gold, it may neverthelefs, when combined more intimately by fufion, elude this method of trial. Mixtures of gold with fmall proportions of platina were therefore kept in fufion for feveral hours, with a very ftrong fire, and afterwards diffolved in aqua regia. The folutions were diluted confiderably with water, and a folution of pure fixt alcaline falt gradually added, fo long as any effervefcence or turbidnefs enfued. The liquors proved paler than when the two metals had been diffolved feparately, but retained colour enough to betray the platina. As the degree of colour was not here fo great, as might have been expected from the quantity of platina which there was reafon to believe they contained, I tried to difcover the platina in them by fome character more confpicuous. I put into the filtered liquors fome plates of pure tin: the tin prefently contracted an olive hue, and threw down a large quantity of brownifh precipitate, as it does from the common folutions of platina: it was obfervable, that the tin plates were often fenfibly acted upon even while the liquor was overcharged with alcali.

It has been further fuggefted, that fince a part of platina is precipitated as well as gold by fixt alcaline falts, if only this part be mixed with gold, it will elude this trial, and be thrown down by alcalies again, along with the gold, from the folution of the compound. To determine this point, I melted with gold a precipitate of platina made by fixt alcali, and kept them in ftrong fufion for an hour and a half: they feemed to unite more eafily than gold does with the crude platina, and formed a fmooth neat bead, which hammered pretty well into a thin plate before it cracked, and appeared internally uniform and equal. This compound being diffolved in aqua regia, the folution diluted with a little water, and a folution of fixt alcaline falt added by degrees till the acid was more than faturated,

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the liquor became, not indeed colourlefs, but fo pale, that it could hardly be judged to contain any platina : neverthelefs, on putting into it fome tin plates, they quickly fhewed, as in the foregoing experiment, that it held a very confiderable quantity of platina. It appears therefore that in all thefe circumftances the platina remains partially diffolved in the neutralized liquor; and that on this foundation, fmall proportions of it, mixed with gold, may be difcovered, either by the colour of the liquor after precipitation with alcali, or, in a more fenfible manner, by further precipitation with tin. In all the above experiments the folutions were diluted with water, not as being a circumftance advifable where gold is to be thus examined, but that the ufefulnefs of this way of trial might be eftablifhed with greater certainty.

Volatile alcaline falts or fpirits have the fame effects as the fixt alcalies on folutions of platina, but their effects on folutions of gold are in fome circumftances different. After the acid has been fatiated, and all the gold precipitated, an addition of the volatile alcali beyond this point rediffolves fome part of the gold, fo that the liquor becomes yellow again though there be no platina in it. For this trial therefore, only the pure fixt alcalies are to be ufed, which, in whatever quantity they are added, have not been found to rediffolve any of the gold.

III. *Precipitation by mineral fixt Alcali.*

THE vegetable fixt alcalies ferve only for diftinguifhing whether gold is mixed with platina or not : they are infufficient for the purification of the precious metal, as they always precipitate a part of the platina along with the gold. With the mineral alcali, or the alcaline bafis of fea falt, the cafe is otherwife. Though this alcali, as appears from Marggrafs experiments, precipitates, equally with the vegetable, all the common metallic bodies, gold, ſil-ver, copper, iron, tin, lead, zinc, biſmuth, regulus of antimony, cobalt, &c. yet in ſolution of platina it produces no precipitation or turbidneſs; ſo that when this alcali is mixed with a ſolution of gold containing platina, the gold alone is precipitated, and all the platina remains diſſolved. The manner of obtaining this alcali from the acid with which it is united in ſea ſalt, as it would in this place too much interrupt the hiſtory, is referred to the appendix.

The mineral alcali is in many places, particularly in the eaſtern countries, found native, either in a pretty pure ſtate, or blended chiefly with earthy ſubſtances, from which it is eaſily ſeparated by ſolution in water. I have been favoured by Dr. Heberden with a quantity of this native ſalt ſent to him from Teneriff, and find that it anſwers the preſent intention as effectually as the alcali extracted from ſea ſalt. The ſolution of platina efferveſced with it, but in whatever proportions the ſolution of the alcali and of the platina were mixed together, I could not obſerve the leaſt precipitation or cloudineſs.

A ſalt of the ſame nature, though generally perhaps mingled with ſome foreign ſaline matters, is obtained from the aſhes of certain plants, called Kali, which growing chiefly in ſalt marſhes or on the ſea ſhore, the marine ſalt is ſuppoſed to be imbibed by them, and to be decompounded, or to have its acid ſeparated, partly by the power of vegetation in the plant itſelf, and partly by the burning. The beſt ſort of theſe aſhes is ſaid to be prepared at Alicant in Spain, from an annual procumbent kali with ſhort leaves like thoſe of houſeleek. The aſhes, which are one of the common kinds of potaſh in France, and there called *ſoude* or *ſoda*, are brought to us, under the name of *Spaniſh aſhes* or *bariglia*, in hard ſpongy maſſes, partly whitiſh or grey, and partly blackiſh. From theſe maſſes the ſaline part

part is extracted pure by powdering and digesting them in water. Though it might be suspected that this salt, in virtue of its containing not only the mineral but a portion of vegetable alcali, would precipitate part of the platina as well as gold, I could not find that solution of platina suffered the least alteration from it, any more than from the native or marine alcalies.

How far these salts may suffice, for the perfect separation of platina and gold that have been intimately combined with one another by fusion, I have not yet had direct experience. But it may be proper to observe, that though both the native alcali and bariglia are supposed generally to contain some sea salt in its whole substance, which for some purposes renders them unfit, yet this salt does not appear to be here of any disadvantage, for pure sea salt occasioned no precipitation or turbidness in a solution of platina, any more than in solution of gold. The platina employed in these experiments was such as had been cupelled with lead and urged afterwards with repeated strong fires, page 570.

IV. *Precipitation by sal ammoniac.*

The alcaline salts in the two foregoing articles precipitate the gold, and leave the platina wholly or partially dissolved in the liquor. Sal ammoniac has a contrary effect, precipitating great part of the platina, and leaving all the gold dissolved; and on this principle platina may be discovered in gold as readily and as effectually as on the other. The metal being dissolved in aqua regia, add a little solution of sal ammoniac made in water: if the gold contained any platina, the liquor will instantly grow turbid, and a fine yellow or reddish precipitate will quickly fall to the bottom: if the gold was pure, no precipitation or change of transparency will ensue.

V. *Separation by inflammable liquors.*

INFLAMMABLE ſpirits, which revive gold from its ſolution in form of yellow films, have no ſuch action on ſolution of platina. This experiment affords a ſure criterion for diſtinguiſhing whether gold has been debaſed by platina, or whether platina holds any gold, and likewiſe an infallible method of recovering the gold perfectly pure. If the compound be diſſolved in aqua regia, the ſolution mingled with twice its quantity or more of rectified ſpirit of wine, and the mixture ſuffered to ſtand for ſome days in a glaſs ſlightly covered, the gold riſes to the ſurface, leaving the platina diſſolved. The golden pellicles may be collected, by pouring the whole into a filter juſt large enough to contain it: the diſſolved platina will paſs through, leaving the gold upon the paper, which is to be waſhed with freſh portions of hot water till the liquor runs through perfectly colourleſs. The paper is then to be ſqueezed together, and burnt in a crucible previouſly rubbed on the inſide with chalk, which prevents the ſmall particles of the gold from lodging in the cavities: when the matter has fully ſunk down, ſome nitre is to be added, and the fire increaſed to bring the gold into fuſion. This proceſs is accompanied with one inconvenience, the ſlowneſs of the ſeparation of the gold from the ſolution: this may be ſomewhat expedited, by employing a ſpirit that has been diſtilled off from ſuch vegetables as give over an eſſential oil.

The ſame intention is anſwered very ſpeedily, by pure eſſential oils. The metal to be examined being diſſolved in aqua regia, add to the ſolution about half its quantity of any colourleſs eſſential oil: ſhake them well together, and then ſuffer them to reſt: the oil riſes immediately to the ſurface, carrying the gold with it, and leaving the platina

tina diſſolved in the acid underneath. The oil, loaded with the gold, appears of a fine yellow colour, and on ſtanding for a few hours, throws off great part of its metal in bright films to the ſides of the glaſs. The oil may be taken off from the acid before this ſeparation happens, well ſhaken with water to waſh off ſuch parts of the platina as may adhere to it, and then ſet on fire in a crucible: when thoroughly burnt out, the reſiduum is to be melted with nitre as in the preceding experiment. After the ſeparation of the oil employed at firſt, it may be proper, for the greater ſecurity, to add a little more; which, if any part of the gold ſhould have been left in the acid, will effectually take it up.

The gold is taken up ſtill more readily, and perhaps more perfectly, by the ſubtile fluid called æther or æthereal ſpirit of wine, the preparation of which has been already deſcribed in the hiſtory of gold. Though this fluid is too expenſive to be employed for the purification of gold in the way of buſineſs, it may be of uſe in the aſſaying of gold ſuſpected to be debaſed with platina. Indeed the purifications by the common vinous ſpirits and eſſential oils are not to be recommended to the refiner, who can better avail himſelf of the method pointed out in the following article.

VI. *Precipitation by green vitriol.*

The moſt effectual and advantageous method of purifying gold from the metallic bodies commonly found mixed with it, appears to be, by diſſolving it in aqua regia, and precipitating with a large proportion of a filtered ſolution of green vitriol. Happily the ſame proceſs purifies it from platina; the vitriolic ſolution precipitating the gold and leaving the platina diſſolved. See the hiſtory of gold, page 160 of this volume. On many repetitions of this experiment, with mixtures of different proportions of the two

metals,

metals, I could never find that any part of the platina was precipitated with the gold, or that any part of the gold continued diſſolved with the platina.

Mr. Scheffer was the firſt who diſcovered this property of platina, of not being precipitated by green vitriol; and the important conſequence of it did not eſcape him. He ſeems to think however, that the precipitation of the gold by vitriol, and waſhing the precipitate thoroughly with water, are not ſufficient for completely purifying the gold from the platina, and directs an additional operation, the amalgamation of the waſhed precipitate with mercury; a proceſs which did not appear to me to be at all needful.

SECT. X.

Experiments on the yellow particles mixed with platina.

THE yellow particles, intermixed with platina as it comes to us, were not only by me, but by every perſon I know of who had examined this mineral, taken to be gold; except only Mr. Marggraf, who ſays they looked like the fineſt gold, but no where hints that they were gold, and even relates ſome experiments which ſeem to prove that they were not what they appeared to be.

" On ſome of theſe yellow grains, in a parting-glaſs, he poured aqua regis, and ſet them in digeſtion together. But though the aqua regis was made to boil, the grains were very little acted on, the liquor hardly receiving a yellow tinge, and ſolution of tin precipitating nothing from it."

