AN INTRODUCTION TO THE ATOMIC THEORY,

COMPRISING

A SKETCH OF THE OPINIONS

ENTERTAINED BY

THE MOST DISTINGUISHED

ANCIENT AND MODERN PHILOSOPHERS

WITH RESPECT TO

THE CONSTITUTION OF MATTER.

BY

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Παντα μετρῳ, και αριθμῳ, και σταθμῳ διεταξας.

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TO

JOHN DALTON, F. R. S.

President of the Literary and Philosophical Society of Manchester,
Corresponding Member of the Academy of Sciences of the Royal Institute of France, &c.

THE AUTHOR OF A THEORY

WITH RESPECT TO THE MODE OF COMBINATION BETWEEN BODIES,

WHICH STANDS FOREMOST AMONG THE DISCOVERIES OF THE PRESENT AGE,

FOR THE UNIVERSALITY OF ITS APPLICATIONS,

AND THE IMPORTANCE OF ITS PRACTICAL RESULTS;

HOLDING THE SAME KIND OF RELATION TO THE SCIENCE OF CHEMISTRY,

WHICH THE NEWTONIAN SYSTEM DOES TO THAT OF MECHANICS;

AND PROMISING TO THROW LIGHT,

NOT ONLY UPON ALL THE ORDINARY SUBJECTS OF CHEMICAL INVESTIGATION,

BUT EVEN UPON THOSE MORE SPECULATIVE QUESTIONS

WITH RESPECT TO THE CONSTITUTION OF MATTER,

WHICH SEEMED TO LIE BEYOND THE REACH OF EXPERIMENTAL INQUIRY;

THIS ATTEMPT

TO PLACE SIDE BY SIDE THE VIEWS OF ANCIENT AND MODERN PHILOSOPHERS,

WITH REGARD TO A SUBJECT,

ON WHICH BOTH HAVE EXERCISED THEIR INGENUITY,

AND MADE TRIAL OF THEIR RESPECTIVE METHODS OF RESEARCH,

IS INSCRIBED,

AS A TRIBUTE OF RESPECT AND ADMIRATION,

BY

THE AUTHOR.

PREFACE.

SOME explanation may perhaps be required for thus presenting to the public, without the pretence of much original investigation, a new Treatise, on a subject already so much discussed, as the Atomic Theory has been.

It might be said, that those who desire to study this department of the science detached from the rest, have, in the elaborate work of Dr. Thomson, entitled, First Principles of Chemistry, a full and circumstantial detail given them of the facts on which it is based; whilst such as are contented with a more general summary, may be referred to an Essay published in 1825 by Professor Turner, which, it is but fair to add, places the subject before us with a clearness and precision, such as I can only endeavour to imitate, and must not hope to surpass.

But the former of these publications, though almost indispensable to the professed chemist, is hardly adapted for the beginner; and the latter, should it be still in print, would require even now many additions and corrections, to adapt it to the present condition of a science so progressive as Chemistry.

Independently of these considerations, it may be observed, that the professed object which the author last alluded to had in view in publishing his manual, differs in some degree from that which I have proposed to myself in the following pages. In Dr. Turner's case, it was advisable to avoid all topics of merely speculative interest, in order to present, in the shortest possible compass, an outline of the actual state of our knowledge on the subject discussed. The medical pupil, to whom he more especially addresses himself, has too many objects to accomplish in the limited time usually allotted him, to allow of his indulging in any discursive flights over the collateral regions of inquiry that so abundantly present themselves; he must press onwards in a straight line towards his goal, seizing only in his way on those prominent points of science, that have a connexion, more or less intimate, with his main object, the acquirement of professional information.

The Essay here introduced to the public, is addressed to rather a different class of students, to individuals generally of a more advanced age, who, having completed their academical education, and, if they have not mispent their time, having imbibed somewhat of the spirit of ancient literature and philosophy, apply themselves to the study of modern science, less with the idea of deriving advantage personally from the numerous practical applications of which it admits, than with the hope of enlarging the sphere of their knowledge, and of correcting that narrowness of thinking, which is the almost unavoidable consequence of an exclusive devotion to a single class of writers, and one line of intellectual occupations.

To them, therefore, a mere detail of facts might be unsatisfactory, and an occasional reference to the opinions of philosophers, with whose works they are familiar, cannot be otherwise than agreeable.

It may be well, too, for the lovers of antiquity, occasionally to observe, with what different success the same inquiry has been prosecuted in ancient and modern times; and thus to clear their minds of a prepossession, sometimes even now entertained, though but rarely avowed, that the researches of the present age are less calculated to train and invigorate the understanding, than those of the ancients, because they are in general more directed towards objects of a practical, and therefore, as is supposed, of a less intellectual description.

Should the time arrive, which, as a well-wisher to the University, I trust is not far distant, when such alterations shall be introduced into our scheme of education as will give *fair play* to the modern sciences, by rendering them integral parts of our system, or at least by holding out to their prosecution encouragements, in the shape of prizes and scholarships, similar to those now afforded to a proficiency in classical, and even in oriental literature; I flatter myself, it will be found, that the faculties of youth will be as much improved by an attentive study, of the truths of experimental science, and of those methods of research, by means of which these truths have been arrived at, as they have hitherto been by that of the most approved models of Grecian or Roman Philosophy.

To chemical investigations especially, a similar objection cannot be urged, to that sometimes advanced against a devotion of the mind to mathematical inquiries; as, in most speculative questions of a general nature, in which the former science is concerned, absolute demonstration can hardly be attained, and our decision is determined by a balance of probabilities, the estimating which is well calculated to call into action other faculties, besides those employed in the task of rigorous deduction. The pursuit of chemical inquiries combines therefore some of the advantages derived from the investigation of moral evidence, together with that of being concerned on subjects, which, from their very nature, exclude altogether that interference of party feeling, and of local prepossessions, which is apprehended from the consideration of subjects connected with human passions and interests, and which, perhaps, affords the most plausible pretext for the preference given in this University, for the discussions of the ancients on moral and metaphysical subjects, over those of the moderns.

Never indeed was there an epoch in the history of Chemistry, when it could be so truly said, as at present, to offer the means for disciplining and enlarging the intellect of those who cultivate it, owing to the opportunity held out for a profound and comprehensive review of its fundamental laws, and of their mutual relation one to the other.

We are arrived at a resting place in the career of discovery, from which vistas open to us in all directions, presenting the most extensive and the most varied prospects of nature; it is from this point that we are enabled, better than at any former stage of our progress, to contemplate the phenomena of chemistry, in connection with those of electricity; to consider those subordinate laws of combination, on which philosophers are still divided; to examine the facts relating to *Isomorphism,* as well as the still more perplexing ones with respect to bodies called by Berzelius *Isomeric;* and to speculate upon the new views which Dr. Prout has partially unfolded concerning *merorganization.*

The commanding station, which we now occupy, may even enable us to extend our survey beyond those objects that belong to the exclusive domain of chemistry, and detect by the light which that science has afforded, the source from whence animals and vegetables obtain their *ultimate* principles, and the means by which they elaborate them into the various *proximate* ones which result from the functions of life; whilst even the causes on which depend those great natural processes which modify the external face of our globe, such as earthquakes, hot-springs, volcanos, and a variety of other destructive as well as reproductive agencies constantly at work, no longer seem placed beyond the limits of scientific inquiry, but connect themselves with discoveries which have already rewarded our exertions.

For the attainment of the eminence, whence these prospects of nature have disclosed themselves, we are mainly indebted to the last generation of chemists, and above all to the illustrious President of the Royal Society, whose death science has lately had to deplore; but, considering the unexampled rapidity with which one discovery of his succeeded another, and the eagerness with which he continued to press forwards into new regions of inquiry, it is not wonderful, that he should have left a large portion of the field that he had traversed unexamined, its boundaries ill-defined, and its treasures in a great degree unexplored.

> For life did never to one man allow
> Time to discover worlds, and conquer too.

It is for the present race of chemists therefore, to fill up the magnificent outline that has been traced out for them by their predecessors, and to cull the fruits thus brought within their reach; neither will the present Treatise be thrown away, if it succeeds in attracting some fresh labourers to the harvest, by contributing to make known its abundance and extent.

Above all, should it have any effect within the University, in enhancing the respect entertained for the department of modern knowledge which it professes to illustrate, and in thereby inducing some few of those, who resort to our Colleges without any object more definite than that of acquiring general information, to regard it as a pursuit worthy to divide their hours of study with the literature of past ages, I shall feel amply rewarded for the trouble the undertaking has cost me,—as well by the consciousness of having supplied the individuals themselves with a new and delightful source of intellectual occupation, as by that of having enlisted under the banners of Chemistry a larger number of volunteers, drawn from a class of society, capable of promoting its progress, not only by their own exertions, but also by the encouragement which their example and patronage would afford to the cause of Modern Science in this country.

Oxford, September 5, 1831.

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CHAPTER I.

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THE subject which I propose to consider in the present Essay, is one that appears to have perplexed mankind from the earliest dawn of philosophical inquiry, having exercised and baffled the ingenuity at once of the Hindoos, the Egyptians, the Phœnicians, the Greeks, the schoolmen of the middle ages, and the still darker metaphysicians of Germany.

It is also one that relates to bodies infinitely too minute to be objects of our senses*, however sharpened by habits of observation, or assisted by the most perfect mechanical contrivances, and which therefore, if brought at all within the compass of our knowledge, must be contemplated by the superior subtlety of mental vision alone.

Hence the subject may seem to be one in which the peculiar resources of modern science would avail us but little, and which ought therefore to be abandoned altogether by the experimentalist, as belonging to the exclusive province of metaphysics. And yet perhaps it will not be difficult to maintain, that there is a peculiar propriety in connecting this discussion with the discoveries of modern chemistry, as being in itself eminently calculated to recommend the inductive method of research, since it shews how much light may be occasionally thrown upon the darkest subjects of human inquiry, by the determination of an assemblage of minute and apparently isolated facts.

What indeed can be a greater triumph for the Baconian school of philosophy, than to find that the labours of a few microscopic chemists, of men whose ideas might be supposed to be in a manner limited to the narrow field which their researches embraced, have nevertheless done more towards the

* According to Dr. Thomson, it may be demonstrated that the size of a particle of lead does not amount to so much as $\frac{1}{[illegible]}$ of a cubic inch.

elucidation of one of the most abstruse questions on which the human mind can be engaged, than was effected by the profoundest intellects of the ages that preceded them, furnished with all the learning of the times in which they flourished, and inured to habits of abstract and subtle disquisition.

To the members of an University like that to which I belong, consisting, as it does, of persons of whom the greater part may be presumed from their previous education to be conversant with ancient philosophy, and many, I trust, have since imbibed something like a taste for modern science, it will not perhaps be uninteresting to consider the notions entertained by the most distinguished persons in the ancient, as well as the modern world, with respect to the constitution of matter; nor will the view I propose to take of this subject be unimproving, if, without weakening our respect for antiquity, it adds one more proof of the benefits arising from experimental science, and of the unexpected advances in speculative knowledge that often flow from the investigation of a few apparently mean and insignificant details.

We cannot indeed extol too highly the vigour and grasp of intellect displayed by some of the philosophers of antiquity, which appear almost to justify the glowing language of the Roman poet, and to have indeed burst the barriers which nature herself had imposed on human speculation.

Vivida vis animi pervicit, et extra
Processit longe flammantia mœnia mundi.

But we must at the same time recollect that these very barriers have receded before the march of discovery, and that whole provinces, into which the ancients only penetrated by a few desultory and random incursions, have been added to the domain of modern science—real and substantial possessions, which hold about the same relation to the visionary regions of knowledge existing in the imagination of the latter, as the lands explored by Columbus bear to the fabulous Atlantis.

Hence, unless we attribute a positive degeneracy to men of modern growth, an opinion which neither the condition of the arts nor the progress of civilization justifies us in entertaining, we should expect the views of nature presented to us at the present day to be more lofty and comprehensive than at any former period, in proportion to the greater extent of the field which our researches now embrace.

Indeed, if the contrary opinion has at any time prevailed, the fault seems attributable, not so much to the condition of the sciences themselves, as to the teachers of them, who perhaps are often too sparing in those general inferences which the facts themselves are calculated to suggest; inferences, which though in all cases more or less conjectural, have their use nevertheless in expanding the powers of the mind, and in imparting a livelier interest to the subject under consideration.

The disciplined understanding indeed may be more secure from error, if the details are presented to it perfectly divested of theory; but where the object of the instructor is to train the mind as well as to inform it, there is probably as much gained by inculcating correct habits of generalization, as by storing the memory with the particulars which we employ as the basis of our reasoning.

Should such be the case, the present Essay may in some measure supply a deficiency that exists in the annual course of Lectures I am in the habit of delivering, as in the latter the press of matter obliges me to confine myself to a bare statement of what has been ascertained with regard to the laws of combination, without touching upon those speculative opinions respecting the constitution of matter, which have been so remarkably confirmed by the progress of modern discovery.

Two opinions on this subject have divided the ancient as well as the modern world; the first, that matter is composed of an assemblage of particles incapable of farther division; the second, that there is no limit to its divisibility, the smallest conceivable body still consisting of an infinity of parts.

For an exposition of the former doctrine we commonly appeal to the writings of the Epicureans; but the notion itself may be traced much farther back. It formed indeed the groundwork of the cosmogeny of Democritus, and was by him derived from Leucippus, who is generally regarded as its author.

It is however stated, that the same opinion was held by Moschus, a Phœnician, who is supposed by some to have flourished before the Trojan war, and if, as has been imagined, the monads of Pythagoras were corpuscular atoms, the Egyptians, from whom that philosopher derived so many of his tenets, may probably have a claim also to this*.

It has been likewise shewn by Mr. Colebrooke† that the Hindoos from a very early period have embraced the doctrine of atoms, although the actual date of the system of philosophy into which this opinion enters is not fully made out.

According to Kanadi, the author whom he quotes, atoms constitute the last term of the division to which matter can be subjected. They are too small to be objects of sensation, for the particles of dust that are seen in a sunbeam, which are the most minute of visible things, are composed of several of them. They are simple and not compounded, otherwise the series would be endless, and were it pursued indefinitely, there would then be no difference of magnitude between a mustard seed and a mountain, a gnat and an elephant, each alike containing an infinity of particles. The ultimate atom therefore is simple. The first compound consists of two atoms, and the next of three double atoms; for if only two were conjoined, magnitude could hardly ensue from their union, since the latter must be produced either

* This seems confirmed by a passage in Aristotle's metaphysics, in which it is said that Pythagoras considered his monads as possessed of size; *τας μοναδας ὑπολαμβανουσι εχειν μεγεθος.* lib. xii. c. 6. Stobæus however says, that Ecphantus was the first who regarded the Pythagorean monads as corporeal. *Eclog. physicæ*, lib. i. c. 3.

† Asiatic Researches for 1824.

by the size or the number of the particles: it cannot be by their size, and must therefore be by their number. The atom, then, is laid down to be the sixth part of the mote which we see in the sunbeam.

Such was the doctrine that appears to have been most current among the Hindoo philosophers; but Mr. Colebrooke informs us, in another memoir, that it was objected to by the orthodox, some of whom, who professed to found their opinions on the text of the Indian scriptures, even argued against the existence of a material world, as was the case with some of those who rejected the atomic theory in Greece, with Berkeley in England, and with the more modern school of natural philosophy hardly yet extinct in Germany.

Nor is it surprising that notions which have stood their ground till the present advanced state of science, should have been broached at so early a period: as the first poets are pregnant with the grandest conceptions, so the earliest philosophers often light upon the most sublime truths; astonishing us with an intermixture of the noblest views of nature with the most crude and vulgar conceits, and often leaving to their successors little more than the task of selecting from the mass of error the grains of truth which are disguised by and confounded with it.

Thus in the writings of Lucretius, we are struck in one page by the philosophical spirit which seems to anticipate the discoveries of modern times, in propounding a system not very different from the doctrine of *latent heat**, and maintaining, in opposition to Democritus, that the descent of heavy and light bodies *in vacuo* is equally rapid†; and in the next are provoked at the puerile manner in which the poet attempts to account for the independence of the Will, by imagining an occasional deviation from a straight line to take place spontaneously in some of his atoms, whilst descending through space.

It is the same with that part of his system which relates to the formation of the material world; we shall see reason

* Lib. i. v. 901.

† Lib. ii. v. 238.

perhaps to consider the position, that all bodies are composed of a certain number of ultimate particles, more consistent than any other with the discoveries of the present day; but we are not therefore the less sensible of the absurdity of supposing the beautiful variety of nature to be the result of a fortuitous concourse of insentient atoms, differing from each other solely in the mechanical properties of size and figure.

The doctrine itself is not the less probable, because it fails to account for every thing which some of its supporters pretended to deduce from it, neither has it any natural tendency to atheism, although adopted by a sect of philosophers, who fancied they could dispense in their systems with the intervention of a Deity.

Nor do the original atomic theories appear to have been atheistical; on the contrary, the same philosophers, who proposed this view of the subject, considered matter, we are told, as wholly passive, and therefore admitted, as a necessary consequence, the existence of a moving principle which should be distinct from matter.

This, by some of the school of Thales, was pushed even to the opposite extreme of pantheism; for we are told that even the effects of magnetism and other motions of inorganic substances, were attributed to an animated principle. Thales, says Aristotle, seems to suppose any thing productive of motion to be sentient, for he said that a stone possessed a soul because it moved iron*.

Indeed, as Cudworth has observed, there is a natural alliance between the atomic system and theology; the distinct

* Εοικε δε Θαλης κινητικον τι την ψυχην ὑπολαμβανειν, ειπερ τον λιθον εφη ψυχην εχειν, ὁτι τον σιδηρον κινει. Aristotle de Animâ, lib. i. c. 2. Was not this the doctrine of Parmenides? See Sydenham, Dissert. on the Doctrine of Heraclitus, prefixed to his translation of Plato. If indeed all motion arises from a principle of vitality inherent in and pervading matter, and if this living principle be identical with the soul of the universe or God, then it will follow that all the varied phenomena of nature are manifestations of one and the same essence.

notion which it conveys of the attributes of matter clearing the way to a more easy demonstration of incorporeal existencies, by convincing us that there are phenomena not referable to material causes, and therefore not explicable by the corpuscular hypothesis.

The theory, however, which has been commonly received under the name of the Atomic Philosophy is that contained in the writings of Epicurus and his followers; and of this Dr. Good in his Book of Nature has given a sketch sufficiently clear and detailed for the limits of the present Essay, so that I shall in this instance spare myself the trouble of adding any thing of my own, and merely insert the substance of that which he has offered on the subject.

"The atomic philosophy of Epicurus," says Dr. Good, p. 61, "in its mere physical contemplation, allows of nothing but matter and space, which are equally infinite and unbounded, which have equally existed from all eternity, and from different combinations of which every visible form is created. Anterior to the formation of the universe, space and matter existed uncombined, or in their pure, elementary state. Space, in its elementary state, is absolute and perfect void; matter, in its elementary state, consists of inconceivably minute seeds or atoms, so small that the corpuscles of vapour, light, and heat are compounds of them; and so solid, that they cannot possibly be broken or abraded by any concussion or violence whatever. The express figure of these primary atoms is various; there are round, square, pointed, jagged, as well as many other shapes. These shapes, however, are not infinitely diversified; but the atoms themselves of each existing shape are infinite or innumerable. Every atom is possessed of certain intrinsic powers of motion. Under the old school of Democritus, the perpetual motions hence produced were of two kinds; a descending motion, from the natural gravity of the atoms, and a rebounding motion, from collision or mutual clash. Besides these two motions Epicurus supposed that some atoms were occasionally possessed of a third, by which, in some very small degree, they descended in an oblique or curvilinear direction, deviating from the common and right line anomalously.

These infinite groups of atoms, flying through all time and space in different directions, and under different laws, have interchangeably tried and exhibited every possible mode of rencounter; sometimes repelled from each other by concussion, and sometimes adhering to each other from their own jagged or pointed construction, and from the casual interstices which two or more connected atoms must produce, and which may be just adapted to those of other figures, as globular, oval, or square.

Hence the origin of compound or visible bodies; hence the origin of large masses of matter; hence, eventually, the origin of the world itself. When these primary atoms are closely compacted, and but little vacuity lies between, they produce solids, such as stones and metals; when they are loose and disjoined, bodies of lax texture, as wood, water, and vapour.

The world, thus generated, is perpetually sustained by the application of fresh tides of elementary atoms, flying with inconceivable rapidity through infinite space, and occupying the posts of those that are as perpetually flying off. Yet nothing is eternal or immutable but these elementary atoms themselves. The compound forms of matter are perpetually decomposing and dissolving into their original corpuscles; to this there is no exception, minerals, vegetables, and animals, in this respect all alike, and new combinations proceeding continually from the matter into which they dissolve.

But the world itself is a compound though not an organized being; sustained and nourished, like organized beings, from the material pabulum that floats through the void of infinity. The world itself must therefore in the same manner perish; it had a beginning, and it will have an end. Its present crasis will be decompounded; it will return to its original, its elementary atoms, and new worlds will arise from its destruction.

Space is infinite, material atoms are infinite, but the world is not infinite. This, then, is not the only world, nor the only material system that exists. The cause that has produced this visible system is competent to produce others; it has been acting perpetually from all eternity; and there are other worlds, and other systems of worlds, existing around us."

This doctrine, of matter consisting of an assemblage of indivisible particles, seems to have kept its ground during the most flourishing periods of Greek philosophy under various modifications, the idea of one elementary matter deriving its form and properties from the shape and union of the particles composing it, being a simplification of the original hypothesis of Anaxagoras, who imagined distinct particles for each distinct substance, contending that every body in nature is maintained, not by the assimilation to its own texture of that from which it derived nourishment, but by the introduction into its system of new particles of the same nature with those whose waste they were to supply. This may account for the statement of Plutarch, that Anaxagoras maintained all the phenomena of nature to have been produced by the Divine Mind at one and the same time; for though the individual objects of sensation may be undergoing a continual change and renewal, still, according to his system, the parts of which they are made up would have existed from the beginning of time, ready at any moment to start into being, forming, according to their respective natures, aggregates of bone, muscle, blood, as well as of stone, water, or air, which would possess in the aggregate precisely the same qualities as their constituent particles.

> Ossa videlicet è pauxillis atque minutis
> Ossibus, sic et de pauxillis atque minutis
> Visceribus viscus, gigni, sanguenque creari
> Sanguinis inter se multis coëuntibus guttis.
> Ex auræque putat micis consistere posse
> Auram, et de terris terram concrescere parvis;
> Ignibus ex ignes, humorem humoribus esse;
> Cætera consimili fingit ratione, putatque.

The conditions however of his system relieved him from the same necessity to which Epicurus was reduced, of supposing his particles indivisible; for as the minutest conceivable portions of each substance would possess precisely the same properties as the *whole*, the size and shape of the component parts could not affect the nature of the aggregate arising from them; whereas Epicurus, imagining these properties to have arisen from the very figure and magnitude of the particles, was obliged to imagine the latter to be invariable, in order to explain the unchangeableness of the laws of nature, and the continual production of the same bodies.

According to either of these systems therefore only one kind of elementary matter was supposed, the different properties which distinguish bodies being in the one case supposed to emanate from the mechanical differences in their atoms, and the various arrangements of them arising out of these primary distinctions, whilst in the other the properties in question were imagined to have been stamped by the *fiat* of the Almighty upon different portions of this first matter, so that the aggregates afterwards produced were nothing more than magnified representations of the qualities equally inherent in the minutest conceivable part.

Both these systems therefore may be considered as opposed to that of Empedocles, who brought forwards, or at least first called public attention to, the theory of all matter being resolvable into four elements*, those of earth, air, fire, and water, by the intermixture of which in various proportions he supposed all other substances to be generated. Still, however, they had this in common, namely, that the elements in question were not considered by Empedocles, as they have been by those moderns who adopted his views, primarily distinct in their nature, but to have proceeded from various combinations or modifications of the *first mat-*

* Diogenes Laërtius, viii. 31, states that Pythagoras taught that doctrine—*στοιχεια τετταρα, πυρ, ὑδωρ, γην, αερα.* It is probable that the reverence for the number *four* may have induced many Pythagoreans to fix upon this number of elements rather than any other.

ter. Thus those varieties in the objects of nature, which according to Anaxagoras arose from similar variations in the properties originally impressed on the particles of matter by the hand of the Deity, and according to Democritus emanated from the various combinations of atoms, in substance the same, but in shape and size different, were accounted for by Empedocles in a manner at least more consistent with modern opinions, by four different kinds of matter variously mingled and combined.

It must however be added, that many who professed to follow his tenets, imagined that these elements not only were successively produced by a gradual condensation of the matter from which they all proceeded, the rarer elements being generated first, the heavier last in order, (according to a process which some astronomers have imagined to be taking place at present in the matter composing comets, and the bodies of which nebulæ consist;) but they even admitted the possibility of their mutual conversion at any subsequent period, thereby doing away with the very idea of an element in the modern sense of the term, and leading us to imagine that they regarded them rather as representing the four possible states in which matter can exist, corresponding to the solid, liquid, gaseous, and igneous conditions recognised by certain moderns, than as essentially distinct. Thus Ovid:—

Hæc quoque non perstant, quæ nos elementa vocamus;
Quasque vices peragant, animos adhibete, docebo.
Quatuor æternus genitalia corpora mundus
Continet; ex illis duo sunt onerosa, suoque
Pondere in inferius, tellus atque unda, feruntur:
Et totidem gravitate carent, nulloque premente
Alta petunt, aër, atque aëre purior ignis.
Quæ quanquam spatio distant, tamen omnia fiunt
Ex ipsis, et in ipsa cadunt; resolutaque tellus
In liquidas rorescit aquas: tenuatus in auras
Aëraque humor abit: demto quoque pondere, rursus
In superos aër tenuissimus emicat ignes;
Inde retro redeunt, idemque retexitur ordo. *Met.* XV. 237.

Empedocles seems also in another point of view to approach more nearly to modern ideas than most of his contemporaries, in accounting for the combinations amongst his elements by two powers which he called Love and Discord, or in modern scientific language, Affinity and Repulsion. Indeed it is remarkable, that the most ancient philosophy of any with which we are acquainted, that philosophy which the most distinguished of the Greeks borrowed from, too often without acknowledgment, from which Plato adopted his *Ideas*, and Aristotle his *First Matter*, affords, even in the imperfect and disguised condition in which it has come down to us, a nearer approximation to the principles of modern science, than the doctrines of the Grecian schools that succeeded it; as if, according to the conjecture of some writers, there really had existed amongst the priests of Egypt, or in more eastern climes, a philosophy carefully concealed from the vulgar, which rivalled that of the present day, but of which a few scattered fragments only have been preserved by the blind reverence of the periods succeeding, when all knowledge had been lost of their purport, or the relation they might have borne to the scientific structure of which they formed a part.

That such a suspicion is not altogether without foundation, will perhaps be shewn in a subsequent part of this Essay, when I come to speak of the Pythagorean doctrine of numbers: at present it will be more to the purpose to consider the influence which the dogmas of this school would exert upon their opinions with regard to the infinite divisibility of matter.

It may be remarked in general, that whilst the existence of particles incapable of further division formed a necessary condition in the scheme of those, who, like Democritus and Epicurus, accounted for the properties of bodies on principles purely mechanical, so the opposite doctrine seems to have been in general adopted by such as took different views of natural phenomena.

It was reasonable, however, to expect, that greater importance would be attached to this question by the former class of theorists, than by the latter; with the one it constituted, as it were, the key-stone of their scientific edifice, with the other it was a problem of very subordinate interest; and accordingly, whilst the disciples of Epicurus employ all their talent and ingenuity in inventing arguments in favour of the doctrine of atoms, we find it somewhat difficult to collect the opinions of philosophers of other schools on this point, until indeed the prevalence of the Epicurean system made it worth the while of its impugners to level an attack at the doctrine of atoms, as a means of demolishing the fabric built upon their assumption.

Thus Plato accounted for the origin of things by supposing two principles to have existed from all eternity, viz. Ideas and Matter; by the first of which he intended to express the conception of those general laws by which the course of nature is at present regulated, the models as it were of those properties by which bodies are characterized; and by the latter, a crude amorphous matter destitute in itself of all qualities, but capable of retaining any that might be impressed upon it.

The former must have existed from the beginning of time in the Divine Mind, because, although the phenomena of nature may vary, the principles on which these phenomena depend are fixed and invariable, and the material on which these properties have been impressed must have been in itself destitute of them, because, as in preparing a perfume, we are obliged to choose as a basis some ointment which is destitute of any odour of its own, and as in moulding a statue we ought to select a material capable of retaining any form, but from which we can completely efface that which it may happen at the time to possess; so the Divine Artificer would have stamped the images of those eternal ideas which emanated from his own intelligence, upon a something which was entirely destitute of all form and characters of its own.

Satisfied apparently with thus accounting by these sublime abstractions for the qualities of bodies in general, and reconciling the fluctuation of external objects with the immutability of the Divine Mind, Plato seems to have troubled himself little about the mode in which the subordinate varieties of matter might have arisen from its great primary distinctions; and though he sometimes amused himself with those mechanical speculations which engrossed the attention of the corpuscular philosophers, yet he evidently attached but little importance to such inquiries.

Thus he on the one hand appears to contend for the infinite divisibility of matter, whilst on the other he adopts the Pythagorean doctrine of four elements deriving their characteristic distinctions, in some measure at least, from the shape of their component particles. Those of fire he supposes to be a four-sided pyramid; those of air an octaedron; those of water an icosaedron; those of earth a cube; and he further accounts for the mutual convertibility of the three former elements one into the other, by the mathematical relation between the figures of their molecules; a four-sided pyramid being composed of four equilateral triangles, an octaedron of eight, and an icosaedron of twenty.

Earth, on the contrary, consists of particles, whose figure being a cube bears no mathematical relation to that of the three former, and hence this element is not convertible into the rest*.

The doctrines of Aristotle on these points appear to have approached to those of Plato, except that he equally rejected the Platonic doctrine of Ideas and the Pythagorean one of Numbers.

He admits a *substratum* bearing the same relation to all the productions of nature, which iron does to the saw, or marble to the statue fabricated out of it, so completely denuded of properties, that we can scarcely admit its materiality, but receiving from the hand of God the various qualities it possesses, as the iron and the marble in the cases above mentioned acquire their forms from the artificer.

He does not allow of the four elements of Empedocles, because the substances called such by that philosopher are convertible one into the other; but he agrees that they re-

* Plato in Timæo.

present the four primary affections of matter perceived by our senses, of hot, cold, dry, and moist, into which all others appear to be resolvable*.

