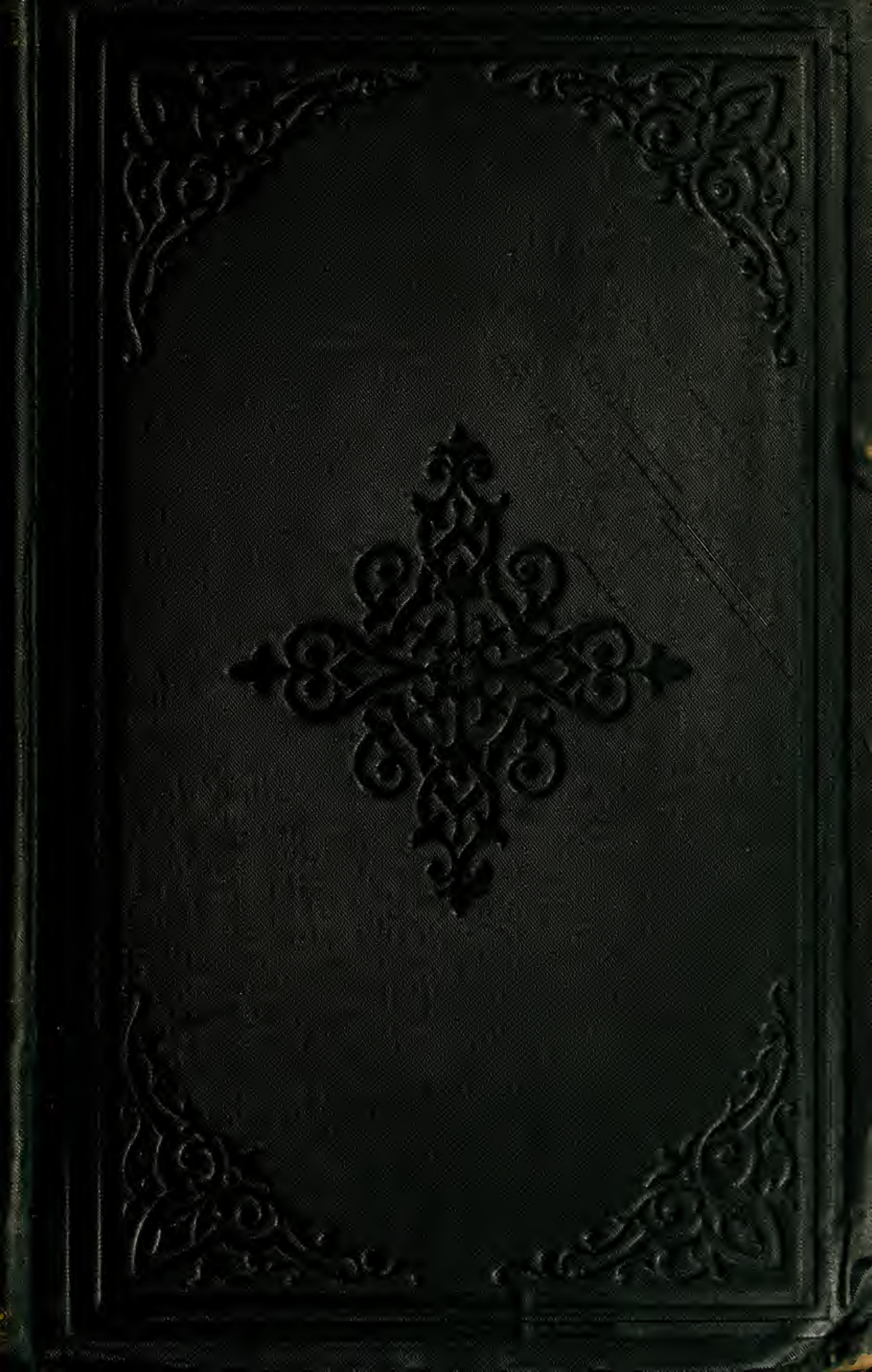

# THE METALLIC ALLOYS.

## A PRACTICAL GUIDE

FOR THE

MANUFACTURE OF ALL KINDS OF ALLOYS, AMALGAMS,
AND SOLDERS, USED BY METAL-WORKERS;

TOGETHER WITH THEIR

CHEMICAL AND PHYSICAL PROPERTIES AND THEIR
APPLICATION IN THE ARTS AND THE
INDUSTRIES;

WITH AN APPENDIX ON THE COLORING OF ALLOYS.

TRANSLATED AND EDITED CHIEFLY FROM THE GERMAN OF

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ILLUSTRATED BY SIXTEEN ENGRAVINGS.

PHILADELPHIA:
HENRY CAREY BAIRD & CO.,
INDUSTRIAL PUBLISHERS, BOOKSELLERS AND IMPORTERS,
810 WALNUT STREET.

LONDON:
SAMPSON LOW, MARSTON, SEARLE & RIVINGTON, LIMITED,
ST. DUNSTAN'S HOUSE, FETTER LANE, FLEET STREET.
1889.

PHILADELPHIA:
COLLINS PRINTING HOUSE,
705 Jayne Street.

# PREFACE.

It is not claimed that the work here presented actually fills a void in our technical literature, but it is believed that there is no other recent one in the English language on the Metallic Alloys which combines with practical usefulness a sufficiently popular character for those readers who have not made Metallurgy and its kindred Arts objects of special study. The endeavor has been made to offer a book which fully treats on all matters relating to the subject, and which will explain to the Mechanic and Artist the properties of the metallic alloys and amalgams as far as they find application in any branch of technology and the industries.

The principal portion of this volume is a translation of the German work, *Die Legirungen* by A. Krupp, to which such additions have been made as seemed necessary to bring it up to the present time. In the older works many alloys, which have in modern times assumed great importance and form the basis of large branches of industry, are scarcely mentioned, as for instance the valuable alloys of aluminium, German silver, phosphor-bronze, etc. These have been fully treated in this volume, as have been the behavior of the different metals towards one another, the various methods of manufacturing alloys, and their specific properties. Great care has been exercised in aiming to select only such receipts as have stood the test in practice, and hence it is hoped that the work may, to all persons professionally interested in the manufacture and use of alloys, amalgams, and solders, prove a reliable guide.

The scope of the work has been enlarged by the addition of an Appendix, giving approved receipts for bronzing and coloring alloys.

W. T. B.

Philadelphia, October 15, 1888.

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## APPENDIX.

### COLORING OF ALLOYS.

# THE METALLIC ALLOYS.

## A PRACTICAL GUIDE

FOR THE

## MANUFACTURE OF ALL KINDS OF ALLOYS, AMALGAMS, SOLDERS, ETC.

## I.

### INTRODUCTION.

THE term alloy, in its most general acceptation, means the mutual combination of two or more metals. When one of the metals, however, entering into combination is mercury, the result is not usually termed an alloy, but an amalgam. At the present time the belief prevails—we may even say it is universal—that alloys are not always mere mechanical mixtures of different metals, but are constituted in accordance with the laws of definite chemical combination.

The earliest historical data in reference to the development of the art of preparing, so to say, new metals by melting together several metals are very meagre, and though it appears from several passages in sacred as well as profane history that no metallic compound was in more general use with the ancients than brass, the mode of its manufacture is left in obscurity by the historiographers of subsequent ages. Pliny says that a flourishing trade in brass was carried on in Rome shortly after the founding of that city, and that Numa, the immediate successor of Romulus, formed all the workers in this alloy into a kind of community.

The Greeks possessed considerable knowledge in the art of mixing metals, and knew how to prepare alloys with special properties which rendered them suitable for particular purposes. They understood, for instance, the preparation of alloys which were especially hard, or well adapted for casting. The oldest alloys we know of always contain copper, which is, no doubt, due to the fact that this metal occurs native in many places, and is also readily reduced from its ores. Next to alloys containing copper, we find those of the noble metals—silver and gold—with a base metal, generally copper.

It is not difficult to explain why the noble metals were alloyed in early times with other metals. On the one hand, these metals were much more expensive than at the present time, and, being subject to considerable wear on account of their softness, it was but natural that some one, recognizing the great similarity between the heavy metals as regards ductility, weight, and lustre, should have instituted experiments in order to see how these metals would behave towards each other when melted together. Experience then showed that by melting together, for instance, a certain quantity of silver with copper, the properties of silver, especially its white color, were retained, while the hardness and power of resistance of the alloy were considerably increased.

There can scarcely be any doubt that the alloys of copper with tin, generally called bronze, were the earliest mixtures of metals, because zinc, in a metallic state, has only been known at a later period, while tin was known in the earliest historic times. Next in historical order follow the alloys of the noble metals with each other and with copper. Mercury, which occurs free in nature, was also known to the ancients, and its metallic properties recognized by them, as is evident from the name—hydrargyrus (water-silver)—by which it was designated. It is certain that compounds of it, which, at the present time, are designated as amalgams, were used by the Greeks and Arabians. From what has been said, it would seem likely that the ancients understood the art of fire-gilding metallic articles with the assistance of gold amalgam; and, in fact, some old statues which had evidently been gilded have been found—the best example of it being the statue of the Roman emperor Marcus Aurelius, which now stands in front of the capitol at Rome.

Up to the commencement of the reign of Charlemagne, when the development of the technical arts commenced in Europe, the only mixtures of metals were the alloys of copper, tin, zinc, silver, and gold, and some amalgams. To prepare other alloys a greater knowledge of chemistry was required than that possessed by the early races of mankind. The development of chemistry was principally due to the Arabs, and, especially to those settled in Spain—the Moors—who were well learned in the chemical sciences and in all branches of natural history, and probably well aware of many mixtures of metals still used at the present time. At later periods it was alchemy, the vague hallucination of making gold from lead and other base metals, which prompted men to undertake investigations fruitful of chemical deductions and promotive of a knowledge of the metals. Many an alchemist found in his crucible alloys, which he threw away, unsatisfied, because they did not possess the properties of the desired gold, but which at the present time are profitably used. It may be said without exaggeration that modern chemistry would not have reached such a degree of excellence if it were not for the great abundance of facts collected by the alchemist to be marshalled into a science hereafter.

From what has been said, it will be seen that at the time when chemistry as a science did not exist, considerable was known in regard to alloys, and we find that in the middle ages a large number of mixtures of metals were used in the different arts and industries. The preparation of the alloys, however, was always effected in a very crude manner, but little being known about the definite proportions in which the metals had to be melted together in order to obtain alloys of determined properties. The only exception to this were the alloys obtained by the direct melting together of the pure metals, for instance, those prepared from the noble metals and copper. As is well known, everything relating to coinage had reached a considerable degree of excellence in the middle ages, and the fineness of a mixture of metals which was to be used for coinage could be determined with considerable accuracy.

The art of preparing alloys, however, became only a branch of chemistry when the latter, somewhat more than a century ago, entered the ranks of the sciences. The chemists gradually investigated all the bodies occurring in nature, and showed how from minerals a series of metals could be gained which were not known up to that time. These metals were examined in regard to their intrinsic properties and their behavior towards each other, and it was observed that a great number of their mixtures possessed properties which made them suitable for technical purposes.

Of the sixty-four elementary or simple bodies at present recognized, no less than fifty belong to the class of metals. Several of these are of recent discovery, and are, as yet, imperfectly known. Nevertheless, there is but a small number of them which cannot be used for the preparation of alloys.

Though it may be said that our knowledge of chemistry has advanced so far that at present all metals of importance in the arts and industries are known, our knowledge of the metals themselves cannot be considered complete, as, during the last twenty years, several new metals have been discovered which may become of a certain importance in the preparation of alloys. The fact that these metals are very rare at the present time, and that their preparation is connected with enormous expense, is not adverse to this conjecture, since many examples could be enumerated of bodies which a short time ago were considered expensive rarities, but are now produced on a large scale, and used for industrial purposes.

From what has been said in the preceding, the science of metallic alloys must be considered as a branch of knowledge which, though brought to a high degree of perfection, is by no means complete. It rather opens a wide field for the activity of the chemist, and the invention of a new alloy belongs to the most important and valuable discoveries, since nearly every alloy possesses certain specific properties which make its application to many branches of industries especially valuable.

## II.

## PHYSICAL AND CHEMICAL RELATIONS OF METALS.

Before proceeding with the description of the manufacture of alloys, it will be necessary to give a general review of the physical and chemical properties of the metals; such knowledge of the elements to be alloyed being required in order to proceed according to a determined plan, as otherwise satisfactory results could only be obtained by a happy accident.

Most of our readers, no doubt, possess this information, but memory might fail some of them, and some essential, though elementary, details may escape others. Nevertheless, a book like this should be complete, and include all the rudiments absolutely necessary for the understanding of the subject without the trouble of searching for the information in other books.

Chemists divide the elementary bodies into two large groups, viz., the metals and metalloids or non-metals, the latter term being decidedly preferable for the second group, as it definitely expresses the existence of an essential difference between these two groups of elementary bodies. Though chemists do not by any means agree as to which bodies are to be termed metals and which non-metals, it is not difficult for our purposes to give certain distinctive characteristics, so that, as regards the metals to be considered in connection with the manufacture of alloys, a sharp boundary can be drawn between them and the non-metals in the actual sense of the word.

### a. *Physical Relations of the Metals.*

By the term metal is, as a rule, understood in ordinary life, a body, which, besides high specific gravity, a characteristic color, and especially a characteristic lustre, shows other definite properties. It is, for instance, frequently supposed that all metals possess a high degree of ductility, that they are opaque, fuse only at a high temperature, and, on exposure to the air, undergo a slow alteration or, as is the case with the so-called noble metals, retain their color under all circumstances.

The properties above named undoubtedly belong to the metals ordinarily understood by that term and chiefly used in the industries. In considering, however, the bodies termed metals from the standpoint of the chemist, we find that many of them, which must unquestionably be included in that group, show properties differing very much from those enumerated above. If we first turn to the ordinary well-known metals, we find them distinguished by a characteristic lustre, termed metallic lustre, this property being even possessed in a very high degree by such metals as appear entirely lustreless in consequence of their chemical properties (*i. e.*, in contact with the air). If a lump of lead be cut across with a knife, the fresh surfaces show a beautiful lustre, but will very speedily tarnish by the lead undergoing a rapid alteration on exposure to the air.

Besides high specific gravity and metallic lustre, other general properties are ordinarily ascribed to metals, prominent among which is ductility. It is, however, well known to every one handling metals that they manifest great variations in capacity of extension under the hammer or between rollers. Some of them, like gold and silver, may be obtained in exceedingly thin leaves, while others, like antimony and bismuth, appear to be perfectly unmalleable. Similar differences are noticeable in the tenacity of the metals; some of them can be drawn out into very fine wire, while others are altogether destitute of ductility.

Even the property of opacity belongs only conditionally to the metals, for gold and silver are translucent in thin plates, the former transmitting green rays and the latter blue rays, though none of the other metals have been obtained in sufficiently thin leaves to allow of the transmission of light.

From what has been said it will be seen that the properties of metals vary very much from those ordinarily ascribed to them, and the same must be said in regard to their fusibility. While some fuse at a temperature below that of boiling water, others melt only at the very highest temperature, and the determination of the exact point is a matter of great difficulty. Certain of them soften before actual fusion occurs, so that they can be hammered or welded into compact masses. There are, however, some points in which all metals to be discussed here agree:—

They are distinguished by great weight: lead, iron, gold, and platinum being representatives of those prominent in this respect.

They are, as a rule, very ductile bodies: copper, silver, gold, etc., being representatives of this group. Others, like zinc, antimony, and bismuth, show, however, a high degree of brittleness.