" Having picked out the yellow grains from ſome platina that had been treated with arſenic, ſal alembrot, &c. he mixed them, their quantity being but ſmall, with half a dram of lead, and cupelled them with the lead: the proceſs being finiſhed, the remaining button was greyiſh-black, flatted, and cracked about the edges, like thoſe obtained

tained in the cupellation of crude platina, and weighed about half a grain. This little bead was put upon a fresh cupel, with one grain of gold that had been parted with silver, and twenty grains of granulated lead: after cupellation, he had a fair gold button, yet still somewhat flat, curled, and with a kind of net-work on the surface, in colour like gold but paler, weighing exactly two grains, hard indeed, but bearing pretty well to be reduced into plates. To this he added four grains of the finest laminated silver, and twenty grains of granulated lead; and on repeating the cupellation obtained a button not yet quite round, and weighing five grains. He flatted it, for it was considerably malleable; made it red hot; and tried to part it with purified aquafortis: but the aquafortis, though made to boil, would not sufficiently act on it. He therefore poured off the aquafortis, and found the plate very little corroded. After washing it several times with distilled water, and heating it red hot, it weighed four grains, and was found to be brittle, and just perceptibly yellowish. He added to it six grains more of fine silver, with twenty grains of granulated lead, and cupelled again: the button weighed thirteen grains, and consequently had gained an increase of three grains. It was very malleable, and being flatted, made red hot, and digested in purified aquafortis, the aquafortis attacked it briskly, leaving some black plates, which being washed, and ignited under a muffle, appeared of a fine gold colour, and weighed one grain."

In this last experiment it is probable, that the smallness of the quantity occasioned some deception. If we conclude from it, that the yellow particles were not gold, because the gold that was melted with them was recovered without increase; we must conclude for the same reason, either that they were not platina, or that the platina was destroyed in the cupellation or dissolved by the pure aquafortis. The

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experiment with aqua regis ſeems liable to the ſame difficulty; for if the yellow grains were not gold becauſe they did not diſſolve in aqua regis, for the ſame reaſon they either were not platina, or platina did not diſſolve in aqua regis.

I have already mentioned the facts which induced me formerly to believe that the yellow particles mixed with platina are really gold: ſee page 487. I have ſince repeated thoſe experiments with the ſame event, and made another which may perhaps be thought more deciſive.

Twelve ounces, or 5760 grains, of platina rich in yellow particles, were placed in three ſcorifying diſhes under a muffle, and kept of a ſtrong red heat for two or three hours, in order to diſſipate any mercurial or other foreign matter by which ſome of the yellow grains might be enveloped. All the yellow particles, that could be diſtinguiſhed by a good magnifying glaſs, being then picked out, which employed two perſons for ſeven or eight hours, their weight amounted to 47 grains: ſome of them were all over yellow; others were in part yellow, and in part like the grains of platina.

Theſe picked particles were cupelled with ſomewhat more than thrice their weight, viz. 150 grains, of lead, which in ſix different aſſays had yielded a ſilver bead amounting to between a 9525th and a 9527th part of its weight. The cupelled maſs was of the ſhape of a kidney-bean, grey, rough, brittle, with a cavity in the internal part correſponding to the ſhape of the outſide. The maſs, broken in pieces, was laid on a freſh cupel, and urged with a very ſtrong fire for five or ſix hours. It was leſs brittle than before, filed ſmooth, and appeared of a pale yellowiſh colour.

The metal being then digeſted and boiled with aqua regia in a Florence flaſk, greateſt part of it diſſolved, a ſmall quantity

quantity of whitiſh powder, probably ſilver, remaining at the bottom of the veſſel. The gold-coloured ſolution being poured into a ſolution of green vitriol, a precipitate like that of gold ſoon fell. After ſtanding till next day, that the precipitate might fully ſettle, greateſt part of the liquor was decanted off, and the remainder, with the precipitate, poured upon a filter: when the liquor had run through, the powder was waſhed on the filter with freſh portions of water. When dry, the filter with the precipitate were put into an aſſay crucible, and kept red hot till no more flame or ſmoke appeared. Some nitre was then thrown in by little and little: at firſt a ſlight fulguration aroſe; at length the whole appeared in quiet fuſion, and being poured out into a mould, I obtained a lump of high coloured, malleable, pure gold, weighing between eighteen and nineteen grains.

S E C T. XI.

Of the mineral hiſtory of Platina.

OF the mineral hiſtory of this metal very little is as yet known with any certainty. Though new to Europe, the hiſtory even of its diſcovery is as obſcure as that of the metals of moſt ancient uſe: it may be preſumed, that the little advantage which promiſed to reſult from it, on account of its want of fuſibility, occaſioned it at firſt to be neglected; and that the fraudulent purpoſes, to which it was afterwards found to be applicable, occaſioned the knowledge of it to be concealed.

It is ſuppoſed by ſome, that platina is the produce of the Eaſt Indies as well as of the Weſt, and that its analogy with gold has been known alſo for a conſiderable time in the former as well as in the latter. The foundation of this ſuſpicion is, that the late profeſſor s'Graveſande had in his

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poffeffion a ponderous metallic body, reckoned heavier than gold, fuppofed to be a mixture of gold and platina, faid to have been brought by the Dutch Eaft-India fhips from China, and to have been there fold at a high price. Dr. Brownrigg however informs me, that having lately made enquiries about this fubftance in Holland, he learnt from profeffor Allamand, that it is indeed a mixture of platina and gold, but that there was a miftake in regard to the place it had come from, which was not the eaft but the weft Indies.

That the platina brought into England is the produce of the Spanifh weft Indies, appears unqueftionable; but in what particular places or in what form it is met with, is far from being clear. Some fpeak of its being found in great abundance, like fand, in certain rivers in the province of Quito. A perfon who had been upon the fpot informed me, that it came from the mountains near Quito, or between Quito and the South fea; that great part of the land at the bottom of thofe mountains is covered with it, the floods, which come after heavy rains, wafhing the mineral down with them. Another perfon, concerned alfo in the importation of it, affirmed that it was found in Peru, in a gold mine, which had been formerly deftroyed by an inundation and lately drained; whether originally contained in the mine, or brought by the flood, was not known.

It has been reported, and without contradiction, ever fince the platina became known here, that in order to prevent the frauds which might be practifed with a fubftance of fuch qualities, the king of Spain had ordered the mines that afford it to be ftopt up; an account which, if literally underftood, feems to imply that platina is not plentiful on the furface of the earth. Whatever may be in this, whether the prohibition was made againft the working of

mines

mines of platina, or the exportation of platina lying at day, or both; we may obſerve, that the ſetting at large even of the little quantity that has hitherto been made publick, far from being productive of any ill conſequences, has been the means of effectually preventing thoſe abuſes, which platina could not fail of giving occaſion to, while confined to a particular part of the world, and while the exiſtence of ſuch a ſubſtance was in general unknown. In the papers laid before the royal ſociety ſoon after the platina came here, there is an account of gold having been taken in payment from ſome Spaniards, which being mixed with platina was ſo brittle that it could not be diſpoſed of, and which could not be refined in London, ſo that it was quite uſeleſs. I have been informed that the Dutch refiners at Dort have long complained of their meeting with gold adulterated with a ſubſtance which they could not ſeparate, which they called *diabolus metallorum*, and which they now judge to have been no other than platina; and that our jewellers, &c. for many years paſt, have avoided making uſe of the Spaniſh gold for any curious works, on account of its having frequently a mixture of a ſubſtance which renders it intractable, and which is often viſible to the eye in ſmall diſtinct grains like thoſe of platina, as if the gold had been melted by a heat not ſufficient for the perfect diſſolution of the platina, which when diſſolved would have given an ill colour to the maſs (ſee page 526). The more the platina became known, the leſs danger there was of any frauds of this kind, and we have now nothing to fear from it; the experiments already made having diſcovered eaſy means of diſtinguiſhing with certainty gold debaſed by platina, and of completely parting the two metals, however they may be blended together by accident or deſign. The refining of gold from platina is now no more difficult than the refining of it from any other metal.

It is the general opinion that platina is found in the ſame form in which it is brought to us. The obſervations on the appearance of the grains, and the matters mixed with them, mentioned at the beginning of this eſſay, induced me, on the firſt examination of it, to think that it had been ground in mills with quickſilver. Marggraf, whoſe platina came from London, and probably from the ſame parcel with that in which I had obſerved the drops of quickſilver, ſeems to have entertained a ſuſpicion of the ſame kind; for he doubts whether the platina is a native mineral, or a metallic recrement from which the Spaniards have extracted the perfect metal it contained. I have ſince been informed that the quickſilver we obſerved among it, which doubtleſs influenced Marggraf as well as me, did not come with it from the weſt Indies, but was added here by the proprietor with a view to get out the golden particles.

Some accounts however ſeem to countenance the above conjecture, that platina is found in large maſſes, and is reduced into ſmooth grains by ſtamping and grinding. A ſubſtance in ſmall grains, like the platina as brought to us, one ſhould think could hardly be called a ſtone, as platina is by don Antonio d'Ulloa.

D'Ulloa is the firſt writer I have met with who mentions platina by name. In his voyage to South America, in 1735 and the following years, ſpeaking of the gold and ſilver mines of Quito, he relates, that in the territory of Chocò there are mines, in which the gold is ſo enveloped in other mineral ſubſtances, bitumens, and ſtones, that they are obliged to uſe quickſilver for its ſeparation; that ſometimes they find mineral ſubſtances which, from their being mixed with platina, they chuſe to neglect; that this platina is a ſtone *(piedra)* of ſuch reſiſtence, that it is not eaſily broken by a blow upon an anvil; that it is not ſubdued by calcination; and that it is very difficult to extract the metal it contains even with much labour and expence.

Some have suspected that the *piedras del Inga* or *Inca*, described by the same author as being untransparent and of a leaden colour, and which were made into mirrours by the ancient Indians, consist of platina mixed with a stony matter. This mineral cannot be the same with that to which he gives the name of platina in the foregoing paragraph, for he expressly mentions that the piedra del Ingo is soft, and liable to be broken by a slight blow. The Inca stone is now pretty common, and as the French translator of the papers on platina (see page 447) observes, appears to be no other than a ferrugineous mineral of the pyrites or rather mundick kind.

Alonso Barba mentions a substance, under the name of *chumpi*, which seems to have more resemblance to the platina of d'Ulloa. He describes the chumpi as a hard stone, of the emery kind, participating of iron, of a grey colour shining a little, very hard to work because it resists the fire much, found in Potosi, Chocaya, and other places, along with blackish and reddish ores that yield gold. If platina is really found in large masses, either generally or only now and then, one might reasonably expect those masses to be such as are here described.