In addition to a *substratum* capable of receiving the properties impressed upon it, and *form*, by which its existence becomes cognisable to our senses, Aristotle adopts as one of his first principles, *privation*, or the absence of matter, which seems to correspond with the Epicurean vacuum, and to these he adds (*νους*) *intelligence*, as the prime mover of the whole; in this latter respect improving upon the doctrine of the corpuscular philosophers of his time, who imagined motion without a mover, and causation without a cause.

With regard to atoms, he contends against the arguments of Democritus on this subject; but admits that matter may be made up of particles which are actually, though not potentially, indivisible.

Εν τῳ συνεχει, he observes, *ενεστι μεν απειρα ἡμιση, αλλ' ουκ εντελεχειᾳ, αλλα δυναμει. Nat. Auscult.* l. viii. c. 12.

The above brief outline of the dogmas entertained by the philosophers of antiquity on the constitution of matter, may be sufficient to convince us how complete a division of opinion existed on the subject; and if, without heeding the authority of names, we regard only the arguments alleged in support of either side, we shall find perhaps an equal difficulty in arriving at any decision.

The advocates of the doctrine of ultimate atoms contended, that without such an arrangement there would be no permanency in the existing system of things; that the particles of which matter is composed, worn down more and more during a period of indefinite extent, would have been by this time unable to form any thing possessing bulk and solidity; or else would produce substances of a very dif-

* So Milton:—

For hot, cold, moist, and dry, four champions fierce,
Strive here for mast'ry, and to battel bring
Their embryon atoms.

ferent kind from what they gave rise to formerly, when in a less comminuted condition.

They argued, that as every thing in nature which comes under our observation possesses a definite size, or at least one circumscribed within certain boundaries, so also must the parts of which these substances themselves consist.

They contended that the races of animals, and the tribes of plants, could not have preserved their uniformity for so long a period, if the particles out of which they were formed had undergone any change in size and figure; for from these primary qualities arose, according to the Epicurean doctrine, all the distinctive marks by which we know one substance from another.

The arguments alleged in proof of the infinite divisibility of matter appear in general, so far as I can understand them, to be rather of a metaphysical than a physical nature.

By Leibnitz the existence of atoms was opposed, as inconsistent with two of his leading dogmas;—the law of Continuity, and the doctrine of a Sufficient Reason.

The very notion of an atom, he contends, implies that of absolute hardness; now if two bodies perfectly hard, and therefore altogether inelastic, were to meet with equal and opposite motions, they must both necessarily stop at once. Hence to suppose the existence of bodies so constituted as to pass instantly from a state of rapid motion to one of perfect rest, is inconsistent with the law of Continuity, which implies that no change can take place abruptly, or without passing through the intermediate gradations.

The existence of atoms he considered also to militate against the doctrine of Sufficient Reason; but his reasonings are too obscure to become intelligible without such a previous sketch of his almost forgotten opinions on this subject, as would be out of place in the present Essay.

More intelligible are the arguments advanced against the doctrine of atoms by the Cartesians, though those philosophers likewise confined themselves to the "high priori road," and contented themselves for the most part with proving, that no body can be considered in a mathematical sense incapable of division.

Such at least are those of cardinal Polignac in his Anti-Lucretius*, except indeed where he directs his attack at those particular tenets of the Epicureans, respecting the angular shapes of their particles, in which, I conceive, the atomic philosophers of the present day do not feel it necessary to concur.

Keill, in his *Lectiones Physicæ*, read before this university, has stated the mathematical objections at considerable length, and appears to have sufficiently demonstrated that no substance can be conceived so minute, as not to contain an infinity of parts. So long as you allow to the particles of matter extension, he contends that you must admit them to consist of parts; and whatever consists of parts must be set down as capable of division.

And it was doubtless to evade an argument of this kind, that Zeno, amongst the ancients, contended that matter was made up of a number of points not possessed of extension, an hypothesis with which the doctrine of monads entertained by Leibnitz seems pretty nearly to agree. In either case, however, the difficulty meets us, of imagining the property of extension to belong to a body taken collectively, when the same is not predicated of its component parts: and it was to reconcile this apparent inconsistency that the Abbé Boscovich, who may be considered a disciple of Leibnitz, as well as an improver upon the system of his master, framed his theory of the Constitution of Matter†.

He supposes, in common with the philosophers above alluded to, that matter is made up of a number of unextended, indivisible points, which, however, never touch each other, owing to the mutual repulsion subsisting between them, so soon as they come within a certain distance of each other; which repulsion increasing gradually in proportion as they are made to approach nearer and nearer, becomes at length too powerful for any force to overcome.

* See also Grandis Instit. phil. secundum Principia R. Descartis part iv. c. 3.

† Philosophiæ Naturalis Theoria, Viennæ, 1759.

This theory agrees with the fact that there is no such thing in nature as absolute contact; and the impenetrability of matter, which gives us the first idea of extension, is, according to Boscovich, nothing more than the resistance opposed by the physical points of which matter consists to the approach of another body within a certain distance of itself.

Thus he supposes that the points of matter alternately attract and repel each other, according to the distance that separates them, until they either come very close to, or are removed to a comparatively great distance from each other: in the former case they are repelled, in the latter attracted; the former force preventing mutual contact, the latter, which, when considered as acting between the earth and bodies upon it, is no other than gravitation, drawing them all together.

He instances two particles combined in the form of water. These have, first, the repulsion which produces impenetrability; secondly, at an increased distance, the attraction which causes aggregation. Now if by some cause, such as heat, the second particle be removed to a greater distance, (still within insensible limits,) so that the water is converted into vapour, at this third distance repulsion acts, producing elasticity; but to this also there are certain limits; for the particles cannot be separated (that is, the aeriform nature or repulsion between them increased) beyond a certain point, where it is overcome by attraction; or, in other words, we have a fourth distance, where attraction acts, and beyond which it prevails *ad infinitum.*

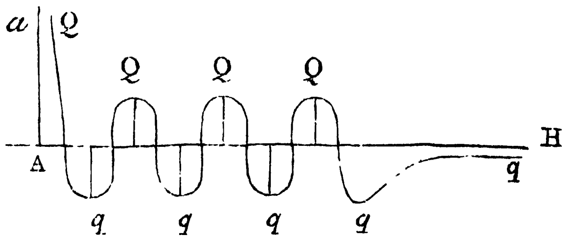
This law he expresses by an equation which is represented geometrically by a curve intersecting a straight line in certain places. The ordinates of the curve represent the attracting and repelling forces of two particles; the one supposed to be stationary at the point *A*, the other placed at successive distances along the straight line towards *H*.

The ordinates of the curve, when above the straight line, indicate repulsion; when below it, attraction.

The points of greatest attraction and repulsion will therefore be those in the axis corresponding to those in the curve marked by the letters *Q. Q. Q. Q.* and *q. q. q. q.* respectively;

and it is seen that when the particle reaches such a point, the contrary force begins to operate; and that where the curve intersects the straight line, the forces of repulsion and of attraction are in equilibrio.

Now these points are termed by Boscovich the limits of cohesion, because particles placed on those points remain unaltered in their position.



The line of the axis *A H*, and that of the perpendicular *A a* being both asymptotes to the curve *Q. Q. Q. Q. q. q. q. q.*, corresponds to the condition that the repulsion at *a* and the attraction at *H* is infinitely great; hence a particle impelled by any force from *H* towards another at *A*, can never come into perfect contact with it, neither if driven from it can it recede to an unlimited distance, owing to the constantly operating force of attraction.

The learned Dr. Good, in his Book of Nature, remarks, that the difficulties chargeable upon the doctrine of an infinite divisibility of matter are not touched by this theory of Boscovich's, but remain in as full force as before it. "If," says he, "the monads, or ultimate points of matter here adverted to, possess body, they must be as capable of extension, and consequently of division, as material body under any other dimension or modification: if they do not possess body, then they are as much nonentities as the primal or amorphous matter of Plato or Aristotle. Again, we are told that these points or monads are endowed with certain powers, as those, for example, of attraction and repulsion. But powers must be the powers of something; what is this something to which these powers are said thus to appertain? If the ultimate unextended points before us have nothing but these powers, and *be* nothing but these powers, then are such powers powers of nothing, powers without a substratum, and consequently, as much nonentities as in the preceding argument. Visible or sensible matter, moreover, it is admitted by Boscovich and his disciples, is possessed of extension; but visible or sensible matter is also admitted to be a mere result of a combination of unextended atoms;— how can extension proceed from what is unextended? of two diametrical opposites, how is it possible that either can become the product of the other."

I confess I do not see the case in quite the same light as Dr. Good; for it seems to me that the merit of Boscovich's system consists in explaining, so far as such a subject admits of being explained, in what manner the idea of extension may arise, from the resistance offered by a number of physical points of matter to the approach of a foreign body, thus shewing that the possession of dimensions, as of breadth, length, and thickness, and consequently of parts, which we imagine to be implied in the very definition of extensibility, is not altogether inseparable from it.

Dr. Good therefore, it may be observed, takes for granted the point required to be proved, namely, that because matter in every shape in which it comes before us possesses extensibility, and consequently parts, therefore that the units composing it do the same. Now it was the very object of Boscovich's treatise to explain, that even the idea of extension may resolve itself into something more simple, namely, into resistance to external pressure, and that physical points even, if endowed with powers of attraction and repulsion, might produce impenetrability, or in other words exclude foreign bodies from a portion of space; and the notions of substance, figure, and bulk, are nothing but different modes of considering this primary property of matter.

Yet though the ingenuity of Boscovich may have invented a theory that allows us to maintain in argument the doctrine of particles mathematically indivisible, without enabling our antagonist to convict us of an absurdity, it can hardly persuade any one of their reality, nor am I disposed to disagree with

Dr. Good in his concluding sentences, in which he remarks, that the "lesson taught us by all such fine-spun and fanciful hypotheses is, the impossibility of philosophizing without a basis of first principles, without the establishment of certain postulates to be taken for granted in all the subsequent discussions."

"We must have them in physics as well as metaphysics, in matter as well as in morals; and hence the best physical schools in Greece, as well as in more modern times, have found it necessary to take it for granted—what in fact can never be absolutely demonstrated—that matter in its ultimate parts consists of solid, impenetrable, and moveable particles of definite sizes, figures, and proportions to space; from different combinations of which, though invisible in themselves, every visible substance is produced *."

Ingenious indeed as the theory of Boscovich may be, and skilfully as it seems to evade the difficulties that beset us so soon as we attempt to assign limits to the divisibility of matter, the mass of mankind will be glad to escape from such obscure and abstract speculations, by waving entirely the mathematical question, and confining themselves simply to the inquiry, whether it be not most consistent with sound philosophy to admit in a physical sense the existence of atoms; that is, of bodies, not destitute indeed of parts, but having those parts held together by a force capable of resist-

* It is curious that Dr. Priestley, the Coryphæus, as he may be termed, of materialism, has, in attempting to shew that mind is not spiritual, been led by the tenor of his argument to push Boscovich's doctrine so far, as almost to deny the materiality of body; for he contends that we have no proof of substance being any thing more than powers of attraction and repulsion, thus denying to it solidity, impenetrability, and the like. "Since matter, he concludes, has in fact no properties but those of attraction and repulsion, it ought to rise in our esteem; as making a nearer approach to the nature of spiritual and immaterial beings, as we are tempted to call those which are opposed to gross matter." See Priestley on Matter and Spirit, p. 37. and History of Discoveries relating to Vision, p. 454.

ing any natural means which can be brought to separate them.

By such a supposition, whilst we evade the objections already alleged against the theory of atoms, we at the same time may avail ourselves of the authority of even those Greek philosophers who were most opposed to the system of Epicurus, but who nevertheless found themselves obliged to adopt the idea of atoms, which, though potentially, were not actually divisible, as we see from the passage of Aristotle already quoted.

If the application of the term *atom* in such a sense be objected to, we may answer that the same remark will apply with reference to the particles of an homogeneous body, as to the parts of one consisting of heterogeneous elements.

Supposing, for example, gold or iron to consist of several elementary matters, which yet had been bound together from the beginning of time by some attraction too strong for any earthly power to separate them, such substances, however composite, ought perhaps to be considered, *quoad nos*, elementary, since in their relation to ourselves, and to all the substances of which we have any experience, they act as elementary bodies would do.

In like manner, if we had reason to believe that there existed in nature bodies of whatever dimensions, the parts of which were indissolubly united, they might, I conceive, without impropriety be denominated *atoms*, or at least be classed with such bodies.

Such probably was the meaning of Democritus, when he spoke of atoms of considerable weight and size; not that he would persuade us that such bodies were without parts, but that he considered the cohesion of the latter as too great to be overcome*.

* Heraclides Ponticus (not Heraclitus, as Dr. Good by mistake has stated), and after him Asclepiades of Bithynia, substituted in their system the term ογκοι, as more appropriate for masses of matter, than the term ατομοι employed by Democritus; but then, by a further deviation from the system as entertained by Epicurus, he supposed these particles not only to be incongruous

The question therefore now before us resolves itself simply into this, whether there be any reason to conclude from the review of natural phenomena that the Deity has assigned a limit to the divisibility of matter? since, if such be the fact, we may fairly speak of and reason upon the ultimate particles to which the division can be carried as atoms, although they may be proved mathematically to consist of an infinite number of points.

Now this is the very view which has been taken, not only by the ancient philosophers already alluded to, but also by Newton, who in this particular adopts the principles of the Epicureans, and even supports them by arguments of the same description as those conveyed to us in the verses of the illustrious Roman poet.

"All things considered," he says, "it seems probable, "that God, in the beginning, formed matter in solid, massy, "hard, impenetrable, moveable particles, of such sizes, "figures, and with such other properties, and in such pro-"portion to space, as most conduced to the end for which "he formed them; and that these primitive particles, being "solids, are incomparably harder than any porous bodies "compounded of them; even so very hard as never to wear "or break to pieces; no ordinary power being able to di-"vide what God himself made one in the first creation.

"While the particles continue entire, they may compose "bodies of one and the same nature and texture in all ages; "but should they wear away, or break in pieces, the nature "of things depending on them would be changed. Water "and earth composed of old worn particles would not be of "the same nature and texture now with water and earth "composed of entire particles at the beginning. And there-"fore, that nature may be lasting, the changes of corporeal "things are to be placed only in the various separations, "and new associations, and motions of these permanent

(*αναρμοστοι*), but also liable to be broken and altered (*θραυστοι* and *παθητοι*). Hence this latter doctrine cannot be appealed to on the present occasion. See Sprengel's Hist. of Medicine, vol. ii.

"particles; compound bodies being apt to break, not in the "midst of solid particles, but where those particles are laid "together, and touch in a few points*."

Yet, notwithstanding these authorities, there were some who still saw reason to adhere to the opposite opinion, which had been maintained by Des Cartes and Leibnitz, and which was also preferred in more modern times by the speculative reasoners of Germany, to whom the atomic theory was unpalatable, perhaps for the same reasons that it was disregarded in the metaphysical schools of Greece, being stigmatized as crude and unphilosophical from the very simplicity of its fundamental positions.

Kant and his followers preferred accordingly regarding matter as penetrable throughout, and as owing its present condition to the balance between the two forces of contraction and expansion. If the former alone existed, the whole universe would be reduced to a mere mathematical point; if the latter, it would spread itself equally over all space. But owing to the operation of the former power, matter is compressed to a certain limit, beyond which the opposite force operates with superior energy, and thereby prevents any further contraction.

When two kinds of matter shew an affinity one for the other, it is because they are actually penetrable, and when a perfect solution of one substance in another takes place, both are infinitely subdivided, so that each ingredient is uniformly diffused throughout the mass.

It must be confessed that this, which has been called the Dualist system, presents, even in the form in which I have here exhibited it, but an obscure and imperfect image to the mind; but the more modern German schools of natural philosophy appear to have pushed their opinions much further, as they endeavoured to explain every thing by two forces, expansion and attraction, of which what we call Matter was the result.

This attempt at the complete annihilation of substance

* Horsley's Newton, vol. iv. page 260.

this entire resolution of all the phenomena presented us by the senses into the effects of forces, which are yet not admitted to belong to any *substratum*, seems as repugnant to our notions on the one side, as the attempt of Epicurus to explain every thing by the mechanical properties of his atoms is on the other; and few, I conceive, excepting those whose minds are in a manner preoccupied by the dogmas of this philosophy, which from metaphysics extended its empire into the domain of science, and even of natural history, will consider the theory in question of sufficient weight to operate with them as an impediment to the reception of truths based upon the more substantial and palpable footing of experiment.

CHAPTER II.

Outline of the facts ascertained in modern times with respect to the combinations between bodies—Proportions in which they unite together are in general definite as to quantity, and limited in point of number—Wenzel's and Richter's researches on this subject—Opinions entertained by Mr. Higgins—Generalized view of the phenomena presented by Dalton, who established that every substance enters into combination in certain fixed proportions, of which the larger are multiples of the smallest—Whether these proportions are to be considered in all cases as multiples also of the combining proportion of hydrogen—Mechanical contrivance for facilitating the calculation of the quantity of any one body requisite to combine with a given quantity of another—What body ought to be assumed as unity—Exceptions to the law of multiples considered—Dr. Prout's opinion with respect to the doctrine of definite proportions—Gay-Lussac's theory of volumes—Relation existing between the volumes and the quantities of bodies which combine—And likewise between their combining proportions and their specific gravity.

Berzelius' canons with respect to chemical combination—Exceptions to their universal application—His symbols to express the nature and composition of bodies—Professor Whewell's objections to them considered.

Inference in favour of the existence of atoms from the laws above detailed—Weights of the atoms of different bodies stated—Their figure—Their relative size—Correspondence between the atomic weight and specific heat of different substances—Objections of Dr. Prout to the atomic theory noticed—Subordinate laws of combination according to Dalton—His fundamental principle, as to the most powerful combination being a binary one, disputed by Berzelius.

Other arguments in favour of ultimate atoms derived from crystallography—Curious law which determines the position of the faces of crystals—Mitscherlich's researches on isomorphism—Evidence of the truth of his principle—And refutation of the objections urged against it—Instances of the same substance assuming two crystalline forms nowise related, and likewise of two bodies differing altogether in their properties, being formed of the same elements in the same atomic proportions—Attempt to explain the latter phenomenon by adopting Dr. Prout's views with regard to bodies considered by him as "*merorganized*"—These same views applied also to the accounting for the virtues of mineral waters by the energy imparted by certain ingredients present, in extremely minute proportions.

Inference as to the existence of atoms derived also from the doctrine of isomorphism—Explanation on the same principle of the anomalies presented by the analysis of certain varieties of the same mineral—Tendency of isomorphous bodies to crystallize together—Which may explain the difficulty of separating completely certain salts when mixed—As has been noticed by the author to be the case with those of lime and magnesia.

HAVING in the preceding chapter reviewed the opinions of the most distinguished philosophers anterior to the present age, with respect to the constitution of matter, and shewn how completely they failed in arriving at any conclusion calculated to command assent, I propose in the next place to consider the laws more recently determined with respect to the definite proportions in which bodies combine; after which we shall be better prepared to understand what degree of assistance has been derived towards the solution of this problem from modern experimental research.

Let it not, however, be imagined, that I mean to represent the value of the important discovery, of which I am about to offer a sketch, as though it were mainly dependent on its relation to an inquiry, which, like the one alluded to, is purely speculative; its practical importance, as we shall afterwards find, gives it a much higher claim; and we should dislodge the reputation of its inventor from the solid foundation on which it stands, if we were to attempt to rest it on the accidental circumstance of its having afforded an additional argument against the position, that matter is infinitely divisible.

All minds, nevertheless, are not cast in the same mould, and there may be some, who, from natural bias, or from habits acquired by education, attach greater importance to the theoretical than to the practical results of a discovery;

and who would therefore pay an attention to the doctrine of definite proportions from finding it throw light upon a question of speculative interest, which they might not bestow upon it from its relation to a science, with respect to the details of which they feel indifferent.

Nor will even those of a more matter-of-fact disposition deny, that an additional triumph will have been reaped by modern science, if it can be shewn to have achieved, as it were incidentally, and on ground not its own, that which the philosophy regarded by us with a reverence at once so just and so natural left unaccomplished, and to have discovered a series of facts, which, if not absolutely decisive of the question alluded to, lend at least a much greater preponderance to the corpuscular theory over that opposed to it, than it had attained in any former period at which its pretensions were discussed.

No sooner had modern chemistry made sufficient advances in the art of manipulation, to allow of a frequent appeal to the balance in experimenting, than what before could only have been conjectured, or at most taken for granted without direct proof, became a matter of demonstration; the identity of composition belonging at all times to the same body, in whatever manner it may be produced, then becoming established by every correct analysis.

It was shewn moreover, that if two ingredients are capable of uniting in more than one proportion, the nature of the substances produced by their union often bore no sort of relation one to the other, but belonged frequently to a distinct class of bodies. One of them, for instance, might possess acid properties, the other be tasteless and inert; or one might be combustible, whilst the other supported or extinguished flame.

It could not fail too to be remarked, that in those cases in which the chemical properties of the combining bodies were in a manner effaced by the union that took place between them, the number of combinations of which they were susceptible did not appear to be indefinite; that on the contrary there were few instances in which they exceeded four or five at the most; and that, when the ingredients were presented to each other in intermediate quantities, the resulting compounds were not in reality distinct substances, but mixtures of two or more of the combinations known to exist.

This point being ascertained, it was natural that the relation, which the several compounds consisting of the same ingredients might bear one to the other, should be a subject of inquiry; and it is only surprising that men of science should so long have overlooked the simple law, by which the combinations between bodies are now shewn to be regulated.

The first step towards the determination of this point was made about sixty years ago by a German chemist named Wenzel, who, in a work entitled *Lehre von den Verwandschaften*, published at Dresden in 1777, shewed, by a series of analyses which are now admitted to be remarkably accurate, although they met with little attention at the time, that when two neutral salts decomposed each other, both the resulting compounds were exactly neutral. Thus supposing sulphate of silver and nitrate of barytes to be brought into contact, there would result two neutral salts consisting of nitrate of silver and sulphate of barytes; and if to the nitrate of silver that resulted phosphate of soda were added, we should then obtain phosphate of silver and nitrate of soda, both alike neutral.

Let the quantities employed be 19.7 grains of dry sulphate of silver, (which consist of 5 grains of sulphuric acid and 14.7 of oxide of silver) and 16.5 grains of nitrate of barytes, (containing 6.75 grains of nitric acid, and 9.75 grains of barytes;) we may then represent the changes that take place by the following diagram, adopting the method introduced by the Swedish chemist Bergman, to whom we are indebted for much of our information on the subject of chemical decompositions.

	Nitrate of Silver 21.5 grains.		
Sulphate of Silver 19.75 gr.	Oxide of Silver 14.75 grains.	Nitric Acid 6.75 grains	Nitrate of Barytes 16.5 grains
	Sulphuric Acid 5.00 grains	Barytes 9.75 grains	
	Sulphate of Barytes 14.75 grains.		

According to this diagram, the substances to the right and left without the hyphens are the ones brought into contact, and those above and below the straight lines are the new bodies resulting from the play of their mutual affinities. The quantities of each substance, and also those of their component parts, are given in the diagram; so that it appears at first sight that exactly five grains of sulphuric acid will neutralize or destroy the properties of 14.75 grains of oxide of silver, and of 9.75 grains of barytes; and that just 6.75 grains of nitric acid will be required to neutralize the same quantities of these bodies.

It follows, therefore, that five grains of sulphuric acid are equivalent to 6.75 of nitric acid, and *vice versa* 14.75 grains of oxide of silver to 9.75 of barytes.

By the same rule, when the 21.5 grains of nitrate of silver resulting from the above process are presented to 7.5 grains of dry phosphate of soda, the following changes take place:

Nitrate of Soda 10,75 grains.

Nitrate of Silver 21.5 gr.	Nitric Acid 6.75 gr.	Soda 4.0 gr.	Phosphate of Soda 7.5 gr.
	Oxide of Silver 14.75 gr.	Phosphoric Acid 3.5 gr.	

Phosphate of Silver 18.25 gr.

It follows then, from the above facts, that 5.0 grains of sulphuric, 6.75 of nitric, and 3.5 of phosphoric acid, are chemical equivalents; as are also, for the same reason, 4.0 grains of soda, 9.75 of barytes, and 14.75 of oxide of silver.

Accordingly upon this principle, Richter, a Prussian chemist, following in the footsteps of Wenzel, endeavoured to ascertain the relative capacities of saturation belonging to the several acids and bases, and to express them by a scale of numbers*; thus rendering chemistry, which had before been conversant merely with the *qualities* of matter, a science

* In his work called *Anfangsgrunde der Stochiometrie.* Breslau, 1792; and in a periodical publication, entitled, *Uber die neuen Gegenstande der Chemie,* which appeared at various intervals between the years 1792 and 1802.

also of *quantity;* and providing it in a manner with a new instrument of research, by enabling it to call in the assistance of calculation to check and correct the unavoidable errors of experiment. The results of Richter's researches were published in a table, of which the following is an abridgment.

Equivalent quantities of

Alumina	525	Carbonic acid	577
Magnesia	615	Muriatic	712
Ammonia	672	Oxalic	755
Lime	793	Phosphoric	979
Soda	859	Sulphuric	1000
Strontian	1329	Nitric	1405
Potass	1605	Acetic	1480
Barytes	2222	Tartaric	1694

Thus, for instance, it would appear from this table that 000 grains of sulphuric acid saturate 525 grains of alumina, 615 ditto of magnesia, and such quantities of the other earths as are denoted by the number attached to each name; and in like manner that 2222 grains of barytes saturate 577 ditto of carbonic, 712 of muriatic acid, &c.

Two inquiries might have been suggested by the consideration of this table of Richter's; the one having for its object a mere amplification or extension of it, the other an investigation of an analogous kind.

It was in the first place to be determined, whether the same law, which had been pointed out with respect to a few of the acids and bases, held good generally throughout nature, and particularly whether it prevailed where two or more combinations between one body and another existed; and 2dly, if this were the case, whether any relation could be traced between the quantities of those substances which entered into combination in more than one proportion.

Thus, for example, if in a salt known to consist of sulphuric acid and potass, the acid had been found to combine with the alkali in the proportion of 1000 to 1605, and a new compound consisting of the same ingredients were discovered; it might be inquired whether any relation existed between the number of 1605 representing the quantity of potass present in the former salt, and that indicating the proportion in which the same alkali occurred in the compound afterwards recognised.

Now supposing the quantity of alkali in this latter case to have been estimated at 802.5, or exactly half the former number, the coincidence would scarcely have appeared to us as merely accidental; and if the same relation had been observed in a variety of analogous instances, we must then have been compelled to regard it as indicating a law of nature, and as produced by some cause operating generally throughout matter.

Now, though in this identical instance the relation between the two compounds of sulphuric acid with potass is not correctly expressed by the numbers given, yet it seems rather remarkable, that an approximation at least to the real composition of some of the substances so related, should not have been sooner obtained from the analyses from time to time conducted, and that nearly thirty years should have elapsed, not only without any attempt to extend the law of Richter's to bodies more simple than those on which he had operated, but even without any idea having been entertained of the numerical relation existing between the quantities of a substance which combines with another in more than one proportion.

It would appear, that we owe to Mr. Higgins, formerly of Pembroke college in this university, the first enunciation of this latter fact, as in a work published by him in 1789, entitled, "A Comparative View of the Phlogistic and Anti-"phlogistic Theories;" he distinctly states, that one ultimate particle of sulphur and one of oxygen constitute sulphurous acid, whilst one ultimate particle of sulphur and two of oxygen constitute sulphuric acid; and moreover that in the compounds of azote and oxygen the ingredients are to each other in the proportion of 1 to 1, 2, 3, 4, 5, respectively.

He also throughout his work adheres to the corpuscular hypothesis, supposing matter to combine particle to particle, though in this latter respect indeed he only followed the notions of former chemists, who, if they thought at all upon the subject, generally leaned to the opinion that chemical combination took place between the ultimate molecules of matter, and not, according to the Kantian doctrine, owing to a mutual penetration of one substance by another.

It is a pity for Mr. Higgins' reputation that he had not struck out this idea a few years later, when, as its correctness could have been substantiated by an appeal to facts, it is probable that his genius might have overleaped the boundary, that separates the point to which we are led by his researches from that afterwards attained by Mr. Dalton.

As it was, the want of precision in chemical analysis rendered it impossible at that time to collect a number of instances sufficient to establish the law as holding good universally; neither does it appear from the cursory manner in which Mr. Higgins makes mention in the work alluded to of the relation between the proportions in which bodies combine, and from his never returning to the subject until the principle had become generally adopted amongst chemists, that he was sufficiently alive to its importance, to have attempted to follow it even through those cases to which it might at that time have been extended.

In the year 1808 Mr. Dalton published the first volume of his New System of Chemical Philosophy, in which he gave a brief outline of those notions respecting the constitution of matter, which, it appears from Dr. Thomson's statement, he had explained to him and others both privately and through the medium of public lectures, for some years antecedent to that date *.

In this work he announces as a general fact, that when two bodies combine, the union takes place betwixt their component particles, in the proportion of 1 of the first to 1

* He had even communicated so early as 1803 to the Manchester Society, an Essay containing an outline of his speculations.

of the second, 1 of the first to 2 of the second, 1 to 3, and so on.

If this be allowed, it will follow, that from the relative weight of the elements constituting any given compound that of their ultimate atoms may be inferred*; and hence when either of the same ingredients occurs in a known proportion in other bodies, the number of its atoms present in them may admit of being determined.

He therefore states, that it is one great object of his work "to shew the importance and advantage of ascertaining the relative weights of the ultimate particles, both of simple and compound bodies; the number of simple elementary particles which constitute one compound particle; and the number of less compound particles which enter into the formation of one more compound particle."

To illustrate these views, he has placed at the end of his volume a plate, in which thirty-seven bodies, including most of the supposed chemical elements, are represented by appropriate symbols; and in the explanation annexed the

* This of course must be understood with certain limitations. Where a substance combines with another in several proportions we are only sure that one of them represents the atomic weight, and in choosing amongst the number must be guided by other considerations derived from a general review of the compounds which it contributes to form.

Thus if *B* combines with *A* in the proportion of 8 to 10, and of 16 to 10, one of these quantities will represent the weight of an atom, but we cannot be certain from this alone which it may be. We are not at liberty to infer, that because the smaller of the two quantities of *B* is 8, that this therefore is its combining proportion; for it is just as likely that it may be 16, and that two atoms of *A* may be present in the former combination, and only one in the latter. Thus the proportions of the ingredients may be expressed equally well by representing

A 20, *B* 14. or *A* 2 atoms, *B* 1.
A 10, *B* 14. or — 1 ——— 1.