With the exception of mercury, they are all solids at an ordinary temperature and become fluid only at higher temperatures, the degree of heat at which this takes place varying, however, very much.

They are, without exception, excellent conductors of heat and electricity; that is, they rapidly absorb them, but just as rapidly yield them up again.

These general points quite exhaust the physical properties of metals possessed by them in common. It remains to be remarked that they show considerable differences in regard to specific gravity, ductility, conductivity, etc., which will be referred to in speaking of the special properties of the metals available for alloys.

### b. *Chemical Relations of the Metals.*

Chemically, the metals are distinguished by their ability to form combinations with the non-metallic elements; the combination with the oxygen of the air being especially energetic. The affinity of the different metals for oxygen, however, varies greatly, the majority of the metals used in ordinary life combining with it at an ordinary temperature. This phenomenon can be readily observed on the previously-mentioned lump of lead. The fresh surfaces lose their lustre by the lead combining with the oxygen from the air, which gives rise to a coating of oxide. Copper, having less affinity for oxygen, remains bright for some time and then acquires a brown-red coloring, which is also due to the formation of a layer of oxide. Many other metals remain bright at an ordinary temperature, and only lose their characteristic lustre by oxidation taking place at a higher temperature—this last phenomenon being, for instance, observed with tin and antimonial metals which become oxidized by heating. In ordinary language all metals losing their metallic lustre at an ordinary temperature or by heating are termed *base metals*, while the term *noble metals* is applied to those which have so little attraction for oxygen that they cannot be induced directly to unite with it even at high temperatures. The number of noble metals is very small in comparison with that of the base metals and of those more frequently used; mercury, silver, gold, and platinum only can be actually counted among them.

From what has been said, it will be seen that the metals may be divided according to their behavior towards oxygen, such a division being in fact well supported, as we will have occasion to demonstrate in the course of our explanations.

In a chemical sense, the metals can be further divided with reference to certain physical properties into heavy and light metals. There is a series of metals whose specific gravity is so small that they float upon water, that of some of them being not greater than ordinarily exhibited by glass. Chemists term such metals light metals, in contradistinction to those which are distinguished by great weightiness.

The properties of the light and heavy metals allow, however, of an easy separation as regards their chemical relations, and, by taking these relations into consideration, the result will be a suitable division of the metals into determined groups which, together with their special properties, will be mentioned.

The metals belonging to the group of light metals have a very small specific gravity, which does not exceed four (the weight of a volume of water being always taken as a unit). These metals find but a limited application by themselves, most of them having such strong affinity for oxygen as to be very speedily converted into oxide on coming into contact with the air. Only two of them, magnesium and aluminium, form an exception in this respect, and are, therefore, used in the arts and industries, though only to a limited extent. According to their occurrence, these metals are divided into several groups, viz: *alkali metals*, *metals of the alkaline earths*, and *metals of the earths proper*.

To the alkali metals belong *potassium, sodium,* and *lithium,* and a few other very rare minerals, which have only become known in more modern times. The two first-named metals occur generally in the ashes of land and marine plants, but, on account of their great instability, are not employed in technics, and serve only for the preparation of certain seldom-used metals. Lithium is a very widely diffused element, being found in many micas, in feldspar, in the ashes of many plants, and in sea-water; it has also been detected in certain meteorites. It is the lightest solid known, being lighter even than any known liquid.

The metals of the alkaline earths have nearly the same properties as the alkali metals, but their affinity for oxygen, though very considerable, is somewhat less. Chemists include in this group *calcium,* occurring in gypsum, limestone, and many other minerals; *barium,* contained in heavy spar; and *strontium,* the principal naturally-occurring compounds of which are the sulphate, or *coelestin,* and the carbonate, or *strontianite.* Like the alkali metals, the metals of the alkaline earths do not find a direct application in the industries, their great affinity for oxygen rendering such use impossible.

The metals of the earths proper occur in many minerals, and a large number of metals belonging to this group are known, but only two of them—*aluminium,* occurring in alumen, clay, feldspar, and a large number of other minerals, and *magnesium,* found in dolomite, etc.—have any claim to our attention on the ground of their technical importance. Their affinity for oxygen is not so energetic as that of the other metals of this group, since both can be kept in contact with dry air without entering into combination with oxygen, aluminium even retaining its lustre for a comparatively long time.

All light metals have, however, the property of readily decomposing water, the alkali metals and metals of the alkaline earths effecting this at an ordinary temperature. When a piece of potassium is thrown upon water, a vigorous development of hydrogen immediately takes place. The metal melts in consequence of the heat liberated by the chemical process, and the developed hydrogen ignites. The metal combines immediately with the oxygen to potassium oxide, which dissolves in water. After the combustion of the potassium, a colorless globule, consisting of the melted potassium oxide, floats upon the surface of the water. With a peculiar fizzing noise this globule suddenly bursts into pieces, which speedily dissolve in the water to potassium hydroxide.

The metals of the earths proper act less energetically on meeting with water, though they decompose it at a boiling heat; magnesium, for instance, when strongly heated in contact with air burning with the development of considerable light and heat.

The heavy metals, *i. e.*, those which are chiefly used in ordinary life, can, according to their chemical behavior, be brought into four well-defined groups, the group into which each metal is to be placed depending on its behavior in contact with hot water-vapor or with water in the presence of an acid. In reference to this we distinguish the following groups:—

1. Metals which decompose water at the ordinary temperature in the presence of an acid, and which possess the further property of decomposing water at a higher temperature (at a red heat). To this group belong iron, zinc, nickel, cobalt, chromium, cadmium, tin, and a few rarer metals.

2. Metals which decompose water at the temperature of a red heat, but lack the property of decomposing water in the presence of an acid. Of the more important metals only antimony and tungsten belong to this group.

3. Metals which are incapable of sensibly decomposing water either at a red heat or in the presence of an acid, and are entirely indifferent towards it at an ordinary temperature. The metals belonging to this group, of which bismuth, lead, copper, and mercury are representatives, possess, however, the property of oxidizing when heated red hot in contact with air.

4. Noble metals are, finally, such as do not combine with oxygen when strongly heated in contact with air, and at a red heat remain entirely indifferent towards water. Silver, gold, and platinum are the most important of the metals belonging to this group.

Besides the metals enumerated in the preceding groups there are a number of others which, according to their behavior, belong to one or the other. But, as previously mentioned, these metals are of no technical importance, being on account of their rarity too expensive to be used for industrial purposes. Moreover, we would here remark that among the enumerated metals are some, for instance cobalt and tungsten, whose application in the industries is very limited, though they can be procured in large quantities. A more extensive use may, however, be found for them in the future, as has been the case with nickel, with which nothing could be done for a long time, but which is now used in large quantities in the preparation of very important alloys.

Metals can be mixed by melting them together, the bodies obtained in this manner being termed alloys. *An alloy may, therefore, be designated as a mixture of two or more metals formed by fusion.* Although the majority of metals can be fused together in any proportions desired, so that the number of alloys can be almost increased to any extent, we find that certain metals combine with special ease in determined proportions of weight. Such an alloy may be considered as a chemical combination, while those prepared by melting together metals in proportions chosen at will may be viewed as a mixture of two liquids, for instance, of water and alcohol; the greater the quantity of one constituent the more the mixture will show the properties of that constituent. But while this is true of many mixtures of metals, it would be incorrect to accept it as a fact in regard to all alloys, because in many cases a small admixture of one metal suffices to thrust the properties of another into the background. We see, for instance, that certain metals possess the property of considerably hardening other soft and ductile ones, and, furthermore, that certain bodies not belonging to the metals exert a still greater influence upon the properties of a metal. It will, therefore, be necessary briefly to consider these bodies.

Carbon, sulphur, phosphorus, and arsenic are the most prominent of the non-metallic bodies, which are capable of changing to a considerable degree the properties of a metal, and these bodies being much used for that purpose in the industry, we will have to consider their combinations with the metals, though they do not belong to the actual alloys.

The exceedingly great influence exerted by these bodies upon the properties of metals, even if admixed only in very small quantities, is best shown by the behavior of iron.

Pure iron, such as is used for piano strings or good shoe nails, is a metal of great hardness and extraordinary tenacity, which can only be fused at the highest temperature capable of being produced in our furnaces. It contains at the utmost one-half per cent. of foreign substances, consisting of varying quantities of manganese, silicium, and carbon. But iron containing a quantity of foreign substances amounting to 1½ per cent., of which carbon constitutes the greater portion, shows, however, entirely different properties and is termed *steel.*

As is well known the properties of steel are quite different from those of iron. It is harder, more elastic, and more tenacious, and fuses somewhat more readily. By still further increasing the carbon in the iron to about three per cent., we have what is known as cast-iron. It is more fusible than steel, but brittle, and cannot be worked under the hammer (it cracks). According to the content of carbon, it shows a gray to nearly white color (gray and white cast-iron) and a crystalline structure.

A content of sulphur or phosphorus exerts a still greater effect upon the properties of iron than one of carbon. Iron, containing but a few thousandths of sulphur, can only be worked in the heat; if hammered in the "cold" it cracks; it has become what is termed "cold-short," *i. e.*, brittle when cold. With a still smaller content of phosphorus, the iron cannot be worked with the hammer, even at a red heat, and at a white heat cracks under the hammer; it has become "red-short" or "hot-short." The admixture of these bodies (carbon, sulphur, and phosphorus) with the metals is frequently an unintentional one, it being due to the nature of the ores used.

Before proceeding with the description of the properties of the alloys and the manner of their manufacture, it will be convenient in order to avoid unnecessary repetition later on to give a short sketch of the special properties of the separate metals. As previously mentioned, some metals can be readily combined according to certain fixed proportions. In such case we have not alloys in the actual sense of the word (*i. e.*, mixtures of metals), but rather chemical combinations.

By a chemical combination is understood the union of two or more simple elements in unalterable proportions or multiples thereof. Each element possesses the property of combining the other according to a proportion of weight admitting of no variation whatever, and the quantity of weight, which enters into the combination, and is capable of so completely invalidating the properties of the other bodies that, so to say, a new body is formed, is termed the atomic or indivisible weight. The names of the most important elements are given in the annexed table, together with their symbols and atomic weights, which express the proportions in which they combine together, or simple multiples of those proportions. The symbols are formed of the first letters of the Latin names of the elements, a second letter being added when the names of two or more elements begin with the same letter.

*Table of elementary bodies with their symbols and atomic weights.*

NON-METALS.

| Name. | Symbol. | Atomic weight. | Name. | Symbol. | Atomic weight. |
|---|---|---|---|---|---|
| Hydrogen | H | 1 | Phosphorus | P | 31 |
| Chlorine | Cl | 35.5 | Boron | Bo | 11 |
| Oxygen | O | 16 | Carbon | C | 12 |
| Sulphur | S | 32 | Silicium | Si | 28 |
| METALS. | | | | | |
| Sodium (Natrium) | Na | 23 | Nickel | Ni | 58 |
| Potassium (Kalium) | K | 39.3 | Copper (Cupruni) | Cu | 63.4 |
| Calcium | Ca | 40 | Mercury (Hydrargyrum) | Hg | 200 |
| Magnesium | Mg | 24 | | | |
| Aluminium | Al | 27.4 | Silver (Argentum) | Ag | 108 |
| Zinc | Zn | 65 | Gold (Aurum) | Au | 196 |
| Cadmium | Cd | 112 | Platinum | Pt | 197.5 |
| Lead (Plumbum) | Pb | 207 | Antimony (Stibium) | Sb | 120 |
| Iron (Ferrum) | Fe | 56 | Arsenic | As | 75 |
| Chromium | Cr | 52.2 | Bismuth | Bi | 208 |
| Manganese | Mn | 55 | Tin (Stannum) | Sn | 118 |
| Cobalt | Co | 59 | Tungsten or Wolfram | W | 184 |

# III.

## SPECIAL PROPERTIES OF THE METALS.

a. *Alkali-metals.*—As previously mentioned, the alkali-metals occur in the ashes of land and marine plants, potassium especially in that of land plants and sodium in that of marine plants. Both metals can be prepared in large quantities by treating their carbonates, potassium carbonate or sodium carbonate, with charcoal and chalk in iron retorts at a white heat. They are brilliant-white with a high degree of lustre. At an ordinary temperature they are soft and may be easily cut with a knife. They have a very low melting point, potassium melting completely at 144.5° F., and sodium at 207.5° F. Exposed to the air both metals rapidly oxidize, and must, therefore, be preserved under a fluid containing no oxygen (petroleum). In consequence of these properties neither potassium nor sodium can be used in the industries, and serve only for the indirect preparation of some metals. For instance, by a combination ot aluminium and chlorine with potassium or sodium, the latter, in consequence of their stronger affinity for chlorine, withdraw it from the combination, whereby the aluminium is liberated. Several other metals can be prepared in a similar manner.

b. *Metals of the alkaline earths.*—To this group belong, besides calcium, occurring in limestone, gypsum, and several other minerals, barium and strontium. The affinity of these metals for oxygen is so great, that, like potassium and sodium, they have to be kept under petroleum, and are not used in the form of metals in the industries.

c. *Metals of the earths proper.*—The most important of this group for our purposes is aluminium (Al; atomic weight 27.4). It is the most widely distributed metal on earth. It is never found in the metallic state, but always combined with oxygen, and in this form $Al_2O_3$ is the basis of many of the commonest rocks, and the chief constituent of most clays. It is found in porphyries, igneous rocks, and in connection with quartz in granite, gneiss, mica, schist, syenite, and some sandstone. There is, therefore, an abundance of cheap raw material, but as the processes for the production of the metal have heretofore depended on the use of expensive chemicals, it is so costly that it is far from occupying its true place in the arts. It is usually produced by heating the double chloride of aluminium and sodium, or the native double fluoride or cryolite with sodium. A mixture of 10 parts of the double chloride, 5 parts of fluorspar or cryolite, and 2 parts of sodium is thrown upon the red-hot hearth of a small reverberatory furnace, and the dampers are closed to prevent the entrance of air. Intense reaction occurs, and the materials are completely liquefied. When the reduction is finished, the slag (consisting of a mixture of common salt and aluminium fluoride) and the reduced aluminium are run out through a hole at the back of the furnace. In preparing the metal from cryolite, this mineral is mixed with half its weight of common salt, and the mixture is heated with sodium in an iron or earthen crucible. The metal obtained by reduction with sodium usually contains more or less silicon, iron, and admixed slag.

The following description of the methods in vogue at Salindere, France, is given by E. D. Self:—*

The process differs from the one first used industrially in that the double chloride of aluminium and sodium is substituted for the single chloride $Al_2Cl_6$, though it is very hygroscopic, and, on becoming moistened, oxidizes to $Al_2O_3$. The material chiefly employed at Salindere is bauxite, and the process consists, briefly, of the following steps:—

1. Preparation of the aluminate of soda and the solution of this salt to separate the oxide of iron contained in the ore.

2. Preparation of $Al_2O_3$ by precipitating it from the soda solution with $CO_2$.

3. Preparation of the mixture of $Al_2O_3$, carbon and salt, and drying and treating with chlorine gas to obtain the double chloride.

4. Treatment of the double chloride with sodium to obtain metallic aluminium.

The aluminate of soda $Al_2O_3.3\,(NaO)$ is produced by calcining a mixture of bauxite ($Al_2O_3$ and sesquioxide of iron) and carbonate of soda, and then dissolving and filtering off the soluble aluminate from the sesquioxide of iron. The alumina is now precipitated from the soda solution by $CO_2$ thus:—

$$Al_2O_3.3(Na_2O) + 3CO_2 + 3H_2O =$$
$$Al_2O_3.3H_2O + 3(Na_2CO_3).$$

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* Journal Franklin Institute, March, 1887.