Of the same kind perhaps also is the mineral mentioned by several authors under the name of Spanish emery, *Smiris Hispanica*, which should seem, from the accounts given of it, to be no other than platina or its matrix. The *smiris* is said to be found in the gold mines, and its exportation prohibited; to contain films or veins of native gold; to be in great request among the alchemists; to have been sometimes used for the adulteration of gold; to stand, equally with the noble metal, cupellation, quartation, antimony, and the regal cement; and to be separable from it by amalgamation with mercury, which throws out the *smiris* and retains the gold; properties strongly characteristic of platina;

platina, and which do not belong to any known ſubſtance beſides. This debaſement of gold *per extractum ſmiridis Hiſpanici* is mentioned by Becher in his *minera arenaria*, and ſeveral times hinted at in his *phyſica ſubterranea*. Both Becher and Stahl indeed call the ſubſtance, which the gold receives from the emery, an earth, whereas platina is undoubtedly a metal; but this does not at all invalidate our ſuppoſition, for they give the name of earth alſo to the ſubſtance which copper receives from calamine in being made into braſs, which is now known to be metallic.

From theſe obſervations I have been led to ſuſpect that the European emerys likewiſe might poſſibly participate of platina. If this was certain, it would account ſatisfactorily for the uſe which ſome of the alchemiſts are ſaid to have made of emerys and other ferrugineous ores; and we ſhould no longer doubt, or wonder, that by treating gold with theſe kinds of minerals, they obtained a permanent augmentation; that this augmentation, though it reſiſted lead, antimony, aquafortis, and the regal cement, was ſeparable, as Becher owns it was, by quickſilver; and that, when it exceeded certain limits, it rendered the gold pale and brittle.

If emery contains platina, I imagined it might be diſcoverable by boiling the powdered mineral in melted lead, and afterwards working off the lead upon a teſt or cupel. The experiment was made with eight ounces of the fineſt powder of common emery, and the ſame quantity of lead, which were covered with black flux to prevent the ſcorification of the lead, and urged with a ſtrong fire for two or three hours. The lead became hard, rigid, of a dark colour, and a granulated texture, as if it had really imbibed ſome platina from the emery; but in cupellation it worked almoſt entirely off, leaving only a bead about the ſize of a ſmall pins head, which was probably no other than ſilver contained in the lead.

I repeated the experiment, with ſome variation, thinking to obtain a more perfect reſolution of the emery by vitrefying it with the lead. Two ounces of fine emery, and ſix ounces of minium, were well mixed together, and urged with a ſtrong fire, in a cloſe crucible, for an hour: they melted into an uniform dark browniſh glaſs. The glaſs was powdered, mixed with four ounces of fixt alcaline ſalt and ſome powdered charcoal, and put into a freſh crucible, with ſome common ſalt on the ſurface: The fire was pretty ſtrongly excited, but the fuſion was not ſo perfect as could be wiſhed, and only about two ounces of lead were found revived. This lead had ſuffered nearly the ſame change as that in the foregoing experiment, and like it, gave no appearance of platina on being cupelled.

It ſeems to follow from theſe experiments, that the emery employed in them contained no platina; but as it is not to be ſuppoſed that all emerys are of one compoſition, other ſorts may deſerve to be ſubmitted to the ſame trials. As gold is contained in ſome parcels of common minerals, and by no means in all the individuals of any one ſpecies; platina may poſſibly in like manner be found in ſome European ores, though there is not the leaſt footſtep of it in other parcels of the ſame kind of ore.

S E C T. XII.

General Obſervations.

THE foregoing hiſtory has brought us acquainted with a mineral ſubſtance, whoſe metallic aſpect, great weight, malleability, and perfect miſcibility with all the common metallic bodies, are ſufficient characters of its being a true metal: --- which abides fixt and uncalcined in the ſtrongeſt fires, is nowiſe ſcorified by nitre, or by lead or biſmuth, nor diſſolved by vitreous bodies, and which

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is therefore a perfect metal, of the ſame claſs with gold and ſilver, and perhaps more perfect, or leſs alterable, than they : --- which, with the colour of ſilver, poſſeſſes the ſpecific weight, and ſeveral other of the reputedly moſt diſcriminative properties of gold ; reſiſting, equally with gold, many agents, which diſcolour, corrode, diſſolve, or ſcorify ſilver and the baſe metals, as air and ſulphureous exhalations, the nitrous, marine, and vitriolic acids both in their liquid ſtate and when reſolved by fire into fume, and ſulphur and antimony in fuſion : --- with theſe valuable properties of gold, it adds ſome to gold itſelf, making it both leſs ſoft and leſs fuſible, which no other alloy does : hence a due proportion of it bids fair to remove thoſe inconveniencies, which the enamellers complain of, when they work upon plates either of fine gold or of alloyed gold.

2. Though platina undoubtedly belongs to the ſame genus of bodies with gold and ſilver, of which genus no more than theſe three ſpecies have hitherto been diſcovered ; and though it agrees with gold in many properties which have been univerſally ſuppoſed diſtinctive of the ſpecies : yet there are other important characters in which it remarkably differs from gold. Its white colour ; its want of fuſibility ; the ſingular alterations which it produces in ſome of the other metals, and in gold itſelf ; its being difficultly and ſparingly acted on by hepar ſulphuris, by which gold is plentifully diſſolved ; its ſolution in aqua regis giving no ſtain to the ſubſtances which by ſolutions of gold are tinged red or purple ; its being in part precipitated from its ſolution by ſal ammoniac, which does not in the leaſt precipitate gold ; its being precipitated only partially by vegetable fixt alcalies and by volatile alcalies, and not in the leaſt by the mineral alcali or by ſolution of green vitriol, by all which gold is precipitated entirely ;

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its precipitates by alcalies having nothing of the fulminating power, which precipitates of gold poſſeſs in a more eminent degree than any other known kind of matter; its ſolutions in aqua regia ſuffering no decompoſition from eſſential oils or æther, by both which gold is imbibed from the acid, nor from inflammable ſpirits by which gold is revived and thrown out in its proper form; its being rejected, on trituration, from its ſolution in quickſilver, while gold is retained and continues diſſolved; its being ſeparable from gold, in virtue of theſe diverſities of affinity, without augmentation or diminution of either metal, as eaſily and as perfectly as any one metal is ſeparable from any other; are characters abundantly more than ſufficient for eſtabliſhing a ſpecific difference between platina and gold.

3. The author of the letter from Venice, mentioned in page 447, enters into ſome alchemical ſpeculations on this ſubject, which the nature of the preſent hiſtory requires that I ſhould give ſome account of. He imagines, that as platina is a ſpecies of the ſame genus with gold, its differences from gold are only accidental, proceding either from ſome heterogeneous body radically united with it, or from the want of a glutinous tinging ſulphur. To which of theſe cauſes its imperfection is owing, he does not determine: its being leſs ponderous than gold, the black points diſcovered on its grains by a microſcope, and a part of it being precipitated from aqua regia by alcalies while a part continues diſſolved, are brought as arguments for the former; its want of fuſibility, its ſolution wanting the power of ſtaining animal ſubſtances and of producing a purple with tin, and its not being ſeparated from its ſolution by inflammable liquors which have an affinity with ſulphurs, for the latter. In the one caſe by purging the platina of its heterogeneous matter, and in the other by introducing the tinging ſulphur, he thinks it will become gold. This laſt, it ſeems, is eaſy enough to be done,

bodies having a natural difpofition and appetite for receiving the principle which is wanting for their perfection: but in the firft cafe there are no hopes of fucceeding, for to root out an impure matter, with which a metal is radically combined in its firft formation, he admits not to be in the power of any other agent than the philofophers ftone itfelf. Of thefe notions it is fufficient to obferve, that they are drawn from a fuppofition which cannot be admitted till fome facts fhall be produced to make it probable, viz. that all the bafe metals are no other than gold vitiated by fome impure fubftance.

4. Vogel adopts an opinion, that platina is not a true metal or femimetal of a peculiar kind, but a mixed mineral, the drofs of the amalgamation-works in which gold is feparated by quickfilver from a mixed ore. This opinion he attributes to Marggraf; and in a periodical pamphlet publifhed at London, it is faid that Marggraf fuppofes platina to be not only the effect of reiterated amalgamation, but to be a part of the mercury itfelf fixed by fome matter in the ore or metal it was amalgamated with. All I can find in Marggraf relative to this point is the following paffage. "We cannot fay with certainty whether platina is an actual ore, or whether it is a ftream-mineral which has been torn off and carried away by water from entire veins, or whether thirdly it may not poffibly be a mere metallic recrement, from which the Spaniards, as being the owners of the works, have already perhaps extracted the perfect metal." I do not apprehend that the latter part of this fentence will admit of the improbable interpretation that has been given of it. The author feems to me to have meant no more, than that the platina poffibly has not come to us in its native form, but has been ground with quickfilver to extract the gold intermixed with it; a fufpicion which I had myfelf expreffed alfo in the firft paper in the Tranfactions, and which the mercurial globules found among the platina could not fail to produce.

APPENDIX.

Page 4, 5. Portable Furnaces.

A CONVENIENT grate for theſe furnaces may be formed of four or five iron rings, placed within one another, each furniſhed with three pins at equal diſtances projecting from its circumference: the pins of the inner ring drop down into correſponding notches made in the next, and the pins of this ſecond ring into notches in the third: the notches are made in the middle of the ſpaces between every two pins. Thus we have a grate compoſed of moveable parts, and which we can enlarge or diminiſh at pleaſure, ſo as to fit into furnaces of different widths, by adding or removing a ring on the outſide: the ſpaces for admitting air to paſs up through the fuel, and the aſhes to drop down, are likewiſe more equally diſtributed than in thoſe of the common conſtruction. I have had ſome iron grates of this kind caſt, and find them to anſwer well: the rings are about five eighths of an inch deep, a quarter of an inch thick, and their diſtances from one another ſomewhat more than half an inch: the inner ring is an inch and a half in diameter, and three pins projecting inwards prevent any coals from falling through this ſpace.

Inſtead of binding the black lead pots with wire, they may be ſurrounded with iron or copper hoops. The advantage of a hoop round the mouth has been already mentioned: another may be fitted between the doors, and as the wideſt part of the furnace is that included between the

 hoops,

hoops, two ſlips of iron or copper, paſſing from one hoop to the other on oppoſite ſides, and ſcrewed to each, will keep them immoveable in their places: theſe ſlips ſerve likewiſe to carry handles for lifting the furnace by.

It may be proper to obſerve that even the unſound or cracked pots, unfit for the purpoſes of crucibles, and which are ſold for a much lower price than the ſound ones, if properly ſecured with hoops or wires, will make uſeful and durable furnaces. In all caſes it will be expedient to waſh over the inſides with Sturbridge clay diluted with water; and where the furnace is deſigned for continued ſtrong fire, or for ſtanding the action of corroſive bodies, as in fuſion *trans carbones* (page 21) it may be lined to ſome thickneſs, with a lute compoſed of the ſame clay, beaten up with about twice its meaſure of coarſe ſand, or rather of glaſs-houſe pots in coarſe powder.

Page 66. Glaſſes gilt on the edges.