As by the former mode, where we state the composition thus:

A 10, *B* 7. or *A* 1, *B* 1.
A 10, *B* 14. — *A* 1, *B* 2.

weights of their atoms are given according to the above mode of calculating them.

In the second volume of his work, published in 1810, he confirmed these views by facts derived from a consideration of the compounds of oxygen with hydrogen, azote, carbon, sulphur, and phosphorus, which were shewn to combine in such definite proportions, as might be reconciled to his principle; and the investigations of Berzelius, Thomson, and others, have since extended the same to all classes of chemical compounds whatsoever.

It will however be at once perceived that Mr. Dalton's doctrines comprehend two propositions, which, though mutually related, and by him closely associated, are in reality distinct; the former, a question of fact, namely, whether it be true that the proportions in which bodies combine follow any numerical law; the second, a matter of theory, whether, granting the preceding proposition, the circumstance may be accounted for by supposing that the union takes place between the atoms that constitute the substances in question, and that in each the atoms are themselves characterised by a difference in point of weight.

To establish the first point, I will give the following examples taken from bodies whose composition has been determined with sufficient exactness:

Oxygen with Hydrogen.

Hydrogen 1, Oxygen 8*; form Water.
——— 1, ——— 16; —— Deutoxide of Hydrogen.

Oxygen with Carbon.

Carbon 6, Oxygen 8; form Carbonic Oxide.
——— 6, ——— 16; —— Carbonic Acid.

Oxygen with Sulphur.

Sulphur 16, Oxygen 8; form Hyposulphurous Acid.
——— 16, ——— 16; —— Sulphurous Acid.
——— 16, ——— 24; —— Sulphuric Acid.

* In all these cases the number expresses the relative weight of the combining proportions.

Oxygen with Nitrogen.

Nitrogen 14, Oxygen 8; form Nitrous Oxide.
——— 14, ——— 16; —— Nitrous Gas.
——— 14, ——— 24; —— Hyponitrous Acid.
——— 14, ——— 32; —— Nitrous Acid.
——— 14, ——— 40; —— Nitric Acid.

Hydrogen with Sulphur.

Hydrogen 1, Sulphur 16; form Sulphuretted Hydrogen.
——— 1, ——— 32; —— Bisulphuretted Hydrogen.

Hydrogen with Carbon.

Hydrogen 1, Carbon 3; form Light Carburetted Hydrogen.
——— 1, ——— 6; —— Olefiant Gas.
——— 1, ——— 19; —— Naphthaline.

The same relation extends also to compounds of the above simple bodies. Thus:

Potass with Carbonic Acid.

Potass 48, Carbonic Acid 22; form Carbonate of Potass.
—— 48, ——— 44; —— Bicarbonate of Potass.

Potass with Oxalic Acid.

Potass 48, Oxalic Acid 36; form Oxalate of Potass.
—— 48, ——— 72; —— Binoxalate of Potass.
—— 48, ——— 144; —— Quadroxalate of Potass.

Alumina with Sulphuric Acid.

Sulphuric Acid 40, Alumina 18; form Sulphate of Alumina.
——— 40, ——— 36; —— Disulphate.
——— 40, ——— 72; —— Trisulphate.

It is even found to hold good in the combinations between salts. Thus:

Carbonate of Magnesia with Carbonate of Lime.

Carb. of Magn. 5.25, Carb. of Lime 6.25; form Magnesian Carb. of Lime.

Carb. of Magn. 5.25, Carb. of Lime 12.50; form Bitter Spar.

And in the combinations of one sulphuret (or sulpho-salt) with another. Thus Berzelius mentions four combinations of sulphuret of arsenic with sulphuret of potassium, in which the proportions appear to be as follows:

	Sulphur. Potass.	Sulphur. Arsenic.
1st Combination.	8.92.	14.75. or 1 to 1.
2d ————	8.92.	29.50. or 1 to 2.
3d ————	26.76.	29.50. or 3 to 2.
4th ————	8.92.	354.00. or 1 to 24.

The legitimate inferences from these facts are; that the proportion of oxygen which unites with the substances mentioned is 8, that of hydrogen 1, that of carbon 6, that of sulphur 16, or some multiple of the above numbers; and that the same law extends to these more elementary bodies, which Richter had laid down with regard to their primary compounds; namely, that the same quantity of *A* which combines with a given weight of *B*, will be required to combine with that proportion of *C* which unites with the supposed quantity of *B*.

Hence the combining proportions of the above substances are termed chemical equivalents, and the following numbers will represent those of a few of the elementary substances most familiar to us.

	Chemical equivalent.
Hydrogen	1
Carbon	6
Oxygen	8
Phosphorus	12
Azote	14
Sulphur	16
Sodium	24
Potassium	40

Now it will be remarked, that the numbers representing the chemical equivalents of all the bodies above enumerated, are multiples by a whole number of that of hydrogen, which is at once the lightest body known, and that of which the combining quantity is the smallest; a circumstance first pointed out by Dr. Prout in his interesting Memoir* on the relation

* Ann. of Phil. vol. vi. 1815.

between the specific gravity of bodies in their gaseous state, and the weight of their atoms, where it was also shewn that they were all, according to the best analyses then made, multiples of twice the atomic weight of hydrogen, and most of them of four times that quantity.

This idea, in favour of which we are prepossessed from the simplicity which its adoption would introduce into the series of numbers representing the combining proportions of bodies, is countenanced by the elaborate researches of Dr. Thomson in his First Principles of Chemistry; but other philosophers, as Berzelius, question the correctness of such a generalization*; and we must admit, with Mr. Herschel, that it is doubtful whether such accuracy in chemical analysis has yet been attained, as to enable us to answer positively for a fraction not exceeding the 300th or 400th part of the whole quantity to be determined; and this degree of exactness at least would have been required to verify the law satisfactorily in the higher parts of the scale†.

It seems also assuming too much, in the present state of our knowledge, to pronounce absolutely that hydrogen, the lightest body known, is therefore the lightest in nature; and whatever inherent probability there may be in the idea of other substances being multiples of this body, depends entirely upon the latter supposition.

I believe indeed that I shall not be misrepresenting Dr. Prout's opinions, if I remark that, in the paper alluded to, he seems to have noticed the relation between the numbers which, on the authority of other chemists, he gives as the atomic weights of the several elementary substances enumerated, chiefly as a presumption in favour of the idea of their being possibly compounded of oxygen and hydrogen, of which they appeared to be multiples.

Indeed, if we could ascertain, that there were any two or three undecompounded substances, to whose atomic weight

* Thus, according to this chemist, the atomic weight of chlorine is 35.43, and not 36.0, as Thomson states it to be; and that of bromine 78.26.

† Introduction to the Study of Natural Philosophy, p. 307.

those of all other bodies in nature bore this relation, we might with some degree of plausibility conjecture, that these were the elements out of which the rest were formed; but there is no necessity for assuming, that one of them would prove to be hydrogen, or even any other of the bodies which have yet come under our cognisance.

The combining weights of the different bodies, whether simple or compound, being ascertained, it is easy to see how conveniently the sliding rule of Gunter may be applied, in the manner originally proposed by Dr. Wollaston*, as a mechanical substitute for the tedious arithmetical calculations that would be requisite for determining the exact proportion of one substance equivalent to a given quantity of another.

It is not my business to describe the principle on which the sliding rule is constructed; but as the divisions in it are logometric, it is evident, that if we arrange in a tabular form a series of names indicating a number of different substances, and place them one below the other at intervals corresponding to the differences between the weights of their combining proportions, a moveable scale of numbers annexed to such a table will afford us the means of ascertaining by mere inspection the exact proportion of all the other bodies enumerated that will be required to combine with, or neutralize, a given quantity of any one of them.

Thus in the table, the bodies are so disposed, that if the number 10, which Dr. Wollaston fixed upon for the chemical equivalent of oxygen, be shifted exactly opposite to the name of that substance, we shall find all the others mentioned in the table likewise opposite to the number representing their combining proportion; thus sulphur will stand opposite to 40, iron to 34½, zinc to 41; now if we wish to learn how much of the three latter substances will combine with 14½ of oxygen, we find, by shifting the number 14.5 on the sliding rule opposite to the word oxygen, that 29 of sulphur, 50 of iron, and 59 of zinc are the respective quantities; these, in the altered position of the

* Phil. Trans. for 1814. part i.

scale, being the numbers in a line with the names of the three bodies alluded to.

This instrument, which is capable of solving a number of problems of importance both to the scientific and manufacturing chemist, and thus of affording a great saving of the time that would be otherwise spent in arithmetical calculations, is now sold by the makers of philosophical apparatus in a variety of different forms, all however constructed on the same principle, and is too generally known to require to be illustrated by a plate.

It will be immediately perceived that the number here fixed upon for the atomic weight of oxygen is one perfectly arbitrary, and that the same purpose would be answered, if we chose to substitute any other body as our standard, and any other number as expressive of its combining proportion, provided only that the other substances introduced into the table maintain the same relation one to the other as in the scale of Dr. Wollaston.

Accordingly the atomic weights of bodies have been represented on several different systems.

Thomson, Wollaston, and Berzelius, for example, refer all substances to oxygen, on the ground that there is no other principle which possesses so wide a range of affinities, or enters as a component part into so many important combinations. By Thomson its atomic weight is made 1, by Wollaston 10, by Berzelius 100, a difference of little moment, as it merely involves the necessity of expressing in the one case by whole numbers, what in the other is done by fractional parts.

Thus the following are the chemical equivalents of the five bodies below enumerated, according to these three schemes.

	Thomson.	Wollaston.	Berzelius.
Hydrogen	0.125	1.25	12.5
Carbon	0.75	7.5	75.0
Oxygen	1.00	10.0	100.1
Azote	1.75	17.5	175.0
Iron	3.5	35.0	350.0

Mr. Dalton, on the other hand, prefers taking for his standard hydrogen, and I am inclined to think that there is an advantage in so doing, as the mind apprehends somewhat more readily the relation between the atomic weights of bodies, when they are thus compared with that which is the lightest substance known, than when referred to oxygen, by means of a descending, together with an ascending scale of numbers, as in the instance before us.

This latter scale would also possess an additional recommendation, if it should eventually turn out that the combining proportions of other bodies are multiples of that of hydrogen, as we should then be able to dispense entirely with fractions, and express by whole numbers the relation which the equivalents of all bodies bear one to the other. The oxygen scale, on the other hand, *necessarily* involves the employment of decimals, which in an affair of memory seem objectionable, and if they cannot be entirely done away with, should at least be introduced as sparingly as possible.

Leaving, however, the comparative merits of the two scales of chemical equivalents to be settled by each person according to the facility he finds in applying them to his purposes, let us consider the exceptions that have been adduced to the laws with regard to the construction of bodies, and see how far they are calculated to throw doubts upon the soundness of the principle which is taken for granted equally which ever of these scales we employ.

In the first place, it sometimes happens that the only known combination existing between two bodies is not in the proportion which would be indicated by the number representing their respective chemical equivalents.

Thus 1 of hydrogen combines with 8 of oxygen, and the latter with 14 of nitrogen. We should therefore infer, that the quantity of hydrogen which would combine with 14 of nitrogen ought to be 1, whereas it is 3; the only known compound of the latter ingredients being ammonia, which consists of 14 by weight of nitrogen and 3 of hydrogen.

In other cases, where several combinations of two bodies occur, the ratio between the numbers is not as 1—2—3 or a multiple of the smallest, but as 1—1½—2, or some other intermediate quantity.

It may be observed, however, that in these cases the very exception seems to prove the rule; for with regard to the first case, although 3 is not the equivalent of hydrogen, yet it is a multiple of that quantity; and with regard to the second, the relation of one half or one quarter of the smaller number is always preserved in the other combining quantities, so that it is plain that a certain regularity is still maintained in the midst of these apparent anomalies, and that the combinations take place even here agreeably to some fixed and settled principle.

Many of these exceptions indeed have disappeared, in proportion to the progress of discovery: thus a few years ago we were acquainted with only two compounds of sulphur and oxygen, the sulphurous and sulphuric acids, the former composed of 16 sulphur and 16 oxygen, the latter of 16 sulphur and 24 oxygen, the proportion of oxygen in the two compounds being therefore as 2 to 3.

But the discovery of the hyposulphurous acid has since removed this anomaly, by presenting us with a compound of 16 sulphur and 8 oxygen, so that the proportion of the latter is to that in which it exists in the second as 1 to 2.

It is probable, therefore, that in many cases the exception is only apparent, whilst in others it seems not unlikely that two equivalents of one ingredient may combine respectively with two, three, and four equivalents of the other, as in the oxides of lead*, which, according to Dr. Thomson, consist of

Lead	$104\times2=208$	Oxygen	$8\times2=16$
——	$104\times2=208$	———	$8\times3=24$
——	$104\times2=208$	———	$8\times4=32$

* And in the compounds of hydrogen and carbon, stated in p. 37, where it will be seen, that if the chemical equivalent of carbon is fixed at 6, the ingredients are in the following ratios, viz:

H.	2	*C.*	1
H.	1	*C.*	1
H.	2	*C.*	3

Instances of the same kind are very common among compounds of an organic nature, and their frequent occurrence has led some distinguished chemists to doubt the truth of the atomic theory altogether.

"The numbers," says Dr. Prout, "conventionally employed by chemists, and termed atomic weights, or chemical equivalents, I am disposed to view in a very different light from that in which they are usually viewed at present.

"Supposing them to be correct, they no doubt represent in general the quantities in which bodies most usually combine, but by no means always. Indeed they appear to me to be often nothing more than one term of a natural series peculiar to each body, and determining its composition. Thus 9, the number assumed to represent the combining weight of water, is to be considered only as one term of the series 3 : 6 : 9 : 12 : 15, &c. in all which proportions (and perhaps in still lower submultiples of them) this fluid enters into combination, perhaps quite as often as in the proportion 9, especially in the organic kingdom.

"Chemists have already a glimpse of this important fact, when they speak of bodies uniting to others in the proportions of two, three, or more atoms, which, in fact, are nothing more or less than different terms of a natural series, such as that above alluded to."

No doubt the view here taken by Dr. Prout of the composition of bodies affords an exact expression of the phenomena divested of all hypothesis; but I am not aware of any facts which do not equally admit of being referred to the theory more commonly adopted, neither do I see the absurdity of supposing, that in organic compounds, where the terms of the series, according to Dr. Prout, are in the case of water represented as 3. 6. 9. 12. 15., the true relation may be as 9 : 18 : 27 : 36 : 45 corresponding to 1 : 2 : 3 : 4 : 5, atoms of water.

Both these modes of expressing the relation between the quantities of the ingredients which constitute an existing combination come to the same point, and if we only keep in view the possibility of combinations occurring, especially in the organic kingdom, in the more complex relation of 4 or 5 proportionals of the one, to one or more proportionals of the other, we shall perhaps be as little liable to have our experimental researches warped by the theory to which we endeavour to accommodate them, as we should be by confining ourselves to the more general expression of the fact in the manner which Dr. Prout has recommended.

Not long after Mr. Dalton in England had directed the attention of chemists to the relation existing between the weights of bodies which combine in different proportions, Messrs. Gay-Lussac and Humboldt in France established a similar correspondence between the volumes of oxygen and hydrogen which unite together, proving that they combined in the proportion of one volume of the first to two of the second. Shortly after the publication of Mr. Dalton's first volume, the French philosophers extended the same inference generally to the combinations between gases; shewing that they united in the exact proportions of 1 volume of the one, to 1, 2, 3, or some other whole number of volumes of the second. Thus one volume of carbonic acid and one volume of ammonia form carbonate of ammonia; one of nitrogen and three of hydrogen form ammonia; one of chlorine and one of hydrogen form muriatic acid. The same law applies to vapours, such as those of alcohol and ether, as well as to true gases.

Monsieur Gay-Lussac even rendered it probable that the combinations between solids and gases follow the same principle; that quantity of the former uniting with one or more volumes of the latter, which, if existing in the form of vapour, would have occupied an equal bulk.

Thus carbon 6 and oxygen 16 by weight form carbonic acid; hence 100 cubic inches of oxygen will combine with 12.7 grains of carbon.

For 100 cubic inches of oxygen weigh 33.8888, and,

$$16 : 6 :: 33.8888 : 12.7.$$

Now 12.7 grains of carbon may be shewn to occupy when in vapour 100 cubic inches, or exactly the same space as

33.8888 grains of oxygen, so that the combining quantities of the two bodies correspond in volume no less than in the number of atoms of which a volume of each is made up.

When aeriform fluids combine together, and produce by their union a new gas, they generally contract in bulk, or occupy less space than they did when separate. Now Monsieur Gay-Lussac found that when this takes place, they contract either to one half, one quarter, one third, two thirds, or some other quantity bearing an exact proportion to their antecedent bulk. Thus, carbonic oxide 2 volumes, with oxygen 1 volume, form together 1 volume of carbonic acid gas, there being a contraction of $\frac{1}{3}$rd; 3 volumes of hydrogen, and 1 of nitrogen form 2 volumes of ammonia, the gases contracting to one half, and so with the rest.

Thus we perceive that whether we regard the weight or the volume of the bodies which enter into combination with each other, a very simple relation seems to exist between them, the quantity of the one being either equal to that of the other, twice as great, three times as great, or some other multiple of its quantity; whilst the weights of the respective quantities would appear, so far as experiment has gone, to follow the same law.

Hence a correspondence must exist between the volumes of different bodies that unite, and their specific gravities; and Dr. Prout has shewn with much sagacity that the combining proportions of the several gases bear in the majority of cases the same ratio to that of hydrogen, which their specific gravity does to that of the latter body; and that in other instances their specific gravity is half as great. In the cases of oxygen and fluosilicic acid gases alone, the specific gravity would, according to this method of reckoning, exceed that of hydrogen twice as much as its combining proportion does, which may be seen in the following table, where the weights of the chemical equivalents of a few gaseous bodies and their specific gravities are stated as compared with hydrogen, which is represented in both instances by unity.

	Chemical equivalent by weight.	Specific gravity as compared to hydrogen.
	First Series.	
Oxygen	8	16
Fluosilicic acid	26	52
	Second Series.	
Carbon vapour	6	6
Phosphorus vapour	12	12
Azotic gas	14	14
Sulphur vapour	16	16
Tellurium vapour	32	32
Chlorine gas	36	36
Arsenic vapour	38	38
Selenium vapour	40	40
Iodine vapour*	124	124
	Third Series.	
Ammoniacal gas	17	8.5
Hydrocyanic acid vapour	27	13.5
Deutoxide of azote	30	15.0
Muriatic acid	37	18.5
Hydriodic acid	125	62.5

In the year 1808 the celebrated Swedish chemist Berzelius, in consequence of a perusal of Richter's work, was induced to undertake an investigation of the numerical proportions in which different bodies combine, so as to neutralize each other. The views of Dalton becoming at that time known, his ideas expanded as he proceeded, and he was thereby encouraged to undertake a series of analyses unrivalled perhaps for their number and accuracy, which have appeared in successive volumes of the Memoirs of the Academy of Sciences of Stockholm, and in other publications. The results of these labours have led him to lay down certain laws relative to chemical combinations, which, though in general only to be considered as corollaries from those determined by Dalton, claim nevertheless a short separate consideration. These views are indeed necessary for the due understanding of his nomenclature, and of the symbolical

* The relation between the atomic weight and specific gravity of compound gases and vapours, may be seen in Dr. Thomson's First Principles, vol. ii. Appendix, Table II.

of oxygen. Thus the persulphate of iron contains 1½ proportional of oxygen; and hence when we combine with it phosphoric acid, which consists of 2 atoms of oxygen to 1 of phosphorus, the ratio of oxygen in the base and in the acid will be as 1½ to 2.

In the subsalts too, which are composed of 1 proportional of acid and 2 of base, the law of Berzelius does not hold good when the acid contains an uneven number of proportionals of oxygen. Thus we have

	In the base.	In the acid.
A nitrate of alumina containing of oxygen	2	5
Ditto	3	5
An arseniate of iron	2	3
A nitrate of lead	2	5
An acetate of lead	2	3
An acetate of copper	2	3
A nitrate of bismuth*	2	5

To none of these instances does the law of Berzeliu seem to apply, so that although the determination of th general truth of the remark by experiment affords a valu able confirmation of the theory of definite proportions, y it would seem, that it cannot be depended on *à priori*, b yond the limits embraced by the theory of which it is one the consequences.

Berzelius has invented a number of symbols† to denc the different bodies met with in nature, whether simple compound, and to express the relation they bear to ea other, as well as the proportion of their elements.

Simple bodies not metallic are denoted merely by initial letter of the Latin name of each; thus S. denc

* Instances of the same kind may be taken likewise from sulpho-salts, a class of compounds investigated by Berze himself. Thus in the neutral sulpharseniate of potass, two portionals of sulphur are composed with the potassium, and proportionals with the arsenic; in the sulpharseniate of soda same relation exists, and so with the rest.

† For a list of these symbols see the Appendix.

sulphur, C. carbon, P. phosphorus, O. oxygen, H. hydrogen.

A metal, whose initial letter is not common to any other elementary body, is denoted, like the preceding substances, by that letter alone, as U=uranium, K=kalium (potassium) L=lithium. But if the initial be common to another metal, or to either of the simple non-metallic substances, then the two first letters are taken, as Si=silicium, Au=aurum; whilst, if both the first and second letters be common to more than one metal, the first *different consonant* is then annexed to the initial letter, instead of the second letter of the name. Thus Sb. denotes antimony, (stibium) Sn=tin, (stannum.)

When the compounds of any of these simple bodies with oxygen are to be expressed, Berzelius uses the symbol of the substance, with as many dots over it, as there are proportionals of oxygen; thus oxide of copper with one proportional of oxygen is indicated by $\dot{Cu}$, the same with two proportionals by $\ddot{Cu}$; sulphurous acid is $\ddot{S}$, sulphuric acid $\dddot{S}$; but when two proportionals of the base are combined with the oxygen, Berzelius prints the initial letter with an horizontal line drawn through it; for which device, however, others have substituted a similar mark underneath the letter—thus we denote the presence of two atoms of hydrogen in water (which is Berzelius's present view of the constitution of that fluid) by $\underline{\dot{H}}$; and of the same number of atoms of the metal aluminium combined with three of oxygen in alumina by $\underline{\dddot{A}}$.

To express salts, the symbols of the acid and base are brought into juxtaposition, with as many dots over each symbol as correspond with the number of proportionals of oxygen belonging to each; and when either of the component parts have more than 1 proportional, a figure annexed indicates the number.

Thus $\dot{Cu}\ \dddot{S}$ is sulphate of copper with 1 proportional of acid; $\dot{Cu}\ \dddot{S}^2$ sulphate of copper with 2 proportionals.

To express compound salts, the symbols for each are brought together by means of an hyphen +; and if the quantity of either exceeds a single proportional, the number is indicated by a figure placed immediately after the hyphen. Thus alum being, according to Dr. Thomson, compounded of 1 proportional of sulphate of potass, and 3 proportionals of sulphate of alumina, is written thus:

$$\dot{K}\,\dddot{S} + 3\,\underline{\dddot{Al}}.\,\dddot{S}$$

or more completely, to express the number of proportionals of water present.

$$K\,\dddot{S} + 3\,\underline{\dddot{Al}}\,\dddot{S} + 25\,\underline{\dot{H}}.$$

whilst as, according to Phillips, it consists of 2 proportionals of sulphate of alumina, united to 1 of bisulphate of potass, it ought to be represented as follows:

$$\dot{K}\,\dddot{S}^2 + 2\,\underline{\dddot{Al}}\,\dddot{S}$$

By Berzelius himself it is at present considered a compound of 1 atom of sulphate of potass, with 1 atom of trisulphate of alumina, and 24 atoms of water; hence the symbol is

$$\dot{K}\,\dddot{S} + \underline{\dddot{Al}}\,\dddot{S}^3 + 24\,\underline{\dot{H}}.$$

The majority of English chemists have hitherto appeared disinclined to the adoption of symbols, which, it must be confessed, tend to give a *crabbed* look to scientific treatises, somewhat appalling to beginners.

Nevertheless I agree with Professor Whewell*, that the time is not far distant when it will be impossible to dispense with them in chemistry; for the existing nomenclature, however ingeniously constructed it may be, seems incapable of adapting itself to the expression of the various combinations which will probably be discovered, and even now is with difficulty rendered applicable to compounds of more than two ingredients.

" In this latter, the most simple case supposable," observes Professor Whewell, " though there may be no difficulty in expressing the composition clearly by means of the usual

* Journal of the Royal Institution, May, 1831.

language of chemistry, yet the nomenclature is often imperfect.

" Thus the words *hyposulphate*, *sulphite*, *sulphate*, are defective, in not shewing the relative quantity of oxygen in the acid; and moreover, such terms are liable to become improper by the discovery of new compounds. The same may be said of such expressions as *per*oxide, *per*sulphate.

" Nor is this nomenclature capable of extending itself, by virtue of its own rules, in proportion as discovery extends. If new combinations of manganese and oxygen should hereafter be discovered, they must receive arbitrary, and probably anomalous designations. The oxide, deutoxide, peroxide, manganesious, and manganesic acid, do not at all obviously refer to compounds, in which the proportions of oxygen are 1, 1½, 2, 3, 4; and if we should find a combination in which the proportion of acid is 2½ or 3½, there is no denomination ready for it, nor would it be easy to find a good one. This applies equally to very many cases.

" In other cases phrases are used, as the *sulphato-tricarbonate of lead* for instance, which, though capable of a right interpretation, do not sufficiently interpret themselves; and even such can only be constructed for a few detached instances.

" When the constitution is at all less simple than in the above examples, the expression to describe it becomes still more difficult to construct. If we have 3 proportionals of lime and 4 of silica, there is no very compendious chemical name for the compound."

On the other hand, where the compound consists of more than two ingredients, the received nomenclature is obviously incapable of expressing its composition, except by a roundabout phraseology, for which symbols might be conveniently substituted, with the additional advantage too of avoiding all hypothesis, which is almost necessarily introduced into this mode of describing it.

Thus stilbite is said to be 1 proportional of trisilicate of lime, combined with 4 proportionals of trisilicate of alumina, and 6 proportionals of water; whereas all we are warranted by direct experiment in asserting is, that 15 proportionals of silica, 4 of alumina, 1 of lime, and 6 of water are present. The manner therefore in which these are arranged is hypothetical, and as such, ought not to make a part of the definition of the substance.

But though, for these reasons, it seems that a system of symbols will soon become indispensable, yet it by no means follows, that the principle on which those of Berzelius are constructed is the best possible, and Professor Whewell has pointed out certain objections to which his method is liable, owing to the use of signs adopted in algebraical formulæ in a different sense from that in which they are there employed.

Thus, to express that stilbite is composed of 4 proportionals of trisilicate of alumina united with 1 of trisilicate of lime, Berzelius indicates, as we have seen, the number of proportionals of the former compound, by a multiplier annexed to it in the following manner:

$$4\,\underline{\dddot{Al}}\ \dddot{Si}^{3}+\dot{Ca}\ \dddot{Si}^{3}.$$

thereby representing, that the former component part is added to the latter, so as to make up the mineral alluded to; and this he does, by means of a combination of symbols usually employed in algebra to denote multiplication. Professor Whewell accordingly prefers the method adopted by Mr. Herschell in his Memoir on the hyposulphurous acid*, in which the component parts of each ingredient are enclosed in brackets, and merely connected one with the other by means of the symbol of addition.

Thus, instead of writing

$4\,\underline{\dddot{Al}}\ \dddot{Si}^{3}+\dot{Ca}\ \dddot{Si}^{3}$, he would substitute

$4\,(\underline{\dddot{Al}}\ \dddot{Si}3)+(\dot{Ca}\ \dddot{Si}3\dagger)$.

He also objects, for the same reason, to the mode adopted

* Edinburgh Phil. Journal, vol. i. 1819.

† Professor Whewell expresses alumina by the initial letter A only, and lime by C; but the difference between his method and Berzelius, is perhaps seen more clearly by retaining in both instances the same symbols for each of the constituents.

by Berzelius for indicating oxygen; namely, by dots placed over the symbol of the base; and proposes, as more consistent with algebraical rule, that this element should be expressed in the same manner as the rest; viz. by its symbol connected by the sign of addition to the body combined with it; thus,

fe + 2*o* will be deutoxide of iron.

As however the perpetual recurrence of oxygen in compounds of every description renders a brief mode of indicating its presence desirable, I should here be disposed to sacrifice correctness to convenience, and retain Berzelius' mode of notation, even though it may militate in some degree against established rules.

It would be impossible to enter further in this place into an explanation of Berzelius's symbols, and of the objections raised against them, without alluding to the more theoretical parts of the subject; the best apology perhaps for introducing which, is the difficulty that must always be felt in treating the subject, even in the superficial manner I have here done, without the aid of some such connecting link as the atomic theory supplies.

I proceed therefore to shew, that the facts above detailed admit of being explained on a few very simple postulates by the corpuscular theory, whilst, if we adopt the one opposed to it, they appear, if not irreconcilable to its principles, at least in no degree accounted for by them.

If matter be infinitely divisible, no reason can be assigned why bodies should unite in certain proportions, and not in others; we should rather expect, that, as their smallest conceivable portions differ in quantity only, and not in quality, from the largest, they should all possess the same affinities, and that consequently the number of combinations taking place between different substances should be as infinite, as are the parts into which they themselves admit of being separated.

Such in fact was the opinion of Berthollet, who contended, that bodies have in reality an equal tendency to combine in any proportion whatsoever, and that the effects we usually attribute to chemical or elective attraction depend upon the operation of cohesion, elasticity, and other forces; yet even he did not pretend to deny, that in *point of fact* the generality of simple bodies affect certain combinations in preference to others; nor would it have been easy for him to have accounted for this preference to certain definite quantities, if nature had set no limit to the divisibility of matter.

But if we assume, as we are bound to do on the principles of the atomic theory, that combination takes place only between the *ultimate* particles of which matter is composed, and that each distinct elementary substance is composed of atoms, differing from the rest in point of density or weight, the law, which I have stated with respect to the combination of bodies, will be seen to flow necessarily from these data.

For let us suppose two substances, which we will call A and B, to combine with each other in three different proportions, and that these proportions be represented, so that the quantity of A remaining the same, the quantity of B varies. Under these circumstances, it is evident, that the compounds will probably consist of 1 atom of A with respectively 1, 2, and 3 atoms of B, and that the combining quantities of B must be the same as the weight, either of one, or of several of its atoms; in other words, it must either correspond with its atomic weight, or be some multiple of it.