The formation of the double chloride by the action of chlorine on a mixture of alumina, carbon, and salt is thus expressed :—

$$Al_2O_3 + 3C + 2NaCl + 6Cl = Al_2Cl_6.2NaCl + 3CO.$$

Finally, the reduction of the double chloride by sodium is :—

$$Al_2Cl_6.2NaCl + 6Na = 2Al + 8NaCl.$$

Considerable difficulty was at first experienced in the manufacture of aluminium to find a flux whose density was low enough and, at the same time, was free from iron. Cryolite, however, seems to answer the purpose very well, and produces a very fusible slag, beneath which the metal collects. The proportions for the constituents of a charge are: Double chloride 200 lbs., cryolite 90 lbs., sodium 70 lbs.

The double chloride and cryolite are mixed, and then divided into four equal parts. The sodium is divided into three parts, and is so put in that it has a layer of the double chloride and cryolite beneath it on the hearth of the furnace, and between it in successive layers, the top one being composed of the cryolite mixture.

As heat is applied the first flow is melted slag, then aluminium, and finally a gray cinder containing small portions of the metal.

F. Lauterborn, of Dortmund, has patented in Germany the following process of preparing aluminium from aluminium sulphate by means of antimony and coal at a high temperature: The crude aluminium sulphate is freed from water by heating in crucibles or upon a hearth, and the resulting porous mass pulverized.

100 parts of aluminium sulphate, 50 of coal, and 72 of antimony are mixed, and after adding fluor spar, sodium carbonate, or sodium sulphide for the formation of slag, the mixture is heated in a crucible or furnace until it melts, and for some time kept in flux by means of a blowing engine. The specifically very heavy sulphide of antimony formed settles on the bottom of the crucible, but is converted into slag by the addition of sodium. The antimony is regained as regulus from the sulphide of antimony by means of iron in the known manner.

At the present time strenuous efforts are made to cheapen the manufacture of the metal. The Cowles Brothers, of Cleveland, Ohio, have lately invented a process of reducing the refracting ores of many metals by electrical means, which promises to become very important in the arts. They construct a rectangular box of fire-resisting material, lined with a mixture of fine charcoal and lime. It has a removable cover, which is perforated with openings to allow the escape of gases evolved. In the sides of this furnace the electrodes—two plates of gas carbon—are let in by means of which the current of a powerful dynamo-electric machine is introduced. The charge consists of a mixture of the coarsely crushed ore and coke fragments. The essential feature of the process consists, therefore, in employing in the furnace a substance like carbon, whose high resistance to the passage of the current causes the production of a prodigiously high temperature, and which, at the same time, is capable of exercising a powerful reducing action on the ore. With such an arrangement of apparatus and by the use of a powerful electric current, the inventors have succeeded in reducing aluminium from corundum, boron from boracic acid, and silicium from quartz. They have greatly cheapened the cost of aluminium-bronzes and brasses, and it is expected to be able to produce pure aluminium in quantity at much lower prices than has heretofore been possible.

The greatest value of aluminium, perhaps, is in the wonderful alloys it is capable of producing. These are very numerous and always satisfactory, alloyed with wrought iron and steel, giving certain properties that enable those metals to be cast successfully and without blow-holes; with copper, the beautiful gold bronze; with silver, the *tiers argent* of the French; and with zinc, nickel, tin, and manganese, it forms valuable and characteristic alloys, giving to them qualities of great tensile strength, immunity from oxidation, and other advantages.

Aluminium is a white, highly lustrous metal; it may be beaten out or rolled into thin foil or drawn out into fine wire. It is quite hard, melts at a very high temperature (at about that of silver), and shows a density after fusion of about 2.56, which can be increased to 2.67 by hammering. Air has no oxidizing action upon it at any temperature, and it is not attacked by fused nitre or by nitric or dilute sulphuric acid, sulphuretted hydrogen, or the alkaline sulphides. Hydrochloric acid and solutions of the alkaline hydroxides dissolve it readily, hydrogen being evolved. Aluminium has been found to be of considerable use in the manufacture of jewelry, in the mountings of astronomical instruments, and in the construction of balance beams and chemical weights.

*Magnesium* (Mg; atomic weight 24) is another metal belonging to this group. This element, in a state of combination, occurs widely distributed, and is found in a great variety of minerals. Metallic magnesium is now obtained on a considerable scale by heating the anhydrous chloride with sodium and distilling the crude product. It possesses a silvery white color, and acquires a high lustre by polishing. When strongly heated in contact with air it burns with a bright, white light, rich in chemically active rays.

Recent experiments made in Charlottenburg, Germany, on the tensile strength of metallic magnesium, show that it is higher than that of aluminium and brass and nearly equal to that of bronze or Delta metal. Its specific gravity is 1.75. At a temperature of 842° F. it can be rolled, pressed, worked, and brought into complicated forms. Screws and threads can be made of magnesium, and these are considerably sharper and more exact than those from aluminium.

d. *Heavy metals.*—To this group belong the metals of the most importance to the industries. They are divided according to their chemical behavior into several subdivisions, named after the most common metal occurring in them. We speak, therefore, of a zinc group, iron group, silver group, etc., and this division will be here retained, it being very suitable to make clear the connection existing between certain minerals.

### 1. *Iron Group.*

(Iron, manganese, cobalt, nickel, chromium, uranium.)

Among the metals belonging to this group iron is most widely distributed and most frequently used. It forms, however, but a small number of alloys available in the industries. Nevertheless, on a close examination it will be found that many alloys contain a small quantity of iron, which, however, has not been added intentionally, but been introduced as a contamination of the metals constituting the alloy. But, as we will see later on, a very small quantity of a metal frequently suffices to exert considerable influence upon the physical properties of an alloy.

*Iron* (Fe; atomic weight 56).—Native iron is of exceedingly rare occurrence, but it enters into the composition of many of those extraordinary stones known to fall from the air called meteorites. The iron as furnished by the iron works is never pure, but always contains small quantities of carbon, manganese, silicon, and other bodies. Chemically pure iron can be obtained by reducing peroxide of iron by hydrogen at a red heat, or by remelting the purest varieties of malleable iron with an oxidizing flux in order to remove the last traces of combined carbon. The physical properties of the metal vary very considerably according to the means adopted for its production. When obtained by reducing peroxide of iron by hydrogen at the lowest possible temperature at which the change can be effected (according to Magnus between 600° and 700° F.) it forms a dark-gray powder, which combines energetically with oxygen, taking fire spontaneously when slightly heated and thrown into the air. When, however, the reduction takes place at a higher temperature, the metallic powder agglutinates to a sponge of filamentous texture, a silvery-gray color, and metallic lustre which is no longer pyrophoric.

Larger and more compact masses may be obtained by removing the last traces of carbon and other foreign substances from the purest commercial wrought iron in the following manner: A small quantity of good wrought iron, such as piano-forte wire or Russian black plate, cut up into small pieces, and either rusted by exposure to steam or mixed with about 20 per cent. of pure peroxide of iron, is to be melted under glass free from metallic oxides, in a refractory crucible, at a strong white heat, the operation requiring about an hour's full heat of a good wind furnace. The small quantity of carbon present in the metal is expended in reducing a portion of the sesquioxide, the remainder passing into the slag. The result is a brilliant well-melted button of metal, which exhibits a decidedly crystalline structure similar to that observed in meteorites when treated with an etching liquor, and is somewhat softer, but less tenacious than the iron originally employed. This last method of producing pure iron is recommended for experimenting in the preparation of alloys with iron, though, if too troublesome, the best quality of piano-forte wire will answer the purpose.

Iron is very easily oxidized; in a damp atmosphere the rust has a very destructive action and necessitates the employment of varnishes and other preservative coatings. In the melted state or at a red heat iron in contact with the air is rapidly oxidized, and acids attack and dissolve it easily. It does not alloy well with most of the metals, this being largely due to its peculiar condition, the high temperature required for its fusion, etc.

*Manganese* (Mn; atomic weight 55).—Compounds of manganese are very widely distributed, although the element is never found free in nature. One of the most commonly occurring of these compounds is the black oxide or pyrolusite. Manganese being almost always associated with iron, small quantities of it are found in almost every brand of the latter. In regard to its properties, it is closely allied to iron and appears in the form of a reddish-white metallic body, which is quite brittle and so hard as to scratch glass. While pure iron oxidizes only in contact with moist air but remains unaltered in dry air, manganese has a somewhat greater affinity for oxygen, and becomes coated with a layer of rust even in contact with dry air. It has, therefore, to be kept under petroleum. This property prevents the general application of this metal in the industries, but in modern times it is used quite frequently for the production of certain alloys, it having been found that steel containing a certain quantity of manganese possesses a higher degree of hardness.

*Cobalt* (Co; atomic weight 58.7).—Compounds of cobalt appear to have been known to the ancients and used by them in coloring glass. The metal itself was first isolated by Brand in 1733. Metallic cobalt is occasionally found in meteoric iron, associated with nickel and phosphorus. Its principal naturally occurring compounds are the arsenide, *smaltine*, or *tin-white cobalt; cobalt bloom* or *erythrine* and *cobalt glance*. The pure metal is unalterable in air, even when moist, of a red-white color, very difficult to fuse, highly malleable and ductile, and capable of taking a polish; its specific gravity is about 8.9. It is slightly magnetic, and preserves this property even when alloyed with mercury. It bears in many respects a close resemblance to nickel, and is often associated with the latter in nature. It is not used by itself, and only very seldom as an intentional addition to alloys. The protoxide is used in the color industry, the colors prepared from it being much employed in painting glass and porcelain.

*Nickel* (Ni; atomic weight 58).—Chemically nickel is closely related to iron and cobalt, which metals are often associated with it in nature. The word "nickel" is a term of detraction, having been applied by the old German miners to what was looked upon as a kind of false copper.

The arsenide, a copper-colored mineral termed "kupfernickel" (*i. e.*, false copper), and the impure arsenide termed "speiss," formed at the bottom of the melting pots in the manufacture of "smalt," constitute the principal sources of nickel. Nickel ores are found in France, Sweden, Cornwall, Spain, Germany, New Caledonia, and in some localities in the United States, Pennsylvania, however, supplying the greatest quantity. The preparation of metallic nickel is connected with many difficulties. It is generally found in commerce in the form of small cubes of a dull-gray appearance. By melting these cubes at a very high temperature, the metal is obtained as a silver-white mass of considerable hardness, which takes a fine polish, and is unalterable in dry air. Its specific gravity is greater than that of iron, being 8.3 to 8.9, and with about an equal fusibility is far less subject to oxidation and corrosion. Its oxide is white, and defaces the polished metal comparatively little, and is easily removed. Nickel can be either cast or forged, but it is generally used in making alloys or plating more oxidizable metals. It is slightly magnetic at ordinary temperatures, but loses this property on heating.

The malleability of nickel allows of its being chased, as are silver and gold, and with the result of greater lustre, while the qualities of brilliancy, hardness, and durability, whether used solidly or in electro-plating, make it very suitable for table service.

Dr. Fleitmann, of Iserlohn, has devised a simple and successful process of refining and toughening nickel, which is now very largely used. It produces a homogeneous metal, from which castings may be made with much less liability to the presence of blow-holes than with other methods. Fleitmann's procedure consists in adding to the melted charge in the pot, when ready to pour, a very small quantity of magnesium. The magnesium is added in small quantities at a time and stirred into the charge. About one ounce of magnesium is found to be sufficient for purifying 60 pounds of nickel. The theory of the operation is that the magnesium reduces the occluded carbonic oxide, uniting with its oxygen to form magnesia, while carbon is separated in the form of graphite. The nickel refined by this method is said to become remarkably tough and malleable, and may be rolled into sheets and drawn into wire. Cast plates (intended for anodes in nickel plating), after reheating, can be readily rolled down to the required thickness, which greatly improves them for plating purposes, as they dissolve with greater uniformity in the plating bath. Nickel so heated may be rolled into sheets as thin as paper, and has been successfully welded upon iron and steel plates.

Nickel readily alloys with the majority of metals, the resulting alloys possessing properties which for certain purposes render them almost indispensable. The alloys known as argentan, German silver, China silver, similor, argent Ruolz, etc., are prepared with the assistance of nickel. It is also occasionally employed for coinage, nickel coinage having been commenced about 1850 by Switzerland and in the United States in 1857.

*Chromium* (Cr; atomic weight 52.2).—The principal naturally occurring compound of this element is chrome iron-stone. In a pure state the metal forms a gray-white mass, with a melting point higher than that of platinum. In a metallic state it finds no application whatever, but its combinations are used in the color industry, they being distinguished by a special splendor. Nearly the same holds good in regard to the *metallic uranium* (U; atomic weight 240), which occurs in a few rare minerals (pitch-blende), and is used in the manufacture of the peculiarly fluorescent uranium glass.

Among the metals belonging to the iron group nickel is the most important for our purposes, on account of the numerous alloys which can be prepared with its assistance. Among the other metals iron is of some importance, small quantities of it, as previously mentioned, being frequently met with as accidental impurities in many alloys.

### 2. *Zinc Group.*

(Zinc, cadmium, indium, gallium.)

*Zinc* (Zn; atomic weight 65).—The most valuable zinc ore is the native carbonate or *calamine*, which, together with the sulphide or *blende*, constitutes the principal source of the zinc of commerce. Zinc ores occur abundantly in the United States, the best being obtained in New Jersey, Pennsylvania, and Virginia, and in a line of deposits running through West Virginia and the Middle States, across to Illinois, Missouri, and Kansas, and north into Wisconsin. Large quantities are mined in Missouri and other parts of the country and in Europe. Zinc in the metallic state was not familiar to the ancients, although they were accustomed to use its ores in the manufacture of brass. The alchemist Paracelsus, in 1541, makes mention of metallic zinc, but it was doubtless known before his time, and was probably discovered by Albertus Magnus, who called it *marchasita aurea.* It became a regular article of manufacture about 1720, in Germany, and in England fifteen or twenty years later. It has been regularly manufactured in the United States since about 1850, first in New Jersey and later in a number of other localities.

Metallic zinc is a bluish-white metal known to the trade as "spelter." Its properties are rather peculiar, and, as it plays an important part in the manufacture of alloys, will have to be more closely considered. Zinc is hard and brittle, and, when fractured, exhibits a highly-crystalline structure. It experiences very little alteration in the air, it becoming very slowly coated with a permanent and impenetrable coating—a basic carbonate—which renders it very valuable for sheathing and for work exposed to the weather. Zinc can be cast, and makes good architectural ornaments. The castings made at a high temperature are brittle and crystalline; when cast at near the melting-point they are comparatively malleable. Zinc is hardened by working, and must be occasionally annealed.

Zinc at an ordinary temperature shows a considerable degree of brittleness, and if a piece of sheet-zinc be several times bent backward and forward it soon breaks. By heating the zinc, however, to between 230° and 302° F., it acquires a considerable degree of ductility, and can be rolled out into thin sheets. At a still higher temperature it again becomes brittle, and, when heated to 392° F., can readily be reduced to a powder. Its density varies between 6.9 and 7.2, the latter being that of the rolled metal. Zinc melts at 773.5° F. By heating the fused metal but a little above its melting-point with the admission of air, it ignites, and burns with a bright, white flame to a very spongy, pure, white powder, forming the oxide known under the name of "zinc-white," and employed as a pigment. It is chiefly valued for its permanency, as it is not blackened by exposure to sulphuretted hydrogen like white lead. At a white heat zinc boils, and can be distilled. Zinc unites readily with the greater number of metals, and is extensively used in the manufacture of alloys.