SINCE the publication of the firſt part of this work, and probably on the principles there pointed out, theſe glaſſes have been prepared in England, with as durable gilding as thoſe brought from Bohemia and Thuringia. Of the compoſition of the varniſh I can ſay no more with certainty, than that oil of turpentine is an ingredient in it. My worthy friend Mr. Ziegler, in an elegant German tranſlation with which he has honoured this work, deſcribes a varniſh, with the method of uſing it, which appeared from his experiments to be the beſt. Fine tranſparent amber, reduced to powder, is boiled in a braſs veſſel having a valve in its cover (ſee page 368) with as much drying oil as will juſt cover it: generally in five or ſix hours the amber is perfectly diſſolved. Dilute the ſolution with four or five times its quantity of oil of turpentine, and let it ſtand ſome

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days that all the impurities may ſettle to the bottom. That the varniſh may dry the eaſier and acquire the more firmneſs, it is to be ground with a little white lead, or rather with a mixture of white lead and minium. It is to be applied very thin on the glaſs, and the gold leaf rather blown upon the part, ſo as it may ſtick faſt, than preſſed down with cotton. The glaſſes may be laid in a warm place, free from duſt, till the varniſh is fully hardened; after which the gold may be burniſhed, a piece of ſmooth paper being laid between the tooth or ſteel burniſher and the gold. He obſerves that this gilding is durable and of a fine luſtre; and that as the tougheſt varniſhes naturally deſerve the preference, the amber varniſh above deſcribed, promiſes, in virtue of that quality, to be the beſt.

Page 64. Gilding on the covers of books.

THE bookbinders dilute the whites of eggs with water, and moiſten the part to be gilt three or four times with this liquor: when ſo far dried as that the gold may not ſtick without preſſing, the part is ſlightly oiled over before the gold is laid on. Mr. Ziegler, after taking notice of theſe particulars in a note on the above paſſage, adds, that for gilding on taffeta or other ſtuffs, ſome fine powdered maſtich, or white of eggs dried and powdered, is duſted thinly on the ſtuff; and the gold leaf, firſt cut to a proper ſize, is laid on a hot ſomewhat oiled ſtamp, and preſſed down; with care that none of the powder touch the ſtamp, which would occaſion the gold to ſtick to it. Our bookbinders, for gilding on rough leather, follow a practice of the ſame kind, uſing common reſin inſtead of the maſtich or dried whites of eggs: the reſin melting only in thoſe parts where the hot ſtamp is applied and the gold fixed on it, the other parts of the leather remain rough as at firſt,

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and on this account only they prefer the dry refin to the liquid glutinous fubftances.

Page 45, 67. *Melting of Gold.*

BLACK lead crucibles are faid by foreign writers to be accompanied with an inconvenience of rendering the gold brittle and fomewhat pale, efpecially when a new crucible is ufed for the firft time. I had often melted gold in thefe crucibles myfelf, and had been told by different workmen that they generally employed this kind, without obferving any ill effect from them. On further enquiry among the gold-beaters, whofe daily labour is one of the fevereft trials of the toughnefs of the gold which they melt, I cannot find that they have any fufpicion of its being injured by black lead crucibles, though they now make ufe of the Heffian or Englifh more frequently than the black lead, on account chiefly of their greater cheapnefs: one of thefe workmen informed me that "he had once found gold, which was melted in a black lead crucible, to be brittle, but imagined the brittlenefs to have proceeded only from want of fufficient heat, for on melting the gold a fecond time, in the fame crucible, it had the proper toughnefs." The degree of heat is a very material article in the melting of gold: if the gold is but juft brought into fufion it proves always brittle, a pretty confiderable increafe of the fire beyond this point being requifite for giving it full malleability, or for procuring a perfect folution, and an uniform mixture and cohefion of its parts: and when this neceffary fluidity has been obtained, the pouring of the metal into a cold mould will render it as brittle as if the heat had been infufficient at firft. It is probable that the cafe is the fame in all the other metals, though in no one, perhaps, fo eminently as in gold: and we may hence account for

for the brittleneſs, which gold, after fuſion, is frequently found to have contracted, and which has commonly been aſcribed to other cauſes. I have already taken notice, (page 69) that the general opinion among the chemical writers, of gold being made brittle by a piece of charcoal falling on it in fuſion, appeared to be a miſtake, and I have ſince found the ſame obſervation made by Mr. Scheffer, in an excellent paper on the parting of metals printed in the Swediſh tranſactions: he ſays that in the royal mint of Stockholm, the gold is always covered with charcoal in melting, and yet retains the full malleability which it had before.

Page 82. Fuſibility of mixtures of gold and copper.

It has been affirmed, that though mixtures of gold and copper melt eaſier than gold itſelf, inſomuch as to ſerve as a ſolder for it; yet this does not proceed from any increaſe of fuſibility occaſioned by the mixture of the two metals with one another, but merely from copper being more fuſible than gold, ſo that the more copper the mixture contains, the eaſier it ought to melt. Admitting however that copper does melt eaſier than gold, which by no means appears to be the caſe, an increaſe of fuſibility would ſtill follow; for a mixture of gold and copper is a ſolder for fine copper as well as for fine gold.

Page 89. Calcination, &c. of tin with gold.

The experiment in which a mixture of gold and tin, calcined to an aſh grey colour, is ſaid to have melted with eaſe into a yellow glaſs with a regulus at the bottom, I have now tried, but without obſerving any appearance of vitrification --- 1200 aſſay weights of fine gold, and 1800

of

of pure tin, being melted together, the mixt was of a white colour without the leaſt yellowneſs, rough on the ſurface, tolerably bright underneath, eaſy to break, of a broad leafy texture like the beſt regulus of antimony, in weight 2981. Beaten into powder and calcined under a muffle, with a moderate heat, for five hours, it appeared of a light grey colour, and weighed 3283; ſo that it had gained in the calcination above a tenth part of the weight of the mixt, or between a fifth and a ſixth part of that of the tin. The calx was put into an aſſay crucible, which was incloſed in a larger, and urged with a ſtrong fire for two hours: the cover of the outer crucible, made of Sturbridge clay, remained ſound; that of the inner one, made of clay and chalk, melted entirely, and lined the inſide of the crucible with an opake dark-coloured glaſs. The powder, at the bottom, continued unmelted, and to the naked eye looked nearly of the ſame appearance as at firſt, but on viewing it with a magnifying glaſs, ſeveral diſtinct particles of gold were obſerved in it. A little of the powder was mixed with about ten times its quantity of powdered flint glaſs, and expoſed to a ſtrong fire in a wind furnace for ſeveral hours: the glaſs proved nearly tranſparent, uncoloured, a little cloudy, with grains of gold at the bottom.

Page 114. *Gold with ſal microcoſmicus.*

Mr. Pott, in a curious diſſertation on this remarkable ſalt of urine, gives ſome experiments which ſeem to ſhew that this ſalt has little or no action on gold. Ground with gold leaf, and then melted with a blow pipe on a coal, it forms a pearl-like maſs, which in the air becomes a tranſparent ſlime or gelly: this melts again into the ſame appearance as before, and on continuing the fuſion, the gold ſeparates and riſes to the ſurface in form of a maſſive leaf,
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the ſalt remaining whitiſh. When the ſalt was melted in a crucible with equal its weight, or a third of its weight, of gold or aurum fulminans, it received no purple or roſe colour, and did not appear to take up any part of the gold. Ground with gold leaf, and expoſed to the focus of a burning-glaſs about a foot in diameter, it ſmoked, frothed, and flowed long, but at length the gold roſe up to the ſurface, leaving the ſalt clear. One part of the purple calx of gold, precipitated from aqua regia by tin, being mixed with ten parts of the ſalt, and melted in a crucible with a ſtrong fire; moſt of the ſalt roſe over the crucible, leaving a browniſh glaſs, and the gold revived into grains. One part of a calx of gold made with quickſilver, and ten of the ſalt, melted in a ſtrong fire, gave likewiſe a yellow-brown glaſs, and the gold was found revived. One part of gold, two parts of ſal ammoniac, and eight parts of the microcoſmic ſalt, being melted together, the ſalt run all through the crucible, the gold remaining in grains.

Solution of gold in aqua regis is precipitated by ſolution of the microcoſmic ſalt, provided the aqua regis is fully ſaturated with the gold, and the microcoſmic ſolution added in ſufficient quantity. If the mixture of the two ſolutions be poured upon compoſitions for glaſs, the whole boiled down to dryneſs, then well ground together, and brought into fuſion, the gold either wholly diſappears, or hardly a footſtep of it is to be ſeen. A compoſition of three parts of powdered flint, two parts of ſaltpetre, and one part of calcined borax, being treated in this manner with the mixt ſolutions; a blue ſandiver, almoſt like turcois, was found on the top of the melted matter, and a pure blue glaſs underneath. With regard to the blue colour, which may ſeem pretty extraordinary, the author obſerves that ſome variation may happen from the degree of fire, and that the common ruby glaſs, when in giving

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it colour by the flame of wood it is kept too long in a ſtrong heat, changes to an amethyſt blue.

Page 114. *Gold plates for enamelling.*

THAT a certain mixture of alloy is neceſſary in the gold plates deſigned for being enamelled on, I have related on the authority of a writer in the French *Encyclopedie*; who ſays the gold muſt be of the fineneſs of twenty-two carats at moſt, that if finer it will not have ſtrength enough, and that if coarſer it will melt. I am told by an experienced artiſt that this is a miſtake; that ducat gold is generally uſed, whoſe fineneſs appears to be from 23½ to 23¾ carats; and that the fineſt gold is for this uſe the beſt, unleſs where ſome parts of the gold are left bare and afterwards poliſhed, as is often done in watch caſes, ſnuff boxes, &c. for which purpoſes a mixture of alloy is neceſſary; that ſilver is preferred as an alloy to copper, the latter diſpoſing the plates to tarniſh and turn green; and that the plates are ſtrengthened, by covering them on the back ſides with enamel. Thus much is certain, that the finer the gold, the more ſoft and flexible; and the coarſer, the more fuſible it proves.

Page 121, 123. *Touchſtone --- not of the marble kind.*

Mr. POTT alſo has taken notice, that the touchſtone is not of the marble kind; and that black marbles, how well ſoever they may anſwer for receiving a coloured ſtroke from metals, are unfit for the uſe of touchſtones, on account of their being diſſolved by aquafortis. He makes the touchſtone a clayey ſlate, partaking of iron; and finds, that in a ſtrong fire, like many other ferrugineous clayey minerals, it melts perfectly into a blackiſh brown ſlag, and

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that a ſmall quantity of it, mixed with vitreous compoſitions, gives them a notable green tinge. He obſerves that the imperfection of flints, &c. for the uſe of touchſtones, conſiſts in their hardneſs, which occaſions them to give too great brightneſs to the metalline ſtroke, ſo that its colour, and conſequently the proportion of alloy, cannot be exactly judged of.

Page 172, &c. Caſſius's precipitate --- Ruby glaſs.

CASSIUS does not appear, from his treatiſe *de auro*, to have been the diſcoverer either of the precipitation by tin, or of the tinging of glaſs by the precipitate. He deſcribes the preparation of the precipitate, and ſlightly mentions its uſe in this intention; but gives no account of the manner of employing it, nor any practical hint in regard to the operation, except that in ſpeaking of the ſmallneſs of the parts of gold, he ſays that one dram of gold duly prepared will tinge ten pounds of glaſs.