Let us then suppose, that the weight of an atom of A is 8, and that of an atom of B 14; then the combining quantities, in the three compounds stated as above, ought to be no other than those which follow; viz.

$$A\,8+B\,14 \quad A\,8+B\,28 \quad A\,8+B\,42,$$

the numbers attached to B representing, respectively, 1, 2, and 3 atoms of that ingredient.

Accordingly, it is taken for granted by chemists, that some one of the terms of the series representing the proportions in which a body enters into combination with others, indicates the weight of its atoms as compared with other substances.

Thus the following table will denote the atomic weight of substances hitherto undecompounded, referred to hydrogen as a standard of comparison:

Hydrogen	1
Carbon	6
Oxygen	8
Phosphorus	12
Azote	14
Sulphur	16
Calcium	20
Sodium	24
Iron	28
Copper	32
Chlorine	36
Potassium	40

With regard to the shape of the particles of matter, all perhaps we shall be warranted in asserting on the subject is, that there seems no necessity for imagining, that it bears any resemblance to that of the bodies formed by their union.

Dr. Wollaston has endeavoured to shew in his Bakerian Lecture for 1813*, that the octaedral and tetraedral figures are such as might be naturally assumed by a number of perfect spheres, brought into the nearest possible contact one with the other. The obtuse rhomboid, of which a numerous class of solids found in nature are modifications, might have arisen from spheroids, the axes of which should be their shortest dimension, whilst, if they were *oblong* instead of *oblate* spheres, hexagonal prisms would result from their mutual attraction, the centres of bodies of such a figure approaching nearest to each other, when their axes are parallel, and their shortest diameters in the same plane. A cubical figure would result, if two sets of spherical particles, all of the same size, and equal in number, were to combine in such a manner that every particle of the first kind should

* Philosophical Transactions, vol. ciii.

be equally distant from all the surrounding ones of the second kind, and all the adjacent particles of the same description equidistant from each other. Hence a cube ought, as it should seem, to be the form assumed by a compound consisting of two ingredients possessing each an equal number of atoms, whilst the octaedron or tetraedron would be that which a body composed altogether of the same particles would affect.

Now it is curious, that the metals, which we have more reason to regard as simple than the generality of other bodies, crystallize in a octaedral form, though we are at the same time cautioned against relying upon such a principle, by observing that many compounds, as fluor spar for example, possess the same evidence of simplicity *.

The comparative *size* of the atoms of bodies may perhaps be calculated from their atomic weight divided by their specific gravity, if we only take for granted, what few probably will dispute, that every kind of matter possesses in an equal degree the force of gravitation, in proportion to its density.

Thus the weight of an atom of hydrogen is 1, and that of oxygen 8; but, as the specific gravity of oxygen is 16 times that of hydrogen, it would follow, that the volume or bulk of an atom of hydrogen is twice that of an atom of oxygen.

* Whilst this sheet was passing through the press, I observed in the number of the Journal of the Royal Institution for August 1831. a memoir by Professor Daniell on this subject, to which I may refer my readers for further information. It in general confirms the views given in the text, especially by shewing that Mitscherlich's curious experiments relative to the change in the measure of the angles in rhomboedral crystals, brought about by alterations of temperature, might have been predicted from considering their ultimate molecules as oblate spheroids.

The cubical form of crystals he however explains differently from Dr. Wollaston.

If, on the contrary, we adopt the views of Gay-Lussac, and suppose water to be a compound of 2 atoms of hydrogen to 1 of oxygen, then the respective size of their atoms will be the same.

The following Table* may serve to represent the relative size of the atoms of various simple bodies, calculated on the above principle:

Carbon	1.00	Tungsten ..	4.25
Nickel	1.75	Bismuth ..	4.25
Cobalt	1.75	Mercury ..	4.25
Manganese	2.00	Tin	4.66
Copper	2.00	Sulphur ..	4.66
Iron	2.00	Selenium ..	5.4
Platinum ..	2.6	Lead	5.4
Palladium ..	2.6	Gold	6.0
Zinc	2.75	Silver	6.0
Rhodium ..	3.00	Osmium ..	6.0
Tellurium ..	3.00	Oxygen	9.33
Chromium	3.00	Hydrogen ..	9.33
Molybdenum	3.25	Azote	9.33
Silica	3.5	Chlorine ..	9.33
Titanium ..	3.5	Uranium ...	13.5
Cadmium ..	3.75	Columbium	14.0
Arsenic	4.00	Sodium	14.0
Phosphorus	4.00	Bromine ...	15.75
Antimony ..	4.00	Iodine	24.00
		Potassium ..	27.00

Now an inference has resulted from the elaborate investigations entered into by Messrs. Dulong and Petit on the laws of the communication of heat †, which may perhaps eventually throw some light upon the difference of weight that exists between the atoms of bodies. These philosophers remarked, that those substances whose particles were the heaviest possessed the least specific heat; or that the latter, in the greater number of bodies, was inversely as the atomic weight.

* From Thomson's History of Chemistry, vol. ii. p. 313.

† Annales de Chimie, vii. 113, 1818.

The following table will serve to illustrate this point:

	Atomic weight.	By experiment. Sp. Heat.	By calculation. Sp. Heat.
Mercury	25	0.03	0.03
Gold	25	0.03	0.03
Silver	13.75	0.0557	0.0557
Lead	13	0.0288	0.0293
Platinum	12	0.0313	0.0314
Bismuth	9	0.0417	0.0288
Tin	7.25	0.0518	0.0514
Antimony	5.5	0.0680	0.06
Zinc	4.25	0.0884	0.0927
Copper	4.	0.0940	0.0949
Iron	3.5	0.1074	0.11
Sulphur	2.	0.1880	0.19

All gases have been found by Messrs. Delarive and Marcet jun. to have a specific heat in the inverse ratio of their specific gravity.

Waving, however, the speculations, to which this curious connexion between the specific heat and the specific gravity of bodies might give rise, and dismissing as of little moment all reference to the figure and bulk which may belong to the particles of matter, let us merely assume the existence of ultimate atoms possessing different weights, and consider whether we can frame any other hypothesis, which tallies so well with the laws laid down relative to the mode in which combinations take place. Should this be found impracticable, we need not be deterred from embracing the corpuscular theory by the absence of any more direct evidence of its truth, for such a correspondence with the phenomena is in fact all the proof, that can be reasonably expected of the existence of bodies, infinitely too minute to be brought within the cognisance of our senses.

"Philosophy," says Hartley, "is the art of deciphering the mysteries of nature; and every theory, which can explain the phenomena, has the same evidence in its favour, that it is possible the key of a cipher can have from its explaining that cipher."

Now the atomic theory affords a key which exactly corresponds to a very complicated series of effects; and hence, though it wants that complete evidence that would be afforded, if we could shew the existence of the cause, yet it may claim at least our assent, until another be proposed more adequate to account for the phenomena.

It is therefore not without reason, that a profound philosopher of the present day* has pronounced the atomic theory, or the law of definite proportions, which is the same thing presented in a form divested of all hypothesis, as, after the laws of mechanics, the most important which the study of nature has yet disclosed. "The extreme simplicity," he observes, "which characterizes it, and which is itself an indication, not unequivocal, of its elevated rank in the scale of physical truths, had the effect of causing it to be announced at once by Mr. Dalton in its most general terms, on the contemplation of a few instances, without passing through subordinate stages of painful inductive assent by the intermedium of subordinate laws, such as, had the contrary course been pursued by him, would have been naturally preparatory to it, and such as would have led others to it by the prosecution of Wenzel and Richter's researches, had they been duly attended to.

"This is in fact an example, and a most remarkable one, of the effect of that natural propensity to generalize and simplify which, if it occasionally leads to overhasty conclusions, limited or disproved by further experience, is yet the legitimate parent of all our most valuable and our soundest results. Instances like this, where great and indeed immeasurable steps in our knowledge of nature are made at once, and almost without intellectual effort, are well calculated to raise our hopes of the future progress of science, and by pointing out the simplest and most obvious combinations, as those which are actually found to be most agreeable to the harmony of creation, to hold out the cheering prospect of difficulties diminishing as we advance, instead of thickening around us in increasing complexity."

* Herschel's Preliminary Discourse, p. 305.

Fortified with such authority, I shall continue to recommend to my pupils the atomic theory, in spite of the censures cast upon it by an individual, to whose penetration and sagacity in all chemical questions, and more especially in that now under consideration, I have already had occasion to testify.

Dr. Prout, in his Gulstonian lectures delivered this year before the college of physicians, is reported to have said, "that although the atomic theory of Dalton, by connecting chemistry with quantity, was undoubtedly the greatest step that has been made in modern times, yet that by stopping where it did, he is not sure, that the science of chemistry has not been rather retarded by it, than advanced: for to suit the imaginary standards of this bed of Procrustes, real results have been, he fears, too often extended and compressed beyond all legitimate bounds, and thus truth sacrificed to error." "My notion," he continues, "of the atomic theory is, and always has been, that it does not present a just view of the laws which regulate the union of natural bodies, and consequently that it is inapplicable both to organic and inorganic chemistry. The light in which I have always been accustomed to consider it, has been very analogous to that, in which I believe most botanists now consider the Linnæan system; namely, as a conventional artifice, exceedingly convenient for many purposes, but which does not represent nature."

Now, I am afraid, it is but too true, that chemists have often yielded to the temptation, of adapting the results of their experiments to the standard set forth by the theory of definite proportions, and that the operations of *trimming* and *cooking*, so facetiously explained by Mr. Babbage*, are not altogether confined to astronomers.

But I do not see, that the atomic theory of Dalton holds out any stronger temptation to such frauds than the law substituted for it by Dr. Prout, who, as we have already seen in a former part of this Essay, admits, that the quan-

* See his Essay on the Decline of Science, p. 178.

tities in which bodies combine necessarily bear some fixed ratio one to the other, so as to constitute the terms of a natural series. Should then a chemist, who adopted Dr. Prout's principle, be engaged in an analysis, which brought out results irreconcilable with any one of these proportions, he would feel just the same temptation to adjust them to the proper standard by this Procrustean process, as he could entertain, were he a convert to the views of Dalton.

Neither can I quite admit the justice of comparing the atomic theory to the Linnæan system, which latter constitutes an improper basis for a natural arrangement of plants, not because the distinctions on which it is founded do not exist, but because they are influenced by circumstances, often possessing no important connection with the general structure of the vegetable.

The atomic system, on the contrary, seems to bear a nearer analogy to the natural arrangements of Jussieu; which, though they probably do not in all cases represent the exact relations between one species and another, exhibit nevertheless, for the most part, an approximation to them; just as the consequences deducible from the theory of Dalton, even though they should be found now and then to deviate a little from the phenomena themselves, run nevertheless so nearly parallel to them, that they cannot be far removed from a real expression of the truth.

But though we may perhaps embrace the general principle of the atomic system without any probability of being misled by it, greater caution seems necessary with respect to the subordinate laws, or canons, which have been laid down as regulating the combinations between bodies.

The most simple and intelligible I conceive to be those promulgated by our own countryman Dalton; who, though far inferior to his distinguished Swedish competitor for the honours of the atomic theory, in the number and precision of his experimental researches, appears to surpass him, in the sagacity he has shewn in deducing general conclusions from the facts before him.

Mr. Dalton contends, that the most powerful kind of union must be that of atom to atom, which he denominates a binary combination; a doctrine held, as we have seen, by the Hindoos, and possessing, as it were, that intrinsic probability, which was calculated to recommend it to the speculative philosophers of an early age.

We, however, in the present day, who are better satisfied by an appeal to experiment, than by any *a priori* arguments, may be more disposed to admit this principle, from considering, that in the great majority of instances chemical union is followed by condensation; or, in other words, that the specific gravity of a compound is greater than the mean specific gravity of its constituents, when separate. Thus a mixture of oxygen and hydrogen occupies more space, and is of lower specific gravity, than the same condensed into the form of water;—a mixture of hydrogen and nitrogen is specifically lighter, than its compound, ammonia;—a mixture of hydrogen and cyanogen, than prussic acid, the product of their union.

Hence it follows, that in most cases of chemical union, the force of affinity has to overcome the mutual repulsion, which had previously kept the particles at a greater distance asunder, thus rendering the body itself less dense.

Accordingly, when hydrogen and oxygen gases are condensed into the form of water, the attraction between the two gases must have been sufficient to overcome the repulsion, which had previously preserved either body in an aëriform condition.

Now it is evident, that when each particle of A is united to only a single particle of B, the repulsive force, which it has to overcome, will be only half that which it must encounter, when a union takes place between it and two particles of B; and consequently, that the combination in the former instance must be in that proportion stronger.

Hence 1 atom (or 2 volumes) of hydrogen, united with 1 atom (or 1 volume) of oxygen, forms water; a fluid which remains under all common temperatures unchanged, and which therefore until lately was regarded in the light of an element; but 1 atom of hydrogen with 2 atoms of oxygen constitutes the oxygenized water of Thenard, a compound with difficulty formed, and resolved into common water by the application of heat or most chemical re-agents *.

Now if the strongest kind of union be that of atom to atom, or a binary one, it would seem to follow, that where only one combination exists between two bodies, it ought to be in that proportion rather than in any other; and, on the same principle, that where there are two, the first should be a binary, and the second a ternary one, or consisting of 1 atom of the first to 2 atoms of the second.

It must be confessed, however, that this conclusion, plausible as it may be in theory, is not altogether reconcilable with *fact;* for ammonia, the only known combination between hydrogen and nitrogen, consists of 3 by weight of the former to 14 of the latter; now as this number represents the weight of an atom of nitrogen, we have here an instance of the only combination subsisting between two elements, being in the proportion of 1 to 3 atoms †.

We have also seen that water itself is composed of 2 volumes of hydrogen to 1 of oxygen; so that if we assume that the ingredients are united in the proportion of atom to atom, it will follow, that the particles of the former body are mutually kept apart to a distance twice as great as those of the latter, since they occupy at the same temperature double the space: now as most other gases or vapours unite with hydrogen in the proportion of equal volumes, and with oxygen in that of 2 to 1, we must attribute to the atoms of the latter body, double the force of repulsion which belongs to other kinds of matter, in order to reconcile the facts with our theory ‡.

* See some remarks on this subject by Mr. Emmett of Manchester in the Annals of Philosophy, vol. vi. 1815.

† This would be confirmed by the theory of volumes, since 3 measures of hydrogen and 1 of nitrogen are the proportions which form ammonia.

‡ Thus:

Oxygen	1 vol.,	Carbon Vapour	2 vol.;	form Carbonic Acid.
——	1 ——	Sulphur	—— 2 ——	Hyposulphurous Acid.
——	1 ——	Nitrogen	—— 2 ——	Nitrous Oxide Gas.
——	1 ——	Chlorine	—— 2 ——	Euchlorine Gas.

Neither are chemists agreed about the abstract probability of the position which Dalton has taken up, as to the most powerful combination between two bodies being a binary one; on the contrary, Berzelius, until very lately, assumed, that those bodies which possessed the strongest affinity for oxygen, united with it in the proportion of 2 atoms to 1 *; and though he has lately abandoned this idea, yet it is important to know, that all his old tables of the atomic constitution of bodies are constructed on this principle; and consequently that the weights of the atoms of the fixed alkalies, and of several of the metals, are calculated as double that which we must assign to them, according to our mode of considering their composition†.

But though the laws, according to which bodies combine, are still in some degree a subject of debate, all philosophers of the present day seem to concur, with respect to the inconsistency of facts, with the notion of matter being capable of infinite division; nor are there wanting arguments, derived from other branches of modern science, which tend to place the improbability of this opinion in a still stronger light.

If matter were infinitely divisible, it would seem, that a substance could not be made up of particles at all times

* The reasons which Berzelius assigns for this opinion are curious; reminding one of those of the Indian philosopher, for considering that the smallest portion of matter visible to the eye, must consist of at least six atoms. (see p. 5.) Berzelius argues, " that a combination of atom with atom does not exist in nature, because being composed of two spheres, it would only be extended in a linear direction; whereas whatever possesses substance is composed of 3, 4, 5, 6, or some still larger number of spherical atoms; the sphere constituting, as it were, the germ of those geometrical forms, which the crystals of all bodies exhibit with so much regularity." Vol. iii. p. 102.

† The symbols given in the Appendix are corrected according to Berzelius' new views; being taken from vol. xxxviii. of the *Annales de Chimie*, 1828.

the same in point of size and shape. Now a difference in the ultimate molecules seems scarcely reconcilable with the definite form belonging to each aggregate, when its parts are allowed to arrange themselves in their natural order, uninfluenced by disturbing causes.

It has been ascertained by Hauy and others, that every solid body possesses a peculiar geometrical arrangement, from which all the manifold varieties of form it presents can be shewn to be derivable.

All of these figures may be reduced to six primary types, enumerated in works of mineralogy, and the kind of crystallization assumed by the same mineral body, is the result of the apposition of an assemblage of smaller crystals, possessing the fundamental type of the species, in a variety of different modes, all, however, conformable to certain fixed laws.

Thus these secondary forms, infinite as they may appear, are all capable of being classed under certain groups; the members of the same group passing into each other, but not those belonging to different groups.

Now whatever may be the primary cause of these distinctions in crystalline arrangement, their permanency in the same species seems to shew, that each must be made up of parts as unchangeable in size and figure, as in the other chemical and physical properties that belong to them.

Even in the mode in which these secondary crystals are grouped together, a certain regularity seems to be preserved, which bears some analogy to the law of multiples in chemistry. It appears that the numerical exponents or indices by which the positions of the faces of crystals of the same species are regulated, are always related, and generally in a proportion not greater than two, three, or four. Thus it will be seen from Mr. Haidinger's work, (vol. i. p. 73.) that the axes of two scalene four-sided pyramids, of which the one is derived from the other, are towards each other in the ratio of $\frac{1}{2}:1$, if the derived pyramid is more obtuse; in the ratio of $2:1$, if the derived pyramid is more acute than the given one. This regularity, though of course attributable to a very different cause from that of the definite proportions in which the elements of compound bodies unite, is so far connected with the latter, inasmuch as it implies a certain permanency of size and figure in the component particles, which renders the crystals formed out of them subject to laws equally fixed and immutable.

The recent investigations of Professor Mitscherlich seem also, upon the whole, to favour the same conclusions. It may indeed be difficult at present to reconcile with his hypothesis one circumstance which he has announced; namely, that of the same body occasionally assuming two different forms nowise related; but however we dispose of this anomalous fact, the general tenor of his discoveries will be found, if I mistake not, irreconcilable with the doctrine of the infinite divisibility of matter, and most readily accounted for, by assuming the existence of particles identical as to figure, or at least possessing a tendency to group themselves in the same order.

It has been remarked, as a proof of the low state of science in this country *, that the laws of isomorphism (as pro-

* "In England, whole branches of continental discovery are unstudied, and indeed almost unknown even by name. It is in vain to conceal the melancholy truth. We are fast dropping behind. In mathematics we have long since drawn the rein, and given over a hopeless race. In chemistry the case is not much better. Who can tell us any thing of the sulpho-salts? Who will explain to us the laws of isomorphism?" See Mr. Herschel's Treatise on Sound, printed in the Encyclop. Metropol.,

From the verdict of one so eminently qualified to pass judgment on the comparative merits of British and Continental philosophers as the writer here alluded to, there can scarcely be any appeal; neither will it be denied, that the inferiority complained of by him and others, is in part attributable to the culpable apathy, which the government of our own country has been wont to exhibit with reference to abstract science in general.

fessor Mitscherlich's discovery is termed) are but just beginning to attract notice here, whilst they have for several years

It may indeed be true, that in the less abstruse and more popular departments of modern inquiry, such as Zoology, Geology, and the like, extrinsic aid from such a quarter might be dispensed with, the zeal of individuals supplying the place of public patronage; but the same does not apply to the mathematical sciences, which can scarcely ever be duly relished, or successfully pursued, without a devotion of time incompatible with the occupations of those who resort to a profession as a means of subsistence, and a concentration of mind on one branch of study, not often found among those who are placed above this necessity.

I fully coincide, therefore, with the writers who have followed Mr. Herschel in his estimate of the state of science in this country, so far as to regret, as a circumstance which has operated unfavourably, not only upon the advancement of knowledge, but even upon the character of the people in general, the total want of encouragement on the part of government to any researches, save those practical ones, towards which the genius of the British nation is already too exclusively directed. I must however be permitted to add, notwithstanding the respectable source from whence the assertion proceeds, that the writer in the eightieth number of the Quarterly Review, who has taken this view of the subject, appears to have weakened his own case by overstating it; for when he asserts, in corroboration of his opinion with respect to the decline of science, "that "within the last fifteen years not a single discovery or invention, of prominent interest, has been made in our colleges, and "that there is not one man in all the eight universities of Great "Britain who is at present known to be engaged in any train of "original research;" he must surely have forgotten that Mr. Herschel, whom he so justly commends, was but lately a fellow at one of the colleges at Cambridge, that Mr. Babbage and Mr. Airy hold at present the two mathematical chairs in the same university, and that in Dublin, the professorship, which Mr. Lloyd at present occupies, was within fifteen years filled by a Brinkley.

Indeed the strongest argument, I conceive, in favour of the writer's position, viz. that the abstract sciences would be promoted by obtaining the fostering aid of government, might be past engrossed the attention of continental philosophers.

derived from the degree in which they appear to be advanced by such endowments as at present exist; the fact being, that of the individuals who have obtained any considerable reputation for science in Great Britain, there are but few that have not during some part of their lives derived pecuniary assistance and support from their connexion with one or other of our public establishments; and with reference to the present argument, we may with perfect propriety put together the emoluments of our universities, and those of the scientific institutions that have more recently started up. The names of Mr. Davies Gilbert, Dr. Brewster, Mr. Dalton, Dr. Prout, and Dr. Henry, are all that occur to me as exceptions to this remark; of whom the two former are intimately connected with their respective universities, though they do not partake of their emoluments; and amongst the latter there is at least one individual, in whose case a more liberal public patronage would have secured to science the undivided energies of a mind, at present partially withdrawn from it by other indispensable occupations. On the other hand, the names of Herschel, Airy, Whewell, Faraday, Leslie, Thomson, and Ivory among the living, and those of Davy, Wollaston, and Young, amongst those recently deceased, proudly attest the usefulness of endowments, which "though," as Mr. Babbage observes, "seldom sufficient for the sole support of an individual, and very rarely enough for that of a family," yet, by enabling a few persons to prosecute objects of public utility, without an entire sacrifice of their private interests, serve to prevent the feeble torch of science from being completely quenched by the all-absorbing pursuits of personal aggrandizement.

These latter remarks may not be altogether misplaced, at a time, when the legislature of this great empire is said to have seriously debated the expediency, of discontinuing the *only* parliamentary grant made to either of the two English universities—a sum of about nine hundred pounds, voted for the increase of the nine poorest professorships dedicated to modern science in these national establishments, and which may possibly amount to about $\frac{1}{6}$th of the sum, which the same legislature annually exacts from the same bodies, in the shape of taxes, on students admitted, or on degrees conferred!!

And although, since the above statement was made, a brief sketch of these researches has been given by Dr. Turner in the new edition of his System of Chemistry, (1831,) drawn up with his usual clearness, it may not be uninteresting to have a more detailed statement of these new views exhibited in an English dress, for the sake of those who may wish to prosecute the subject further.

I am therefore induced to offer an account of the system of isomorphism somewhat more at length than I should otherwise do, considering that it possesses only a remote relation to the subject of definite proportions, and affords nothing more than a subsidiary argument in favour of atomic theory.

We have seen, that in every case of chemical union two bodies are necessarily concerned; one of which in a positive, the other in a negative state of electricity; and that the oxygen existing in the one bears a certain fixed ratio to that in the other.

Now, if we take either of these two great classes, we shall find, that if the members composing them were distinguished according to the number of atoms of oxygen they respectively contained, we might separate them into several distinct groups; one consisting of those with a single atom of oxygen to the same proportion of base; another, of those with two atoms, and so on.

Thus in the electro-negative class, we remark that carbonic oxide, the hyposulphurous acid*, and the protoxide of azote, for example, belong to a group consisting of 1 atom of base to 1 of oxygen; that the sulphurous, the carbonic, the selenious, the antimonious acids, and nitrous gas belong to one, in which the proportion of the latter to the former is

* According to Mr. Herschel, whom Berzelius follows.—Dr. Thomson however has more recently stated, that it contains 2 atoms of sulphur, admitting at the same time, that an acid of sulphur does exist, in which the proportions are those stated in the text. Phil. Trans. for 1827.

as 2 to 1; that the sulphuric, the silicic, and the selenic acids belong to a group containing 3 atoms of oxygen to 1 of base; whilst in the hyponitrous, arsenious, oxalic, and phosphorous acids, the proportions are 2 of base to 3 of oxygen, and in the nitric, arsenic, antimonic, and phosphoric, 2 of the former to 5 of the latter.

These bodies might be represented, according to the principles of Berzelius' system, by the following symbols, and thrown together into groups, the characters of which should be signified by letters, having attached to them numbers, to denote the relative proportion of base (R) and of oxygen (O), present in the members composing each series.

1st Group —	R 1+O 1	$\dot{C}$, $\dot{S}$, $\dot{N}$.*
2nd ————	R 2+O 1	No instance of this occurs, unless water ($\underline{\dot{H}}$) be one.
3rd ————	R 1+O 2.	$\ddot{S}$, $\ddot{C}$, $\ddot{Se}$, $\ddot{Sb}$, $\ddot{N}$.
4th ————	R 1+O 3	$\dddot{S}$, $\dddot{Si}$, $\dddot{Se}$.
5th ————	R 2+O 3	$\underline{\dddot{N}}$, $\underline{\dddot{As}}$, $\underline{\dddot{C}}$, $\underline{\dddot{P}}$.
6th ————	R 2+O 5	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{N}}$, $\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{As}}$, $\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{Sb}}$, $\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{P}}$.

In the same manner, if we take bodies belonging to the electro-positive class, we shall find them divisible into similarly constructed groups.

Thus there will be one group, consisting of bodies which contain only 1 atom of oxygen, such as potass, soda, lithia, barytes, strontites, lime, magnesia, and the protoxides of the metals.

A 2nd group, containing bodies with 2 atoms of oxygen, to which belong the deutoxide of tin and the peroxide of manganese.

A 3rd group, in which the proportion is that of 3 atoms of oxygen to 2 of base, such as is the case with zircon, glucine, alumina, the peroxides of sodium, of iron, and of many other metals†.

* For the meaning of these symbols, see Appendix.

† The peroxide of potassium alone, according to Berzelius, consists of 3 atoms of oxygen to 1 of base.

Now Professor Mitscherlich has rendered it probable, that several of the bodies belonging to the same group assume crystalline forms, which, if not absolutely identical, are at least nearly related one to the other; and from this it will follow, that, supposing such bodies to be severally united with an equal number of atoms of the same body, their figure ought still to correspond. Thus if we suppose sodium, potassium, calcium, iron, and manganese to agree in the shape of their ultimate particles, they ought, if combined with equal proportions of oxygen, to assume nearly the same crystalline arrangement. Under such a supposition, therefore, they would be called in Professor Mitscherlich's phrase *isomorphous* bodies.

The same remark applies to the electro-negative division in an equal degree; thus the hyposulphurous acid and the protoxide of azote, *may* be isomorphous bodies, although, whether they are in fact so, ought not to be taken for granted without positive proof. The same may be the case with the sulphurous, the carbonic, the selenious and the antimonious acids, and so with regard to all the other groups.

Now it might be expected, that if any two electro-negative bodies, themselves isomorphous, and associated with an equal number of atoms of the same body, as of oxygen, be made to unite with the same base, the crystalline form of the resulting compounds should be related; for the number and form of the atoms of which they are respectively made up being analogous, it is probable that the aggregate arising out of them should be so likewise.

Thus if lime and protoxide of iron are isomorphous, the carbonates of these bases ought to possess a similar crystalline form, and this Mitscherlich has shewn to be the case.

The same observation will apply to bodies belonging to the electro-positive class, when combined with the same acid; and the German chemist cites in his first memoir several examples of this kind, taken from the combinations of different bases with the sulphuric acid.

Thus sulphate of copper and sulphate of manganese are isomorphous; the formula representing their chemical composition being, 1 atom of a base containing 2 atoms of oxygen, combined with 2 atoms of sulphuric acid, and 10 atoms of water, which may be represented by the following symbols:

$$\ddot{R}+2\,\dddot{S}+10\text{ aq.}$$

Other instances of isomorphism taken from the same class of compounds are,

2. Sulphate of iron, and sulphate of cobalt, the chemical formula of which is

$$\ddot{R}+2\,\dddot{S}+12\text{ aq.}$$

3. The sulphates of magnesia, zinc, and nickel, the chemical formula being

$$\ddot{R}+2\,\dddot{S}+14\text{ aq.}$$

4. Sulphates of copper, and of manganese, but mixed in either case with a notable quantity of the other sulphates alluded to, (viz. those of iron, nickel, cobalt, magnesia, and zinc,) their chemical formula being

$$\ddot{R}+2\,\dddot{S}+10\text{ aq.}$$

Their crystalline form the same as the four sulphates of copper and manganese.

5. Sulphates of iron and of cobalt, similar in atomic constitution to the second group, their chemical formula being

$$\ddot{R}+2\,\dddot{S}+12\text{ aq.}$$

but differing from it in the presence of considerable quantities of the five other sulphates.

6. Crystals resembling those of the 3rd group, and agreeing with it in atomic constitution, but differing in their ingredients; containing, besides the magnesia, zinc, or nickel, different quantities of the other four sulphates.

7. Mixtures of sulphate of copper and of zinc; of sulphate of copper and magnesia; of sulphate of copper and of nichel; of sulphate of manganese and of zinc; of sulphate of manganese and of magnesia. These, though they do not contain even a trace of sulphate of iron, or of sulphate of cobalt, exhibit the same crystalline form as the latter, their atomic constitution being the same, viz.

8. Triple sulphates, consisting of the preceding metals and earths, either with potass or with ammonia.

Those containing potass may be represented by the following formula:

$$(\ddot{R}+2\dddot{S}) + (\dot{K}+2\dddot{S}) + 12 \text{ aq}.$$

Those containing ammonia as follows:

$$(\ddot{R}+2\dddot{S})+2(\text{Am}+\dddot{S})+12 \text{ Aq}.$$

Thus it would appear that $1(\dot{K}+2\dddot{S})$ and $2(\text{Am}+\dddot{S})$ are isomorphous, and may be substituted one for the other without altering the crystallization.