*Cadmium* (Cd; atomic weight 112).—Compounds of this metal occur associated with zinc ores, and, being more volatile than zinc, it is chiefly found in the first portion of the distilled metal when the ores are reduced by carbon. Cadmium resembles tin in color, but is somewhat harder; it is white, malleable, and ductile; has a density of 8.7; melts below 392° F., and is nearly as volatile as mercury. The metal is of but little use, except as a constituent of some alloys, especially of those fusing at a low temperature. It is also employed in the preparation of amalgams. The sulphide of cadmium, known as cadmium yellow, is bright in color, and has qualities of great value to artists.

*Indium* (In; atomic weight 113.4).—This rare metal was discovered in 1863 by Reich and Richter in the zinc-blende of Freiberg, and has since been found in a few other zinc ores and in the flue-dust of zinc furnaces. It occurs associated with zinc in blende to the extent of 0.006 to 0.1 per cent., and is best obtained from the crude metal or "spelter." It is a silver-white, soft, ductile metal of specific gravity 7.4. It melts at 348.8° F., and oxidizes at a high temperature. It is less volatile than cadmium or zinc. When heated to redness in the air, it burns with a violet flame, and is converted into the yellow sesquioxide. Heated in chlorine it burns with a yellow-green light, and forms a chloride which sublimes without fusion at an incipient red-heat in soft, white laminæ.

*Gallium* (Ga; atomic weight 69.9).—This metal was discovered in 1875 by Lecoq de Boisbaudran in a zinc-blende from the mine of Pierrefitte, in the valley of Argeles, Pyrenees, and has likewise been found, though always in very small quantity, in blendes from other localities. Gallium is a hard metal, somewhat whiter than platinum, and acquires a good polish by pressure. It is sectile, and somewhat malleable. Its specific gravity is 5.9, and its melting-point 86.2° F., so that it liquefies when pressed between the fingers. Frequently, also, it remains liquid for a long time, even when cooled nearly to 0°. The melted metal adheres to glass, forming a mirror whiter than that produced by mercury. When heated to bright redness in contact with the air it oxidizes merely on the surface, and does not volatilize.

### 3. *Tungsten group.*

(Tungsten, molybdenum, vanadium.)

Among the three metals forming this group, which, as regards their properties, approach the iron group, tungsten alone has found some application in the manufacture of alloys.

*Tungsten* (Wo; atomic weight 184).—This element is very sparingly distributed in nature, its principal native compounds being *wolfram,* a tungstate of iron and manganese, calcium tungstate or *scheelite* and lead tungstate. Metallic tungstate forms an infusible steel-gray crystalline powder of specific gravity 17.4. In modern times general attention has been drawn to tungsten by its property of imparting an exceedingly high degree of hardness to steel when mixed with it in small quantities. Compounded with other metals it forms exceedingly hard, infusible alloys.

The other two metals of the tungsten group, molybdenum (Mo; atomic weight 96) and vanadium (V; atomic weight 51.3) have only been found in small quantities in some rare minerals, and have thus far found no application in the manufacture of alloys.

### 4. *Tin group.*

(Tin, titanium, zirconium, thorium.)

This group contains the metals above mentioned, but with the exception of tin they are of no industrial importance whatever, and belong to the greatest rarities. We, therefore, have only to deal with tin.

*Tin* (Sn; atomic weight 118).—Native tin is exceedingly rare, but it can be readily extracted from tin-stone or *cassiterite*, occurring in great abundance in Cornwall, Devonshire, Malacca, and Banca, the tin obtained from the latter place being exceptionally pure. A considerable quantity of tin ore is obtained from Saxony, South America, and Australia. Small quantities of the ore are found in California and other States west of the Mississippi, in Maine and in Alabama. It is only worked at Ashland, Clay Co., in the latter State, and there only since 1883.

Commercial tin is never pure. The following table shows a set of analyses given by Bruno-Kerl.*

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* Metallhüttenkunde, 1873.

| | Banca. | | British. | | Peruvian. | | Saxon. | Bohemian. | |
|---|---|---|---|---|---|---|---|---|---|
| | I. | II. | I. | II. | I. | II. | | I. | II. |
| Tin . . . | 99.961 | 99.9 | 99.96 | 98.64 | 93.50 | 95.66 | 99.9 | 99.59 | 98.18 |
| Iron . . | 0.019 | 0.2 | — | — | 0.07 | 0.07 | — | — | — |
| Lead . . | 0.014 | — | — | 0.20 | 2.76 | 1.93 | — | — | — |
| Copper . | 0.006 | — | 0.24 | 0.16 | — | — | — | 0.406 | 1.60 |
| Antimony | — | — | — | — | 3.76 | 2.34 | — | — | — |
| Bismuth . | — | — | — | — | — | — | 0.1 | — | — |

Chemically pure tin is a white metal with a strong lustre; it has a specific gravity of 7.28 to 7.4, according to the method of preparation, the purest being lightest. It scarcely oxidizes in moist air, and entirely retains its metallic lustre in dry air. It possesses but little tenacity, but is quite malleable, and can be rolled into very thin plates (tin-foil). It is highly crystalline, and when bent gives out a crackling noise, the so-called "tin-cry," caused by the crystals rubbing against each other. It possesses a peculiar odor. It melts at 453° F. When fused in contact with air it acquires a film of oxide, and at a white heat burns with a bright flame, and is converted into a whitish powder, known as "putty-powder," and used in the arts for polishing.

Unmanufactured tin comes into market as "block tin," as "grain tin," and in small bars or "sticks." Block tin is cast in ingots or blocks in moulds of marble; grain tin is made by heating these ingots until very brittle, and then breaking them upon stone blocks; it is sometimes granulated by melting and pouring into water.

Tin, though soft by itself, possesses the remarkable property of imparting to certain alloys a high degree of hardness. It being quite indifferent towards certain organic acids it is extensively used for coating other metals, as iron, copper, lead, etc.

### 5. *Lead group.*
### (Lead, thallium.)

*Lead* (Pb; atomic weight 207).—This metal is much used in the manufacture of alloys. It is so soft that it may be easily scratched with the finger nail, but it has too little tenacity to be drawn into fine wire, although some lead wire is found in the market. It is very malleable, and is extensively used in the forms of sheet-lead and lead-pipe. It was formerly employed for casting statues, but its use for this purpose has been almost entirely abandoned at the present time, experience having shown that, though such statues resist the action of the air quite well, they gradually sink together.

Pure lead is a bluish-white, lustrous, inelastic metal; when freshly cut or melted it shows a bright surface, which, however, rapidly tarnishes on exposure to the air. It is very heavy, its specific gravity being 11.4, and is easily fusible, melting at about 620° F. It boils and volatilizes at a white heat, but cannot be distilled from closed vessels. The affinity of lead for oxygen is so great, that in melting the surface becomes coated with a yellow layer of oxide; on removing this layer with a hook, the pure white color of the metal shows itself, but immediately disappears again. In this manner large quantities of lead can in a short time be converted into oxide. The alloys of lead are distinguished by great fusibility, a valuable property for some purposes, and by being, as a rule, much harder than the lead itself.

*Thallium* (Tl; atomic weight 203.64) is a metal very much resembling lead. It is widely distributed, being found in iron and copper pyrites, in blende, in native sulphur, and in lepidolite. It is most profitably extracted from the flue dust of the pyrites burners. It has a strong metallic lustre, but quickly tarnishes by oxidation. Its specific gravity is about 11.8, and it is softer even than lead. Several alloys exhibiting characteristic properties have been prepared with the assistance of thallium, but the metal is too expensive to be used for technical purposes.

### 6. *Silver Group.*

(Silver, mercury, and copper.)

The metals belonging to this group are of great importance in the manufacture of alloys, copper being especially distinguished in this respect, since there are an exceedingly large number of alloys used for various industrial purposes of which it forms the principal constituent. The other two metals belonging to this group are also much employed for the same purpose, and it may be said that this group is the one deserving special attention of all interested in alloys.

*Copper* (Cu; atomic weight 63.4).—This metal has been known from very early times, it being found native in many parts of the earth and required, therefore, simply to be melted in order to obtain it in a form suitable for technical purposes. It was used for the manufacture of tools and weapons long before the discovery of methods for the extraction of iron.

Copper has a characteristic yellowish-red (copper-red) color, but on exposure to the air becomes gradually coated with a brown layer of oxide. Heated to redness in the air it is quickly oxidized, becoming covered with a black scale. It has a specific gravity of 8.9, and is tough, very malleable, and ductile, so that it can be rolled out into very thin leaves and drawn out to fine wires. It melts at a bright red heat, and seems to be slightly volatile at a strong white heat.

Copper combines with a great number of metals, the resulting alloys belonging to the most important known. All alloys known as bronze, brass, argentan, etc., contain copper in varying quantities, and possess properties which render them indispensable for certain branches of the metal industry.

*Mercury* (Hg; atomic weight 200).—This remarkable metal, sometimes called *quicksilver*, has also been known from remote times, and, perhaps more than all others, has excited the attention and curiosity of experimenters by reason of its peculiar physical properties. Metallic mercury is occasionally found free and in union with silver and gold, but its chief source is the sulphide or *cinnabar*. Mercury has a nearly silver-white color and a very high degree of lustre. It is liquid at ordinary temperatures and solidifies only when cooled to —40° F. In this state it is soft and malleable. The density of pure mercury is 13.596. It boils at 662° F., but volatilizes to a sensible extent at all temperatures. In regard to its behavior in the air, it is a medium between the metals, readily combining with oxygen and those which show no special affinity for it. Since it does not combine with oxygen at an ordinary temperature and retains its metallic lustre even in a moist atmosphere, it is generally included among the so-called noble metals.

But when it is heated for some time to near its boiling point, it slowly absorbs oxygen and is gradually converted into a bright-red, crystalline powder—mercuric oxide. By heating the oxide thus formed somewhat stronger, it is again decomposed into its constituents, oxygen and metallic mercury.

Mercury readily alloys or, as it is generally called, *amalgamates* with other metals, forming in many cases definite chemical combinations. The amalgams are either liquid, the degree of fluidity depending on the quantity of metals compounded with the mercury, or they form solid bodies with perceptible crystallization and frequently a high degree of hardness. Several of these amalgams are employed in the arts, tin amalgam in the manufacture of mirrors, amalgams of tin, gold, and silver by dentists.

*Silver* (Ag; atomic weight 108).—This element is frequently found in the metallic or native state crystallized in cubes or octahedra, which are sometimes aggregated together. It is more frequently met with, however, in combination with sulphur, forming the sulphide of silver, which is generally associated with large quantities of the sulphides of lead, antimony, and iron. The metal has been known from very early times, and although quite widely diffused is found in comparatively small quantity, and hence bears a high value which adapts it for a medium of currency. It has a characteristic (silver-white) color, which it retains even when fused in contact with air, and by reason of this property has to be classed with the noble metals. Its specific gravity is about 10.48 and may be increased by hammering. It is harder than gold, but somewhat softer than copper, and next to gold is the most ductile of all metals. It can be rolled out into thin leaves, so that a small quantity of silver suffices to cover a large surface, and on account of its toughness can be drawn out into wires so fine as to be scarcely perceptible by the naked eye. It melts at about 1680° F.; at a white heat a strong volatilization takes place, whereby the silver is converted into bluish-purple vapor. The behavior of silver when fused in contact with the air is very remarkable. It absorbs a considerable quantity of oxygen without, however, chemically combining with it, the oxygen being again expelled as the metal solidifies.

Silver is too soft to be worked by itself, pure silver being only used for special purposes where the presence of another metal would exert an injurious effect. For all other purposes alloys of silver, especially such as contain a certain quantity of copper, are employed; silver coins and silver utensils consisting, for instance, of an alloy of silver and copper.

### 7. *Gold Group.*

### (Gold and Platinum.)

The metals belonging to this group are distinguished by a high specific gravity, and are the densest bodies known. Their chief characteristic is, however, their slight affinity for oxygen. They can be melted in contact with the air and exposed to the highest temperatures without combining with oxygen. Even their combinations with oxygen, which can be obtained in an indirect manner, are so unstable that on slight heating they yield up the oxygen and are decomposed, the pure metal being left behind. On account of being found in comparatively small quantities they bear a high value and are the most precious of all metals.

*Gold* (Au; atomic weight 196).—Gold has been known from the earliest times, and its comparative rarity, its exceptional color, and its power of resisting atmospheric influences have caused it to be esteemed as one of the most precious metals. As might be expected from its want of direct attraction for oxygen, gold is one of those few metals which are always found in the metallic state, and it is remarkable as being one of the most widely distributed elements, although seldom met with in large quantity in any one locality. Gold has a beautiful yellow color, a strong metallic lustre unalterble in the air, a density of 19.5, is the most ductile of all metals, and can be drawn out into extremely fine wire. It surpasses all other metals in malleability, and can be beaten out into thin leaves which transmit the light with a green color. It has a very high melting point (about 2372° F.) and becomes fluid only at a white heat. It can readily be volatilized at a high temperature produced by means of electricity.

Pure gold is nearly as soft as lead, so that articles manufactured from it would speedily wear out. In order to increase its hardness when used for articles of jewelry or coinage it is alloyed with silver or copper or with both.

*Platinum* (Pt; atomic weight 197.5).—This metal is always found in the metallic state in the form of grains and irregular pieces. As a rule it is, however, not pure, but the grains or pieces are generally associated with a group of other metals possessing similar properties, viz., rhodium, palladium, iridium, ruthenium, as well as gold, silver, and iron. Platinum has a gray-white color, resembling that of some brands of steel. It is heavier than gold, its specific gravity being 21.5. Up to the commencement of the present century platinum was considered infusible, but at the present time a quantity of platinum up to 450 pounds can be readily fused with the assistance of a heat produced by the use of a oxyhydrogen blow-pipe. Platinum is distinguished by great chemical indifference, it being scarcely acted upon by any single acid, but like gold only dissolves in a mixture of nitric acid and hydrochloric acid (nitro-muriatic acid). On account of this indifference and its comparatively great hardness, it is especially used in the manufacture of chemical utensils, it being in this respect equal to gold but cheaper. By taking the value of silver as the unit, that of platinum is to be taken at seven and that of gold at fifteen.

In a certain respect platinum has some similarity with iron: it can be welded, and readily combines with carbon to a mass with a lower melting point than that of pure platinum. Hence, platinum vessels to be heated should always be provided with a coating of another metal to prevent it from absorbing carbon from the flame.

### 8. *Bismuth Group.*

(Bismuth, antimony.)

*Bismuth* (Bi; atomic weight 210).—This element is found in the metallic state, as well as associated with sulphur, copper, and lead. It has a peculiar reddish lustre, a highly crystalline structure, and is little oxidized by the air. Its degree of hardness is small, but it is so brittle as to be readily pulverized in a mortar. It melts at about 500° F., and volatilizes at a high temperature. Its specific gravity is 9.79.

Bismuth being too brittle to be used by itself, its chief employment is in the preparation of certain alloys with other metals. Some kinds of type metal and stereotype metal contain bismuth, which confers upon them the property of expanding in the mould during solidification, so that they are forced into the finest lines of the impression. This metal is also remarkable for its tendency to lower the fusing-point of alloys, which cannot be accounted for merely by referring to the low fusing-point of the metal itself. It is also employed together with antimony in the construction of thermo-electric piles.