A proceſs for making the ruby glaſs has been communicated to me by an artiſt, who ſays he was aſſured it came from Kunkel, and that he had found it a good one for enamelled colour, but had never tried it for glaſs. The gold is directed to be diſſolved in a mixture of one part of ſpirit of ſalt and three of aquafortis; and the tin, in a mixture of one part of the former of theſe acids with two of the latter. The ſolution of gold being properly diluted with water, the due proportion of which is to be found by trials made on a ſmall quantity as mentioned in page 176, the ſolution of tin is added, and the mixture ſuffered to ſtand till the purple matter has ſettled to the bottom. The colourleſs liquor is then poured off; and the purple ſediment, while moiſt and not very thick, is thoroughly mixed with powdered flint or ſand: this mixture is well ground with powdered nitre, tartar, borax, and arſenic, and the compound melted with a ſuitable fire. The proportions of the ingredients are, 2560 parts of ſand, 384 of nitre, 240 of tartar, 240 of borax, 28 of arſenic, 5 of tin, and 5 of gold.

I have not yet had an opportunity of trying this proceſs, but am convinced, that the mixing of the precipitate with the ſand, &c. in a moiſt ſtate is a very material circumſtance, if not the principal one upon which the ſucceſs of the operation depends. Perhaps the moſt certain way would be, not to wait for any precipitation at all, but to moiſten the powders with the purple liquor, grinding them well together, in a moderate warmth, till dry, and if neceſſary, repeating the humectation. Mr. Potts experiments with the microcoſmic ſalt, mentioned in page 619, confirm the utility of this method of mixture.

Page 185. *Quantity of gold collected in rivers.*

In a paper drawn up by Mr. Guettard, from the obſervations of Mr. Pailhès, and publiſhed in the volume of the French memoirs for the year 1761, the gold found in rivers is reckoned an object of more importance than it has been uſually repreſented. It is ſaid that the mint of Touloſe received commonly every year two hundred *marcs*, or one hundred pounds weight, of gold collected from the Ariege, Garonne, and Salat; and that ſince the year 1750, twelve pounds have been carried into the *bureau* of Pamiers, though this *bureau* comprehends at moſt an extent of only two leagues round, and though the whole of the gold is not ſent thither, ſtrangers and hawkers buying it up every day.

Page 186. *Source of the gold found in rivers.*

It has been generally thought that the particles of gold, found among the ſands of rivers, have been torn off by the violence of the ſtream, in paſſing over ſome rich beds or veins. The obſervations of Mr. Pailhès, in the memoir before mentioned, ſeem to prove, that the gold is not confined to any particular ſpot, but diſſeminated, though very ſparingly, through all the adjacent earths; and that the particles found in the rivers proceed from part of the banks waſhed down by floods and rains, the lighter earth being carried away by the current, while the gold particles, with the ponderous black ſands and flints, ſettle to the bottom. The author relates, that thoſe who employ themſelves in collecting the gold, ſometimes anticipate the effect of the floods, by privately cutting down or undermining the banks, that the gold particles may be ſeparated, which occaſions frequent law-ſuits between them and the proprietors of the grounds: That in the town of Pamiers, ſituated on one of the celebrated auriferous rivers, Ariege, on digging for wells or foundations of buildings, the earth thrown up is always found to contain particles of gold: That he has diſcovered abundance of auriferous tracts in other parts of the territory of Foix, inſomuch that he imagines it would even be more difficult to procure water for the waſhing than to find the gold: and that beſides the gold met with in detached particles, the flints that accompany them contain alſo gold, which might be ſeparated to advantage by ſtamping and waſhing. A quantity of theſe flints was ſent by Mr. Pailhès to the academy, but in the aſſays made of them they appeared to be merely ferrugineous, yielding near half their weight of iron, without any mark of gold.

Page 221. *Gold coloured metal.*

THE celebrated Mr. Pott, in a German letter to Von Jufti printed in 1760, affirms that tombac, or a gold coloured metal, may be made from a mixture of copper and tin; and in a further difcuffion of Von Juftis objections, printed in 1762, he gives the particular compofition of this metal. "Take one half-ounce of tin afhes, and four half-ounces of copper: melt them well together, in a clofe luted crucible, with a ftrong fire. Or take one half-ounce of the pureft tin cut in pieces, and fixteen half-ounces of pure copper beaten into thin plates: lay the tin between the copper plates, lute the crucible clofe, and melt with a ftrong fire."

Page 224. *Gold coloured varnifh.*

THE compofition of a gold coloured varnifh, ufed by the Englifh artifts for brafs and filver, was communicated to fome of the French academicians, in 1720 by Mr. Scarlet, and in 1738 by Mr. Graham, and has lately been publifhed in the volume of the French memoirs for 1761. Though I do not apprehend that this varnifh is anywife fuperiour to that defcribed in the page above referred to, I fhall here infert it for the fatisfaction of the reader. "Take two ounces of gum lac, two ounces of yellow amber, forty grains of dragons blood in tears, half a dram of faffron, and forty ounces of good fpirit of wine: infufe and digeft in the ufual manner, and then ftrain through a linen cloth. The piece to be varnifhed muft be heated before the liquid is applied: it receives from the varnifh a gold colour, little different from that of the mercurial gilding, and may be cleaned, when fullied, with warm water." It may be prefumed that the amber is of no great

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ufe in the compofition, this concrete being very fparingly diffolved by the fpirit.

As the fpirit for varnifhes ought to be freed as much as poffible from its phlegm or watery part, and as this is moft conveniently effected by means of fixt alcaline falts, I accordingly directed the fpirit to be fhaken with fo much alcali as fhould be fufficient to imbibe the phlegm. In Meyers very ingenious German treatife on quicklime, publifhed in 1764, it is obferved, that fpirit rectified with thefe falts is unfit for varnifhes, particularly for fuch as are to be applied on gilt works, the fpirit taking up a part of the falt, which darkens the colour, and prevents the fpeedy drying of the varnifh. This obfervation feems to relate to fpirits that have been dephlegmated, not fimply by fuffering them to ftand fome hours on the alcali in the cold, and occafionally fhaking the veffel, but by the application of a confiderable heat; in which laft cafe the fpirit is known to take up a fmall portion of the alcaline falt, but that it diffolves any in the firft is not fo clear. If, however, the fpirit fhould in either way have received an alcaline impregnation, it may eafily be purified by means of a little alum well dried and powdered, the alcali being abforbed by the acid of the alum, and forming therewith a compound not combinable with vinous fpirits. Some perfons, when a perfectly pure fpirit is required, firft dephlegmate it with alcaline falts, and afterwards purify it from fuch part of the alcali as remains in it, by a frefh diftillation from a quantity of alum: perhaps fimple infufion and agitation with the alum would be as effectual, at leaft for the purpofe of making varnifhes, as the more troublefome procefs of diftillation.

Gold

Gold coloured Glaſs, with metallic ſubſtances.

PRECIPITATES of ſilver, baked on glaſs, ſtain it yellow, and likewiſe give a yellow colour on being mixed and melted with forty or fifty times their weight of vitreous compoſitions: the precipitate from aquafortis by fixt alcali ſeems to anſwer beſt. I have likewiſe obtained yellow glaſſes with certain preparations of iron, particularly with Pruſſian blue. But neither with ſilver nor with iron does the colour ſucceed conſtantly, or approach to the high yellow of gold.

The neareſt imitations I have obtained of the colour of gold in glaſs, were produced with antimony and lead. A quantity of crude antimony in fine powder was calcined by a little at a time in a flat iron pan, with care to prevent as much as poſſible its running into lumps, by uſing a very gradual fire, and keeping it conſtantly ſtirring, till at length, when brought to a full red heat, it neither ſoftened nor emitted any fumes. The aſh coloured calx, weighing little more than half of the crude antimony, was put into a crucible, and urged with a ſtrong fire in a blaſt furnace: it melted into a glaſs, dark coloured and opake in pieces of any conſiderable thickneſs, and of a tranſparent yellow when drawn out thin.

Some of this glaſs, reduced to powder, was mixed and melted with four times, three times, and twice its weight of powdered flint glaſs: the glaſs reſulting from the firſt mixture was of a tranſparent pale yellow, from the ſecond deeper, and from the third of a pretty deep yellow, without any mixture of greeniſh or brown. Equal parts of the glaſs of antimony, of flint calcined and powdered, and of minium, formed a glaſs of a high yellow, and with two parts of glaſs of antimony, two of minium, and three of powdered flint, the colour approached ſtill more to that of gold.

gold. All theſe compoſitions were bright and tranſparent, without any ſcum on the ſurface or regulus at the bottom. The laſt exhibited a multitude of ſmall ſparkles interſperſed through its whole ſubſtance, which gave it a beautiful appearance in the maſs, though in the lapidaries hands they were found to be imperfections, ariſing from air bubbles. It is pretty remarkable, that in ſeveral repetitions of this experiment, in a glaſshouſe furnace as well as in my own elaboratory, the product was always full of theſe brilliant ſpecks.

Glaſs of lead and glaſs of antimony make likewiſe a gold coloured glazing for porcelain and earthen ware. The fineſt gold glazing is ſaid to be made with an addition of ſilver. A glaſs of lead is prepared by melting minium or litharge with a third or a fourth part of its weight of powdered flint. This yellow glaſs, reduced into fine powder, is either ſprinkled on the porcelain made red hot, or mixed with beer or other glutinous liquids to a due conſiſtence, and applied with a pencil: the ware is then placed in the furnace, under a muffle, till the glaſs begins to melt, which is known by its gliſtening; after which, while warm from the fire, it is moiſtened with a diluted ſolution of ſilver, and baked again. Or the powdered glaſs of lead is moiſtened with the ſilver ſolution, then melted, and the glazing of the ware finiſhed in one proceſs, by applying on it this compound glaſs. After the baking, the glazed veſſels, while ſtill red hot, are held over the ſmoke of burning ſtraw, &c.

Gold coloured glaſſes without metallic ſubſtances.

THERE are ſundry earthy bodies, as chalk and gypſum, which make a yellow colour in glaſs, eſpecially when the vitrification is procured with borax or alcaline ſalts. Theſe glaſſes however have generally more or leſs of a green tinge, and never, ſo far as I have obſerved, a gold yellow.

Neri directs, for a gold yellow colour, one part of red tartar, and the ſame quantity of manganeſe, to be mixed with a hundred parts of fritt or the compoſition for glaſs.