Perhaps, however, the most remarkable confirmation of these views is afforded by the phosphoric and arsenic acids*, which, as we have seen, are distinguished by containing each 5 atoms of oxygen to 2 of base, and consequently differ from most other electro-negative bodies, in the relation between the number of atoms of oxygen, existing in them and the metallic oxides with which they combine. If it can be shewn, that the crystallization of the salts, which these two acids form with the same base, bears the same resemblance one to the other, which their atomic composition presents, it is evident that the theory of Mitscherlich will thereby obtain a remarkable confirmation.

Now in a memoir published by this philosopher so long ago as the year 1819†, several arseniates and phosphates are described, the crystalline form of which remarkably corroborates his views.

Thus the biphosphate and biarseniate of potass, as they agree in atomic composition, correspond likewise in mineral-

* The discovering, that bodies so different, as phosphorus and arsenic, are nevertheless *isomorphous*, would formerly have been considered of great importance in a theoretical point of view, as serving to refute the Epicurean doctrine, that the properties of matter were derived merely from the different size and shape of their component atoms.—At present, however, we scarcely require this additional reason for discrediting so mechanical a mode of explaining chemical phenomena.

† See Annales de Chimie, vol. xiv. 1820, and vol. xix. 1822.

ogical character; and the same remark applies to the phosphate and arseniate, as well as to the biphosphate and biarseniate of ammonia, and to the biphosphate and biarseniate of baryt.

Professor Mitscherlich also pointed out, that the same holds good with respect to the arseniate and phosphate of soda; but it was found by other chemists, that the arseniate of soda more commonly crystallizes in a form distinctly different from that of the corresponding phosphate; and this circumstance had been brought forward by Professor Marx of Brunswick, as a decisive objection to the doctrine of isomorphism.

Mr. Clarke of Glasgow* has however explained this anomaly, by shewing that the arseniate alluded to differs in fact from the phosphate, with which it had been compared, in point of chemical composition, and consequently ought not, according to the conditions of the theory, to correspond with it in form; the arseniate containing only 15 proportionals of water, whilst the phosphate contained 25.

But Mr. Clarke has not only succeeded in obviating this difficulty, but has also brought forwards a striking confirmation of the correctness of Mitscherlich's doctrine—by discovering a new phosphate of soda, the crystalline form of which corresponds almost exactly with that of the arseniate alluded to, which contained 15 atoms of water.

The objection therefore against the system, grounded upon this want of correspondence between the arseniate and phosphate of soda, has, when properly investigated, been converted into a most triumphant argument in its favour; and with regard to others, that have at various times been brought forward against it, it would appear, that they have either arisen from an imperfect acquaintance with the theory as originally proposed, or have been removed by the modifications it has subsequently undergone.

Thus Hauy and others have pointed out, that several salts, consisting of the same acids with two isomorphous

* See Brewster's Journal, vol. viii. for 1827.

bases, produce salts which crystallize differently; but they overlooked a material circumstance—namely, that the number of atoms of water in the salts specified was not the same.

Thus the sulphate of copper is isomorphous with the sulphate of manganese, because they respectively consist of

$$1(\ddot{R}+2\dddot{S})+10\text{ aq.}$$

but not with the sulphate of iron and of cobalt, on account of the different proportion of water in these latter, whose composition is as follows:

$$1(\ddot{R}+2\dddot{S})+12\text{ aq.}$$

Another set of objections has arisen, from observing a want of *exact* conformity between the figure of bodies considered by Mitscherlich as isomorphous, crystallographers having in many instances discriminated minute differences in the angles of their crystals, which a coarser examination had set down as identical.

The Professor has however modified his system to meet this particular case, and at present is understood to contend for a similarity only with respect to mineralogical character in substances thus constituted, and not a perfect accordance, which indeed could scarcely be expected, unless the form of the primitive atom of the bases were in either instance supposed, not only to be allied, but perfectly the same.

Another circumstance, at first sight not easily reconciled with the doctrine of isomorphism, is the want of all relation between the forms, which salts of the same apparent chemical composition are occasionally found to assume.

Thus arragonite and common calcareous spar, different as they are in point of crystallization, appear to be the same in substance; for the small quantity of strontian, that has been detected in the former, is at present not considered as essential to it.

Mitscherlich has however gone on to shew in a subsequent memoir *, that the same simple body is capable of affording two distinct kinds of crystals, according to circum-

* Annales de Chimie, vol. xxiv. année 1823.

stances at present unknown to us, and has thus rendered it probable, that the difference between these two conditions of carbonate of lime has arisen, from a dissimilarity in the form of the molecules of lime, or calcium, which enter into their composition.

It is curious, that the crystalline form of arragonite corresponds as nearly to that of carbonate of lead and carbonate of strontian, as that of common carbonate of lime does to carbonate of iron; so that we may perhaps conclude, that lime is capable (like sulphur) of assuming two crystalline arrangements, the one of which may be isomorphous with the oxides of lead and strontian, the other with the oxide of iron.

It must be confessed, however, that this is a subject, upon which the immediate inferences from experiment seem to stand in direct opposition to all our preconceived opinions.

At first sight nothing would seem more obvious, than that aggregates made up of the *same* number of atoms, agreeing in their primary properties, whether mechanical or chemical, should produce the same substances; and this accordingly had been taken for granted in all discussions of the kind alluded to.

Lately, however, various facts have come to light, which go to prove, that bodies, which appear to possess precisely the same atomic constitution, may differ remarkably in their properties; nay, that they may even belong to a different class of substances altogether.

Thus we have two distinct substances made up of carbon and hydrogen, in the proportion of 6 by weight of the former to 1 of the latter; the first a gaseous body, olefiant gas, the second a highly volatile liquid *.

Professor Berzelius, in a paper published in the Transactions of the Swedish Academy in 1830, has enumerated several other examples of the kind, distinguishing them by the name of *isomeric* bodies.

The phosphoric acid is one of them; when exposed to

* Faraday, Phil. Transactions for 1825.

a red heat for some time, it acquires new properties, coagulating albumen, and producing white instead of yellow precipitates with nitrate of silver.

The tartaric acid is another case in point, Berzelius having discovered in certain kinds of tartar an acid differing in properties from, though agreeing in chemical constitution with, that more commonly known. The cyanous and fulminic acids are instances still more remarkable *.

Such are the principal examples of the kind taken from inorganic nature; but among organic bodies they would appear, from the researches of Dr. Prout, to be much more numerous.

Thus the sugar from the cane, and from the urine of diabetic patients, agrees as nearly in point of composition with the sugar of milk, manna, and gum arabic, as the several varieties of cane-sugar do with each other; yet the first class of sugars yield oxalic, the second saclactic acid.

Professor Stromeyer concludes, that this discrepancy arises from the dissimilar arrangement of the component atoms, and the different degrees of condensation they have undergone; but it appears to me more probable, that the presence of a portion of some principle, occasionally even too minute to be detected by analysis, may have occasioned the developement of new properties. Dr. Prout is of opinion, that some foreign body, not of itself belonging to the animal or vegetable kingdoms, necessarily enters into the constitution of every substance capable of becoming assimilated, and constituting a part of any organic structure. Bodies containing this admixture he denominated *merorganized*, in order to express this supposed condition, implying that in passing into this state they become partly, or to a certain extent, organized.

Now he accounts for the exceeding diversity of properties possessed by organic bodies, whose chemical composition is

* See also Dumas' Memoir on Oxamide, a substance obtained from oxalate of ammonia, and capable of reproducing it, but possessing entirely distinct properties. Ann. de Chimie, xliv. p. 181.

nearly identical, by the admixture of this small proportion of foreign matter, which by its presence infuses new properties into the mass, and prevents the particles from arranging themselves in their natural crystalline form.

Thus starch is *merorganized* sugar, differing only from the latter by the presence of certain foreign matters, which effect a complete change in its characters.

This curious view is rendered more intelligible by the important researches of Mr. Herschel, detailed in his Bakerian lecture for 1824; in which he has shewn, that the relations of a mass of matter, such as mercury, to electricity, may be even reversed by the presence of an almost infinitesimal quantity of a substance, such as potassium, in an opposite electrical condition.

"That such minute proportions of extraneous matter," says Mr. Herschel, "should be found capable of communicating sensible mechanical motions and properties of a definite character to the body they are mixed with, is perhaps one of the most extraordinary facts that has appeared in chemistry. When we see energies so intense exerted by the ordinary forms of matter, we may reasonably ask, what evidence we have for the imponderability of any of the powerful agents, to which so large a part of the activity of material bodies seems to belong*."

The views here promulgated promise to throw some light upon a subject in which I have long felt a lively interest, namely, the virtues of certain medicinal springs which contain but a very minute proportion of any solid ingredient. Much of their efficacy may doubtless be attributed to the influence of imagination, to change of scene and of habits, and in many cases to the transition from a dense and impure, to a more clear and rarefied atmosphere. But after all these deductions, there seems to be a *residual phenomenon*, to use a phrase of Mr. Herschel's†, requiring a further explanation.

* Philos. Transactions, vol. cxv.

† Preliminary Discourse, p. 158.

Now it seems not improbable, that very minute portions of certain principles may act upon the system with an energy commensurate, not to their own quantity, but to the change their presence occasions in the properties of the more inert ingredients that accompany them.

In this manner we may explain the powerfully tonic effects of certain springs containing a very minute impregnation of iron; the cures effected by waters, such as those of Loueche or Gastein, which appear to approach as nearly as possible to absolute purity; and the efficacy in glandular disorders attributed to certain others, in which a minute proportion of iodine or bromine has been detected.

In a Memoir read before the Royal Society*, on the saline and purgative springs of this country, in which I stated the proportions of iodine and bromine present in each, I expressed myself as being sceptical with regard to any medicinal agency, that could be exerted by so small a quantity, as 1 grain of iodine diffused through 10 gallons of water, the largest quantity in which I had ever detected it. The considerations above stated now induce me to attach more importance to the circumstance of its presence, for it is just as possible *à priori*, that this quantity of iodine should infuse new properties into the salts which accompany it, and cause them to act in a different manner upon the system, as that less than a millionth part of potassium should create so entire a change in the relations of a mass of mercury to electricity. Whether the waters of Cheltenham or Leamington affect the constitution differently from solutions of Glauber salt of similar strength, must be decided by the experience of those on the spot; but granting this to be the case, and there is not wanting testimony in favour of such an opinion, the discovery of these new principles in several of them may serve to explain their superiority.

Dr. Prout has already hinted in his Gulstonian lectures

* Daubeny on the Occurrence of Iodine and Bromine &c. Phil. Trans. for 1830.

at this solution, accounting in this manner for the fatal effects of inappreciable quantities of miasmata diffused through the atmosphere; nor is it unlikely that the system of the Homoiopathics in Germany may have grown out of some facts that had been observed, with respect to the powerful influence exerted on the system, when even very minute quantities of certain active principles were added to common medicaments.

To return, however, to the subject from which we have digressed,—I may remark, that Professor Mitscherlich has as yet explained himself but imperfectly, respecting the general principles, to which he would refer these curious coincidences of crystallographical character.

One thing, however, would seem to be fully established; namely, that a certain correspondence often exists between the crystalline form of compound bodies and the number of their constituent atoms; a circumstance which alone holds out sufficient promise, to induce us to prosecute the inquiry he has set on foot.

Whether indeed all compounds, containing the same proportion of oxygen, are capable of assuming analogous crystalline forms when combined with the same acid, or whether they require to be subdivided into several distinct groups, does not appear from the published memoirs of the discoverer, who, with proper caution, has hitherto contented himself, with proceeding step by step to establish by observation certain isomorphous groups, without as yet venturing to pronounce, how many of them may be parts of a common series.

Yet even taking the facts as we find them, the inferences both of a theoretical and practical nature, which they necessarily suggest, are in the highest degree important.

They in the first place supply us with an additional argument in favour of the existence of atoms, by leading us to conclude, that, as certain bodies assume similar forms, their ultimate particles ought to resemble each other in figure and size; now this correspondence, in either respect, seem

ncilable with the notion of such bodies being suscepti-
of infinite division.

The doctrine of isomorphism also explains the want of correspondence between the analyses of the same body, as given by different individuals, on whose skill in manipulation we can place the fullest reliance.

So diversified indeed were the materials detected in different samples of the same mineral, that the only way of explaining the resemblance in their external characters was by assuming, that some one ingredient gave laws, as it were, to the rest, and stamped its own crystalline form upon the entire mass.

Thus in the mineral called *pyroxene*, Hauy considered the common ingredient which gave it its characteristic figure, to be silicate of lime, and the remaining bodies present, as purely accidental, being interposed amongst the molecules of this the essential substance, without affecting their arrangement.

But the views of Mitscherlich have enabled us to explain this circumstance upon another principle, it being found by Rose, that all the varieties of pyroxene, whatever may be their ingredients, have the same atomic constitution, corresponding with the formula

$3\dot{R}+4\dddot{Si}$, where $\dot{R}$ may be $\dot{C}$, $\dot{Mg}$, $\dot{Fe}$, or $\dot{Mn}$.

Thus too the mineral called *epidote* contains 2 atoms of silicate of alumina combined with 1 atom of a silicate, either of lime, or of protoxide of iron, which are isomorphous bases, its formula being

$$\dot{R}\,\dddot{Si}+\dddot{\underline{A}}\,\dddot{Si}.$$

Now the circumstance which gave the latter hypothesis a decided advantage over the preceding one, was the difficulty of pointing out in some instances, and particularly in that of the garnet species, any one compound, which belonged to all, without exception, of the varieties of this mineral.

They were, it is true, silicates, but the silicic acid was combined, in some cases with alumina, in others with lime, in a third class with oxide of iron, and in a fourth with magnesia. The only base that was found in every one was manganese, and this apparently in too inconsiderable a proportion to influence the crystallization of the mass.

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The following are the results of the analysis of 13 *varieties of garnet, made by the Swedish chemist, Wachtmeister and published in the Stockholm Transactions for* 1823.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Silica	40,60	42,51	41,00	42,00	39,93	35,10	35,64	38,125	37,993	42,450	40,20	40,55	52,107
Alumina...........	19,95	19,15	20,10	21,000	13,45	—	—	7,325	2,712	22,475	6,95	20,10	18,035
Peroxide of iron	—	—	—	—	14,90	29,10	30,00	19,420	28,525	—	20,50	5,00	—
Lime	—	1,07	1,50	4,980	31,66	26,91	29,21	31,647	30,740	6,525	29,48	34,86	5,775
Magnesia	—	—	6,04	4,320	—	—	—	—	—	13,430	—	—	—
Protoxide of iron	33,93	33,57	28,81	25,180	—	—	—	—	—	9,292	—	—	23,540
Protoxide of manganese } ...	6,69	5,49	2,88	2,375	1,40	7,08	3,02	3,300	0,615	6,273	4,00	0,48	1,745
Potass.	—	—	—	—	—	0,98	2,35	—	—	—	—	—	—
Loss	—	—	—	0,145*	—	0,83*	—	0,183*	—	—	—	—	—
Total	101,17	101,79	100,33	100,00	101,34	100,00	100,22	100,000	100,585	100,445	101,13	100,99	101,202

* Including some carbonic acid.

Now it was extremely difficult to understand, upon the old hypothesis, that analogy in the crystalline form of the minerals here enumerated, which had caused them to be ranged under the same species; but the discovery of Mitscherlich solves the whole mystery, by shewing that all the ingredients are silicates of isomorphous bases, any one of which may be substituted for the rest, without altering materially the standard character of the crystallization.

Thus, in all the varieties of garnet above enumerated except one, it will be seen that the constituents are, 1 atom of a silicate of some base containing 3 atoms of oxygen, such as alumina and peroxide of iron, combined with the same quantity of a silicate of a base containing a single atom of oxygen, such as lime, magnesia, protoxide of iron, and protoxide of manganese. Hence in the first instance, the alumina may be substituted for the peroxide of iron, and in the second, the magnesia, protoxide of iron, or manganese for the lime.

In the 13th variety, which cannot be referred to this head, Wachtmeister conceives that the appearance of the mineral indicates the mechanical admixture of certain foreign substances, and hence contends, that its composition ought not to be adduced as invalidating a general law, which twelve other varieties coincide in indicating.

A circumstance, that contributes to render the chemical composition of minerals more complex and diversified, is, the tendency which isomorphous salts appear to have to combine, which is such as to create an extreme difficulty in separating them by artificial means.

Thus all the species of alum (observes Beudant*) have so strong a tendency to mix together, that it is very difficult to counteract it, neither, when once united, can they be completely separated, even by repeated crystallizations. Mixtures of the same kind occur between nitrate of baryte and nitrate of lead, between the nitrates of potassa and soda,

* Mineralogie, page 399.

between the sulphates of iron, cobalt, nickel, &c., and between the sulphates of zinc, soda, and magnesia, &c. &c. These mixtures occur, not only when a solution contains merely the salts of the above mentioned group, but if a great number of salts be dissolved in the same liquid, they will form by preference; so that it may be said, that salts belonging to the same order of composition seek each other, as it were, so as to crystallize together, and mix in every proportion."

In a Memoir which I published several years ago on the methods of separating lime from magnesia*, I pointed out the difficulty which occurs, in separating *completely* by the usual reagents magnesian salts from calcareous ones, or *vice versa*.

Thus for example it would appear from my experiments, that a solution, consisting of 1 grain of sulphate of lime, and 100 grains of sulphate of magnesia, in one ounce measure of water, was not rendered turbid by oxalate of ammonia till many hours afterwards, although the same solution of lime, without the magnesia, became so immediately under the same treatment.

For the same reason it would appear, if my experiments are to be relied on, that bicarbonate of ammonia, which with magnesia alone forms a compound readily soluble in water, when added to a solution containing a magnesian as well as a calcareous salt, carries down a small portion of the magnesia with the carbonate of lime precipitated.

Now as the salts of lime and of magnesia are isomorphous, we may perhaps account for the difficulty of completely separating them by chemical re-agents, on the same principle, by which their tendency to crystallize together is to be explained †.

* In the Edinburgh Philosophical Journal, vol. vii. 1822.

† For some further remarks on this subject, see Appendix.

CHAPTER III.

Uses of the atomic theory in correcting the errors of experiment, and superseding the necessity of so constant an appeal to it—Also from its applicability to cases in which chemical analysis would not be available—as in ascertaining the proportions of bromine and chlorine in a substance found to contain both.

Application of the atomic theory to mineralogy—Minerals shewn by Berzelius to be definite compounds of an acid or electro-negative, with a base or electro-positive body, silica belonging to the former class—Exceptions to this remark, how to be explained.

A natural classification of minerals must be founded on their chemical properties—Objections to one based on crystallization, except it be as a means of distinguishing minerals artificially—Possibility of one day combining the natural and artificial arrangements, by the aid of the doctrine of isomorphism.

Definite proportions prevail in the products of the vegetable and animal kingdoms, and an analogous law may be inferred to hold good in the structure of plants, from the numerical proportion observed in their floral organs, &c. and even may be traced throughout the system of the universe, in the distances of the planets from the sun, and of the satellites from their respective primaries.

It may be interesting, in this stage of the inquiry, to point out a few of the more important practical applications, which the doctrine of definite proportions admits of.

It would indeed be superfluous, to enlarge upon the proofs already afforded, with respect to the greater precision it has introduced into the science,—the wonderful saving of time and labour which is derived from it, not only by the philosopher in his more speculative inquiries, but even by the manufacturing chemist, in the every day operations of his trade.

It is evident, that in the present state of our knowledge, no sooner have we ascertained the exact proportion, in which a new substance unites with any one of those bodies whose atomic weight is already determined, than we are enabled to calculate in what quantities it must combine with all the remainder, so that, instead of being compelled, as heretofore would have appeared necessary, to analyze every existing combination, in order to determine the proportion of its ingredients, we might rest contented, were it not for the sake of obviating the chances of error in any single experiment, with ascertaining the composition of one out of the whole number of compounds, into which the ingredient in question enters.

Thus for example, knowing already the combining quantities of the several alkalies and earths, nothing more would be required for ascertaining the composition of all the sulphates, than to determine what proportion the acid might bear to the base in any single salt, and the number of atoms of acid present, its proportion to the remainder being thence deducible by the common rules of arithmetical proportion, or by the use of the mechanical contrivance of the sliding rule.

It is in this way, that Dr. Thomson and others have laid down the composition of so vast a variety of substances, that, had not the proportion of their ingredients been determinable by the simple law already explained, it might have required ages of laborious experimental research to have completed their analysis.

But the atomic theory is not only useful, by saving the necessity of so frequent an appeal to experiment, as well as by correcting its inaccuracies, but is also available in cases, where the latter would in no degree serve our purpose.

It sometimes happens, that two bodies agree so nearly with respect to the range of their affinities, and the nature of the compounds resulting from their union with the same elements, that we find it exceedingly difficult to separate them by chemical means one from the other.

This agreement in the details holds good, as might be expected, most remarkably between bodies, which, resembling each other most nearly in their primary properties, are thrown together into the same class, such substances bearing to each other a relation, similar to that of two nearly allied families of plants or animals, the members of which can only be distinguished, by an attentive examination of the degree in which their several characteristic properties are developed, or by some secondary difference, which appears to flow but remotely from their leading characteristics.

Thus the fixed alkalies form, with the several acids, salts, which, though differing in point of solubility one from the other, are yet for the most part not so contrasted in that respect, as to afford a ready means of separating them.

The same holds good with respect to several of the earths, and still more strikingly with the compounds of chlorine and bromine.

The latter substances, indeed, I have found myself unable, by any expedient I could devise, to separate completely one from the other*; neither do I find from the original researches of Balard, or the subsequent investigations of Berzelius, on the latter principle, that either of these distinguished chemists pretends to have been more successful.

Perhaps, however, an indirect method of calculating the proportions, in which these two elements exist in a compound ascertained to contain both, may be furnished by a knowledge of their respective atomic weights, if we adopt a formula, similar to that pointed out several years ago by Monsieur Gay-Lussac, as applicable to the case of mixed salts consisting partly of soda and partly of potass, combined with the same acid.

Let us suppose, that we have obtained from a given quantity of the substance under examination 100 grains of a salt, consisting of sulphuric acid, with unknown proportions of soda and potass, but with no other ingredient.

Let us set down the quantity of acid at 50 grains, from which it will follow, that the weight of the two bases will together make up the remaining moiety.

Now had the whole of this latter consisted of soda, the quantity of acid should have been only 40 grains, because

* See my Memoir on the occurrence of iodine and bromine in certain English mineral waters, quoted above.

the atomic weight of sulphuric acid is 40, whilst that of soda is 32, and

As 40 : 32 :: 50 : 40

On the contrary, if the whole had been potass, then, as the atomic weight of this latter is 48, the amount required to neutralize the acid would have been 60 grains; for

As 40 : 48 :: 50 : 60

But if we suppose half the acid to be combined with the one alkali, and half with the other, then, and only then, will the weight of the salt correspond exactly with that obtained in the experiments before us; for

As 40 : 48 :: 25 : 30, and
As 40 : 32 :: 25 : 20

50 + 50 = 100

It is easy to apply this to the case of salts containing bromine together with chlorine, assuming that we are sufficiently acquainted with the respective atomic weights of both these principles.

The hydrobromate and muriate of soda are alike precipitated by nitrate of silver, in the form of an insoluble chloride and bromide of that metal.

Now the atomic weight of silver is stated to be 110
Of chlorine 36
Of bromine 78.36

Suppose therefore we have found the precipitate to weigh 151 grains; and that, of these, 100 grains have been ascertained by other experiments to consist of silver: then

As 110 : 78.26 :: 50 : 35, and
As 110 : 36 :: 50 : 16

100 + 51 = 151

If therefore half the silver were combined with bromine, and the other half with chlorine, the compound produced would amount to exactly 151 grains, which is found to correspond with the quantity actually obtained.

An algebraical formula* has been proposed for determining, on the above data, the amount of the ingredients pre-

* Let $W=$ the number of grains of the mixed salt operated upon,

$a=$ the grain measures of the test which W grains of (p) would require,

$b=$ the grain measures of the test which W grains of (q) would require,

$c=$ the grain measures of the test which W grains of the mixture operated on *have required.*

Suppose $x=$ grains of (p) contained in W grains of the mixture,

$W-x=$grains of (q) ditto, ditto,

$$\text{Then } \frac{W.p}{W.q}=\frac{a}{b}=\frac{p}{q}$$

$$\text{And } \frac{x.p+(W-x)\,q}{W.p}=\frac{c}{a}$$

$$\therefore x+\left(W-x\right)\frac{q}{p}=W.\frac{c}{a}$$

$$\therefore x-x\frac{b}{a}=W.\left\{\frac{c}{a}-\frac{b}{a}\right\}$$

$$x\left(\frac{a-b}{a}\right)=W.\left(\frac{c-b}{a}\right)$$

$$x=W.\left(\frac{c-b}{a-b}\right)=\text{grains of } p.$$

$$W-x=W.\left(\frac{a-c}{a-b}\right)=\text{grains of } q.$$

Say that 200 grain measures of the test are equivalent to 10 grains of muriate of soda, then 10 grains of muriate of potash would require 157.9 grain measures (nearly) of the same test.

Suppose that we have 178.95 grain measures exhausted in one experiment in 10 grains of a mixture of the two salts,

$$\text{Then } x=W.\frac{c-b}{a-b}=10\times\frac{178.95-157.9}{200.\ -157.9}=10\times\frac{21.05}{42.1}$$

$=$ 5 grains of muriate of soda,

$$\text{And } W-x=W.\frac{a-c}{a-b}=10\times\frac{200-178.95}{200-157.9}=10\times\frac{21.05}{42.1}$$

$=$ 5 grains of muriate of potash.

Journal of Science, vol. xx. p. 394.

sent in every conceivable case that may offer; but those, who prefer arriving at the result in a more common-place manner, may perceive by the following table, how easily an approximation may be obtained to the proportion of the bases present, when once we have determined the relative quantities, of the original mixed salts, and of the precipitate caused by the re-agents employed.

Thus let the substance under examination be a salt of soda, and let 100 grains of it form, with nitrate of silver, a precipitate weighing 220 grains. The quantity of bromine and of chlorine which must be present will then be seen by the mere inspection of the following table.

Quant. of salt.		Quant. of precipit.	Quant. of salt.		Quant. of precipit.	Amount of precip. from the two salts.
100 br. sod.	=	184.5 br. silv.	0 ch. sod.	=	0 ch. silv.	184.0
90	——	166.0	10	——	24.3	190.3
80	——	148.0	20	——	48.3	196.3
70	——	129.5	30	——	73.0	202.0
60	——	111.0	40	——	95.5	208.5
50	——	92.5	50	——	121.5	214.0
40	——	74.0	60	——	146.0	220.0
30	——	56.0	70	——	170.0	226.0
20	——	37.0	80	——	195.0	232.0
10	——	18.5	90	——	219.0	237.5
0	——	00.0	100	——	243.0	243.0

The atomic theory has also supplied the foundation for a natural arrangement of minerals, on the principle of their chemical composition—a point, which ought doubtless to stand foremost in the scale of importance, with reference to a study such as mineralogy, which is indebted to chemistry, both for its interest and its advancement, so mainly, as indeed to deserve to be considered rather as an offset from the latter science, than as an entirely independent department of knowledge.

In order to appreciate the assistance, in this mode of classification, that has been derived from the doctrine of definite proportions, it may be sufficient to glance over the tables of the composition of mineral bodies, appended to Mr. Allan's useful little tract, entitled, Mineralogical Synonymes, the second edition of which was, I believe, published about the very time we were presented with a translation of the work of Berzelius, in which, by means of the clue which the recent discovery of Dalton had afforded him, he attempted to elicit something like order out of this apparent chaos.

At first sight indeed nothing could seem more desperate, than the attempt to account, on any fixed and definite principles, for the combinations between one body and another, which these and other tables of the kind exhibited; in which the ingredients themselves not only seemed to be present in every imaginable quantity, but were linked together, without the intervention of any substance, for which they were known to exert an affinity; so that, strange as it would be to suppose, that bodies obeyed different laws, when brought together in the great laboratory of nature, from those which influenced them in our artificial processes, still the idea of extending to crystallized minerals in general the same inferences, which were admitted with regard to ordinary chemical products, was, for many years after the introduction of the atomic theory, ridiculed as absurd and impracticable.

But the difficulties, that stood in the way of such an undertaking, were in a great degree removed by the happy idea of considering the silica, so commonly present in minerals, as acting the part of an acid, and consequently as being combined with the other earths, and with the alkaline and metallic oxides, in definite proportions.

It is no wonder that this innovation was at first resisted; for it could not but give a shock to all our preconceived notions, to extend this generic term to a substance like flint, so remarkably deficient in those sensible properties, the possession of which first led us to apply the name of acid, to such bodies, as *oil of vitriol*, or *aqua fortis*. It may be observed, however, that a similar change has taken place in the acceptation of the term *metal*, as in that of *acid*, and that our forefathers would have been as much startled, at seeing placed under that head a body like potassium, which is lighter than water*; or one like arsenic, which is inflammable, and readily volatilized; as the cotemporaries of Berzelius were by his application of the term *acid* to silica. In either case, the scientific meaning, conveyed by the words in question, had by degrees been so changed from that which originally had belonged to them, that they no more expressed the ideas attached to them by the vulgar, than the sulphur and mercury, in the nomenclature of the alchemist, represented the substances, to which the same names were applied in the common language of the day.

It might afford a curious subject for discussion, how far a complex idea may have its original meaning changed, by being stripped of what was once considered a part of its essence, without losing thereby, as it were, *its personal identity*, or requiring the imposition of a new name, to designate the portion of it that still remained. But in what light soever we regard the propriety of the term, as applied to the substance in question, it is certain that a great point was gained in mineralogy, by establishing, that the earths stand in the relation of acid and alkali one towards the other, and consequently combine together in proportions really as definite, as those existing between other binary compounds before investigated.

Thus in Berzelius' System of Mineralogy we have a class of silicates—minerals in which silica acts the parts of an acid—corresponding with the sulphates, nitrates, and carbonates which we produce in our laboratories; we find this

* So inseparable, by long association, are the ideas of metallic ponderosity and metallic splendour, that the evidence even of the senses may fail in disuniting them. This is well illustrated in the following amusing anecdote. Shortly after the discovery of potassium, Dr. George Pearson happened to enter the laboratory in the Royal Institution; and upon being shewn this new substance, and interrogated as to its nature, he, without the least hesitation, on seeing its lustre, exclaimed, "Why, it is metallic, to be sure!" and then balancing it on his finger, he added, in the same tone of confidence, "Bless me, how heavy it is!" *Paris's Life of Davy*, vol. i. p. 268.

substance in the proportion of one, two, or three atoms, forming silicates, bisilicates, trisilicates, as we have sulphates, bisulphates, and the like; and to complete the analogy, we find the silica combined with 2 bases, as with iron and manganese, in a manner corresponding with the triple salts, of which we have such frequent examples in chemistry.