*Antimony* (Sb; atomic weight 120).—This metal occurs in a native state as well as in connection with other bodies, the sulphide of antimony—known as gray antimony ore, and occurring in long, needle-like crystals—being, however, the chief source. Antimony has a bluish-white color, retains its lustre in the air, crystallizes in rhombohedrals, and has a specific gravity of 6.72. It melts at 842° F., and is volatile at a white heat. In contact with air at a red heat, it takes fire and burns with a white flame and the evolution of hot vapors, forming the trioxide. It is so brittle that it can be converted into a fine powder by pounding in a mortar, and hence, like bismuth, cannot be used by itself. It is, however, an important metal for the manufacture of several useful alloys, and possesses the property of increasing the hardness of a metal, even if only mixed with it in small quantity.

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*Arsenic* (As; atomic weight 75).—This element is often classed among the metals on account of its physical properties, it having a metallic lustre and conducting electricity. But it is not capable of forming a base with oxygen, and the chemical character and composition of its compounds connects it in the closest manner with phosphorus. Arsenic is sometimes found native, but far more abundantly in connection with various metals forming arsenides, which frequently accompany the sulphides of the same metals. In a pure state it is a light-gray body, which under exclusion of air shows a strong metallic lustre, but assumes a black color on coming in contact with the air. It has a specific gravity of 5.7, and volatilizes at a red heat. If arsenic be thrown upon glowing coals, it volatilizes with the diffusion of a peculiar odor somewhat resembling that of garlic. An addition of arsenic renders metals harder and at the same time more brittle, and it is, therefore, somewhat employed in the manufacture of alloys. But, on account of its poisonous nature, its use must be avoided in alloys to be used for the manufacture of utensils in which food is to be preserved.

### *Supplement.*

Alloys are a mixture of two or more metals, but there are some so-called alloys consisting of but one metal whose properties have been changed in a remarkable manner by the addition of a non-metallic element. It has been previously pointed out that the properties of iron are sensibly changed by a very small addition of sulphur or phosphorus, and that carbon acts in a similar manner. It will, therefore, be necessary to give a short sketch of these elements.

*Sulphur* (S; atomic weight 32).—This element is remarkable for its abundant occurrence in nature in the uncombined state. It is purified by distillation, and then forms a crystalline mass of a characteristic pale-yellow color, which melts at 232° F., and at about 780° F. is converted into ruby-colored vapors. By the admixture of organic substances sulphur acquires a black color in melting. The affinity of sulphur for most metals is so great that they combine with it with great energy. If, for instance, copper be thrown into a vessel containing sulphur heated to the boiling point, the combination takes place and is attended with vivid combustion. An intimate mixture of iron and sulphur needs only be slightly heated to effect the union of both bodies, which is accompanied by vivid glowing. The combination can even be induced by moistening a larger quantity of the mixture with water.

The combinations of the metals with sulphur are in most cases distinguished by a high degree of brittleness, a small admixture of sulphur being generally sufficient to impart to them this property. And this property being by no means a desirable one, care should be had in making experiments in the preparation of alloys to use only metals absolutely free from sulphur. It may also be remarked that in such experiments the presence of every foreign body exerts a disturbing influence, and, in order to obtain satisfactory results, it is recommended to use only chemically pure metals.

*Carbon* (C; atomic weight 12).—Carbon is the most widely diffused element, it forming a never-wanting constituent of all animal and vegetable bodies. Few elements are capable of assuming so many different aspects as carbon. It is met with transparent and colorless in the diamond, opaque and black and quasi-metallic in graphite or black lead, velvety and porous in wood charcoal and, under new conditions, in anthracite, coke, and gas-carbon.

In nature carbon appears crystallized in the hexagonal form as graphite, in the tessular form as diamond, and amorphous as coal in the ordinary sense of the word.

For our purposes only the modifications known as graphite or plumbago and as amorphous coal are of interest.

Carbon, for which no actual solvent is known, has the remarkable property of dissolving in considerable quantities in several melted metals, the best known example of this being its behavior towards iron.

As is well known, in the manufacture of iron pure iron is never obtained, but the so-called cast-iron which contains a certain quantity of carbon. There can be no doubt that the carbon is actually dissolved in the iron, for in cooling certain varieties of cast-iron containing much carbon a certain quantity of it is separated out in a crystalline form as graphite.

The content of carbon, as previously stated in speaking of iron, exerts a considerable influence upon the qualities of a metal, the special properties of the various kinds of iron known as wrought-iron, steel, and cast-iron being chiefly due to the varying quantity of carbon they contain. Generally speaking, it may be said a content of carbon makes the metal more fusible, but it is impossible to state in a general way what other influence is exerted upon its properties, this influence depending essentially on the quantity admixed. It is, therefore, only possible to determine in each case the influence exerted upon the properties of a metal by the presence of carbon.

*Phosphorus* (P ; atomic weight 31).—This element is never known to occur uncombined in nature, and its properties render the use of special precautions necessary for its management, it being very inflammable. A stick of phosphorus held in the air always appears to emit a whitish smoke, which in the dark is luminous, this effect being chiefly due to a slow combustion the phosphorus undergoes by the oxygen of the air. Larger quantities of phosphorus exposed to the air become so thoroughly heated by oxidation as to commence to melt and spontaneously ignite. A content of phosphorus in metals is only possible if ores containing phosphoric acid are used in their preparation, whereby a reduction of the phosphoric acid to phosphorus takes place which combines with the metal.

In speaking of iron it has already been pointed out that a small content of phosphorus renders it red-short or hot-short, *i. e.*, it makes it so brittle that it cannot be worked under the hammer even at a red heat. If metals be intentionally mixed with phosphorus, the mixtures—they cannot be called alloys in the strict sense of the word—show also a high degree of brittleness, though it is not so far-reaching as is the case with iron, and the metal acquires certain properties making it especially suitable for many purposes. The so-called phosphor-bronze consists of a mass which besides copper contains a very small quantity of phosphorus, and shows properties rendering it especially desirable for some uses.

The following table shows the specific gravities and melting points of the principal metals :—

| Name. | Date of discovery. | Name of discoverer. | Specific gravity. | Melting point. Degrees F. |
|---|---|---|---|---|
| Platinum | 1741 | Wood | 21.5 | — |
| Iridium | 1803 | Descotils | 21.15 | |
| Gold | — | — | 19.26 | 2192°(?) |
| Mercury | — | — | 15.5 | |
| Palladium | 1803 | Wollaston | 11.80 | — |
| Lead | — | — | 11.33 | 609.3 |
| Silver | — | — | 10.57 | 1832 |
| Bismuth | — | — | 9.80 | 500 |
| Copper | — | — | 8.94 | 2192(?) |
| Nickel | 1751 | Cronstedt | 8.82 | — |
| Manganese | 1774 | Gahn; Scheele | 8.02 | — |
| Iron | — | — | 7.84 | 3632(?) |
| Tin | — | — | 7.30 | 458.6 |
| Zinc | — | — | 7.13 | 773.6 |
| Antimony | — | — | 6.80 | 842 |
| Aluminium | 1828 | Wöhler | 2.56 | — |
| Magnesium | 1829 | Bussey | 1.74 | 773.6 |

*Prices of Metals.*—The prices of metals are subject to so much fluctuation that it is impossible to give a list of great accuracy. The following table, calculated by Bolton,* may be taken as representing approximate values.

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* Engineering and Mining Journal, Aug. 21, 1875.

| Metal. | Statue. | Value in gold per pound avoirdupois. | Price in gold per gramme. |
|---|---|---|---|
| Vanadium | Cryst. fused | $4792.40 | $10.80 |
| Rubidium | Wire | 3261.60 | 7.20 |
| Calcium | Electrolytic | 2246.20 | 5.40 |
| Tantalum | Pure | 2246.20 | 5.40 |
| Cerium | Fused globule | 2246.20 | 5.40 |
| Lithium | Globules | 2228.76 | 4.92 |
| Lithium | Wire | 2935.44 | 6.48 |
| Erbium | Fused | 1671.57 | 3.96 |
| Didymium | " | 1630.08 | 3.60 |
| Strontium | Electrolytic | 1576.44 | 3.48 |
| Indium | Pure | 1522.08 | 3.36 |
| Ruthenium | — | 1304.64 | 2.88 |
| Columbium | Fused | 1250.28 | 2.76 |
| Rhodium | — | 1032.84 | 2.28 |
| Barium | Electrolytic | 924.12 | 2.04 |
| Thallium | — | 738.39 | 1.63 |
| Osmium | — | 652.32 | 1.44 |
| Palladium | — | 498.30 | 1.10 |
| Iridium | — | 466.59 | 1.03 |
| Uranium | — | 434.88 | 0.96 |
| Gold | — | 299.72 | — |
| Titanium | Fused | 239.80 | 0.52 |
| Tellurium | " | 196.20 | 0.43 |
| Chromium | " | 196.20 | 0.43 |
| Platinum | " | 122.31 | 0.27 |
| Manganese | " | 108.72 | 0.24 |
| Molybdenum | — | 54.34 | 0.12 |
| Magnesium | Wire and tape | 45.30 | 0.10 |
| Potassium | Globules | 22.65 | 0.05 |
| Silver | — | 18.60 | — |
| Aluminium | Bar | 16.30 | 0.036 |
| Cobalt | Cubes | 12.68 | 0.028 |
| Nickel | " | 3.80 | 0.008 |
| Cadmium | — | 3.26 | 0.007 |
| Sodium | — | 3.26 | 0.007 |
| Bismuth | Crude | 1.95 | 0.0043 |
| Mercury | — | 1.00 | — |
| Antimony | — | 0.36 | — |
| Tin | — | 0.25 | — |
| Copper | — | 0.22 | — |
| Arsenic | — | 0.15 | — |
| Zinc | — | 0.10 | — |
| Lead | — | 0.06 | — |
| Iron | — | 0.01½ | — |

Many of these prices are, of course, "fancy prices," as it would be difficult to obtain a whole pound of some of the metals named at even these figures. In compiling the table the prices of the rarer metals are obtained from Trommsdorff's and Schuchardt's price lists; the avoirdupois pound is taken as equal to 453 grammes, and the mark as equal to 24 cents gold.

It is evident that the prices of the metals bear no relation to the rarity of the bodies whence they may be derived; for calcium, the third in the list, is one of the most abundant elements. Even indium, one of the most recently discovered elements, stands tenth in the list below strontium. The metals of the alkalies occupy a low place in the table.

## IV.

## GENERAL PROPERTIES OF ALLOYS.

From what has been said in the preceding sections, it will be seen that the properties of the different metals vary very much, and that but few possess properties in common, to which expression has been given by arranging the allied metals in groups. It will next be necessary to consider the alterations which in regard to their properties certain metals undergo by melting together or alloying. The laws of chemistry show that two bodies combine the more energetically the more dissimilar they are in a chemical respect; and the same law applies also in alloying metals.

It would be an error to consider all alloys as chemical combinations, though there are some which are actually such, because we find that the respective metals combine with special ease in such proportions as correspond to the numbers of the atomic weights, and, further, that these compounds crystallize, which would point to an actual chemical combination having taken place.

But in many other instances alloys are simply mixtures, this being principally the case if metals of great chemical similarity are combined together, the alloy in this case showing always the qualities of a true mixture by the predominance of the properties of the metal present in largest quantity.

Mercury combined with certain metals plainly shows, for instance, the properties of a chemical compound: the mass, at first fluid, solidifies under the evolution of heat to a crystalline mass which resists the solvents for the constituent metals far better than the metals themselves; a proof of the existence of a chemical combination even if not especially stable. In many cases the difference between the melting points of the alloy and the metals constituting it indicates a very intimate union, if not the presence of a chemical combination in the actual sense of the word.

On the other hand, alloys prepared from metals resembling each other chemically may be compared with a mixture of two fluids, for instance, of water and alcohol, the mixture always exhibiting properties intermediate between those of its constituents and, in regular gradation, according to the quantity of each that may be present. Silver and copper, for instance, being metals which chemically are quite closely related, can be melted together in all proportions, and the properties of the resulting alloys approach nearest those of the metal present in greatest quantity. With a predominance ot silver the white color prevails and the density of the alloy is nearer that of silver, while with a predominance of copper the properties of the alloy approach more those of that metal.

In view of the great diversities which show themselves in melting together metals, it is very difficult to lay down propositions of general validity in regard to the behavior of the various metals to one another, and hence the following indications must be considered only from a general point of view.

The physical properties of alloys are different from the mean of those of their constituents, the color, hardness, ductility, melting point, and density of the metals being especially altered by melting them together. The *color* of the mixtures frequently varies very much from that of the metals used in their preparation, though, as a rule, it approaches nearest to that of the metal present in greatest quantity. There are, however, some variations in this respect; an alloy consisting, for instance, of determined proportions of gold, silver, and copper, shows a greenish color, which, as is well known, does not appertain to any of these metals.

The *ductility* and *hardness* of the metals also undergo considerable change in alloying. As a rule the ductility decreases, while the hardness compared with that of the metals constituting the alloy increases to a considerable extent. A few metals, for instance antimony, possess in a high degree the property of making the metals harder.

The alloys melt, as a rule, at a temperature lower than that at which the constituent most difficult to fuse becomes fluid. There are, however, some remarkable instances of alloys melting at a much lower temperature than the mean of the fusing points of their ingredients, an alloy of 8 parts of bismuth, 5 of lead, and 3 of tin fusing, for instance at the temperature of boiling water, although the melting point deduced from the means of its constituents is 514° F.

There is no precise law which gives the relation between the specific gravity of an alloy and that of its component metals, it being sometimes greater and sometimes less. In the former case it indicates an approximation, and in the latter a separation of the particles from one another in the process of alloying. It is common among authorities who publish determinations of specific gravities of the alloys to give the calculated as well as the observed specific gravity. The calculated specific gravity is that which the alloy would have if there were neither expansion nor condensation of the metals during the act of combination. The specific gravities should be calculated from the volumes and not from the weights. Dr. Ure gives the rule as follows: Multiply the sum of the weights into the products of the two specific gravity numbers for a numerator, and multiply each specific gravity number into the weight of the other body, and add the products for a denominator. The quotient obtained by dividing the said numerator by the denominator is the truly computed mean specific gravity of the alloy. Expressed in algebraic language, the above rule is—

$$M = \frac{(W + w) Pp}{Pw + pW},$$

where $M$ is the mean specific gravity of the alloy, $W$ and $w$ the weights, and $P$ and $p$ the specific gravities of the constituent metals.

The following table of the alloys whose density is greater or less than the mean of their constituents is given by several writers:—

| *Alloys the density of which is greater than the mean of their constituents.* | *Alloys the density of which is less than the mean of their constituents.* |
|---|---|
| Gold and zinc. | Gold and silver. |
| Gold and tin. | Gold and iron. |
| Gold and bismuth. | Gold and lead. |
| Gold and antimony. | Gold and copper. |
| Gold and cobalt. | Gold and iridium. |
| Silver and zinc. | Gold and nickel. |
| Silver and tin. | Silver and copper. |
| Silver and bismuth. | Iron and bismuth. |
| Silver and antimony. | Iron and antimony. |
| Copper and zinc. | Iron and lead. |
| Copper and tin. | Tin and lead. |
| Copper and palladium. | Tin and palladium. |
| Copper and bismuth. | Tin and antimony. |
| Lead and antimony. | Nickel and arsenic. |
| Platinum and molybdenum. | Zinc and antimony. |
| Palladium and bismuth. | |

The *tenacity* of an alloy is, as a rule, less than that of the most tenacious of the component metals, a very small quantity of lead, for instance, sufficing to decrease the tenacity of gold, which is one of the most tenacious of metals. In a few cases, however, the alloy possesses a higher degree of tenacity than the constituent metals, there being, for instance, an alloy of copper and zinc, which is more ductile than copper, though zinc belongs to those metals which are distinguished by brittleness rather than by ductility.