Kunkel, in his experimental remarks on Neri, ſays that this proceſs gave him more trouble than any other in the book; that the proportions are quite faulty; that the quantity of manganeſe is too much for the tartar, and the tartar too little for the fritt; that one part, or one and a quarter of manganeſe, is ſufficient for a hundred of fritt, but that ſix parts of tartar are hardly enough, eſpecially unleſs the tartar is of a dark red colour almoſt blackiſh; and that he found it expedient to add to the tartar about a fourth of its weight of powdered charcoal. He takes notice that the compoſition ſwells up greatly in melting; that if the glaſs be much ſtirred with the iron, as is cuſtomary for other kinds of glaſs, it will riſe up ſo as to run over the pot, though at firſt no more than half full; and that therefore it muſt be left unſtirred, and worked as it ſtands in fuſion. Speaking afterwards of a yellow enamel tinged with the ſame materials, he adds, that the colour muſt be carefully watched, too long a continuance of fire deſtroying it.

My ingenious friend Mr. Samuel More, in repeating and varying this proceſs with a view to render the colour more perfect, found that the manganeſe is entirely ineſſential to the gold colour, and that the tartar is no otherwiſe of uſe, than in virtue of the coaly matter to which it is in part reduced by the fire. Different kinds of coals, as that of tartar, common charcoal, ſoot, dried blood, &c. on being melted with colourleſs fritts or glaſſes, gave always pale yellow, dark yellow, reddiſh, browniſh, or blackiſh colours, according as the inflammable matter was in ſmaller or larger proportion; the phlogiston, or inflammable part of the coal, seeming to be the direct tinging substance. When the phlogistic matter was thus diffused through glass, he did not find it to be affected by continued strong fire, any more than charcoal is when excluded from the air: though some pots of the coloured glass stood for a fortnight in the glasshouse furnace, they still retained their colour; nor did the most intense fire of a lamp alter it in the least. How fixt the colour when once united with the glass is, we may judge from the indestructibility, by very strong fire in open vessels, even of the superficial browns and blacks which charcoal and soot communicate to glass in its conversion into porcelain: see page 242.

Mr. Pott, in his *neue wichtige physicalisch-chymische materien, &c.* printed in 1762, observes also that common coals give a yellow colour to glass; and that even by cementation, provided the heat is not sufficient to change it towards porcelain, they stain it of the same colour. He says that different coaly matters differ in their tinging power; that caput mortuum of soot, and lamp black, answer better than common charcoal, and that he has known some persons employ the coal of indigo: That the sparkling coal, which remains in the retort after the rectification of the thick empyreumatic animal oils, is one of the most active of these kinds of preparations, being as it were the heavier part of the inflammable substance of the oil, and very rich in colour: That this preparation, powdered and then again burnt a little in a close vessel, is excellent for tinging glass, and gives yellow, brown, reddish or blackish colours according to its quantity: That the fritt must not be very hard of fusion, for if it is, the strong fire will destroy the colouring substance before the glass melts; and that he has found the following compositions to be nearly the best, viz. sand 2 parts, alcali 3 parts; or sand 2, alcali 3, calcined borax 1; or ſand 2, alcali 2, calcined borax 1: That though ſaltpetre is hardly, or very ſparingly, uſed for yellow glaſſes, as it too much volatilizes the colouring ſubſtance; yet here for the moſt part a certain proportion of it, which proportion will be eaſily found by trial, is very neceſſary, for without it the concentrated colouring matter is apt to make the glaſs too dark, and even of an opake pitchy blackneſs.

That there is any material diverſity in the effects of different coals, may be juſtly queſtioned; for Mr. More obtained, with common charcoal, the ſame colours, as with the coals which are here ſuppoſed to be of greater excellence and activity: it is probable, that the only difference conſiſts in their containing different quantities of the inflammable matter, ſo that a little more ſhall be required of one kind than of another, for producing the ſame degree of colour in the glaſs. Nor does the ſoftneſs or fuſibility of the fritt appear to be anywiſe neceſſary, for my friend informs me that he has tinged, with coal, glaſſes which were ſo hard of fuſion, that the glaſsmen could not work them, whereas the above compoſitions are all rather too ſoft to be ſerviceable in the large way.

Page 233. Converſion of green glaſs into porcelain.

Some have complained, that on repeating theſe experiments, the change did not ſucceed; and further enquiry has ſhewn, that ſome ſorts of green glaſs are unfit for this operation. Green glaſs has been chiefly made of vegetable aſhes and ſand, brought into fuſion together by a ſtrong fire: with this kind, which is the green glaſs common about London, the experiments ſucceed in the manner deſcribed. In ſome parts of this kingdom, inſtead of vegetable aſhes, the vitrification of the ſand has been procured princi-

principally by means of another ingredient, the ſlags of the iron furnaces; and glaſs of this compoſition is found not to be convertible into porcelain. The failure of this kind of glaſs ſerves to confirm the general reſults drawn from the former experiments; that earthy and metallic glaſſes made without ſaline matter, are not ſuſceptible of this change; and that the change depends on the ſaline ſubſtance contained in the vegetable aſhes.

Page 314. Machines for blowing air by a fall of water.

I HAVE received an account, from a worthy correſpondent in Swiſſerland, of a machine which he has conſtructed for a ſmelting furnace according to the foregoing directions: he ſays, it has ſo much the advantage of all other kinds of bellows, that it deſerves to be introduced univerſally wherever the ſituation of the place will permit. The only inconvenience he finds in it is, that the cullender and gratings are liable to be ſtopt up by leaves, &c. With regard to the cullender, the obſtruction may be obviated by enlarging the holes. The gratings ought to be of a large ſurface: the wire grating in the ciſtern on the top may be a cylinder nearly as large as the ciſtern will receive, for if it is no more than ſufficient to cover the mouth of the pipe, it will doubtleſs be ſoon choaked up: when ſo much of the cylinder becomes ſtopt, that the water has no longer a free paſſage through, it may be lifted up and cleaned, another being placed in the room of it; without the trouble of turning off the water, or interrupting the going of the machine. The gratings here can be liable to no other inconveniences, than thoſe which are common in other water machines, mills, aquæducts, &c.

Some further improvements have occurred in the conſtruction of theſe machines, by which they may be made effectual.

effectual in cafes where the quantity or fall of water would otherwife be infufficient.

Of conftructing blowing machines with falls of water of great height.

WHERE the height of the fall is great, the quantity of water is ufually fmall; and in all the ways of application that have hitherto been contrived, the height will by no means make amends for the deficiency in quantity.

In the common conftruction of thefe machines, where the upper pipe or funnel is no more than three, four, or five feet high; though the fall fhould be fuch as to admit of the lower pipe being thirty or forty feet or more, it does not appear that any material advantage could refult from fuch a height. For, as the air is admitted into the water only at the top of this long pipe, it cannot, I think, be fuppofed, that the quantity admitted will be the greater for the length of the paffage under the place of its admiffion. Water indeed has been found by Mariotte to run fafter, through an upright long pipe, than through a fhort one: a quantity of water which was forty-five feconds in running through a pipe three feet long, was difcharged in thirty-feven feconds, or near a fixth part lefs time, through a pipe of the fame bore and a double length; fo that as more water paffes fucceffively through the long pipe than through a fhort one, in equal times, more air alfo muft be carried down by it. But in the cafe which we are here confidering, no benefit can be expected on this principle; for as the fupply of water is fuppofed to be limited, the bore of the pipe muft neceffarily be made lefs, in proportion to the increafe which its length may produce in the velocity. If the lower pipe is of fuch height, that the watery column it contains may fufficiently refift the force of the compreffed air in the air-veffel, it fhould feem that any

any further addition to its height could be of no manner of ufe.

We have feen, in the foregoing part of this effay, that it would be more advifable, in fuch cafes, to fhorten the lower pipe, and to lengthen the upper one: by this means the water, acquiring greater velocity at the place of its difcharge from the upper pipe into the lower, is enabled to divide or fpread more, and thus to receive more air into its interftices. The advantage, thus obtained, does not however increafe in fo great a proportion as the height does. From an experiment related in page 310 it appears, that by increafing the height four-fold, the effect was not increafed three-fold; and this even in fmall heights, where the effect is much more influenced by a variation of the height than in great ones.

The obfervations already mentioned point out means of availing ourfelves more advantageoufly of high falls; fo as to produce always with certainty, from a fall of a double or treble height, a double or treble effect if the quantity of water be the fame; or an equal effect, with one half or one third the quantity of water.

Experiments have convinced me, that a fall of fourteen feet is more than fufficient for compreffing the air to fuch a degree, as to be able to fuftain the gage at the height of four feet; or to raife, on an opening of a fquare inch, a weight of about a pound and three-quarters averdupois, or above two pounds troy; a compreffure, which is apprehended to be as great as there will in general be occafion for. Where we have plenty of water, with fuch a fall, we can drive in air, with this force, in any quantity: for if one machine, with a certain portion of the ftream, produces a continued blaft of this ftrength through a pipe of a certain bore, as an inch or three-quarters of an inch; it is evident, that the quantity of air may be doubled, trebled, &c.

at pleaſure, without diminiſhing the compreſſure or force of the blaſt, by adding another and another machine, till all the ſtream is employed. It is plain, in like manner, that the ſame advantage may be received from high falls, by placing one machine over another; that after the water has performed its office in falling through one machine, it is ſtill capable of exerting the ſame action in another and another machine, ſo long as equal ſpaces remain for it to fall through; ſo that the total effect muſt be the ſame, as if a quantity of water, ſufficient for working all the machines, came at firſt in one ſtream.

A fall thus divided into two machines is repreſented in the middle of the annexed plate. In the lower machine, whoſe air-veſſel is ſunk to a conſiderable depth in a pit made in the ground, the water is forced up in the pit, on the outſide of the veſſel, four feet higher than the ſurface of the water within the veſſel, or of the ſtone on which the water daſhes, called by the workmen the daſh-board, (ſee page 287). The air-veſſel of the upper machine having an additional part at one ſide, which performs the ſame office as the pit, the water is in like manner forced up to the ſame height in this outer part; which outer veſſel ſerving as a reſervoir for the machine under it, the water begins to act in this lower machine four feet higher up than the daſh-board of the firſt. Whatever number of machines the fall will admit of, the caſe is the ſame in them all: though in each of them the water falls eighteen feet, yet as it is preſſed up again four feet for the ſucceeding machine, one machine takes up but fourteen feet of the real fall.

The outer veſſel, and its communication with the air-veſſel, may be conveniently formed by an upright partition in the air-veſſel itſelf, not reaching quite to the bottom. The outer diviſion may be open at top, and needs not be

ſo

ſo high as the cloſe air-veſſel; it is ſufficient if it reaches a little more than four feet above the level of the daſh-board, the water, which it is deſigned to receive, not riſing higher than this. In other reſpects, the ſtructure of theſe machines agrees entirely with that of the ſingle ones already deſcribed. It muſt be obſerved only that the cullenders of the lower machines ſhould be, as nearly as poſſible, of the ſame dimenſions with thoſe of the upper ones. For if they are of ſmaller bores, they will not admit of all the water which paſſes through the upper ones, ſo that part of it muſt run to waſte: if they are larger, the water will paſs off too faſt, without producing its due effect. The regulators, deſcribed in page 312, are here particularly uſeful, affording ready means of increaſing or diminiſhing the apertures occaſionally while the machines are at work.