Lastly, these compounds are again combined with others similarly constituted, in quantities still retaining with reference one to the other the same relative proportions.

Thus the mineral called *nepheline* is a silicate of alumina, one from Fahlun, unnamed, a bisilicate. *Felspar*, on the other hand, is a trisilicate of alumina and of potass; *crysolite*, a silicate of iron and manganese; whilst by far the greater number of silicious minerals are examples of the kind last alluded to, in which one silicate is united to another. Thus *aplome* is a compound of silicate of alumina and of iron, with bisilicate of lime; *cross-stone* a bisilicate of alumina, with quadrisilicate of barytes.

It must be confessed, however, that although abundant evidence has been produced, which may satisfy us, that in many minerals the proportions of the ingredients are reducible to the above principles, yet that the results of analysis frequently do not tally with any laws of proportion.

These anomalies, however, Berzelius attributes in part to inaccuracies of manipulation, and in a still greater degree to the intermixture of foreign ingredients, which we observe in our artificial processes in spite of the greatest care in purifying them, and which we need not therefore be surprised to find occurring in a much greater degree, in those natural processes, that have taken place in the interior of the earth, to which crystallized minerals owe their origin.

The various colours, which the same mineral often assumes, serve to prove, that foreign ingredients may insinuate themselves into the substance of a mineral, without affecting the character of its crystallization, and the curious affinity observed by Mitscherlich to prevail between isomorphous salts must tend to favour the intermixture of different compounds without producing any alteration in the external form.

These considerations are sufficient to vindicate the soundness of the principle on which Berzelius has proceeded, and to induce us to adopt it as the basis of a natural system of mineralogy, wherever it appears to be applicable.

A classification of minerals, indeed, founded on their chemical constitution, although totally inefficient as a means of discriminating species, and therefore altogether unfitted for the purposes of an artificial system, is perhaps a more natural one even than that framed from considering the analogies of crystalline form, since the former is nothing but the expression of their fundamental differences and analogies, the latter only of one of the consequences flowing from them.

A system too that should be based on differences of crystallization, would embrace after all but a part of the subject itself, since many bodies occur constantly, and a still larger proportion of them occasionally, in an amorphous condition; so that we should be driven in such cases to have recourse to other characters less susceptible of precision, and subject to a greater degree of variation.

It is also certain, that a classification established on chemical principles, conveys with it information in every respect more interesting, both in a scientific and practical point of view, than one dependant on the external characters merely; the latter indeed may answer the purposes of the few that pursue crystallography as an *end* instead of the *means*, and trace out the varieties of form exhibited in minerals, purely as an exercise of their mathematical ingenuity; but the former must be best adapted to the great mass of mankind, who resort to a system of mineralogy, as a storehouse of information, with respect to the uses, the intimate nature, and the chemical relations of the substances enumerated.

It would be of little consequence indeed which system we adopted, if the two methods always ran parallel; and if it were true, as we might *a priori* conceive, that every variation in the kind and proportion of the constituents was attended with a corresponding one in the physical characters, and every distinction of form derived from a change in the component parts.

But we have already seen that neither of these two propositions can be admitted universally, different substances sometimes crystallizing alike, provided the relation between the number of atoms composing their ingredients continue unchanged; and the same substance assuming under particular treatment a crystallization different from that which it more commonly presents.

I conceive therefore that it will be found necessary to adhere to the chemical constitution of mineral bodies, if we wish to classify inorganic substances on principles similar to those, which have guided Cuvier and Jussieu in their natural arrangements of the animal and vegetable kingdoms.

Such a classification, it will be recollected, by no means supersedes, or interferes with, an artificial one, which, like the Linnean system of botany, should aim at facilitating the discrimination of species merely, and not at pointing out their true relations one to the other.

The older treatises of mineralogy, including even that of Werner, endeavoured unsuccessfully to combine the two methods; but Mohs has devised a system purely artificial, in which bodies are placed together without any reference to their chemical composition, according as they agree in those external characters by which he proposes to discriminate them.

It is not impossible however, that a natural mode of classification may eventually spring up out of this very method of arrangement, since many of the bodies, thus artificially grouped together, appear to be isomorphous, and probably derive their resemblance in form from the analogy in their atomic constitution.

This is well shewn in the tables attached to the "Essay on Mineralogical Classification and Nomenclature," by professor Whewell*; who observes, "that if the chemical analogies of each class were completely and certainly known, we might probably express them by means of an algebraical formula,

* Cambridge, 1828.

in which some of the symbols might have any of several elementary letters substituted for them. Some of the groups and orders, as Garnet, Amphibole, Zeolite, &c., seem to lead to such expressions. But it seems probable that our knowledge of the analogies among minerals, and of their laws and limits, is at present too imperfect to supply us immediately with most of their formulæ.

"When minerals have been sufficiently examined and studied by accurate and intelligent chemists, *in this point of view*, we may hope to see the subject assume a much greater simplicity and order than we can at present detect. And it does not appear too much to say, that by this means no small light will be reflected back upon chemistry, through the relations thus to be discovered among those ingredients which occupy similar places in our formulæ.

"We find here, for instance, that some oxides of metals, as the *protoxides of iron* and *manganese*, seem to belong to one class of earths, as *lime* and *magnesia*; whilst other metallic oxides, such as the *peroxide of iron*, arrange themselves with a set of earths of a different function, as *alumina*. In the same way we find *phosphoric* and *arsenic* acid occurring analogously; we find in some cases *selenium*, in some *arsenic*, in some *tellurium*, imitating *sulphur* in the properties they impress upon metals by their combination.

"Several other probable connections might be pointed out, but for any thing like a systematic induction of this kind, the subject does not appear yet to be ripe."

It is possible therefore, that at some future time, a system of mineralogy, combining the advantages of a natural and an artificial method, may be proposed, which shall be based entirely on the atomic constitution of bodies, and the doctrine of isomorphism, which has proceeded from it, thus affording additional proof of the widely spreading influence of this discovery; yet even at present we need not this further step to convince us, that the law of definite proportions extends throughout the whole of inorganic matter.

Neither do vegetable or animal products appear exempt from its influence, although a provision exists, according to the ingenious views of Dr. Prout, for preventing its interference with the operations of life; a minute portion of some foreign matter being superadded to every definite compound intended to be assimilated, which, either by the interposition of its particles, or perhaps in some other less intelligible way, counteracts the operation of that cohesive attraction, the tendency of which is to impart somewhat of a crystalline character to the mass.

It would, doubtless, be unphilosophical to attribute to the self-same law of nature, the proportion existing between the particles that compose a compound body, and the relation of number that has been traced amongst the parts of the floral organs in plants; yet it may not be without interest to notice, as a proof of the analogy which runs throughout the whole of creation, and as indicating, perhaps, that the law of definite proportions itself, widely spreading as it seems, is but one of the consequences of some more comprehensive principle, the conclusions which the most distinguished botanists of the present day have arrived at, as to what ought to be regarded as the primitive types of monocotyledonous, dicotyledonous, and acotyledonous plants; these constituting the three great classes into which the vegetable kingdom may be divided.

Mons. Decandolle observes*, "that the numbers 4, 5, and their multiples, appear to belong peculiarly to dicotyledonous plants; the number 3, and its multiples, to monocotyledonous; the number 2, and its multiples, to be established among the acotyledonous in the great family of mosses." That exceptions from this standard are numerous, will be evident, when we recollect, that the main principle, on which the artificial arrangement of Linnæus proceeds, is founded on the difference of number in the floral organs; but those, who will take the trouble of perusing the philosophical remarks of the botanist alluded to on this subject, will, I flatter myself, rise with the conviction, that these deviations from the supposed standard may be explained by

* Theorie Element. p. 157.

the interference of other causes, such as the abortion of certain parts, or the adhesion of two or more, so as to have the appearance of one; whilst the existence of the same tendency towards regularity may be traced even in these, by an occasional return to the ideal structure, whenever the causes which usually interfere with it are accidentally removed.

Mons. Decandolle has also shewn, that this numerical proportion exists between the members of the different organs that together constitute the same flower, as well as between the component parts of different flowers belonging to the same class.

Thus the relation of number between the parts of the calyx and corolla is very remarkable, and the deviations from this regularity that are met with, may be referred to the causes above assigned, being most frequent where the parts are most numerous, the chances of abortion or of adhesion being increased in proportion.

The same relation extends likewise to the stamens, subject to occasional deviations, and even in the pistillary system, which presents the greatest anomalies in this respect, it may be observed, that the number of the valves of the pericarp, of the placenta, of the pistillary chord, of the styles, and the stigmas, &c., is always in the proportion of 1 to 1, 1 to 2, 2 to 1; so that one of these organs may serve to determine the rest, allowing for exceptions from abortion, &c.; and that when the parts of the pistils are disposed in a whorl-shaped manner around an ideal or real axis, the number of their parts is in a determinate relation to that of the other parts of the flower, this relation being one of the following:

1 to 1	2 — 5 or its multiples.
1 — 2 or its multiples.	3 — 5 or ditto.
1 — 3 or ditto.	4 — 5 or ditto.
1 — 5 or ditto.	2 — 1.
2 — 3 or ditto.	

Lastly, we learn from astronomers, that the members of the planetary system to which we belong, are themselves subject to a law of an analogous kind.

Bode has observed, that the magnitudes of the several orbits which the planets describe, bear a certain definite proportion one to the other, the distances of Mercury, Venus, the Earth, Mars, &c. from the sun, being that of the numbers 4, 7, 10, 16, 28; so that the differences are as 3, 3, 6, 12. The law was interrupted between Mars and Jupiter, so as to induce him to consider a planet as wanting in that interval; a deficiency long afterwards supplied by the discovery of four new planets in that very interval, all of whose orbits conform in dimension to the law in question, within such moderate limits of error, as may be due to causes independent of those on which the law ultimately rests*.

There cannot be a sublimer subject for contemplation, or one more calculated to elevate our ideas with respect to the Divine attributes, than the correspondence, which may thus be traced between the laws that pervade the whole of creation, from the ultimate particles of matter, which, by their extreme minuteness, baffle our very powers of conception, to those immense aggregates of them, which compose any one of the members of our own planetary system; and as, according to the grand conception of Boscovich, the attraction of gravitation, and that of cohesion, may perhaps turn out to be the same force exerted at different distances, so the various ways, in which, as we have seen, the tendency to definite proportions (if I may so express myself) manifests itself throughout the whole of nature, will perhaps be

* In the 3rd volume of the Cambridge Transactions, Mr. Challis has attempted to extend Bode's law of the distances of the planets from the sun, to the distances of the satellites from their respective primaries. He shews that the differences of the distances of Jupiter's satellites, are very nearly in the ratio of $2\frac{1}{2}$; those of Uranus in that of $1\frac{1}{2}$; authorizing the conjecture, that there are two undiscovered satellites between the 4th and 5th, and one between the 5th and 6th. In the case of Saturn's satellites, the ratio is further departed from, perhaps from the interference of the ring.

eventually traced to the same law; of which, what is called the atomic theory, comprehensive as it may be, is only one of the consequences.

It is this indeed, which constitutes the most striking distinction between the effects of art and of nature, the provisions of finite and of infinite intelligence;—the former accomplishing its purposes by a multitude of particular contrivances and regulations, which being made to meet each circumstance as it arises, are inconsistent one with the other, and at the best are applicable to a limited number only, out of the infinite variety of possible cases;—the other producing an immense series of effects by a few very simple laws, which not only harmonize exactly one with the other, but are afterwards found to be themselves the consequences of a still smaller number of first principles.

CHAPTER IV.

Other arguments in favour of the existence of atoms considered —from the limited extent proved to belong to the atmosphere of the sun and planets by Dr. Wollaston, and to the earth's atmosphere by professor Leslie—from the existence of a limit to evaporation in all bodies, according to Mr. Faraday.

Speculations as to the nature of the elements of matter.

Inquiry how far the doctrine of definite proportions was anticipated by Pythagoras, or by the Egyptians, from whom that philosopher derived his tenets—Sense which he attached to the word *number*—Reflections as to the knowledge of the physical sciences possessed by the priests of Egypt, and by other eastern nations—Services rendered to science by Democritus, who is shewn to have led the way in that path of experimental research, which has conducted the moderns to the laws of definite proportions, and to other important results.

HAVING presented a short outline of those chemical researches, which afford the most convincing evidence that matter consists of indivisible particles, I shall conclude this Essay, by pointing out one or two additional proofs in favour of the same theory, derived from modern observation or experiment.

For the first of these we stand indebted to one, who might be termed emphatically a *microscopic philosopher*, a man less remarkable perhaps for depth and range of intellect, than for the extraordinary acuteness of his mental vision— the quickness with which he descried distinctions, and seized upon analogies, indiscernible to mankind in general.

Dr. Wollaston, in his very ingenious memoir, published in the Philosophical Transactions for 1822, has shewn, that, on the hypothesis of matter being infinitely divisible, there ought, strictly speaking, to be no positive limit to the extent of our atmosphere, but that each of the planets would be surrounded by an aërial fluid, gradually decreasing indeed in density in proportion to the distance from its surface, but still indefinite in point of extent.

For the force of repulsion, which tends to keep the particles of an aëriform fluid at a certain distance apart, must operate wherever any portion of air exists, and although in the higher regions of the atmosphere the repulsive force would be diminished by the rarity of the medium, yet, in consequence of that very rarity, it would be in a less degree counteracted by the superincumbent pressure.

On the other hand, if we suppose the atmosphere to be made up of atoms, or to consist of a finite number of elementary molecules, the parts of which are linked together by a bond which nothing can disunite, it will follow, that at a certain height above the surface, the force of gravity, which tends to draw the particles towards the earth, would counterbalance the power of elasticity or mutual repulsion, which gives them a contrary tendency, and wherever that point exists, there a boundary to the extent of the atmosphere must be found.

Dr. Wollaston, though unable to discover by his method, what might be the case with respect to our own atmosphere, has rendered it probable, that that which surrounds other of the celestial bodies belonging to the same system, is limited in extent.

He shews, for instance, that if all space were filled with matter, as on the supposition of the atmosphere being unlimited would be the case, the heavenly bodies must attract to themselves an aërial fluid of more or less density, in proportion to their respective bulks.

He therefore proceeds to inquire, whether the atmosphere surrounding the sun is of that density, which it ought to be from the attraction of a mass of matter of its enormous magnitude. As the density of air may be estimated by its power of refracting the rays of light, the degree in which the apparent position of a planet, when seen through a solar atmosphere, differs from its real one, may serve to measure the density of the medium, which intercepts its rays.

The occultation of Venus by the body of the sun furnished him with the means of determining this question, and it was concluded from the observations made upon this planet, that its apparent position was not in the least affected by any refraction of the rays proceeding from it through a solar atmosphere, thus justifying the conclusion, that none existed of that density which would have surrounded it, had matter been uniformly diffused throughout space.

To obviate the objection arising from the heat of the sun, which might diminish the density of its atmosphere in a degree beyond calculation, a corresponding series of observations was made with respect to Jupiter, and with similar results; the atmosphere surrounding that planet not appearing of the density, which would have belonged to it under the same circumstances.

Professor Leslie *, availing himself of a suggestion thrown out by the celebrated Kepler, has been conducted to the same final result by a very different train of argument, as he infers from the phenomena of twilight, that the atmosphere surrounding our own planet is likewise of limited extent †, thus establishing by direct inference, what Dr. Wollaston concluded to be the case from analogical reasoning.

Mr. Faraday, in an ingenious Memoir read before the Royal Society ‡, has corroborated these views respecting the limited extent of the atmosphere, by shewing that there is nothing anomalous in such an arrangement, other bodies being subject to a law of an analogous kind. He proves,

* See article Meteorology in the Supplement to the Encyclopædia Britannica. It may be doubted however, whether professor Leslie's conclusions exactly meet the question, since they do not appear to disprove the possibility of an atmosphere pervading space, provided it be so attenuated, as not to reflect in an appreciable degree the rays of light, and consequently not to interfere with the phenomena of twilight.

† According to Kepler, the atmosphere extended to about 49 miles above the earth's surface; but professor Leslie, from other considerations, calculates it, as ascending to the height of 1638 miles.

‡ On the limits to evaporation, Phil. Trans. for 1826.

for instance, that contrary to what was commonly thought, there is a certain temperature, and for most bodies not a very low one, at which all evaporation of their substance is stopped, the force of gravity belonging to the particles which compose them, here counterpoising the force of repulsion, which tends to separate them beyond the limits of cohesion.

Between 60 and 70 of Fahrenheit quicksilver rises in vapour, until the vessel containing it is filled with an *atmosphere* of that fluid, a fact which is substantiated by suspending over it a sheet of gold leaf, which soon becomes whitened and impregnated by the volatile metal.

Hence it would appear, that under ordinary temperatures the force of repulsion was more than a match for that of gravitation. But if we reduce the heat to that of Zero, although the mercury retains its fluidity, still no evaporation takes place from its surface, the elasticity of its particles being no longer sufficiently powerful to overcome the resistance opposed by their weight.

Now, I think, it may be inferred, agreeably to the principles on which Dr. Wollaston has proceeded, that if the matter composing this metal had been capable of infinite division, evaporation would have gone on in it at all temperatures up to the point of the absolute privation of heat. For in this case, the repulsive force caused by caloric ought to be exerted between the smallest portions of matter as well as the larger ones, so that, however feeble the power of repulsion may be, yet, as we suppose it exerted on parts of matter so minute, as to possess in a still slighter degree the counteracting force of gravity, it would continue to produce a certain effect.

From all these concurrent arguments, we seem to be justified in concluding, that a limit is to be assigned to the divisibility of matter, and consequently that we must suppose the existence of certain ultimate particles, stamped, as Newton conjectured, in the beginning of time by the hands of the Almighty with permanent characters, and retaining the exact size and figure, no less than the other more subtle qualities and relations which were given to them at the first moment of their creation.

The particles of the several substances existing in nature may thus deserve to be regarded as the alphabet, composing the great volume which records the wisdom and goodness of the Creator; since the characters which go to make it up, far from appearing to be thrown together by chance, and collected into unmeaning groups, as the Epicureans contended to have been the case, denote in every page, by the import they convey, the agency of mind, and speak a language, which, so far as it is intelligible to our finite faculties, is every way worthy of its divine Author.

Whether, according to the doctrine of some philosophers, these particles all belong to one original kind of matter, the πρωτη ὑλη of the Greeks, impressed with certain distinct properties, or with various modifications of the same—or whether, as others imagine, there were several elementary kinds of matter originally produced, which, by their intermixture and union, give rise to the infinite variety of appearances which diversify the face of creation—is a question to which no decisive answer can be returned.

The latter is the most easily intelligible hypothesis, and is moreover favoured by the fact, that the products of the animal and vegetable kingdom are all ascertained to arise out of a very few simple principles.

It would also be somewhat confirmed, if it should turn out that the atomic weights of the different bodies, which we regard as simple, bear a numerical proportion one to the other; an opinion which may still be tenable, even if it should be shewn, that the doctrine laid down by Thomson, as to their being all multiples of hydrogen, is to be viewed as erroneous.

On the other hand, it must be confessed, that the progress of discovery, instead of bringing us nearer to the knowledge of these elements, increases the difficulty of even conjecturing what they are likely to prove. Formerly nothing could seem more plausible than the doctrine of four elements, a notion introduced, as we have seen, into Greece by the Pythagoreans, but which appears to have been held both in Egypt and in India* for a long time previous to the epoch at which they flourished.

In modern times it long formed the creed of most persons who professed to reason upon such subjects, and even at the present day it is firmly rooted in the minds of the multitude, who, in philosophy, and in medicine, adopt the exploded theories of the age antecedent, just as the lower orders are wont to bedeck themselves in the cast-off habiliments of their betters.

We however have lived to see every one of these supposed principles reduced to other simpler forms of matter, whilst the bodies, that have most effectually baffled our powers of analysis, are often very scantily diffused throughout nature, and very limited in the range of their affinities.

Yet, if they are compounds, it might be expected that, like the products of the animal and vegetable kingdoms, they should be found occasionally convertible one into the other, if not by the powers of art, at least by the agency of natural causes: and the unchangeableness of their properties might therefore lead us to conjecture, that they are to be viewed rather as modifications of one primary matter, impressed by the Creator with characters sufficiently distinct to give each of them a place as separate and independent bodies, but yet so far approaching one to the other, as to constitute them links of a common series.

This view of the subject might be preferred by those, who contend for the law of continuity, as laid down by Leibnitz, and to which Boscovich has taken so much pains to accommodate his system; for if, according to this doctrine, nature does nothing *per saltum*, but passes from one change to another by minute and imperceptible gradations, it would seem more agreeable perhaps to analogy to sup-

* The Hindoos held that there were five elements, viz. earth, air, fire, water, and spirit.

pose a series of elementary substances, whose properties, like those of the metals, approach very near one another, than to imagine only three or four, so strongly contrasted in their natures, as the more common opinion assumes*.

But I fear I shall be accused of having deviated too far from that sobriety of thinking, which modern science so peculiarly exacts of her votaries, if I pursue these speculations further; I shall therefore conclude by considering, what grounds there may be to conjecture, that the ancients, who anticipated us in the corpuscular theory itself, had obtained any glimpse of the doctrine of definite proportions, on which the former is mainly built.

There have not been wanting among the learned individuals, who have contended, and with some appearance of probability, that a more profound knowledge of physics than any that has been transmitted to us by the ancients, may have belonged to the priesthood of Egypt and Chaldæa, and that the latter thus acquired that power over nature, which, under the disguise of magic, or other of the occult sciences, was employed by them, as one of the main instruments for augmenting their influence over the vulgar.

"There are traces," says bishop Berkeley†, "of pro-

* The curious researches of Cagniard de la Tour afford a considerable confirmation of the law of continuity; they shew, that as the solid condition passes by imperceptible gradations into the liquid, so does the liquid into the aëriform; whilst the still more recent ones of Mr. Faraday indicate, that the property of existing in a gaseous state is the exclusive condition of none, and that, as all bodies may be fused and probably volatilized by the addition of heat, so there are none, that may not be made to pass into a liquid or solid state, by its abstraction. Is it not probable, that future discoveries may also point out links connecting all the simple substances into one uniform series, as the researches of the geologist, combined with those of the comparative anatomist and the vegetable physiologist, bid fair to do with regard to the families composing the animal and vegetable kingdoms?

† On Tar Water, p. 141.

found thought in the Platonic, Pythagorean, Egyptian, and Chaldaic philosophy. Men in those early days were not overlaid with languages and literature. Their minds seem to have been more exercised and less burdened than in later ages, and, as so much nearer the beginning of the world, to have had the advantage of patriarchal lights, handed down through a few hands."

In corroboration of this view it might be contended, that tables for calculating the motions of the heavenly bodies, such as the places of the sun, moon, and planets, and rules for determining the phases of eclipses, have existed among the Brahmins, from a period more ancient than that, to which, with us, the history of the heroic ages is supposed to extend.

The system, on which these tables were constructed, implies, according to some, a considerable knowledge of geometry, arithmetic, and even of the theoretical part of astronomy; and, though at present in the hands of men, who follow its rules without understanding its principles, could hardly have been constructed originally without the existence of a body of science, the magnitude and extent of which may well excite our surprise.

Such was the opinion expressed by professor Playfair *, no mean judge of such matters, in consequence of an attentive study of the facts brought together on the subject by the learned Bailly †; though others have discredited this inference, and have maintained, that a continued and patient observation of stated occurrences was all that would have been required, in order to obtain the data for calculating such events.

The advocates for the claims of the ancients have however further to allege, that the germs of two of the most important discoveries of modern times, viz. the Copernican system of the heavens, and the Daltonian theory of definite

* On the astronomy of the Brahmins, in the Transactions of the Royal Society of Edinburgh, vol. ii. (1790.)

† Traité de l'Astronomie Indienne et Orientale, par Bailly, Paris, 1787.

proportions, are to be found amongst the dogmas of Pythagoras, who is generally admitted to have derived whatever is most valuable in his philosophy, from the priesthood of Egypt, a country which he appears to have visited, shortly before the power of that body received its first shock, in consequence of the Persian invasion under Cambyses.

With regard to the first, we have the authority of Plutarch* and others, for affirming, that the revolution of the world round a central fire was taught by the Pythagoreans, who even were aware of its moving in an oblique circle, and that the form of the temple of Vesta at Rome, in the midst of which stood the sacred fire, was typical of this belief. Accordingly these philosophers, he assures us, maintained, that our globe, far from being, according to the vulgar idea, the centre of the universe, held only an insignificant place among the members of one of innumerable planetary systems; and in this opinion, he says, that Plato, in his mature age, coincided.

It may however be replied, that although the testimony of ancient writers proves, that these philosophers had obtained a glimpse of the truth, it shews, at the same time,

* Νουμας δε λεγεται και το της Ἑστιας ἱερον περιβαλλεσθαι, τῳ ασβεστῳ πυρι φρουραν· απομιμουμενος, ου το σχημα της γης, ὡς Ἑστιας ουσης, αλλα του συμπαντος κοσμου, ου μεσον οἱ Πυθαγορικοι το πυρ ἱδρυσθαι νομιζουσι, και τουτο Ἑστιαν καλουσιν και μοναδα· την δε γην, ουτε ακινητον, ουτε εν μεσῳ της περιφορας ουσαν, αλλα κυκλῳ περι το πυρ αιωρουμενην, ουτε των τιμιωτατων, ουτε των πραγματων του κοσμου μοριων ὑπαρχειν· ταυτα δε και Πλατωνα φασι πρεσβυτην γενομενον διανοησαι, περι της γης, ὡς εν ἑτερᾳ χωρᾳ καθεστωσης, την δε μεσην και κυριωτατην ἑτερῳ τινι κρειττονι προσηκουσαν. Plutarch. tom. i. p. 67 in Vitâ Numæ.

Φιλολαος ὁ Πυθαγορειος, γην κυκλῳ περιφερεσθαι περι το πυρ, κατα κυκλου λοξου, ὁμοιοτροπως ἡλιῳ, και σεληνῃ. Plutarch. de Plac. Phil. lib. iii. c. 13.

Πλατων, Πυθαγορας, Αριστοτελης, ειπον, διερχεσθαι τον ἡλιον, παρα την λοξωσιν του ζωδιακου κυκλου, δι' οὑ φερεται λοξοπορων ὁ ἡλιος, και κατα δορυφοριαν των τροπικων κυκλων. Plutarch. de Placitis Phil. lib. ii. c. 23.

that they had but an incorrect and distorted view of it; for it is plain, from the quotations given below, that the sun and moon, as well as the earth, were supposed by them to revolve round this central fire; a sufficient indication, that they were still far from apprehending the relation in which these bodies stand towards each other.

So correct is the remark, that truth, though frequently touched, is rarely held fast in the dark; or, to adopt the theory of the opposite party, so imperfect and confused shortly becomes our recollection of her features, when the daylight, which disclosed them to us, is succeeded by a second night of ignorance.

With respect to the second great discovery alluded to, the doctrine of definite proportions, the language of the Pythagorean school is vague and mystical; and it would require more learning and patience than I can lay claim to, in order to disentangle the conflicting statements that have been made with regard to the doctrine of *numbers*, by which the laws of chemical combination may be conceived to have been shadowed out.

From some passages that might be quoted, it would seem, as if Pythagoras attributed to *numbers* a real existence, and considered them, as Plato did his *ideas*, the eternal archetypes of things; from others, that he meant to designate the *thing* numbered, confounding the *monad*, or that which is single, indivisible, and therefore perfect, with one, the most perfect of all numbers, and that to which all others are allied. Accordingly, the *monad* is used to signify the Deity, as being the first great cause, one and the same throughout all space, and in all time; whilst substance, or the world, is figured under the term *duad*, as being formed by the union of qualities, derived from the Deity himself, with amorphous matter.

In other cases the founder of this school, or more probably his exoteric followers, attributed mysterious and magical powers to numbers, imagining the whole universe to be formed and kept together by virtue of them.

Yet it would seem, from some expressions that occasionally occur in the midst of this unintelligible rhapsody, that a more philosophical meaning was intended to be conveyed, and that the favoured disciples of this school were given to understand by the doctrine of numbers, something very analogous at least to the sublime discovery of modern date, that no combination can take place between the elements of matter, except in certain fixed numerical proportions.

Thus, according to Jamblichus*, number, as perceived by the understanding, (abstract number,) is that which subsisted in the Divine mind prior to all other things, by and out of which all bodies are brought into order, and linked together in an indissoluble series.

Number is represented by Hippasus †, one of the pupils of Pythagoras, as the first model employed in the creation; the rule according to which the Almighty determined to operate, with respect to the world he was about to call into existence.

By Philolaus, another of the same school, it is said to be the bond sustaining by its power the permanent existence of every thing upon earth.

If these sentences are not sufficiently clear, we may perhaps interpret their meaning by the aid of a passage taken from another of the later interpreters of the Pythagorean philosophy; who seems to say, that the founder of that school did not assert that things were produced, out of number, but according to, that is, in the proportion of number ‡,

' Το *προ παντων ὑποσταν εν θειῳ νῳ, αφ' οὑ, και εξ οὑ, παντα συντε-*
και μενει ταξιν αλυτον συνδιηριθμημενα. Jamblichus in Nicomachi Arithm. p. 11. editio. Arnhem.

† *Οἱ δε περι* Ἱππασου *ακουσματικοι, αριθμον ειπον παραδειγμα πρωτον κοσμοποιΐας.* Και *παλιν κριτικον κοσμουργου θεου οργανον.*

Φιλολαος δε φησιν, αριθμον ειναι της των κοσμικων αιωνιας διαμονης την κρατιστευουσαν και αυτογενη συνοχην. Id. ibid.

και συχνους μεν Ἑλληνων *πεπεισμαι, φαναι Πυθαγοραν εξ*
' *παντα φυεσθαι· αυτος δε ὁ λογος απορησας ερχεται, πως ἁ μη δε εστιν επινοησαι, και αγονα δε, ουκ εξ αριθμου, κατα δε αριθμον ελεγε*

an expression which the abbe Barthelemi*, who wrote several years before the modern doctrine of definite proportions was propounded, interpreted in the very sense in which I have here attempted to explain it.