The changes taking place in the physical conditions in alloying the various metals are, however, not yet thoroughly known, and it will, therefore, be necessary to mention especially prominent properties in speaking of the various alloys.

In the preceding it has been shown by a few examples that the physical properties of alloys differ very essentially from those of their constituent metals. This change in their properties extends, however, still further, namely, to their chemical behavior. The alloys of certain precious metals, for instance, that of platinum and iridium, show the remarkable property of being attacked by acids, to which the pure metals are entirely indifferent. The alloys of other metals show similar phenomena, which may perhaps be explained by the fact that the alloys on coming in contact with an acid form, in a certain sense, a galvanic element, electricity, as is well known, being developed by two metals being brought into contact with an acid. Moreover, it is also known that many chemical processes may take place under the influence of electricity which otherwise would only proceed with difficulty.

The researches of physicists have explained many of the remarkable phenomena in regard to alloys, the physical cause, for instance, why the melting point of many of them is lower than that of the most fusible of the constituent metals having been sufficiently elucidated. But, as regards the change in their chemical properties, the question is still unsettled, and though many experiments have been made to settle it there still remains a wide difference of opinion in regard to it. Most writers now agree, however, in considering some alloys as chemical compounds and others as mixtures, but they differ as to whether any particular alloy is the one or the other.

## V.

## PREPARATION OF ALLOYS IN GENERAL.

ALLOYS are generally prepared by directly melting together the metals which are to take part in the mixture. At a first glance this would seem a very simple affair, requiring scarcely any explanation, but in fact great skill and judgment are necessary for the successful accomplishment of the object. Some alloys are in fact very difficult to prepare and require special precautionary measures.

The utensils used in the manufacture of alloys differ according to whether they are to be prepared on a small or large scale. For small quantities the use of a crucible is recommended, but for manufacturing on a large scale a reverberatory "open-hearth" furnace is used, which is preferably heated with gas prepared in a special furnace. Special precautions must be observed to preserve a deoxidizing flame within the furnace. A small portion of the heat, which otherwise could be used for melting the metals, is sometimes lost thereby, but the great advantage is gained that as long as the gases of combustion passing over the metals absorb oxygen, the melting metals will actually remain in a metallic state. This is especially of great importance with metals which readily oxidize when exposed in a fused state to the action of the air. It may here be remarked that the oxides formed by careless work from the metals seldom take part in the formation of the alloy, so that even if the quantities of metals have been accurately weighed the resulting alloy will not show the desired composition, since the portion of the metals converted into oxide does not enter into the alloy.

For preparing alloys on a smaller scale in a crucible, special precautionary measures must be taken against oxidation of the metals. For this purpose the surface of the metals is covered with bodies which prevent the access of air without, however, exerting any influence whatever, or at least only to a very small extent, upon the metals. In many cases anhydrous borax is used; but independently of the fact that borax is rather expensive and unnecessarily increases the cost of the alloys, its employment is accompanied by many evils. It is well known that in borax a portion of the boric acid is not perfectly saturated, and that in melting borax with base metals a certain portion of the acid is always absorbed, which with the sodium borate forms double salts of a glassy nature. Hence by fusing metals under borax a certain portion of them will be lost by forming a combination with the borax.

Glass consists of a mixture of silicates, and forms, when thrown upon fusing metal, a coating which completely excludes the access of air to the surface of the metal. Though it has also the property of absorbing certain metals when brought in contact with them in a liquid state, the influence it exerts upon alloys is, generally speaking, much less than that exerted by an equal quantity of borax. If the metals to be fused together are such that a combination with carbon need not be feared, the fusing mass can also be protected from the influence of the oxygen of the atmosphere by covering it with a layer of pulverized charcoal. Many manufacturers are in the habit of throwing a certain quantity of fat upon the heated metal before fusion. The fat on being suddenly strongly heated decomposes and evolves a considerable quantity of gas, which exerts a protecting influence upon the surface of the metals. After the evolution of gas has ceased, there remains a very finely divided carbon which protects the metals from oxidation.

For the preparation of alloys from noble or costly metals it is recommended to effect the fusion in crucibles of graphite or of graphite mixed with clay, as the metal readily and completely separates from such crucibles. In regard to graphite crucibles we would draw attention to a circumstance which, though unimportant in itself, may become very disagreeable in preparing alloys from costly metals. It sometimes happens that a graphite crucible a short time after being placed in the furnace bursts with a loud crack, and the metals contained in it fall into the fire from which they have to be rescued with considerable trouble. This phenomenon in most cases is due to faulty work in the making of the crucible. If; for instance, the mass of the crucible contains a small bubble filled with air or moisture, these bodies will expand strongly on heating, and this expansion may go so far as to cause the bursting of the crucible. But, as this defect cannot be recognized from the appearance of the crucible, it is recommended to test every crucible before using it for melting metals. This is done by putting them in a place where they gradually become strongly heated. Bad crucibles crack in most cases, and the others are sufficiently dried out so that they can be used for melting the metals without fear of cracking.

In preparing alloys the metal most difficult to fuse should be first melted and the more fusible ones only introduced after the complete fusion of the first. The varying densities of the metals to be combined frequently render the formation of a homogeneous mass very difficult. Moreover, in many alloys certain chemical combinations are readily formed while the rest of the metals form alloys, the preparation of which was not intended.

If two metals with greatly varying densities are alloyed and the mass is allowed to be quiescent, it will be observed that, after cooling and taking from the crucible, it shows clearly perceptible layers varying in color and appearance. By chemically examining these layers it will be found that each of them contains different quantities of the metals used in alloying. To obtain in such case as homogeneous an alloy as possible, the metals, while in a state of fusion, must not be allowed to remain quiescent, but an intimate mixture be effected by vigorous stirring, sticks of dry soft wood being in many cases used for this purpose. By stirring the fused mass with one of these sticks, the wood is more or less carbonized according to the temperature of the mass. In consequence of the dry distillation of the wood taking place thereby, there is evolved an abundance of gases which, by ascending in the fused mass, contribute to its intimate mixture. The stirring should be continued for some time and the alloy then cooled as rapidly as possible.

Many alloys possess the property of changing their nature by repeated remelting, several alloys being formed in this case, which show considerable differences, physically as well as chemically. The melting points of the new alloys are generally higher than those of the original alloy, and their hardness and ductility are also changed to a considerable extent. This phenomenon is frequently connected with many evils for the further application of the alloys, and in preparing alloys showing this property, the fusion of the metals and subsequent cooling of the fused mass should be effected as rapidly as possible.

While formerly only a few alloys were known, a large number are at present used in the industries, and we find very rare metals sometimes employed for the preparation of alloys with special properties. One of the principal causes of this advance in the industry is the progress of mechanics. We need only to consider the pillow-blocks of shafts and axles in order to understand the varying demands made by the engineer as regards the properties of alloys. How different must be the nature of an alloy which serves for the construction of the pillow-block of an axle revolving with a light load perhaps once in a second, from that which has to bear a heavily-loaded shaft making many revolutions per minute! For many purposes alloys are required excelling in great ductility, for others the chief requisite is hardness, others again must have a high degree of elasticity, and still others as low a melting point as possible. It will be readily understood that these different demands can only be satisfied by adding to the alloys suitable quantities of metals of varying properties.

Though most heavy metals are at the present time used in the manufacture of alloys, copper, tin, zinc, lead, silver and gold are more frequently employed than others, the alloys of these metals being at the same time those which have been longest known and used. In modern times the alloys prepared with the assistance of nickel have also become of great importance, as well as those of which aluminium forms a constituent.

Every one who occupies himself more closely with alloys knows how meagre is the amount of information which has been gained upon this important branch of metallurgy, and that much is to be expected from the progress of chemistry. The metallurgist, if left to himself, cannot be expected to arrive at certain results, because, probably, he may be wanting in chemical knowledge or in the methodical course of investigation, which must be possessed by those who are qualified to successfully prosecute such researches. These qualifications are so much the more indispensable when it is remembered that every new alloy, by the fact of its properties being different from those of its constituents, may be regarded as a new metal. Before proceeding with the description of the most important alloys, it may be convenient to say a few words about the best methods of making experiments in the preparation of new alloys.

It is known that the elements always combine with one another in certain quantities by weight which are termed atomic weights. (A table of the atomic weights of the principal metals is found upon page 42.) By mixing the metals according to equivalent quantities, alloys of determined, characteristic properties are, as a rule, obtained. If these properties do not answer the demands made of the alloy, the object is frequently attained by taking two, three, or more equivalents of one metal. An exception to this rule is only made in certain cases, and especially where, according to experience, a very small quantity of a metal suffices considerably to change the properties of the alloy. It is then most suitable to prepare the mixtures serving for the experiment according to thousandths, and with every new experiment change the proportion between the separate metals a certain number of thousandths.

For combining metals with non-metallic elements, for instance with sulphur or with phosphorus, it is, however, not sufficient to choose the proportions according to thousandths, it being necessary to add these bodies according to ten thousandths. For these elements the form in which they are used is also of importance, which, however, will be referred to in speaking of them later on. We would, however, here remark that the application of the term alloy to such metals, which are, so to say, contaminated by phosphorus or sulphur, is entirely incorrect. We use it, however, for want of a better one, since it at least indicates that we are not dealing with a pure metal.

## VI.

## COPPER ALLOYS.

ALTHOUGH, on account of its great ductility and tenacity, the uses of unmixed copper in the arts are various and highly important, its employment for many purposes is connected with difficulties. It is, for instance, seldom cast in consequence of the difficulty of obtaining sound strong castings, they being always blown even if the work is done with the greatest care. Besides the properties of the copper itself certain alloys of it have others, which render them especially suitable for certain industrial purposes, and, moreover, it is possible to impart to copper alloys all the properties which can be possibly expected: they can be made soft and very hard, brittle and elastic, malleable and non-malleable, etc.

The manufacture of copper alloys is always attended with certain difficulties, since the copper itself has a very high fusing point, and the presence of very small quantities of foreign bodies exerts a great influence upon its properties and upon those of its alloys. It will therefore be necessary to say a few words about this influence.

A content of lead amounting to from $\frac{1}{1000}$ to $\frac{3}{1000}$ somewhat increases the ductility of copper to be rolled; but the presence of one full thousandth of lead renders the metal unfit for the preparation of brass, which is to be rolled out into sheets or drawn out into wire. By adding to copper up to $\frac{3}{1000}$ of lead, it acquires the property of being red-short or hot-short, and by increasing the content of lead to one per cent. it becomes entirely useless, it being both red-short and cold-short. A content of lead always exerts an injurious influence upon the properties of copper, this influence being more strongly observed at a higher temperature than at an ordinary one.

A content of iron exceeding $\frac{3}{1000}$ has also an injurious effect upon the properties of copper, rendering it hard and brittle. Small quantities of nickel affect copper injuriously in making it less malleable, the evil being still further increased if besides this metal a small quantity of antimony be present. Antimony and arsenic by themselves mixed with copper considerably decrease its highly-valued property of ductility. Copper containing only $\frac{1}{1000}$ of antimony can no longer be worked for sheet-brass. Bismuth acts in a manner similar to antimony. Zinc mixed with copper up to $\frac{6}{1000}$ makes it red-short. Certain alloys of copper and zinc can, however, be well worked, the most important of such alloys being brass. A content of tin and silver seems not to have an injurious effect upon the properties of copper, and these two metals, if added in certain proportions, give alloys which are distinguished by special valuable properties.

An admixture of cuprous oxide, which is sometimes found in brands of copper, makes the metal both red-short and cold-short, especially if present in larger quantities, and further imparts to it the disagreeable property of considerably contracting in casting. Moreover, the castings from such copper show an unequal density, so that plates of it cannot be used for copper-plate printing. It may here be remarked that most brands of copper found in commerce contain certain quantities of cuprous oxide, it being claimed that an admixture of one-half to two per cent. of it is even beneficial, as it counteracts the injurious influence of foreign metals upon the copper.

Besides the above-mentioned metals, many brands of copper found in commerce frequently contain bodies belonging to the non-metals, such as sulphur, silicium, and phosphorus. The influence of these bodies is, as a rule, very injurious.

A content of sulphur makes the copper red-short and castings of it blown. By a content of silicium the copper loses its pure red color and acquires one shading into white, its ductility being at the same time considerably affected. Copper containing nearly two per cent. of silicium can only be rolled in the cold, as it cracks in the heat. With a still greater content of silicium the copper becomes a yellowish-white metal of extraordinary brittleness, so that it can no longer be worked to advantage.

A content of phosphorus exerts a considerable influence upon the properties of copper, generally increasing its hardness and at the same time making it more fusible. With an admixture of $\frac{1}{1000}$ of phosphorus the copper can only be rolled in the cold, while with a still greater content it becomes brittle in the cold. Some alloys of copper with phosphorus, known as phosphor-bronze, are, however, used for certain industrial purposes on account of their special properties, they being distinguished by particular tenacity, ductility, and beautiful color. These combinations will be referred to later on.

According to the more recent researches by Hampe, copper shows the following behavior towards admixtures :—

With a content of between $\frac{2}{1000}$ and $\frac{22}{1000}$ of cuprous oxide, the properties of the copper are not sensibly affected, it becoming red-short only in the presence of $\frac{67}{1000}$; and a content of this compound always acts in such a manner as to increase the brittleness of the metal more in the cold than in the heat. One-thousandth of arsenic exerts no influence upon the copper, but $\frac{20}{1000}$ of it render it cold-short and hard. It only becomes red-short with $\frac{10}{1000}$ of arsenic, but is not cold-short, which is contrary to the opinions formerly held in regard to the influence of arsenic upon copper. Antimony acts similar to arsenic, except that a smaller quantity of it is required to make the copper red-short.

A content of one and a half thousandths of lead exerts no influence upon the properties of copper; a slight brittleness in the heat shows itself, however, with a content of $\frac{3}{1000}$, which becomes strong with one of $\frac{4}{1000}$, and is clearly perceptible in the cold.

According to these more recent researches a content of bismuth exerts an especially injurious influence upon the properties of copper, an infinitely small quantity sufficing to decrease the ductility in the heat, while with a content of $\frac{5}{1000}$ the copper becomes strongly red-short and sensibly cold-short.

A considerable portion of the copper occurring in commerce is extracted from minerals containing a number of other metals, this holding especially good in regard to those brands obtained from gray copper ore or fahl ore.* Experts can tell from the external properties of the metal, especially by the color, fracture, and ductility, whether it is suitable for certain purposes or not. But it is, of course, impossible to recognize in this manner the quantities of foreign bodies. In buying a large lot of copper for alloys it is, therefore, recommended to subject it to an accurate chemical analysis in order to be sure that it is free from lead and bismuth, which are especially injurious.