Of blowing machines with low falls of water.

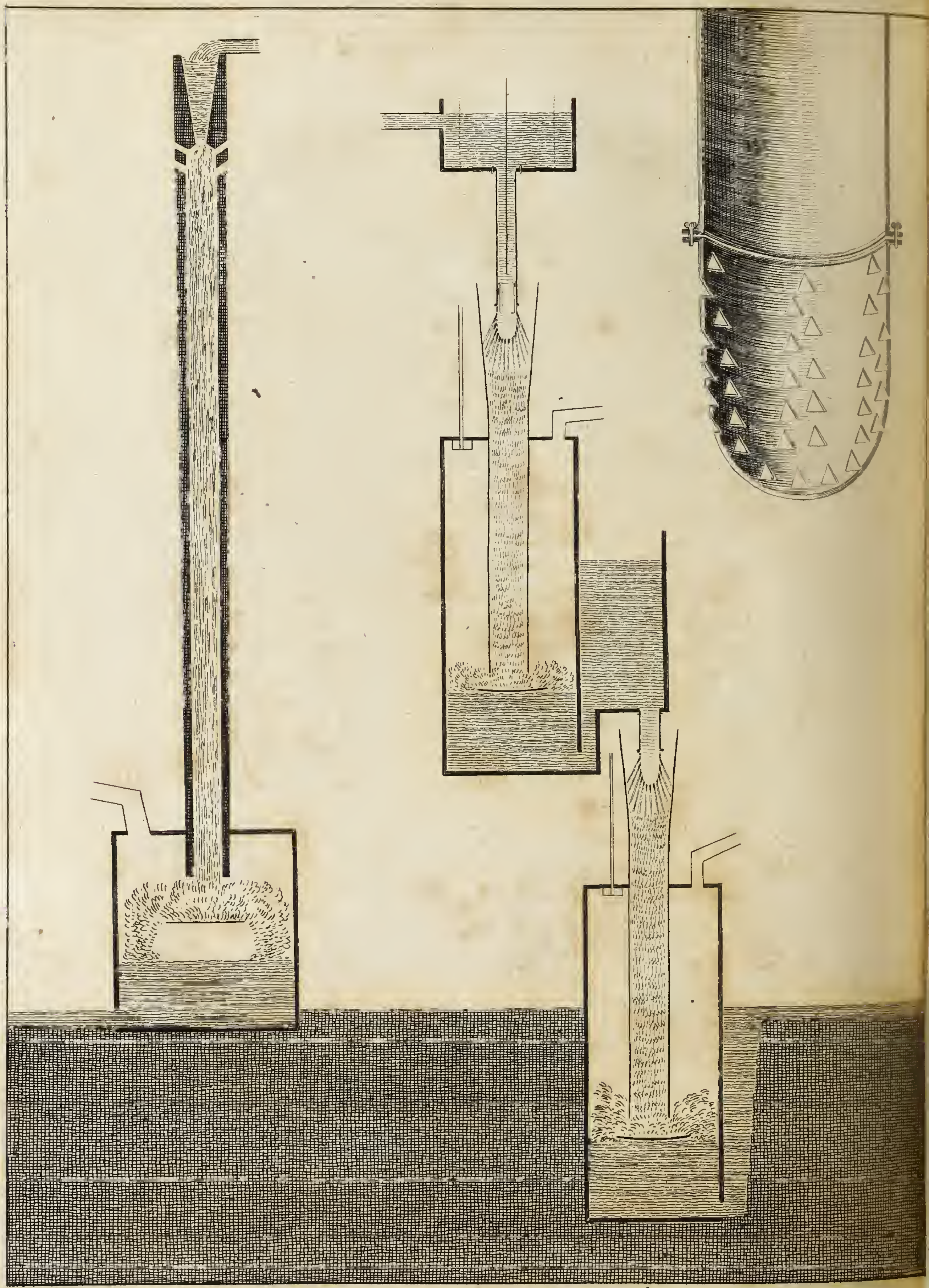
THE dimenſions hitherto given are ſuch as appear the moſt advantageous. Much lower falls, however, than thoſe which the foregoing machines are calculated for, as ten, eight, or perhaps ſeven feet, may be made to afford a ſtrong blaſt. To produce ſuch a compreſſure of the air in the air-veſſel, as to raiſe the gage four feet, a fall of about ſix feet is neceſſary for the lower pipe. If the upper pipe is only about a foot and a half or two feet, the water, when divided by means of the cullender, will carry down a certain quantity of air; and though the quantity, from an equal ſtream of water, will not be ſo great as when the fall is higher, yet, as there are in many parts of the kingdom, large bodies of water running with ſuch a deſcent, the deficiency may be compenſated, as already taken notice, by enlarging or multiplying the machines.

For many purpofes ftill lefs falls will fuffice. The fmiths bellows, as we have formerly feen, raifes the gage only about fourteen inches; and fuch a compreffure, it is prefumed, may be gained from a fall of five feet or lefs. Small falls may be applied alfo to another purpofe, of no little importance, the ventilation of mines and coal-pits, or the driving in of frefh air, in the room of that, which the mineral vapours have rendered unwholefome or pernicious.

In all thefe machines it muft be obferved, that the height of the column of water, falling through the pipe, determines, not the actual force of the blaft, but the greateft force which can be given it in that machine; that the height of the gage is always the meafure of the actual force; that this force depends on the width of the pipe through which the air is difcharged from the air-veffel, and may be diminifhed, or increafed in any degree up to the greateft that the column of water can refift, by widening or narrowing the aperture of the pipe; that different machines will give blafts of equal force through pipes of greater or lefs width, according to the greater or lefs quantity of air which the water carries down with it; and that therefore the fize of the blaft-pipe muft be adjufted by trial for each particular machine.

The diftance of the dafh-board under the pipe may likewife admit of fome variation, and require to be regulated according to the fize of the pipe. In fome of the common machines, this diftance is three or four feet or more; but fo large a fpace is apparently a difadvantage; for fo much of it, as is more than fufficient for the free paffing off of the water, is entirely ufelefs, being, in effect, fo much taken off from the height of the fall. The diftance of fix inches, laid down in the foregoing machines, is defigned for a circular pipe of twelve inches diameter; in which cafe, the area, by which the water is difcharged

all



all round, is juſt double to the area of the pipe, and conſequently more than large enough for letting the water off without impediment.

Explanation of the Plate.

THE two blowing machines, repreſented on the plate, are both drawn to one ſcale, that the eye may judge more readily of their comparative heights and dimenſions. The ſupports of the reſervoirs, &c. are not expreſſed, that the eſſential parts may be the more diſtinct.

The machine on the left hand is that of Dauphiny, deſcribed in page 274, with a fall of about thirty feet. The other is a natural fall of twenty-eight feet, formed into two artificial ones of eighteen feet each; ſee page 310 and 634. This double machine, though ſomewhat lower than the other, may be preſumed to have twice its effect, in virtue of the diviſion; beſides the advantage of the more free admiſſion of air, and the ſpreading of the ſtream through a pipe of a much larger bore, by which it is enabled to carry down in its interſtices a much greater quantity of air. The dotted lines, in the upper reſervoir, repreſent a cylindrical grating of iron wire, to keep back weeds, &c. The diviſion of the air-veſſel, and the courſe of the water from the upper machine to the lower, are apparent from the figure.

On the right hand is a perſpective view of the cullender, ſcrewed to the upper pipe, drawn to a larger ſcale, to ſhew the diſpoſition of the holes. The holes may be made wider than formerly propoſed, as an inch each ſide, to prevent any danger of their being choaked up.

Page 321. Black Diamond.

I HAVE been favoured with a ſight of this ſtone, and am aſſured it is a true diamond. At a diſtance, it looks uniformly black; but on closer examination, it appears in some parts transparent, and in others charged with foulness, on which the black hue depends.

Page 359. Indian ink from lamp-black and glue.

SINCE the experiments on the composition of Indian ink were made, I have met with an account in Du Haldes history of China, which seems to confirm them. He gives three receipts for the preparation of this commodity, two taken from Chinese books, and the third communicated by a native to one of the missionaries. The colouring material in all of them is lamp-black, to which is added, in one, a quantity of horse-chesnut burnt till the smoke ceases: he does not determine whether the wood or the fruit of the horse-chesnut tree is meant, but adds, from the Chinese author, that if used in over-proportion, it inclines the black colour to a violet. The conglutinating matter, in one of the prescriptions, is a thin size of neats leather; in another, a solution of gum tragacanth; and in the other, a mixture of size with a decoction of certain vegetables to us unknown. The first, viz. lamp-black and size, which is that from verbal communication, is the very composition which our experiments pointed out. As to gum tragacanth, it certainly is not the conglutinating ingredient in any of the samples of Indian ink that have come under my examination, the vegetable gum not putrefying with water as the Indian ink does: if gum was really made use of, gum tragacanth should seem the most unfit for the purpose, on account of its difficult and imperfect solution in water. The vegetable decoctions or infusions I cannot apprehend to be of any manner of use where size is employed, unless it should be to give a scent to the composition, in which intention, musk and other perfumes

perfumes are ſaid to be frequently mixed with it. The author obſerves that the Chineſe have inks of different goodneſs and price; that the moſt eſſential difference proceeds from the quality of the lamp-black; and that the beſt lamp-black is the ſoot of oil, which is burnt in lamps, in apartments fitted up for this purpoſe. The Chineſe, according to his account, imagine the differences in the ſoot of different oils, &c. to be much greater than the experiments related in page 342 give room to believe they are.

Page 369. Black varniſh for metals.

The workmen frequently employ for this purpoſe, as I am informed, a mixture of lamp-black with the ſcummings, &c. of different oil paints: the mixture is applied with a pencil, and the piece afterwards baked in an oven, with a heat ſomewhat greater than is uſed for the papier machè. Naples yellow, a ſuperfluous ingredient in the black varniſh, is the baſis of the dark brown which we ſee on ſome iron ſnuff-boxes, this pigment changing to a brown in baking with the varniſh.

Page 596. Separation of the alcali of ſea ſalt.

1. *Purification of ſea ſalt.*

Pure marine ſalt is a combination of the mineral alcaline ſalt with marine acid: but all the common ſorts of this ſalt have a mixture of one or more ſaline matters of a different compoſition, their baſis, inſtead of an alcaline ſalt, being an earth; which earth is generally the ſame with that called magneſia, though ſometimes, perhaps, it may be of the calcareous kind.

1. Theſe

1. These salts with an earthy basis are discovered, by dissolving the marine salt in water, and dropping in a solution of any alcaline salt. The earth, of whatever kind it be, precipitates; the acid, which held it dissolved, quitting it, to unite with the superadded alcali; so that by continuing to drop in more of the alcaline solution, till it ceases to occasion any precipitation or cloudiness, we produce in the liquor, instead of the salt with an earthy basis, a true neutral salt with an alcaline basis.