This interpretation will likewise enable us to attach a meaning to the words of Aristotle, when he states, "that the Pythagoreans considered existing things to be an imitation of numbers †," that is to say, they supposed them to bear the same fixed and simple relation one to the other, which a series of whole numbers does to unity ‡; and, when we consider how much all sects of Grecian philosophers borrowed from Pythagoras, we need have the less scruple in tracing to him the doctrine so clearly laid down by the Platonizing Jew, Philo, or whoever was the author of the Book of Wisdom: who says expressly, "*that God ordained all things in measure, number, and weight* ||."

There seems, therefore, strong reason to believe, that

παντα γιγνεσθαι. Stobæi Eclogæ Physicæ.—A passage, which though very corrupt, may probably be thus translated.

"I am well aware that many of the Greeks contend, that Pythagoras said that every thing sprung out of number. But the real subject of dispute is, in what manner he imagined the invisible world, and things not generated, to have been produced (I do not say from number) but according to number."

* We must here observe, that Pythagoras did not affirm that all things were formed by the virtue of numbers. If, in contempt of his express words, some of his disciples, imputing a real existence and secret virtue to numbers, have considered them as the constituent principles of the universe, they have so grossly neglected to unfold and explain their system, that we must be obliged to leave them to their impenetrable profundity. *Voyage of the younger Anacharsis.*

† Μιμησιν ειναι τα οντα των αριθμων. Arist. Metaph.

‡ As some moderns consider all other bodies to be multiples by a whole number of the lightest; a position, which Dr. Thomson (regarding that body to be hydrogen) has attempted to establish by a series of elaborate experiments.

|| Παντα μετρῳ, και αριθμῳ, και

something very like the theory of definite proportions was inculcated among the priests of Egypt, from whom Pythagoras derived his philosophy; as we have seen a similar doctrine to have prevailed even amongst the Hindoos.

It still, however, may admit of a question, whether the principle itself was gathered by the slow process of experiment and observation, or was received in consequence of its inherent probability, and some vague analogy with the laws of harmony in musical sounds; for if, on the one hand, it may seem strange, that mere speculative inquiry should have led to the anticipation of such a physical truth, it seems, on the other hand, improbable, that researches could have been carried on with the precision necessary to establish these conclusions, unless the people at large had attained to a degree of proficiency in the mechanical arts, which seems incompatible with their general condition, with the monuments of that remote period that have come down to us, and with the ease with which they were overrun by the semi-barbarous hordes that successively invaded them.

We have had, even in the present age, the example of a poet*, who, without any practical knowledge of botany, framed in his closet a system with respect to the metamorphoses of the parts of plants, which was found wonderfully conformable to the conclusions afterwards deduced from an extensive survey of facts, by one of the first botanists of the age†; and there is therefore no absurdity in supposing, that the sages of Egypt may, by a similar happy generalization, have arrived at the perception of this simple doctrine of definite proportions, merely from a feeling of its conformity to the harmony of creation, without ever ascending to it, as the moderns have done, by the gradual discovery of subordinate laws.

Nothing certainly can afford a more convincing proof of

* Goethe: see his Essay on the Metamorphosis of Plants, translated by De Gingens, Geneva, 1826.

† See Mons. Decandolle's various writings, especially his Organographie, and his Theorie Elementaire de la Botanique.

the soundness of a principle in science, than thus to find, that it had previously held a place amongst the speculations of a mind, which, like that of the German poet alluded to, may be said to *belong to that exalted region*, where the provinces of poetry and philosophy in a manner meet, and are blended together; but it would be unfair to adjudge to the anticipator of a great truth, the honour belonging to its discoverer; to adjudge to Goëthe the meed due to Decandolle, or to Pythagoras that claimed by our countryman Dalton.

It is one thing for a metaphysical mind dwelling continually upon abstract speculations, to entertain, as it were in the spirit of prophecy, views that may be found afterwards to harmonize with the conclusions of inductive science, although but little intelligible until the latter have been promulgated; and another, to ascend by slow and successive steps to some grand general principle, which being followed through its various bearings, proves a guide in all succeeding ages to the discovery of unknown truths.

A recent French writer, however, M. Salverte*, in a work of some ingenuity and research, though not always remarkable, it must be confessed, for sound judgment, has pointed out the various means employed of old by the Hierophant to impose upon the imaginations, and subjugate the minds of the people, and has endeavoured to shew, that some of the artifices adopted for that purpose were such, as imply a knowledge of the physical sciences, similar, if not equal, to that which we are apt to set down as the exclusive privilege of the present age.

He attempts to get over the objection arising from the low condition of the people, by supposing this knowledge to have been confined to a few individuals, and therefore to have exerted no influence upon the character of the nation at large. It may indeed be admitted, that if the primary object of the initiated was power, not so much over nature as over the minds of the people, whatsoever science they possessed would have been locked up within the sacred

* See Salverte sur les Sciences occultes. Paris, 1829.

colleges; and that even there, the majority of its members would be made acquainted only with those secrets that were calculated to impose upon the multitude, whilst the scientific principles on which they depended, were imparted only after a long period of probation, and to a limited number of the highest grade of adepts.

Where every thing depended upon secrecy, divulgement would be considered as the deepest of crimes; and where all without the pale of the sacred colleges were regarded as profane and semi-barbarous, even the gratification of vanity would be sought rather in mystifying and deluding the people, than in enlightening them.

Under such circumstances the destruction of the colleges by a foreign invader, and the slaughter or dispersion of their inmates, might have caused the almost total destruction of those treasures of knowledge, which the labours of successive generations had brought together; for though the remnant that escaped into foreign lands would probably carry with them a knowledge of certain secrets, yet the chance would be much less of the few, that possessed the true key to such mysteries, surviving the general persecution of their order.

In this manner might the science they possessed gradually dwindle away, until little remained, save a collection of such processes as were best calculated to excite terror and surprise, and an assemblage of dogmas and observances, the meaning and intent of which were lost, and misunderstood in the mystical language in which they were conveyed.

Hence, though it may be true, that Pythagoras obtained from the Egyptians some glimpses of their learning, and though it is even possible, that he, and a few of his original disciples, may have been made acquainted with certain of the scientific truths which they possessed, yet it is very conceivable, that the Greeks in general should know but little more of the esoteric doctrines of this school, than has been reported to us in the works that have reached our time; so that they should value this philosophy, rather for its mystical tenets and ascetic observances, than for the truths that might be darkly shadowed out under a veil of oriental allegory.

Whatever degree of knowledge therefore may have been possessed by the Egyptian priesthood, or their disciple Pythagoras, one thing at least is certain, namely, that we are ourselves as little indebted to either for our actual information on such subjects, as we are to Roger Bacon for our method of manufacturing gunpowder, the ingredients of which he indicates in one of his works by an anagram, which is not difficult to be deciphered at present, but which conveyed no meaning, before the nature of this compound had become known.

Neither can it be shewn, that either the Pythagorean philosophy itself, or those schools that imbibed its spirit and adopted its tenets, at all contributed to the discovery of the physical truths alluded to; it would rather seem, that by engaging the mind in speculations on subjects beyond the reach of the human intellect, and by inculcating habits of thinking altogether at variance with those which can avail us in the investigation of nature, they must have proved a fatal obstacle to the progress of such inquiries.

If any share in the discovery of the laws of combination, as at present established, can be assigned to the ancients, it is to the first propounders of atomic theory, rather than to the authors of the Pythagorean system of numbers, that the praise is due.

To Democritus indeed we owe the first outline of a scheme of philosophy, which appeals exclusively to sense and observation, instead of arbitrary assumed principles *; which ad-

* "Atque hi omnes, (scilicet Empedocles, Anaxagoras, Democritus,)" says lord Bacon, "mentem rebus submiserunt. At Plato mundum cogitationibus, Aristoteles vero etiam cogitationes verbis adjunxit; vergentibus etiam tunc hominum studiis ad disputationes et sermones, et veritatis inquisitionem severiorem missam facientibus." *De Principiis, secundum Fabulam Cupidinis et Cœli.*

These remarks of lord Bacon apply, it must be confessed, to a mits no dogmas, but what are clearly apprehended, and may therefore be fairly grappled with; and which, therefore, after having had to struggle for centuries with prejudices derived, on the one hand from the perverse use of its doctrines to inculcate atheistical opinions, and on the other, from the partiality felt by the learned for verbal and metaphysical subtleties, has at length been found to agree better than any of its rival systems with the results of experimental science.

To Democritus also we are indebted, not only for having made a more frequent appeal to observation than most of his cotemporaries, but also for having set the example of questioning nature by experiment; a circumstance the more to his honour, as being so contrary to the genius of the age in which he lived.

"Accordingly," as lord Bacon has observed, "the doctrine of atoms, from its going a step beyond the period in which it was advanced, was ridiculed by the vulgar, and severely handled in the disputations of the learned, notwithstanding the profound acquaintance with physical science, by which its author was allowed to be distinguished, and from which he acquired the character of a magician."

"However," he continues, "neither Aristotle with all his logical acuteness, (though like the Ottoman sultans he laboured to destroy all his brother philosophers, in order to rest undisputed master of the throne of science,) nor Plato with his sublime speculations, could effect the subversion of the doctrines of Democritus.

"Though the former systems were best suited for declaimers in the schools, the latter, cherished by those who wished to obtain a deeper insight into nature, appears to have kept its ground during the most flourishing periods of Roman literature, since Cicero always speaks of it with re-

part of Aristotle's works only; but to this part the genius of the age had at that period given a prominency, which threw into the shade the better portions, and caused the impugners of the scholastic systems to pass this too sweeping censure upon the character of his philosophy.

spect, and Juvenal, who, like poets in general, probably echoed the prevailing sentiment of the age in which he wrote, mentions its author as a noble exception to the general stupidity of his countrymen,

—cujus prudentia monstrat
Summos posse viros, et magna exempla daturos,
Vervecum in patria, crassoque sub aëre nasci.

"The destruction of this philosophy," concludes lord Bacon, "is to be traced to Genseric and Attila, not to Plato and Aristotle. For when all human knowledge suffered shipwreck, the systems of the latter, being of a more flimsy and tumid texture, floated down to us; whilst the solid fabric of the corpuscular philosophy sunk to the bottom, and was forgotten*."

* My readers will do well to consult the original in lord Bacon's Latin works, ("*De Principiis, &c.*" quoted in the preceding page,) as I have been obliged to drop in my translation much of that ingenious and beautiful metaphor, for which this illustrious writer is so distinguished.

ADDITIONAL NOTES.

Note to p. 17, on the Doctrine of Sufficient Reason.

Those who desire to see the bearing of this dogma upon the question as to the existence of atoms, may read the remarks on this subject in Euler's Letters to a German Princess, vol. II.

Additional Note to p. 22, on Boscovich's System.

"The easiest method of solving all the difficulties attending the subject of the subtlety of light, and of answering Mr. Euler's objections to its materiality, is to adopt the hypothesis of Mr. Boscovich, who supposes matter is not impenetrable, as before him it had been universally taken for granted; but that it consists of physical parts only, endued with powers of attraction and repulsion, taking place at different distances, that is, surrounded with various spheres of attraction and repulsion, in the same manner as solid matter is generally supposed to be." Priestley then goes on to develope Boscovich's views, and continues, "The most obvious difficulty, and indeed the only one that attends this hypothesis, as it supposes the mutual penetrability of matter, arises from the difficulty we meet with in attempting to force two bodies into the same place. But it is demonstrable, that the first obstruction arises from no actual contact of matter, but merely from powers of repulsion. This difficulty we can overcome; and having got within one sphere of repulsion, we fancy that we are now impeded by the solid body itself. But the very same is the apprehension of the generality of mankind with respect to the first obstruction. Why, therefore, may not the next resistance be only another sphere of repulsion, which may only require a greater force to overcome it, without disordering the arrangement of the constituent particles; but which may be overcome by a body moving with the amazing velocity of light?

"This scheme of the *mutual penetration of matter*, first occurred to Mr. Michell on reading Baxter on the Immateriality of the Soul. He found that this author's idea of matter was, that it consisted, as it were, of bricks cemented together by an immaterial matter.

"These bricks, if he could be consistent in his reasoning, were again composed of less bricks, cemented likewise by an immaterial mortar, and so on *ad infinitum.* This putting Mr. Michell upon the consideration of the appearances of nature, he began to perceive that the bricks were so covered with this immaterial mortar, that, if they had no existence at all, it could not possibly be perceived, every effect being produced, at least in nine instances in ten certainly, and probably in the tenth also, by this immaterial, spiritual, and penetrable mortar.

"Instead, therefore, of placing the world upon the giant, the giant upon the tortoise, and the tortoise upon he knew not what, he placed the world at once upon itself; and finding it still necessary, in order to solve the appearances of nature, to admit of extended and penetrable immaterial substance, if he maintained the impenetrability of matter; and observing further, that all we perceive by contact, &c. is this penetrable immaterial substance, and not the impenetrable one; he began to think that he might as well admit of penetrable material, as penetrable immaterial substance; especially as we know nothing more of the nature of substance than that it is something which supports properties: which properties may be whatever we please, provided they be not inconsistent with each other, that is, do not imply the absence of each other.

"This by no means seemed to be the case, in supposing two substances to be in the same place at the same time, without excluding each other; the objection to which is only derived from the resistance we meet with to the touch, and is a prejudice that has taken its rise from that circumstance, and is not unlike the prejudice against the Antipodes, derived from the constant experience of bodies falling, as we account it, downwards," &c. &c. *Priestley on Matter and Spirit*, p. 19.

Note to p. 58, on Dr. Wollaston's views respecting Crystallization.

I ought perhaps to have noticed, that the fundamental form at present considered as characterizing most of the metals is the hexaedron, from which the octaedral figure belonging to the crystals of several is deduced. See Haidinger's Treatise on Mineralogy.

Note to p. 71, on the Doctrine of Isomorphism.

After the preceding pages had gone through the press, I met with some remarks in the Annals of Philosophy (N°. for September 1831.) on the doctrine of Isomorphism, which, as proceeding from an individual so distinguished in crystallography as Mr. Brooke, ought not to be passed over entirely without observation.

The lateness of their appearance, indeed, puts it out of my power to give to the objections he has brought forwards, the consideration they appear to deserve; but in order to place the whole question in as complete a manner as my limits permit before my readers, and to prevent them from placing an undue reliance on the soundness of the theory, by which, in the text, I have thought it convenient to connect together the facts that have been ascertained upon the subject, I shall here briefly notice the substance of his remarks.

Mr. Brooke justly observes, that the doctrine of absolute identity of form, in the bodies, which, according to Mitscherlich, replace each other, must be given up; so that the term *plesiomorphous*, proposed by Mr. Miller of Cambridge, might perhaps be more applicable to such substances, than that of *isomorphous* in general use at present.

Even in this modified sense, however, the truth of the position is contested by Mr. Brooke, who prefers explaining the diversity of chemical composition, that exists among minerals belonging to the same species, on Hauy's principle stated in page 83 of this volume, rather than on that substituted for it by Mitscherlich.

It seems impossible, however, to apply the former theory to the case of the garnet species, according to the analysis given of them in page 84, neither has Mr. Brooke attempted so to do; we must therefore admit, in this instance, a positive substitution of one earthy ingredient for another, a circumstance which makes it necessary to inquire, not whether silica, alumina, and peroxide of iron, or lime, magnesia, and protoxide of iron, do replace each other *under certain circumstances*, but whether they are capable of doing so *under all.*

Now the facts alleged by Mr. Brooke are sufficient to enable us to answer this latter question in the negative, by shewing that two minerals possessing different kinds of crystallization, may nevertheless be composed of isomorphous bases, combined with the same acid. But that this should be the case need the less surprise us, when we find from Mr. Brooke, that minerals possessing the very same ingredients sometimes crystallize differently;—for such assuredly is the inference which must be derived from the fact, that paranthine sometimes consists of 1 atom of bisilicate of soda, with 1 of silicate of alumina; in which case its composition differs in no respect from that of sodalite.

But even this is less remarkable, than the difference of figure subsisting between calcareous spars, and those arragonites which are devoid of strontian, or than that which has been pointed out with regard to sulphur, when crystallized in different ways.

These, undoubtedly, are facts, that can be explained neither by the doctrine of isomorphism, nor by any other that has yet been invented, and which may serve to convince us, that our knowledge of the subject is as yet imperfect, and that our theories embrace only a part of the problem to be solved.

But as they apply equally to all the explanations given, they present no obstacle to our extending the views, which we have seen to be so manifestly true in the case of the garnet species, to other minerals in which the circumstances are similar;—the analyses given in page 84 are alone sufficient to assure us, that certain bodies are in this case substituted one for the other without affecting the figure of the mineral: the facts detailed by Mr. Brooke contain nothing to shew that the same may not take place in others—they merely prove that there are causes of which we know nothing that affect the character of the crystallization, thus rendering it possible for bodies, not only *isomorphous*, but even to all appearance *identical*, in point of composition, to assume different forms.

It may, however, be remarked, that in the case of stilbite, which Mr. Brooke has brought forwards as an exception, he has overlooked the presence in it of 6 atoms of water, a circumstance which constitutes a chemical difference between that mineral and paranthine, and that, even if this ingredient had not been present, we should not be at liberty to conclude *a priori*, that because a mineral consisting of 2 atoms of silica in combination with a particular base possesses a certain kind of crystallization—therefore that one consisting of 3 atoms, or of 1 atom of silica with the same, or an isomorphous base, must be similarly circumstanced. Such a position would indeed strike at the very root of a chemical arrangement of minerals, the great majority of which consist of some proportion of silica and alumina, isomorphous acids, with some proportion of soda, lime, magnesia, or other isomorphous bases. I therefore cannot believe that Berzelius meant to give such an extension to the doctrine of isomorphism as would lead to these absurd consequences, and must protest against being understood to adopt any such views myself.

I shall now take leave of Mr. Brooke, in the hope that his remarks may contribute to excite attention to the real difficulties which beset the doctrine of isomorphism, but that they will not lead us to overlook or disregard the facts that appear to be established, on the faith of independent and multiplied experiments, with regard to the substitution of certain substances for others without any corresponding change taking place in the crystallization of the mineral thereby produced.

Note at the end of Chapter II. p. 86, on Berthollet's views respecting Chemical Combination.

Since the general reception of the atomic theory, the views of Berthollet respecting the influence of quantity upon chemical combination, appear to have been abandoned in this country, from an impression that the latter doctrine is inconsistent with the former.

But this is not altogether the case, for, even if we admit Berthollet's hypothesis, it would not necessarily follow, that the combinations between bodies should be indefinite; it is conceivable, that they still may take place in atomic proportions.

This perhaps may be explained by a few examples. Berzelius mentions (in a memoir on some compounds that depend on weak affinities*) that if magnesia be thrown down from its solution in sulphuric acid by ammonia, it retains a portion of acid, amounting to about 2 per cent. of the whole quantity, the composition of the precipitate being 67.5 per cent., magnesia 1.6 sulphuric acid, water 30.9. He therefore concludes that 1 atom

* Edinburgh, Phil. Journal, vol. i. 1819.

of subsulphate of magnesia is combined with a great number of atoms of hydrate of magnesia. Now the reason, why the ammonia was unable to separate this last portion of acid, by the same attraction, which enabled it to abstract from the earth the remainder, could only be, either the superior affinity subsisting between a small number of atoms of sulphuric acid for a large number of atoms of magnesia, or that of a small quantity of subsulphate of the earth for a larger one of hydrate. Berzelius has shewn, that this union of 1 atom of one substance with a very large number of atoms of another takes place frequently: thus in the sulpho-salts, 1 atom of sulphuret of potassium may combine with 24 of sulphuret of arsenic. (See page 38.)

In order to reconcile these statements with Dalton's views, we may perhaps suppose, 1 atom of the triple salt composed of sulphuret of potassium and sulphuret of arsenic, to be combined with several of the sulphuret of arsenic alone, and in the foregoing instance, a single particle of common sulphate of magnesia to be united with several of the hydrate. In either case, the inference would be the same; viz. that the affinity of a number of atoms of one salt for a smaller number of atoms of the other, added to that of the constituents of the latter, one for the other, was sufficient to counteract the influence of the substance added.

Berzelius is disposed to extend Berthollet's views generally to salts held in solution in the same menstruum, and consequently to the case of mineral waters.

Thus he conceives, that in such cases, as many salts really exist, as could be formed out of the whole number of acids and of bases present, the relative proportion of these salts depending upon the balance between the quantity of these latter, and their relative tendencies to combine.

"If," says Berzelius, "the physician inquires of the chemist, what the proportion, which these salts bear to each other in any given case, may be, the latter must reply, that this is a question as to which we are at present entirely in the dark, as the proportions depend, not only on the quantity of the acids and bases present, which admits of being ascertained, but also upon the relative force of affinity subsisting between the one and the other, for determining which we have as yet no data whatsoever."

Now, granting the above to be a correct statement, this practical consequence seems to follow, which physicians would do well to bear in mind in their imitations of natural springs, namely, that the medical properties of two mineral waters, exactly agreeing in the nature and quantity of the active ingredients that can be obtained from them by analysis, may be materially modified by the introduction of a third substance, although one in itself perfectly inert.

Let us, for example, suppose, that we have dissolved in two equal portions of water the same quantities of muriate of magnesia and sulphate of soda, both of which exert in different ways a certain action upon the animal functions, and that we afterwards introduce into one of the solutions a little carbonate of lime, a substance not known to possess any medical virtue whatsoever. It is clear, that according to the old hypothesis the two waters ought to produce similar effects upon the constitution; but, according to the views we have been advocating, it may be conceived that the ingredients of the carbonate of lime would in part be divided between the other constituents of the mineral water, so as to diminish the actual quantities of sulphate of soda and muriate of magnesia, and to substitute for them a small proportion of carbonate of soda and muriate of lime, salts, which might communicate to the water, properties that did not belong to it before.

Thus, to take the case of the Buxton water. Dr. Scudamore finds, that every gallon furnishes him on evaporation with the following saline principles; viz.

		Containing of	
	Gr.	Acid.	Base.
Muriate of magnesia....	0.58	0.377	0.203
Muriate of soda........	2.40	1.290	1.110
Sulphate of lime	0.60	0.352	0.248
Carbonate of lime......	10.40	4.570	5.830

But as sulphate of soda is a more soluble salt than sulphate of lime, he chooses to represent the composition of the water, as follows; consistently with the views of Dr. Murray, who contended that the ingredients of a mineral water combined in such a manner, as to form the most soluble salts, viz.

Sulphate of soda	0.63
Muriate of lime	0.57

Muriate of soda	1.80
Muriate of magnesia	0.58
Carbonate of lime	10.40

In reality, however, all that we are warranted in asserting, if we wish to steer clear of hypothesis, is, that the water contains the following acids and bases; viz.

Sulphuric acid	0.352	Magnesia	0.203
Muriatic acid	1.667	Soda	1.110
Carbonic acid	4.570	Lime	6.078

which, if the views that we have just brought forward are correct, would constitute the following salts in unknown proportions; viz.*

Sulphates of magnesia.	Muriates of lime.
——— soda.	Carbonates of magnesia.
——— lime.	——— soda.
Muriates of magnesia.	——— lime.
——— soda.	

Now, if we were to prepare an artificial water, by dissolving together salts similar to those extracted from the Buxton spring, but leaving out the carbonate of lime as inert, the mixture would contain only,

Muriate of magnesia	Sulphate of magnesia,
——— soda,	——— soda;

and would thus be deficient in two active ingredients, muriate of lime and carbonate of soda, which its natural prototype possesses.—*See an article by the author in the second number of the London Review, on Mineral Waters.*

* In the above, we have chosen to adhere to the old nomenclature respecting the muriates, not from any doubt of the correctness of Davy's views on this subject, but from a wish to simplify our statement as much as possible, by making it run parallel with that of Dr. Scudamore, in all particulars, except in that which bears upon the point under consideration.

APPENDIX.

When the preceding sheets had gone through the press, they were submitted to Dr. Prout, who after perusing them favoured me with the following remarks, which I gladly insert, as serving to explain more fully those peculiar views of his to which I have alluded.

"Sackville-street, Sept. 12, 1831.

"DEAR SIR,

"I WAS much gratified by a perusal of your Essay on the Atomic Theory: there are, however, a few points in which I am more immediately concerned, apparently requiring some remarks, and which I shall consider in the order they occur.

In page 39 you observe, 'I believe, indeed, that I shall not be misrepresenting Dr. Prout's opinions, if I remark that in the paper alluded to he seems to have noticed the relation between the numbers......chiefly as a presumption in favour of the idea of their being possibly compounded of oxygen and hydrogen, of which they appear to be multiples.' The original opinion to which I was led by the observations of others, and innumerable experiments (never published) of my own, was, that the combining or atomic weights of bodies bear certain simple relations to one another, frequently by multiple, and consequently that many of them must necessarily be multiples of some one unit; but as the atom of hydrogen, the lowest body known, is frequently subdivided when in combination with oxygen, &c. there seems to be no reason why bodies still lower in the scale than hydrogen (similarly however related to one another, as well as to those above hydrogen) may not exist, of which other bodies may be multiples, without being actually multiples of the intermediate hydrogen. Such was my *opinion* in general terms; my *speculations*, I confess, went further, and were indeed pretty much as you have stated them to be.

" Page 44 and 62, you remark, with respect to the general notion of atomic series rather than units, ' that you are not aware of any facts which do not equally admit of being referred to the theory more commonly adopted, and that you do not see the absurdity of supposing that in organic compounds where the terms of the series are, as is the case of water, represented as 3 : 6 : 9 : 12, &c. the true relations may not be as 9 : 18 : 27 : 36 corresponding to 1 : 2 : 3 : 4 atoms of water;' and again, ' that you do not see that the theory of Dalton holds out any stronger temptation to fraud than the laws substituted for it by me.'

" To reply to the first of these remarks as it ought to be replied to, and indeed as I perhaps *could* reply to it, would lead me far beyond my present purpose; I shall therefore merely observe, that by adhering to a single term (with reference to which I am quite aware all others may be expressed) great difficulties often occur, and the real (often very simple) compositions of bodies are so masked and *apparently* misrepresented, that they cannot without difficulty be recognised in some instances.

" With respect to the second objection, I may remark, that my notions were not proposed with the expectation that they would make honest men of knaves: though it may be worth while to observe, that by diminishing the number, the *amount* of error is likely to be diminished.

" The series given for water, I wish it to be observed, applies to its combination with carbon, and perhaps some other bodies; but in uniting with bodies having different combining series, the aqueous series itself *may* become modified or different—and hereby hangs, if I am not much mistaken, a very curious tale, which I hope some one will tell ere long better than I am able to do.

"At page 62, you speak of the '*censures* I have cast on the atomic theory.' Now this is a much stronger term than I am willing to allow. There is no one can possibly have greater respect for Mr. Dalton, and all that he has done, than myself, and I am a firm believer in his principles *as far as they go*, because I believe them to be founded in truth. What I meant to say was, that they do not contain *all* the truth, and that consequently in *their present state* they are inadequate to explain the operations of nature. It is however my opinion, that the system of Dalton, even in its present state, on account of its great simplicity and convenience, never will nor ought to be superseded; and that consequently it will continue to be employed for these reasons, just as the Linnean system continues to be employed for very similar reasons by botanists; and here I may remark, by the by, that I referred to botany in my lectures rather for the sake of illustration, than from any close analogy between this science and chemistry, which I was well aware did not exist.

"Pages 68 et seq. you speak of the doctrines of *isomorphism* and *isomerism;* and though I do not observe that you allude to any thing that I have said on the subject, I am anxious to make a few remarks on a passage in my lectures, which from the terms employed may be liable to be misunderstood. I have said that the continental chemists have succeeded in establishing the curious and important doctrines of isomorphism and isomerism—doctrines totally inexplicable upon the principles of Dalton and Berzelius, but which seem to me to flow necessarily in conjunction with some others from the principles which I have long considered as regulating the union of bodies in nature.' In the lectures as delivered, these doctrines were very briefly explained, and I wish here to remark, that I mean nothing more by the above than that the doctrines in the abstract, or generally speaking, are established, which I believe to be the case; as for the details, I always considered many of them exceedingly unsatisfactory. So long ago as 1815, I was led to infer that relation in *weight* might indicate a relation also in *size* among the atoms of bodies*; and that many of those striking and curious analogies in property, form, &c. which I thought I observed among bodies atomically related, might depend upon one or other of these circumstances. But, as soon after this period I relinquished chemistry in general, I thought little more of the matter, till the doctrines of Mitscherlich were announced. I merely mention this, but without advancing the shadow of a claim to the honour of the discovery of isomorphism, which, as far as I know, is entirely due to the eminent philosopher above mentioned. With respect to *isomerism*, in my lectures as originally written, I alluded to three varieties or modifications of this principle as existing in bodies—one in which the same elements are differently arranged; a second, in which the arrangement (still crystalline) is different, but which difference depends upon the presence of minute quantities of foreign bodies; and a third, which I have provisionally termed *merorganization*, in which the general arrangement, besides being peculiar, may be also supposed to be subject to or influenced by the same causes which produce the peculiar arrangements in one or both the other two varieties. All these varieties, I believe, are inexplicable upon the principles of Dalton *as they at present stand*, but on these principles *as they may be extended*, I have strong hopes that one day or other the two first varieties at least will be explained.

"You allude to the speculations of M. Decandolle on the forms of plants, and I will amuse you with a speculation of mine on the same subject, viz. that these forms are somehow or other connected with the oxygen series 2 : 4 : 6 : 8, &c. and the isobaric series of carbon and water 3 :

* See Annals of Philosophy, VII. 113. where the general principles on which this notion was founded are briefly stated with another view, viz. that of explaining the relation between the doctrine of atoms and of volumes.

6 : 9 : 12, &c. I think I could bring forward many curious circumstances illustrative of this opinion.

"I remain, dear sir, Yours very truly,

"W. PROUT."

"P. S. I approve of your ingenious observations on mineral waters, which, I think, throw considerable light on their constitution. My professional pursuits keep me away so much from chemical details, that it is very possible I may have committed some errors in the preceding observations. If so, I beg you will correct them. W. P."

Remarks by Mr. Dalton on certain passages in the text relative to the laws of definite proportions.

THE same motive, that induced me to solicit the preceding remarks from Dr. Prout, namely, a wish to put forth no statements, in the scientific portion at least of my work, of a doubtful or debateable kind, unaccompanied by the objections that might be raised against them, led me to submit the preceding pages, when printed, likewise to Mr. Dalton, who has in consequence favoured me with the following comments on certain passages in the 2d chapter.

The modesty of the author has indeed chosen to represent these notes of his as scarcely worth publication in their present form; but I am sure that I should be doing an injustice to my readers by withholding them, even supposing a more critical eye should detect any inaccuracies, which have escaped me, during the hasty attention I have been able to give to their contents.