Formerly copper alloys were considered a mixture of the constituent metals, but in modern times they are considered from a different point of view, it being the generally accepted opinion that definite chemical combinations are formed from the copper and the foreign metals, which dissolve in the excess of metal present and impart certain properties to it. We find, for instance, that from alloys consisting of a metal difficult to fuse and one with a very low melting point (one of copper and zinc for instance) the greater portion of the readily

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* It contains copper, antimony, arsenic, and sulphur.

fusible metal can be separated by long-continued melting, a portion of it being, however, retained with such tenacity that it cannot be removed.

As previously mentioned the number of copper alloys is very large, the most important being those with tin, zinc, nickel, gold, silver, platinum, and mercury, and, further, with aluminium; the alloys of copper with lead, antimony, and iron are less frequently used.

After giving a brief introductory sketch of the alloys of copper with the precious metals, which have been used since very remote times, we will first speak of the alloys of copper with the base metals, they being of special interest for industrial purposes, and, besides, present more technical difficulties in their preparation.

*Auriferous copper alloys.*—Gold, as previously mentioned, having but a slight degree of hardness, must be alloyed with other metals in order to prevent its wearing off too strongly, copper and silver, either by themselves or together, being generally used for the purpose. Besides the fact that the gold alloys show a greater degree of hardness than the pure metal, the color of the latter is also changed by alloying with silver or copper, there being gold with a color shading into white (alloyed with silver) and other varieties shading into red (alloyed with copper). There is also a green gold which is an alloy of gold, silver, and copper.

According to the purpose for which gold alloys are to be used, they are prepared either with copper or silver alone or with the assistance of both metals. The gold coins of Europe consist always of an alloy of gold with copper, a content of silver, which must, however, be very small, being due to the use of argentiferous gold. The preparation of alloys of gold and of silver has become very extensive on account of them being used for coinage and articles of jewelry, and will be referred to later on.

*Argentiferous copper alloys.*—The alloys of copper with silver are extensively used for coinage and silverware. As may be seen from the properties of both metals, these alloys possess a considerable degree of ductility, and if the proportions in which the metals are mixed are so chosen that the copper slightly predominates, their properties are almost exactly a mean between those of the two metals. They will be fully discussed later on, and we only mention here that most alloys of silver and copper contain more of the former than of the latter metal.

The alloys of the other noble metals, especially those of the platinum group, find but a limited application in the industries; we will refer to them later on.

*Alloys of copper with the base metals.*—Although the number of alloys of copper with the base metals is very large, those known under the general terms of brass and bronze are so extensively used in the various industries as to make most of the others appear unimportant in comparison. Bronze has been known from very remote times, and was used by the ancients in casting statues and other ornaments. The bronze used by the pre-historic nations contained no lead, and came nearest to what is at the present time designated by the term bronze, *i. e.*, an alloy of copper and tin. The bronze used by the Romans and post-Romans was rarely an alloy of pure copper and tin, but contained usually more or less lead.

Brass, the other important alloy of copper mentioned above, was manufactured by cementing sheets of copper with calamine or carbonate of zinc long before zinc in a metallic form was known.

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# VII.

## BRASS, ITS PROPERTIES, MANUFACTURE, AND USES.

THE several compounds produced by the combination of copper and zinc in different proportions are included in the collective term brass, some varieties, however, being known by specific names, as pinchbeck, tourbac, etc. The first account of the alloy of copper and zinc transmitted to the present times was written by Aristotle, who states that a people who inhabited a country adjoining the Euxine Sea prepared their copper of a beautiful white color by mixing and cementing it with an earth found there and not with tin, as was apparently the custom. Strabo also alludes to the preparation of the alloy of copper and zinc by the Phrygians from the calcination of certain earths found in the neighborhood of Andêra, and other authors, in the time of Augustus, speak distinctly of cadmia and its property of converting copper into *aurichalcum*, under which title the zinc alloy was subsequently known. Several writers of the Christian era who have referred to this compound are not more explicit than their predecessors; still it is evident, from various recent analyses of old alloys, that zinc was contained in many of those prepared about the commencement of the present era.

The manufacture of brass was introduced in 1550 in Germany by Erasmus Ebener, an artist of Nürnberg, who prepared it by fusing copper with so-called *tutia fornacem* or furnace cadmia. By direct melting together of the two metals, the alloy was very likely first obtained in 1781 in England, where the art of obtaining the zinc in a metallic form became known a short time previously to that period.

Brass, as already mentioned, should actually contain only copper and zinc, but most varieties found in commerce contain small quantities of iron, tin, arsenic, and lead. In many cases these admixtures are due to contaminations mixed with the ores from which the copper or zinc is extracted, while in others they have been intentionally added in order to change the ductility, fusibility, etc. of the alloy. Copper and zinc can be mixed together within very wide limits, the resulting alloys being always serviceable. Generally speaking, it may be said that with an increase in the percentage of copper the color inclines more towards a golden, the malleability and softness of the alloy being increased at the same time. With an increase in the percentage of zinc, the color becomes lighter and lighter, and finally shades into a grayish-white, while the alloys become more fusible, brittle, and at the same time harder. Just as different as the properties of the respective alloys is also the cost of production, the price of brass increasing with the greater percentage of copper. Very extensive researches have been made in regard to the behavior of alloys of copper and zinc, which may be briefly expressed as follows:—

An alloy containing from 1 to 7 per cent. of zinc still shows the color of copper or at the utmost only a slight yellow tinge. With 7.4 to 13.8 per cent. of zinc the color of the alloy undergoes a considerable change, it being a pleasant red-yellow. With from 13.8 to 16.6 per cent. the color may be designated a pure yellow, while that of alloys containing up to 30 per cent. of zinc is also yellow, but not pure. It is a singular fact that with a content of over 30 per cent. of zinc a red color appears again, which is most pronounced with equal parts by weight of the metals, an alloy of 50 parts of copper and 50 of zinc having almost a golden color, but exhibiting also a high degree of brittleness. With a still higher percentage of zinc the gold color rapidly decreases, becoming reddish-white with 53 per cent., yellowish-white with 56 per cent., and bluish-white with 64 per cent.; with a still higher content of zinc the alloy acquires a lead color.

The physical properties of alloys of copper and zinc differ very much according to the quantities of copper and zinc contained in them. Alloys containing up to 35 per cent. of zinc can only be converted into wire or sheet in the cold, those with from 15 to 20 per cent. being the most ductile.

Alloys with from 36 to 40 per cent. of zinc can be worked in the cold as well as in the heat. With a still higher percentage the ductility decreases rapidly, and an alloy with, for instance, from 60 to 70 per cent. of zinc is so brittle that it cannot be worked. If, however, the content of zinc is increased up to a maximum (70 to 90 per cent.), the ductility increases again and the alloy can be worked quite well in the heat (but not at a red heat).

Brass shows always a crystalline structure, which is the more pronounced the more brittle the alloy is, and hence that prepared from equal parts of copper and zinc shows the most distinct crystalline structure.

In connection with this some researches in regard to metals becoming crystalline, made by S. Kalischer,* may be of interest. By heating rolled zinc to from 302° to 338° F., it suffers a series of permanent changes without its external appearance being directly altered. It loses its clear sound and becomes almost without sound, like lead. It can be more readily bent, but breaks more easily, and in bending emits a noise similar to the "cry of tin." All these alterations are due to a change in the molecular structure of the zinc; it becomes crystalline. This crystallization can be readily rendered perceptible by dipping a heated strip of zinc into a solution of sulphate of copper, the copper, which is immediately precipitated, showing clearly perceptible crystallization. The fracture of the rolled and heated zinc is also crystalline. To avoid this change it is recommended not to exceed a temperature of 266° F. in manufacturing sheet-zinc. Sheets of cadmium and of tin become crystalline at about 392° F. Sheet-iron and sheet-copper are also crystalline, but sheet-steel is not. Kalischer

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* Carl's Repert., 1882, p. 193.

examined four varieties of sheet-brass constituted as follows :—

| | Parts. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Copper | 66 | 62.5 | 60 | 56.8 |
| Zinc | 34 | 37.5 | 40 | 43.2 |

Samples Nos. I. and II. were undoubtedly crystalline, and sample No. III. showed traces of crystallization, while No. IV. did not become crystalline even by heating.

Sheets of tombac composed of—

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Copper | 73.74 | 80.38 | 90.09 |
| Zinc | 25.96 | 19.29 | 9.91 |
| Tin | 0.30 | 0.33 | — |

were all crystalline. No crystallization could be observed in bronze-sheets composed of—

| | Parts. | |
|---|---|---|
| | I. | II. |
| Copper | 90 | 88.23 |
| Zinc | 5 | 8.82 |
| Tin | 5 | 2.95 |

Rolled lead is crystalline, but rolled fine silver and gold are not. By reason of these observations and experiments Kalischer is of the opinion that the crystalline state is natural to most metals of which they can be deprived by mechanical influences, but many can be reconverted into it under the influence of heat.

If a very ductile brass is to be prepared, great care must be had to use metals of the utmost purity, since exceedingly small admixtures of foreign metals suffice considerably to injure the ductility, rendering the fabrication of very thin sheets or fine wire impossible.

The tenacity of brass, as shown by many experiments, is also intimately connected with its composition, that containing about 28.5 per cent. of zinc showing the greatest absolute tenacity. The tenacity depends, however, to a considerable extent, also on the mechanical treatment the metal has received. A piece of brass of 0.001 square inch breaks with the following loads:—

| | | | |
|---|---|---|---|
| Cast brass | breaks with | 2777.5 | pounds. |
| Ordinary wire | " | 7293 | " |
| Hand-drawn thin wire | " | 9080.5 | " |
| Annealed thin wire | " | 7100 to 8628 | " |

The molecular structure of brass can be much changed by treatment, it becoming more brittle by continuous manipulation, so that in drawing wires they must be frequently annealed to prevent them from becoming brittle. If brass is strongly heated and rapidly cooled, its hardness decreases, its behavior in this respect being opposite to that of steel. Brass which, for instance, as a constituent of machines, is subjected to repeated shocks becomes brittle and fragile.

A very important factor in brass is its melting point, there being great deviations in this respect, which are readily explained by the great difference in the melting points of the two constituent metals. Generally speaking, the fusing point of brass lies at about 1832° F. If brass in a fused state is kept for some time in contact with air, its composition undergoes an essential change by the combustion of the greater portion of the zinc contained in it, which explains the change of color frequently observed in brass fused for some time in contact with air.

Old copper derived from worn-out copper articles is frequently used in the manufacture of brass. Such copper contains, however, generally foreign metals in the shape of solder, etc., which may exert either a favorable or an injurious influence upon the properties of the brass. Lead, tin, and iron are the most frequently occurring contaminations. If the brass is to be used for castings, their injurious influence is not so great as in the manufacture of thin sheet or wire. To brass intended for castings up to two per cent. of lead is frequently added, such addition making the alloy somewhat harder, and depriving it at the same time of the disagreeable property of fouling the tools in working, which is of special importance in filing and turning. In casting brass containing lead care must, however, be had to cool the castings very rapidly, as otherwise the lead readily separates in the lower portion of the casting and produces unsightly spots.

By a slight addition of tin the brass becomes more fusible, somewhat denser, and takes a better polish; it is also rendered somewhat less brittle. The presence of a small quantity of iron increases the hardness of brass considerably, such brass on exposure to the air being, however, easily stained by rust.

In the arts brass is commonly employed in the construction of scientific apparatus, mathematical instruments, small parts of machinery, and for many other purposes. A distinction is generally made between sheet brass used in the manufacture of wire and sheets, and cast-brass which requires no further mechanical manipulation than turning and filing. A number of alloys occur in commerce under various names, but, as regards their composition, they must be included in the generic term, brass, though some of them are especially adapted for certain purposes.

In the following we give Mallet's table of the properties of copper-zinc alloys:—

| Atomic composition. | Copper. | Specific gravity. | Color. | Fracture. | Tenacity. | Order of— | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Malleability. | Hardness. | Fusibility. |
| Cu Zn | By anal. per ct. | | | | Tons per sq. in. | | | |
| 1 : 0 | 100 | 8.667 | red | — | 24 6 | 8 | 22 | 15 |
| 10 : 1 | 98.80 | 8.605 | red-yellow | coarse | 12.1 | 6 | 21 | 14 |
| 9 : 1 | 90.72 | 8.607 | " | fine | 11.5 | 4 | 20 | 13 |
| 8 : 1 | 88.60 | 8.633 | " | " | 12.8 | 2 | 19 | 12 |
| 7 : 1 | 87.30 | 8.587 | " | " | 13.2 | 0 | 18 | 11 |
| 6 : 1 | 85.40 | 8.591 | yellow-red | fine fibre | 11.1 | 5 | 17 | 10 |
| 5 : 1 | 83.02 | 8 415 | " | " | 13.7 | 11 | 16 | 9 |
| 4 : 1 | 79 65 | 8.448 | " | " | 14.7 | 7 | 15 | 8 |
| 3 : 1 | 74.58 | 8.397 | pale yellow | " | 13.1 | 10 | 14 | 7 |
| 2 : 1 | 66.18 | 8.299 | deep yellow | " | 12.5 | 3 | 13 | 6 |
| 1 : 1 | 49.47 | 8.230 | " | coarse | 9.2 | 12 | 12 | 6 |
| 1 : 2 | 32.85 | 8.263 | dark yellow | " | 19.3 | 1 | 10 | 6 |
| 8 : 17 | 31.52 | 7.721 | silver-white | " | 2.1 | very brittle | 5 | 5 |
| 8 : 18 | 30 36 | 7.836 | " | " | 2.2 | " | 6 | 5 |
| 8 : 19 | 29.17 | 7.019 | light gray | " | 0.7 | " | 7 | 5 |
| 8 : 20 | 28.12 | 7.603 | ash-gray | vitreous | 3.2 | brittle | 3 | 5 |
| 8 : 21 | 27.10 | 8.058 | light gray | coarse | 0.9 | " | 9 | 5 |
| 8 : 22 | 26.24 | 7.882 | " | " | 0.8 | " | 1 | 5 |
| 8 : 23 | 25.39 | 7.443 | ash-gray | " | 5.9 | slightly ductile | 1 | 5 |
| 1 : 3 | 24.50 | 7.449 | " | " | 3.1 | brittle | 2 | 4 |
| 1 : 4 | 19.65 | 7.371 | " | " | 1.9 | " | 4 | 3 |
| 1 : 5 | 16.36 | 6.605 | dark gray | " | 1.8 | " | 11 | 2 |
| 0 : 1 | 0 | 6.895 | | | 15.2 | | 23 | 1 |

In the above table the minimum of hardness and fusibility is denoted by 1.