2. In some sorts of marine salt, the acid united with the earth is the vitriolic. This may be known, by dropping, into a solution of the salt, a solution of chalk, or other calcareous earth, made in the nitrous, marine, or vegetable acids. The vitriolic acid quits the earth which it was before combined with, and joins itself to the calcareous earth, forming therewith a selenitic concrete, not dissoluble or exceeding sparingly, and which therefore settles to the bottom in a powdery form; so that by continuing to drop in a due quantity of the calcareous solution, all the vitriolic acid may be separated with the calcareous earth, while the magnesia, now combined with the acid in which the calcareous earth was before dissolved, remains in the liquor along with the marine salt.

3. There is another method in which we can separate the vitriolic acid, and this without communicating any foreign impregnation to the liquor. Add to the solution of the marine salt, some strong lime-water: the vitriolic acid unites and precipitates with the lime; and the magnesia, thus deprived of its acid solvent, precipitates also. Though this simple process effectually purifies the salt from the combination of vitriolic acid and magnesia (commonly called bitter salt, or bittern) it does not answer so well, for merely distinguishing that acid, as the foregoing method; lime-water producing a turbidness and precipitation in many liquors which contain no vitriolic acid.

4. In many kinds of marine ſalt, the heterogeneous earth is united with the true marine acid: we may always judge that this is the caſe, when the method of trial No. 1 diſcovers that the ſalt contains an earth, and when the calcareous ſolution No. 2, by producing no cloudineſs, ſhews that the acid is not the vitriolic. The combination of either magneſia or calcareous earth, with the marine acid, or with the nitrous acid if ſuch an acid ſhould ever exiſt in marine ſalt, I know of no other means of ſeparating, than decompounding it by alcalies as in No. 1, or careful cryſtallization.

The combination of earth with marine acid I have found to be by much the moſt frequent and moſt conſiderable admixture in the common marine ſalts uſed among us at table. This compound liquefies eaſily in the air, a well known imperfection in the common ſorts of marine ſalt; and on this diſpoſition to liquefy depends its being in great meaſure ſeparable by cryſtallization. The bay ſalts, cryſtallized by the ſlow evaporation produced by the ſuns heat, have much leſs of this deliquiable ſalt, and hence are much leſs ſubject to grow moiſt in the air, than thoſe prepared by the haſty boiling down of the brine; though they generally have a pretty large admixture of the bitter ſalt, which cryſtallizes as perfectly, though not ſo ſoon, as the marine ſalt itſelf.

On this bitter ſalt probably depends a property of the common marine ſalts, which has given occaſion to ſome miſtakes in regard to their compoſition. When common ſalt has been melted in the fire, it afterwards deliquiates very ſpeedily in the air, though before it was of ſuch a kind as to be little diſpoſed to grow moiſt. This does not ſeem to proceed from the ſalt being rendered alcaline, or loſing any of its acid, but from ſuch a tranſpoſition of its acids as we find to happen when artificial mixtures of the

ſame.

ſame ingredients are treated in the ſame manner: the vitriolic acid of the bitter ſalt, looſened from its earth by the heat, unites with ſo much as it can ſaturate of the alcali of the marine ſalt; and the marine acid, diſengaged by the other from this part of the alcali, unites with the magneſia which the vitriolic acid has forſaken, forming therewith, inſtead of the cryſtallizable bitter ſalt, the very deliquiable compound above mentioned. It has been found indeed, that common ſalt gives out a portion of marine acid, when ſolutions of it are haſtily boiled down, or when the dry ſalt is expoſed to ſtrong fire: but the compound of earth and marine acid parts with ſome of its acid in the ſame circumſtances, and Mr. Baumè has ſhewn, in his *manuel de chymie*, that marine ſalt, purified from that compound, does not.

The purification of marine ſalt from its earth, by the addition of alcaline ſalts, No. 1, how uſeful ſoever it may be to the ſaltboiler, muſt never be had recourſe to in the preſent intention, unleſs we have an alcali exactly the ſame with the marine alcali itſelf; for by whatever means we can disjoin the marine alcali from its acid, we ſhall disjoin along with it this extraneous alcali. Nor indeed is ſuch a purification anywiſe wanted here; for in ſeparating the acid from the alcali, we ſeparate it from the earth alſo, and the alcali is afterwards purified from this earth, along with the other earthy matter which it has contracted in the operation, by ſolution in water. For the two firſt proceſſes of the following article, it is ſufficient if the ſalt is well purified from vitriolic acid; and for the third, even that purification is unneceſſary.

2. *Preparation of cubic nitre.*

The acid of common ſalt can neither be expelled from its alcali by fire, nor transferred from it, ſo far as is known, to to any other body. But though we cannot transfer the marine acid from the alcali; we can transfer the alcali, from the marine acid, to the nitrous acid; and from this laſt acid we can ſeparate the alcali pure. The combination of this alcali with the nitrous acid is called, from the figure which it aſſumes in cryſtallization, cubic nitre.

I. Cubic nitre may be prepared, by putting into a glaſs retort ſome common ſalt, pure from vitriolic acid, thoroughly dried over the fire, and reduced to powder; ſetting the retort, on as much ſand as will keep it ſteady, in an iron pot placed in a proper furnace; pouring in thrice the weight of the ſalt, of ſtrong ſmoking ſpirit of nitre, with care to avoid the fumes; immediately luting on a large receiver, with ſome water in it to promote the condenſation of the fumes; and proceeding to diſtillation, with a very gradual fire, increaſed at laſt ſo as to make the bottom of the retort red hot. The marine acid, with part of the nitrous, comes over into the receiver: the marine alcali, combined with the reſt of the nitrous acid, remains in the retort. The maſs of ſalt is to be diſſolved and waſhed out of the retort with diſtilled water or pure rain water, the ſolution filtered, evaporated with a moderate heat till a pellicle begins to appear on the ſurface, and then ſet in the cold: the ſalt ſhoots into cubical or rather rhomboïdal cryſtals, generally cluſtered together.

Mr. Marggraf, in a diſſertation on the beſt method of ſeparating the alcaline ſubſtance of common ſalt, found that two parts of ſmoking ſpirit of nitre, of ſuch ſtrength as inſtantly to fire pure oil of cloves, were ſufficient for one part of purified common ſalt; but of the weaker nitrous ſpirit, called aquafortis, he recommends eight times the weight of the ſalt. He ſays the cryſtals obtained with the ſmoking ſpirit (for he does not ſeem to have actually

 tried

tried the weaker one) were pure cubic nitre, which deflagrated on a burning coal without crackling, and had not the leaſt mixture of common ſalt. Some have reported, that though a pretty ſtrong ſpirit of nitre was uſed in more than double the weight of the ſalt, the reſiduum after the diſtillation conſiſted chiefly of marine ſalt unchanged, with only a ſmall proportion of cubic nitre intermixed. On what cauſe the failure depended, the few experiments I have made on this head do not enable me to judge: perhaps it may be neceſſary that the nitrous ſpirit ſhould be very ſtrong, for a concentrated acid may produce decompoſitions, as well as diſſolutions, which the ſame acid, diluted, is incapable of effecting.

II. Cubic nitre may be obtained alſo in the proceſs of making ſilver into luna cornea, which is the moſt effectual way of purifying ſilver. Solution of common ſalt in water being dropt by degrees into a ſolution of ſilver made in aquafortis, ſo long as any cloudineſs enſues, the marine acid precipitates with the ſilver, as the vitriolic did with chalk in No. 2 of the foregoing article, and the remaining liquor is a ſolution of cubic nitre, blended with the copper which the ſilver contained. How far this copper may be injurious in the intention for which cubic nitre is here wanted, has not been fully examined.

III. The ſtrong affinity of the vitriolic acid to calcareous earth affords a method of obtaining cubic nitre, more eligible than either of the foregoing. Spirit of ſalt is commonly prepared by diſtillation with the vitriolic acid; and in this caſe, what remains in the retort is a combination of that acid with the alcali of the marine ſalt. This compound is common in the ſhops, under the name of *Glaubers ſalt* or *ſal mirabile*. If a ſaturated ſolution of ſal mirabile be made in water, and a ſolution of chalk in aquafortis added by degrees ſo long as it occaſions any

cloudineſs;

cloudineſs; the vitriolic acid and the chalk precipitate together, and the nitrous acid and mineral alcali remain in the liquor, which accordingly, on cryſtallization, yields a true cubic nitre. The ſolutions ought to be well ſaturated, that the milkineſs, which grows fainter and fainter as we continue to add more of the calcareous ſolution, may be the better diſtinguiſhed; and after the cloudineſs ſeems to have entirely ceaſed, a little more of this laſt ſolution may be dropt in, for a ſmall exceſs in its quantity will be of no inconvenience, but a ſmall deficiency, by leaving part of the ſal mirabile undecompounded, will occaſion the mineral alcali, for which this proceſs is only preparatory, to be impure, as will appear in the following operation.

3. *Separation of the mineral alcali from cubic nitre.*

THE marine alcali being by the above methods combined with the nitrous acid, the acid is to be ſeparated from it by deflagration with inflammable ſubſtances. Mix the cubic nitre with one fifth or one ſixth of its weight of powdered charcoal, grinding them thoroughly together: the coal of animal ſubſtances is preferable to that of vegetables, as the latter will leave, after burning, ſome ſmall portion of an alcaline ſalt, of a different nature from that which is here required. Throw the mixture, by a very little at a time, into a large crucible made juſt red hot, covering the crucible, as ſpeedily and as cloſe as may be, after each injection, to prevent the matter from being diſſipated by the ſtrong deflagration which enſues. When the mixture has been all thrown in, and the detonation has ceaſed, the fire may be augmented, and a pretty ſtrong red heat kept up for half an hour or more, the crucible during this time being left uncovered. The nitrous acid being thus burnt out, there remains in the crucible a bluiſh-greeniſh,

iſh-greeniſh alcaline maſs, which is to be purified by ſolution in diſtilled water. It diſſolves more difficultly than the vegetable alcalies, and on duly evaporating the ſolution ſhoots into fine white cryſtals, which do not liquefy in the air. This laſt property of the marine alcali tends to confirm the obſervation already mentioned, that the deliquiation of marine ſalt after fuſion does not proceed from a part of the alcali having been diveſted of its acid.

If the marine ſalt, uſed for the preparation of cubic nitre by the firſt and ſecond proceſſes, contained any ſalt with an earthy baſis, or if the ſolution of chalk in the third way of preparation was employed in too great quantity, the cryſtallization of the cubic nitre will in great meaſure ſeparate thoſe deliquiable compounds; and indeed, without cryſtallization, as the nitrous acid is diſſipated or deſtroyed in the fire, it will leave with the alcali only the earth, which will be ſeparated, as well as the aſhes of the coal, by the diſſolution in water. If the cubic nitre contained any marine or vitriolic ſalt, the marine ſalt will continue after the deflagration unchanged, and the vitriolic ſalt will produce with the inflammable matter a ſulphureous compound.

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