Having, indeed, been permitted by Mr. Dalton to alter or correct them at pleasure, I am in some degree responsible for their publication; but whatever blame may attach to myself for having refrained from exercising the discretionary power confided to me, the work at least will gain in value, by becoming the vehicle for communicating to the public the present views of the Father of the Atomic Theory.

"RESPECTED FRIEND,

"I have occasionally turned my attention to your Essay ever since I received it, and shall now communicate to you a few observations that have struck me. On the 1st chapter I make no remark, further than that it contains matter of interesting information. The head of the 2d chapter announces that *'every substance enters into combination in certain fixed proportions, of which the larger are multiples of the smallest.' According to my views, this is not sufficiently definite: take, for instance, the case of azote and oxygen; here a given weight of azote unites to 1, 2, 3, 4, and 5 proportions of oxygen, which agrees with the observation; but if we begin with the smallest proportion of azote which combines with oxygen, and proceed upwards, we find

84	Azote +	240 Oxygen,	Nitric acid.
105	—— +	240 ——	Nitrous acid.
140	—— +	240 ——	Subnitrous acid.
210	—— +	240 ——	Nitrous gas.
420	—— +	240 ——	Nitrous oxide.

Here we see no multiples of the smallest combining quantity of azote, but the last number; and further, if these numbers are correct, the combining number or atom for oxygen must be 240, and that for azote 84; otherwise we must introduce fractions to express some of the ratios. This one case sufficiently shews that when two bodies A and B combine, we must collect the facts, and then examine whether it is A or B that combines in multiple proportions. Nor is this all: I observe that you conform to the gene-

* This passage occurs only in the table of contents, and is, I admit, not worded with sufficient precision. It will be perceived that the numbers given by Mr. Dalton to represent the combining quantities of azote, are multiples not of the atomic weight given of that body in this Essay, which is 14, but of half of it. Thus:

$$7 \times 12 = 84$$
$$7 \times 15 = 105$$
$$7 \times 20 = 140$$
$$7 \times 30 = 210$$
$$7 \times 60 = 420$$

ral arrangement of British chemists of the day, which was first introduced by Berzelius about 1810 (I believe), and was too hastily adopted by Drs. Wollaston, Thomson, &c. and which Berzelius has been the first to relinquish. I mean

14 Azote +	8 Oxygen,	Nitrous oxide.
14 ——	+ 16 ——	Nitrous gas.
14 ——	+ 24 ——	Sub or per-nitrous acid.
14 ——	+ 32 ——	Nitrous acid.
14 ——	+ 40 ——	Nitric acid.

Now all this *may* be correct; but why are we to conclude that 14 is the proper representative of an atom of azote? I do not think it is. I adopted, 28 years since, my atomic view of the combinations of azote and oxygen (Memoirs, vol. I. 1805), the principle of which I still retain, and in which Berzelius now agrees with me, as you will find by his late table: according to this, the atomic weights will be

⦶o⦶ —	14 Azote +	8 Oxygen,	Nitrous acid.
⦶o —	7 ——	+ 8 ——	Nitrous gas.
o⦶o ⦶o —	14 ——	+ 24 ——	Per- or sub-nitrous acid.
o⦶o —	7 ——	+ 16 ——	Nitrous acid.
o⦶o o o⦶o —	14 ——	+ 40 ——	Nitric acid.

There are many considerations that suggest that the atom of nitrous gas is the most simple of the combinations of azote and oxygen: 1st, its specific gravity; 2d, its readily combining with oxygen, and sometimes also with azote; 3d, its easy resolution by electricity into azote and oxygen; the latter of which, by combination, instantly forms nitrous acid; 4th, the formation of nitrous acid from a mixture of azote and oxygen when electrified, as was done by Mr. Cavendish, in which operation nitrous gas is first formed, and then nitrous acid instantly follows. But I must not enlarge on this head.

Page 37. I should have preferred placing

Hydr. 2	Carb. 6
—— 1	—— 6
—— 1	—— 12

Page 56. "3 combinations of A and B, whose atomic weights are represented by the numbers 8 and 14." In my opinion the presumption would be, that they were composed as follows:

A 16, B 14=2 A+1 B*
A 8, B 14=1 A+1 B
A 8, B 28=1 A+2 B,

unless some reason could be assigned to the contrary from the properties of the compounds. All affinities must be mutual, and 1 atom of A has only the same claim to 2 of B, that 1 of B has for 2 of A.

"Whilst upon this subject, namely, the taking a view of all the ways in which the several combinations of 2 elements may be explained, I will take the liberty of assuming a case: Suppose I find that in 2 elements, A and B, there are the following combinations, namely:

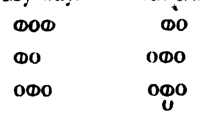
	Grains.		Grains.
A	2	+B	2
A	2	+B	3
A	2	+B	6
A	2	+B	12
A	2	+B	18

and that these 5 are all the combinations I can find experimentally. Now should I be so unlucky as to take the 1st for a binary compound, and consider the atoms of A and B as of equal weights, I should be puzzled to account for the rest of the combinations; the 2d would be 3 atoms of B with 2 of A; the 3d would be 1 atom of A with 3 of B; the 4th, 1 atom of A with 6 of B: and the 5th, 1 atom of A with 9 of B. But I might ask, why should they not be combinations of the intermediate numbers?

"A much more probable supposition would be, to take

* The difference between us may be shewn thus:

My way. Your way.



as the atomic weights, A 2 and B 6; then the 3d would be a binary combination; the 2d and 4th ternary; and the 1st and 5th quaternary; so that there would be no occasion to have more than 4 atoms in any group, and we should have no deficiencies in the combinations.

"Page 57. The numbers denoting the weights of the atoms in this table are, not all, I fear, sufficiently correct. I do not know where we are to look for the exact sp. gr. of hydrogen gas, and if this be not correctly known, then all the atomic weights will be wrong, and the doctrine of volumes be in jeopardy.

"Dr. Wollaston's Lecture in 1813 is an expansion of the ideas I published in 1808. (Chemistry, vol. I. p. 210.) When he mentioned those ideas to me in conversation, (I think in 1810,) he could scarcely credit that I had entertained and published the same, until he brought my book out of his library, and I shewed him the page. He had probably seen it before, but had forgotten it.

"With regard to the Tables at the end, there are several errors, in my opinion, as to the weights both of the simple and compound atoms; but as this is debateable ground, I shall not enter upon it at large. I may observe that my present view of *alum* coincides with that of Berzelius, and was deduced without the knowledge of his. I cannot agree with him in regard to phosphorus, arsenic, minium, &c.; but upon the whole I agree with him as well or better than with others.

"I remain, yours truly,

"JOHN DALTON."

TABLE I.

Table of Chemical Equivalents, Atomic Weights, or Proportional Numbers, Hydrogen being taken as Unity. (See page 41.)

[From Dr. Turner's Elements of Chemistry, third edition, 1831.]

ACID, acetic, ... 50 or 51
c. 1 w * .... 59 or 60
arsenic, (a. 38 + ox. 20 Berz.) 58
arsenious, (a. 38 + ox. 12 Berz.) 50
benzoic, ... 120
boracic, (b. 8 + 0.16) 24
c. 2 w. 42
bromic, (b. 78.26 + ox. 40 Berz.) 118.26
carbonic, (c. 6 + 0.16)...... 22
chloric, (chl. 36 + 0.40) 76
chloriodic, (chl. 72 + iod. 124) 196
chloro-carbonic, (chl. 36 + carb. oxide, 14).............. 50
chlorocyanic (chl. 36 + cyan. 26) 62
chromic, (chr. 32 + ox. 20).. 52
citric, ... 58
c. 2 w. 76
columbic, ... 152
fluoboric, ... 68 ?
hydro-fluoric, ... 19.86
formic, ... 37
fluosilicic, ... 26.86?
gallic? 62
hydriodic, (iod. 124 + hyd. 1) 125
hydrobromic, (b. 78.26 + h. 1.) 79.26
hydrocyanic, (cyan. 26 + hyd. 1) 27
hyposulphurous, (s. 32 + 0.8) 40
hyposulphuric, (s. 32 + 0.40) 72
iodic, (iod. 124 + 0.40) 164
malic, ... (Liebig).. 57
manganeseous ? 52
manganesic, ... 60
molybdous, ... 64
molybdic, ... 72
muriatic, (chl. 36 + hyd. 1).. 37
Acid, nitric, dry (nit. 14 + 0.40).. 54
——— liquid (sp. gr. 1.5) 2 w. 72
nitrous, (nit. 14 + 0.32) 46
oxalic, ... 36
c. 3 w. 63
perchloric, (chl. 36 + 0.56).. 92
phosphorous, (p. 15.71 + 0.12) 27.71
phosphoric, (p. 15.71 + 20) 35.71
saccholactic, ... 104
selenious, (sel. 40 + 0.16).. 56
selenic, (s. 40 + 0.24) 64
succinic, ... 50
sulphuric, dry (s. 16 + 0.24) 40
——— liquid, sp. gr. 1.4838, 1 w. 49
sulphurous, (s. 16 + 0.16) .. 32
tartaric, ... 66
c. 1 w. 75
titanic, ... 48
tungstic, (t. 96 + 0.24).... 120
uric, ... 72
Alcohol, (ole. gas. 14 + aq. vap. 9) 23
alum, anhydrous, ... 262
+ c. 25 w. 487
Alumina, ... 18
sulphate, ... 58
Aluminium, ... 10
Ammonia, (nit. 14 + hyd. 3) 17
Antimony, ... 44
chloride, (ant. 44 + chl. 34) 80
iodide, (ant. 44 + iod. 124) 168
oxide, (ant. 44 + 0.8) 52
deutoxide, (ant. 44 + 0.12) .. 56
peroxide, (ant. 44 + 0.16) .. 60
sulphuret, ... 60
Arsenic, ... 38
sulphuret, (realgar) 54
† sesquisulphuret, (orpiment) 62
persulphuret, ... 78

* C means crystallized, w. water; and the numeral before w, expresses the number of equivalents of water which the crystals contain.

† 1 proportion of arsenic, and $1\frac{1}{2}$ sulphur.

Barium, ... 70
  chloride, (b. 70 + chl. 36) .. 106
  iodide, (b. 70 + iod. 124) .. 194
  oxide, (baryta) 78
  peroxide? 86
  phosphuret, ... 85.71
  sulphuret, ... 86
Bismuth, ... 72
  chloride, (b. 72 + chl. 36) .. 108
  oxide, ... 80
  iodide, (b. 72 + iod. 124) .. 196
  phosphuret, (b. 72 + p. 12) 87.71
  sulphuret, (b. 22 + s. 16) 88
Boron, ... 8
Bromine, ... (Berz.) .. 78.26
Cadmium, ... 56
  chloride, (cad. 56 + chl. 36 .. 92
  oxide, ... 64
  iodide, ... 144
  phosphuret, ... 71.71
  sulphuret, ... 72
Calcium, ... 20
  chloride, (cal. 20 + chl. 36) .. 56
  iodide, ... 144
  oxide, (lime) 28
  phosphuret, ... 35.71
  sulphuret, ... 36
Carbon, ... 6
  bisulphuret, (c. 6 + s. 32) .. 38
  chloride, ... 42
  perchloride, ... 120
  oxide, ... 14
  phosphuret, ... 21.71
Cerium, ... 50
  oxide, ... 58
  peroxide, ... 62
Chlorine, ... 36
  hydrocarburet, (chl. 36 + olef. gas 14) 50
  oxide, (chl. 36 + 0.8) 44
  peroxide, ... 68
Chromium, ... 32
  oxide, ... 40
Cobalt, ... 26
  chloride, (cob. 26 + chl. 36) .. 62
  iodide, ... 150
  oxide, ... 34
  peroxide, ... 38
  phosphuret, ... 41.71
  sulphuret, ... 42
Columbium, ... 144
Copper, ... 64
  chloride, (cop. 1 + chl. 1) .. 100
  bi-chloride, (c. 1 + chl. 2) .. 136
  iodide, (c. 1 + iod. 1) 188
  oxide, (c. 1 + 0.1) 72
  peroxide, (c. 1 + 0.2) 80
  phosphuret, ... 79.71
  sulphuret, ... 80
  bi-sulphuret, ... 96
Copper, (Thomson) 32

Cyanogen, (carb. 2 + nit. 1) 26
Cyanuret of sulphur, (cy. + 1 s. 2) 58
Ether, (olef. gas 2 + wat. vap. 1) 37
Fluorine, ... 18.86
Glucinium, ... 18
Glucina, ... 26
Gold, ... 200
  chloride, (g. 1 + chl. 1) 236
  bichloride, (g. 1 + chl. 2) .. 272
  iodide, (g. 1 + iod. 1) 324
  oxide, (g. 1 + 0.1) 208
  peroxide, (g. 1 + 0.3) 224
  sulphuret, (g. 1 + s. 3) 248
Hydrogen, ... 1
  arseniuretted, (a. 1 + h. 1) .. 39
  carburetted, (c. 1 + h. 2) 8
  olefiant gas, (c. 2 + h. 2) 14
  seleniuretted, (s. 1 + h. 1) .. 41
  sulphuretted, (s. 1 + h. 1) 17
  bisulphuretted, (s. 2 + h. 1) .. 33
Iodine, ... 124
Iridium, ... (Berz.) .. 99
Iron, ... 28
  chloride, (i. 1 + chl. 1) 64
  perchloride, (i. 1 + chl. $1\frac{1}{2}$) .. 82
  iodide, (i. 1 + iod. 1) 152
  oxide, (i. 1 + 0.1) 36
  peroxide, (i. 1 + 0.$1\frac{1}{2}$) 40
  sulphuret, (i. 1 + s. 1) 44
  bisulphuret, (i. 1 + s. 2) 60
Lead, ... 104
  chloride, (l. 1+chl. 1) 140
  oxide, (l. 1+0.1) 112
  deutoxide, (l. 1+0.$1\frac{1}{2}$) 116
  peroxide, (l. 1+0.2) 120
  phosphuret, (l. 1+p. 1) 119.71
  sulphuret, (l. 1+s. 1) 120
Lithium, ... 10
  chloride, (l. 1+ch. 1) 46
  iodide, ... 134
  oxide, (lithia) 18
  sulphuret, ... 26
Magnesium, ... 12
  chloride, (m. 1+chl. 1) 48
  oxide, ... 20
  sulphuret, ... 28
Manganese, ... 28
  chloride, (m. 1+chl. 1) 64
  perchloride, (m. 1+chl. 4) 172
  oxide, (m. 1+0.1) 36
  deutoxide, (m. 1+0.$1\frac{1}{2}$) 40
  peroxide, (m. 1+0.2) 44
  sulphuret, ... 44
Mercury, ... 200
  chloride, (calomel) (m. 1 + chl. 1) 236
  bichloride, (corrosive subl.) 272
  iodide, (m. 1+iod. 1) 324
  biniodide, (m. 1+iod. 2) .. 448
  oxide, (m. 1+0.1) 208
  peroxide, (m. 1+0.2) 216

Mercury, sulphuret, … 216
bisulphuret, … 232
Molybdenum, … 48
oxide, (m. 1 + 0.1) … 56
deutoxide, (m. 1 + 0.2) … 64
Molybdic acid, (m. 1 + 0.3) … 72
Nickel, … 26
chloride, (m. 1 + chl. 1) … 62
iodide, … 150
oxide, (n. 1 + 0.1) … 34
peroxide, (n. 1 + 0.1½) … 38
phosphuret, … 41.71
sulphuret, … 42
Nitrogen, … 14
bicarburet, (cyanogen) … 26
chloride, (n. 1 + chl. 4) … 158
iodide, (n. 1 + iod. 3) … 386
oxide, (n. 1 + 0.1 … 22
deutoxide, … 30
Oxygen, … 8
Palladium, … (Berz.) about … 53
oxide, … 61
Phosphorus, … (Berz.) … 15.71
chloride, (p. 1 + chl. 1) … 51.71
bichloride, … 87.71
carburet, … 22.71
sulphuret, … 31.71
Platinum, … (Berz.) about … 99
chloride, (p. 1 + chl. 1) … 135
bichloride, … 171
oxide, … 107
deutoxide, … 115
sulphuret, … 115
bisulphuret, … 131
Potassium, … 40
chloride, (p. 1 + chl. 1) … 76
iodide, … 164
oxide, (potash) … 48
peroxide, (p. 1 + 0.3) … 64
phosphuret, … 55.71
sulphuret, … 56
Rhodium, … (Berz.) about … 52
oxide, … 60
peroxide, … 64
Selenium, … 40
Silica, … 16
Silicium, … 8
Silver, … 110
chloride, (s. 1 + chl. 1) … 146
iodide, … 234
oxide, (s. 1 + 0.1) … 118
phosphuret, … 125.71
sulphuret, … 126
Sodium, … 24
chloride, (s. 1 + chl. 1) … 60
iodide, … 148
oxide, (soda) … 32
peroxide, (s. 1 + 0.1½) … 36
phosphuret, … 39.71
sulphuret, … 40
Strontium, … 44
Strontium, chloride, … 80
iodide, … 140
oxide, (strontia) … 52
phosphuret, … 59.71
sulphuret, … 60
Sulphur, … 16
chloride, (s. 1 + chl. 1) … 52
iodide, (s. 1 + iod. 1) … 140
phosphuret … 31.71
Sulphuretted hydrogen … 17
Bisulphuretted hydrogen … 33
Tellurium, (Berzelius) … 32
chloride, … 68
oxide, … 40
Tin, … 58
chloride, (t. 1 + chl. 1) … 94
bichloride, … 130
oxide, … 66
deutoxide, … 74
phosphuret, … 73.71
sulphuret, … 74
bisulphuret, … 90
Titanium, … 32
oxide, … 40
Titanic acid, … 48
Tungsten, … 96
oxide, (brown,) (t. 1 + 0.2) 112
Tungstic acid, (t. 1 + 0.3) … 120
Uranium, … 208
oxide, … 216
peroxide, … 224
Water, … 9
Yttrium, … 34
Oxide, (Yttria) … 42
Zinc, … 34
chloride, … 70
oxide, … 42
phosphuret, … 49.71
sulphuret, … 50
Zirconium, … 40
Zirconia, … 48

SALTS.

Acetate of alumina, (Ac. 1 + Al. 1.) 68
c. 1 w. … 77
ammonia, (Ac. 1 + Am. 1) … 67
c. 7. w. … 130
Baryta, (Ac. 1 + B. 1) … 128
c. 3 w. … 155
cadmium, (c. 2 w.) … 132
copper per-oxide, (Ac. 1 + C. 1) … 130
c. 6 w. com. verdigris, … 184
binacetate, … 180
c. 3 w. distilled verdigris, … 207
subacetate, (Ac. 1 + C. 2) … 210
lead, … 162
c. 3 w. … 189
lime, … 78
magnesia, … 70
mercury, (protoxide) c. 4 w. 294

Acetate of potash, ... 98
silver, ... 168
strontia, c. 1 w. 111
zinc, ... 92
c. 7 w. 155
Arseniate of lead, (A. 1+L. 1) .. 170
lime, ... 86
magnesia, ... 78
potash, ... 106
Binarseniate of potash, c. w. 90
Arseniate of soda, ... 110
Binarseniate of soda, c. w. 176
Arseniate of strontia, ... 114
silver, ... 180
Arsenite of lime, (A. 1 + L. 1) .. 78
potash, ... 98
Arsenite of soda, ... 82
silver, ... 168
Carbonate of ammonia, (C. 1 A. 1) 39
Sesquicarbonate of ammonia, (C. $1\frac{1}{2}$ + A. 1 + w. 1.) 59
Bicarbonate of do. 1 w. 70
Carbonate of baryta, ... 100
copper, ... 102
iron, (protoxide) 58
lead, ... 134
lime, ... 50
magnesia, ... 42
manganese, ... 58
potash, ... 70
Bicarbonate of potash, ... 92
c. 1 w. 101
Carbonate of soda, ... 54
c. 10 w. 144
Bicarbonate of soda, c. 1 w. 85
Carbonate of strontia, ... 74
zinc, ... 64
Chlorate of baryta (Ch. 1 + B. 1) 154
lead, ... 188
mercury, ... 284
potash, ... 124
Chromate of baryta, ... 130
lead, ... 164
mercury, ... 260
potash, (Chr. 1 + P. 1) 100
Bichromate of potash, ... 152
Muriate of ammonia, (M. 1 + A. 1) 54
baryta, c. 1 w. 124
lime, c. 6. w. 119
magnesia, ... 57
strontia, c. 8. w. 161
Nitrate of ammonia, (N. 1 + A. 1) 71
baryta, ... 132
bismuth, c. 3. 161
lead, ... 166
lime, ... 82
magnesia, ... 74
mercury protoxide, c. 2 w. 280

Nitrate of potash, ... 102
silver, ... 172
soda, ... 86
strontia, ... 106
Oxalate of ammonia, (Ox. 1 + A. 1) 52
c. 2 w. 71
baryta, ... 114
Binoxalate of baryta, ... 150
Oxalate of cobalt, ... 70
lime, ... 64
nickel, ... 70
potash, ... 84
c. 1 w. 93
Binoxalate of potash, ... 120
c. 2 w. 138
Quadroxalate of potash, ... 192
c. 7 w. 255
Oxalate of strontia, ... 88
Binoxalate of strontia, ... 124
Phosphate of ammonia, c. 2 w. 70.71
baryta, ... 113.71
lead, ... 147 71
lime, ... 63.71
magnesia, ... 55.71
soda, ... 67.71
c. $12\frac{1}{2}$ w. 180.21
Sulphate of alumina, ... 58
ammonia, c. 1 w. 66
baryta, ... 118
Sulphate of copper, (S. 1 + perox. 1) 120
Bisulphate of ditto, ... 160
c. 10. w. (blue vitriol) .. 250
Sulphate of iron, (protoxide) 76
c. 7. w. (green vitriol) .. 139
lead, ... 152
lime, ... 68
c. 2 w. 86
lithia, c. 1 w. 67
magnesia, c. 7 w. 123
mercury, (S. 1 + perox 1) .. 258
Bisulphate of mercury, (peroxide) 296
potash, ... 88
Bisulphate of potash, c. 2 w..... 146
Sulphate of soda, ... 72
c. 10 w. 162
strontia, ... 92
zinc, ... 82
c. 7 w. 145
Sulphate of alumina and potash, 262
c. 25 w. (alum) 487
Nitrate of lead, (T. 1 + L. 1) .. 178
lime, ... 94
potash, ... 88
Bitartrate of potash, ... 180
c. 2 w. (cream of tartar) .. 198
Tartrate of antimony and potash, c. 3 w. (tartar emetic) 363

Names.	Formulæ	Oxygen = 100.	Hydrogen = 1.
Sodium	$\underline{Na}$	581,794	93,239
Potassium	K	489,916	78,515
Ammonia	$\underline{NH^3}$	214,474	34,372
Cyanogen	$\underline{NC}$	329,911	52,872
Hydrosulphuric acid (Sulphuretted hydrogen)	$\underline{HS}$	213,644	34,239
Hydrochloric (muriatic) acid ..	$\underline{HCl}$	455,129	72,940
Hydrocyanic (prussic) acid ..	$\underline{HNC}$	342,390	54,872
Water	$\underline{\dot{H}}$	112,479	18,026
* Oxidule of azote (protoxide of)	$\underline{\dot{N}}$	277,036	44,398
Oxide of azote (nitrous gas) ..	$\dot{N}$	188,518	30,212
Nitrous (hyponitrous) acid	$\underline{\overset{\cdot\cdot\cdot}{N}}$	477,036	76,449
Nitric acid	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{N}}$	677,036	108,503
Hyposulphurous acid	$\dot{S}$	301,165	48,265
Sulphurous acid	$\ddot{S}$	401,165	64,291
Hyposulphuric acid	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{S}}$	902,330	144,609
Sulphuric acid	$\overset{\cdot\cdot\cdot}{S}$	501,165	80,317
Phosphoric acid	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{P}}$	892,310	143,003
Chloric acid	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{Cl}}$	942,650	151,071
Oxygenized chloric acid	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot\cdot\cdot}{Cl}}$	1042,650	167,097
Iodic acid	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{I}}$	2037,562	326,543
Carbonic acid	$\ddot{C}$	276,437	44,302
Oxalic acid	$\underline{\overset{\cdot\cdot\cdot}{C}}$	452,875	72,578
Boric acid	$\overset{\cdot\cdot\cdot\cdot\cdot\cdot}{B}$	871,966	139,743

* The term oxidule is applied to a supposed compound of 2 atoms of base + 1 of oxygen.

Names.	Formulæ	Oxygen = 100.	Hydrogen = 1.
Silicic acid (silica)	$\dddot{Si}$	577,478	92,548
Selenious acid	$\ddot{Se}$	694,582	111,315
Selenic acid	$\dddot{Se}$	794,582	127,341
Arsenious acid	$\underline{\overset{.:.}{As}}$	1440,084	230,790
Oxidule of chrome	$\underline{\dddot{Cr}}$	1003,638	160,845
Chromic acid	$\dddot{Cr}$	651,819	104,462
Molybdic acid	$\dddot{Mo}$	898,525	143,999
Tungstic acid	$\dddot{W}$	1483,200	237,700
Oxide of antimony	$\underline{\dddot{Sb}}$	1912,904	306,565
Antimonious acid	$\ddot{Sb}$	1006,452	161,296
	$\underline{\ddot{Sb}}$	2012,904	322,591
Antimonic acid....	$\underline{\overset{.:.}{Sb}}$	2112,904	338,617
Oxide of tellurium	$\ddot{Te}$	1006,452	161,296
Columbic acid	$\underline{\dddot{Ta}}$	2607,430	417,871
Titanic acid	$\ddot{Ti}$	589,092	94,409
Oxidule of gold.	$\underline{\dot{Au}}$	2586,026	414,441
Oxide of gold	$\underline{\dddot{Au}}$	2786,026	446,493
Oxide of platina	$\ddot{Pt}$	1415,220	226,806
Oxide of rhodium	$\dddot{R}$	1801,360	228,689
Oxide of palladium	$\dot{Pd}$	814,618	130,552
Oxide of silver	$\dot{Ag}$	1451,607	232,637
Oxidule of mercury	$\underline{\dot{Hg}}$	2631,645	421,752
Oxide of mercury	$\dot{Hg}$	1365,822	218,889
Oxidule of copper	$\dot{Cu}$	891,390	142,856

Names.	Formulæ	Oxygen = 100.	Hydrogen = 1.
Oxide of copper	$\dot{Cu}$	495,695	79,441
Oxidule of uranium	$\underline{\dot{U}}$	2811,360	450,553
Oxide of uranium	$\underline{\dddot{U}}$	5722,720	917,132
Oxide of bismuth	$\underline{\dddot{Bi}}$	2960,752	474,495
Oxidule of tin	$\dot{Sn}$	835,294	133,866
Oxide of tin	$\ddot{Sn}$	935,294	149,892
Oxide of lead	$\dot{Pb}$	1394,498	223,484
Minium..................	$\underline{\dddot{Pb}}$	2888,996	462,995
Brown oxide of lead	$\ddot{Pb}$	1494,498	239,511
Oxide of cadmium	$\dot{Cd}$	796,767	127,691
Oxide of zinc	$\dot{Zn}$	503,226	80,649
Oxide of nickel	$\dot{Ni}$	469,675	75,271
Oxide of cobalt	$\underline{\dot{Co}}$	468,991	75,161
Peroxide of cobalt..........	$\underline{\dddot{Co}}$	1037,982	166,349
Oxidule of iron............	$\dot{Fe}$	439,213	70,389
Oxide of iron	$\underline{\dddot{Fe}}$	978,426	156,804
Oxidule of manganese	$\dot{Mn}$	455,787	73,045
Oxide of manganese........	$\underline{\dddot{Mn}}$	1011,575	162,117
Peroxide of manganese......	$\ddot{Mn}$	555,787	89,071
Manganesic acid	$\underline{\overset{\cdot\cdot\cdot\cdot\cdot\cdot}{Mn}}$	1211,575	194,169
Oxidule of cerium	$\dot{Ce}$	674,718	108,132
Oxide of cerium	$\underline{\dddot{Ce}}$	1449,436	232,289
Zircon	$\underline{\dddot{Zr}}$	1140,476	182,775
Yttria	$\dot{Y}$	501,840	80,425

Names.	Formulæ	Oxygen = 100.	Hydrogen = 1.
Glucine	$\underline{\dddot{Be}}$	962,958	154,325
Alumina	$\underline{\dddot{Al}}$	642,334	102,942
Magnesia	$\dot{Mg}$	258,353	41,404
Lime	$\dot{Ca}$	356,019	57,056
Strontian	$\dot{Sr}$	647,285	103,735
Barytes	$\dot{Ba}$	956,880	153,351
Lithia	$\dot{L}$	227,757	36,501
Soda	$\dot{Na}$	390,897	62,646
Peroxide of sodium	$\underline{\dddot{Na}}$	881,794	141,318
Potassa	$\dot{K}$	589,916	94,541
Peroxide of potassium	$\dddot{K}$	789,916	126,593
Sulphate of potass	$\dot{K}\,\dddot{S}$	1091,081	174,859
Sulphate of oxidule (protoxide) of iron	$\dot{Fe}\,\dddot{S}$	940,378	150,706
Sulphate of oxide (peroxide) of iron	$\underline{\dddot{Fe}}\,\dddot{S}^3$	2481,906	397,754
Chloruret of iron (chloride)	$Fe\,\underline{Cl}$	781,863	125,303
Chloride of iron (perchloride)	$\underline{Fe\,Cl}^3$	2006,376	321,545
Chloruret of mercury (calomel)	$\underline{Hg\,Cl}$	2974,295	476,666
Chloride of mercury (corr. sub.)	$Hg\,\underline{Cl}$	1708,472	273,803
Cyanoferruret of potassium (ferrocyanate of potass)	$Fe\,\underline{NC}+2\,K\underline{NC}$	2308,778	370,008
Alum	$\dot{K}\dddot{S}+\underline{\dddot{Al}}\,\dddot{S}^3+24\,\underline{\dot{H}}$	5936,406	951,378
Felspar	$\dot{K}\,\dddot{Si}+\underline{\dddot{Al}}\,\dddot{Si}^3$	3542,162	567,673

ERRATA.

Page 37 l. 13, *for* 19 *read* 9. P. 50 l. 1, *for* persulphate *read* peroxide. P. 65 note, *for* Mr. Emmett *read* Mr. Ewart. P. 106 l. 26, *for* smallest portions *read* smallest conceivable portions.