*Sheet-brass (for the manufacture of sheets and wire).*—Especially pure copper has to be used in the preparation of brass to be suitable for the manufacture of wire. That the use of pure copper is the principal requisite in the manufacture of good, ductile brass is best seen from the great difference in the composition of the various kinds of brass, which all answer their purpose, but contain very varying quantities of copper and zinc. The following table gives the composition of excellent qualities of brass suitable for the fabrication of sheet and wire:—

| Brass. | Place of derivation. | Copper. Per cent. | Zinc. Per cent. | Lead. Per cent. | Tin. Per cent. |
|---|---|---|---|---|---|
| Sheet | Jemmappes . . | 64.6 | 33.7 | 1.4 | 0.2 |
| " | Stolberg . . | 64.8 | 32.8 | 2.0 | 0.4 |
| " | Romilly . . . | 70.1 | 29.26 | 0.38 | 0.17 |
| " | Rosthorn (Vienna) . | 68.1 | 31.9 | — | — |
| " | " . | 71.5 | 28.5 | — | — |
| " | " . | 71.10 | 27.6 | 1.3 | — |
| " | Iserlohn & Romilly | 70.1 | 29.9 | — | — |
| " | Lüdenscheid . . | 72.73 | 27.27 | — | — |
| " | (Brittle) . . . | 63.66 | 33.02 | 2.52 | — |
| " | Hegermühl . . | 70.16 | 27.45 | 0.79 | 0.20 |
| " | Oker . . . | 68.98 | 29.54 | 0.97 | — |
| Wire | England . . | 70.29 | 29.26 | 0.28 | 0.17 |
| " | Augsburg . . | 71.89 | 27.63 | 0.85 | — |
| " | Neustadt . . | 70.16 | 27.45 | 0.2 | 0.79 |
| " | " . . | 71.36 | 28.15 | — | — |
| " | " . . | 71.5 | 28.5 | — | — |
| " | " . . | 71.0 | 27.6 | — | — |
| " | (Good quality) . | 65.4 | 34.6 | — | — |
| " | (Brittle) . . | 65.5 | 32.4 | 2.1 | — |
|  | (For wire and sheet) | 67 | 32 | 0.5 | 0.5 |

The various kinds of brass contain, according to the above table, between 27 and 34 per cent. of zinc, but more recently alloys with a somewhat greater content of zinc are used, it having been found that the toughness and ductility of the brass are thereby increased without injury to its tenacity.

Alloys containing up to 37 per cent. of zinc possess a high degree of ductility in the cold and are well adapted for the manufacture of wire and sheet.

*Cast-brass* being used for the most diverse purposes it is difficult to give a composition of general value, since the demands made on this metal vary much according to the article to be manufactured, it being used for very ordinary wares, such as locks, keys, shields, escutcheons, buttons, hinges, etc., as well as for the finest mechanical instruments and objects of art.

As a rule cast-brass contains more zinc than that which is to be worked into sheet and wire. It is therefore more fusible, but at the same time harder and more brittle than wire-brass. The materials being not chosen with such great care, as for wire, a chemical analysis reveals frequently the presence of a considerable number of foreign metals. The turnings, chips, and other brass-waste are generally utilized by melting them together by themselves or as addition in fusing cast-brass. Such turnings, etc., frequently containing, besides brass, iron and bronze, explain the contamination of the cast-brass with iron, tin, and lead; sometimes a small quantity of arsenic is also found. Cast-brass is also much used in the manufacture of the so-called hard solder for soldering articles exposed to a high temperature. In the following we give an analysis of various kinds of cast-brass, which shows the great variations in its composition :—

| Variety. | Copper. Per cent. | Zinc. Per cent. | Iron. Per cent. | Lead. Per cent. | Tin. Per cent. |
|---|---|---|---|---|---|
| Cast brass from Oker | 71.88 | 24.42 | 2.32 | 1.09 | — |
| “ “ “ | 64.24 | 37.27 | 0.12 | 0.59 | — |
| Black Forest clock wheels | 60.66 | 36.88 | 0.74 | — | 1.35 |
| “ “ “ | 66.06 | 31.46 | 1.43 | 0.88 | — |
| Cast brass from Iserlohn | 63.7 | 33.5 | — | 0.3 | 2.5 |
| “ “ “ | 64.5 | 32.4 | — | 2.9 | 0.2 |
| French yellow brass (Potin jaune) . . | 71.9 | 24.9 | — | 2 0 | 1.2 |
| English sterling metal | 66.2 | 33.11 | 0.66 | 2.0 | — |
| “ “ “ | 66.66 | 26.66 | 0.66 | — | — |

*Ordinary cast-brass* (*potin jaune, potin gris, sterling metal*).—The mixture of metals known under these names is the poorest quality of brass, and its composition varies so much as to make it impossible to state it within narrow limits. This quality of brass is generally prepared by fusing together old brass and brass-waste of all kinds and subjecting it to a casting test. If the fracture is not too coarse-grained and the metal not too brittle, it is used without further addition for articles known under the collective term of brazier's ware (spigots, candlesticks, mortars, etc.). Brass of this quality is readily worked with the file, but difficult to turn.

By adding to ordinary cast-brass a certain quantity of lead and tin, a metal of a somewhat whiter color is obtained, which is called *potin gris* by the French, and is more easily worked with the lathe and file. The so-called "sterling metal" is somewhat harder in consequence of a content of iron, and can therefore be much better worked than ordinary brass. By adding to sterling metal some tin, it acquires still greater hardness and takes a good polish.

*Fine cast-brass.*—Brass to be suitable for the manufacture of fine articles must, besides being readily worked with file and chisel, possess other properties of great importance in the manufacture of such articles. It should allow of being readily cast and fill the moulds exactly. Further, articles of luxury manufactured from brass are frequently to be gilded, and experience has shown that brass of a beautiful color approaching that of gold requires less gold for the purpose than brass of an unsightly pale-yellow color. In order to be enabled to save gold it is, therefore, of importance to manufacture the alloy so as to show a color shading into reddish. Generally speaking, such alloys contain from 20 to 50 parts of zinc to 100 parts of copper; lead or tin, or both, in the proportion of 0.25 to 3 per cent. of each metal being added according to the purpose for which the alloy is to be used. In the following we give the compositions of several alloys which have stood a practical test in this respect.

*Hamilton's metal, mosaic gold, chrysorin.*—The alloys known under the above names have a very beautiful color closely resembling that of gold, and are distinguished by a very fine grain, which makes them especially suitable for the manufacture of casting to be subsequently gilded. The alloys are, as a rule, composed of copper 100 parts, zinc 50 to 55.

In order to obtain a thoroughly homogeneous mixture of the two metals it is recommended first to bring into the crucible one-half of the zinc to be used, place upon this the copper, and fuse the mixture under a cover of borax at as low a temperature as possible. When the contents of the crucible are liquid, heat the other half of the zinc cut in small pieces until almost melted, and throw them into the crucible in portions; stir constantly to effect as intimate a mixture of the metals as possible.

*French cast-brass for fine castings.*—As is well known the bronze industry has reached a high degree of perfection in France, where clock-cases, statuettes, and other articles of luxury are manufactured on a large scale. The so-called bronze used for these articles is, however, in most cases not actual bronze but fine cast-brass. In the following table we give the compositions of a few mixtures of metals generally used by the French manufacturers. They can be readily cast, worked with file and chisel, and easily gilt.

| | Parts. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Copper . . . . | 63.70 | 64.45 | 70.90 | 72.43 |
| Zinc . . . . | 33.55 | 32.44 | 24.05 | 22.75 |
| Tin . . . . | 2.50 | 0.25 | 2.00 | 1.87 |
| Lead . . . . | 0.25 | 2.86 | 3.05 | 2.95 |

### *Bristol Brass (Prince's Metal).*

The alloy known by this name possesses properties similar to those of the above-mentioned French varieties of brass, and can be prepared according to the following proportions :—

| | I. | II. | III. |
|---|---|---|---|
| Copper . . . . | 75.7 | 62.2 | 60.8 |
| Zinc . . . . | 24.3 | 32.8 | 39.2 |

Regarding the preparation of this and similar alloys the same holds good which has been said under Hamilton's metal.

*Malleable brass, Muntz metal, yellow metal, etc.*—These alloys possess the valuable property of being ductile in the heat, and castings prepared from them can be worked warm like iron.

*Yellow metal.*—This metal possesses the property of being less attacked by sea-water than pure copper, and it was formerly much used for ship-sheathing and in the manufacture of nails and rivets coming in contact with sea-water. Since the introduction of iron as material for larger vessels it has, however, lost some of its former importance.

*Yellow metal* or *Muntz metal* (so called after its inventor) consists generally of copper 60 to 62 parts, zinc 40 to 38.

The metal is prepared with the observance of certain precautionary measures in order to obtain it with as uniform a grain as possible, experience having shown that only fine-grained alloys of uniform density can resist the sea-water. To obtain as uniform a grain as possible small samples taken from the fused mass are quickly cooled and examined as to fracture. If the latter does not show the desired uniform grain, some zinc is added to the fused mass. After its distribution through the entire mass a fresh sample is taken and tested, this being continued until the desired object is attained. It need scarcely be mentioned that considerable experience is required to tell the correct composition of the alloy from the fracture. The mass is finally poured into moulds and rolled cold.

*Macht's yellow metal.*—This alloy, consisting of copper 33 parts and zinc 25, has a dark golden-yellow color, great tenacity, and can be forged at a red heat, properties which make it especially suitable for fine castings.

*Bobierre's metal*, consisting of copper 66 parts and zinc 34, is claimed to be especially suitable for ship-sheathing.

From experiments made in regard to malleable brass it has been learned that all alloys containing up to 58.33 per cent. of copper and up to 41.67 per cent. of zinc are malleable. There is, however, a second group of such alloys with 61.54 per cent. of copper and 38.46 per cent. of zinc, which are also malleable in the heat. The preparation of these alloys requires, however, considerable experience, and is best effected by melting the metals together in the ordinary manner, and heating the fused mass as strongly as possible; it must, however, be covered with a layer of charcoal-dust to prevent oxidation of the zinc. By the mass becoming thinly fluid an intimate mixture of the constituent parts is effected. Small pieces of the same alloy previously prepared are then thrown into the liquid mass until it no longer shows a reflecting surface, when it is cast into ingots in iron moulds. The ingots while still red hot are thrown into water, acquiring by this treatment the highest degree of ductility. The alloy properly prepared must show a fibrous fracture and have a reddish-yellow color.

*Aich's metal.*—This alloy, named after its inventor, consists of a brass to which a considerable degree of tenacity has been imparted by an addition of iron. It is especially adapted for purposes where the use of a hard and, at the same time, tenacious metal is required.

According to analyses of various kinds of this metal, it shows, like other alloys, considerable variations in the quantity of the metals used in its preparation. Even the content of iron to which the hardening effect must be ascribed may vary within wide limits without the tenacity, which is the principal property of this alloy, being modified to a considerable extent.

The best alloy, which can be called an Aich's metal, is composed of copper 60 parts, zinc 38.2, iron 1.8. The content of iron must be limited to from 0.4 to 3.0 per cent. Another Aich's metal showing excellent properties is composed of copper 60.2 parts, zinc 38.2, iron 1.6.

The chief property of Aich's metal is its hardness, which is claimed to be not inferior to that of certain kinds of steel. It has a beautiful golden-yellow color and is said to oxidize with difficulty, which makes it of great value for articles exposed to the action of air and water.

*Sterro-metal.*—The properties of this alloy approach closely those of Aich's metal, it consisting, like it, of an alloy of copper, zinc, and iron, but containing a larger quantity of the latter. The composition of the alloy may vary considerably, a little tin being sometimes added. We give in the following an analysis of two varieties of sterro-metal of excellent quality:—

*Sterro-metal from Rosthorn's factory in Lower Austria.*—Copper 55.33 parts, zinc 41.80, iron 4.66.

*English sterro-metal* (*Gedge's alloy for sheathing for vessels*).—Copper 60 parts, zinc 38.125, iron 1.5.

The principal value of this alloy is its great strength, in which it is not surpassed by the best steel. While a wrought-iron pipe broke with a pressure of 267 atmospheres, a similar pipe of sterro-metal stood the enormous pressure of 763 atmospheres without cracking. Besides its strength it also possesses a high degree of elasticity, and on account of these properties is especially adapted for cylinders of hydraulic presses. As is well known these cylinders begin to sweat at a certain pressure, *i. e.*, the pressure in the interior is so great that the water permeates through the pores of the steel. With a cylinder of sterro-metal the pressure can be considerably increased without the exterior of the cylinder showing any moisture.

According to the purpose for which it is to be used, the sterro-metal can be made especially hard and dense, but this change in its properties is less effected by altering the chemical composition than by mechanical manipulation.

If cast sterro-metal be rolled or hammered in the heat, it acquires, besides strength, an exceedingly high degree of tenacity. In hammering the metal special care must be had not to overheat it, as otherwise it easily becomes brittle and cracks under the hammer.

A sterro-metal containing copper 55.04, zinc 42.36, tin 0.83, and iron 1.77 was tested by Baron de Rosthorn, of Vienna, and gave the following results:—*

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* Holley: "Ordnance and Armor."

| Material. | Tenacity. | |
|---|---|---|
| | Lbs. per square inch. | Kilogrammes per sq. centimetre. |
| Sterro-metal cast . . . | 60,480 | 4252 |
| " " forged . . | 76,160 | 5354 |
| " " cold drawn . | 85,120 | 5984 |
| Gun-bronze cast . . . | 40,320 | 2834 |

The specific gravity of this metal was 8.37 to 8.40 when forged or wire-drawn; it has great elasticity, stretching 0.0017 without set, and costs 30 to 40 per cent. less than gun-bronze. It has been forged into guns, cold from the casting.

Of the mixtures of metals termed brass, the alloys given in the preceding are the most important used in the industries. It will, of course, be understood that they by no means exhaust the number of alloys which can be included in the generic term, brass, that number being so large that it can scarcely be enumerated. In examining a variety of brass small variations in its quantitative composition can always be observed. No matter how small these variations may be, they nevertheless exert a great influence upon the physical properties of the respective alloys, so that an alloy differing but little in its chemical composition from another one, may nevertheless vary very much from it in regard to its physical qualities. Many manufacturers are of the opinion that the physical properties of the alloys are also largely influenced by the mode of manufacture, and those whose products are specially distinguished by great uniformity always work according to a determined method. Hence the manufacture of brass is of equal importance with the composition of the alloys.

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# VIII.

## MANUFACTURE OF BRASS.

Before zinc was known in the metallic form, brass, as previously mentioned, was prepared by fusing copper together with zinciferous ores, as calamine or carbonate of zinc, as well as with cadmia, the zinc reduced by this process combining with the copper to an alloy. As is well known, the chemical composition of even the purest ores from the same locality always varies somewhat, and it is not possible with the use of zinc ores to obtain a mixture of metals of determined properties and general uniformity. Manufacturers working according to this old method must, therefore, on the one hand, use very uniform zinc ore, and on the other possess a thorough knowledge of the properties of brass, so as to be able to tell, from the color and fracture of a sample of the fused mass, whether the alloy possesses the requisite qualities or whether it requires the addition of a further quantity of zinc ore or of copper. Though the manufacture of brass with the use of zinc ores is less expensive than the fusion of the pure metals, it is at present carried on in very few places, because the more modern process is connected with less difficulty, and an entirely new uniform product is obtained with greater ease. For the sake of completeness we will briefly describe this antiquated process of manufacturing brass.

A. *Manufacture of brass according to the old method with the use of zinciferous ores.*—Before the ores can be melted they have to be subjected to a preparatory treatment in order to remove, as much as possible, admixtures of foreign metals (lead, arsenic, antimony) which would have an injurious effect upon the quality of the brass. The native calamine, after being calcined in order to expel the sulphur, is ground in a mill, the galena contained in it is removed by washing, and it is then mixed at the same time with about one-fourth of charcoal. This mixture is put into large cylindrical crucibles with alternate layers of granulated copper. Powdered charcoal is then thrown over the whole and the crucibles are covered and luted up. The old form of furnace was a cone with the base downwards and the apex cut off horizontally. The crucibles were placed upon a circular grate or perforated iron plate upon the bottom, with a sufficient quantity of fuel thrown around them, and a perforated cover made of bricks or clay was fitted to the mouth, which served as a register to regulate the heat. After the alloy is supposed to be formed (the time varying from 10 to 20 hours, according to the nature of the calamine and the size of the crucibles), the heat is increased so as to fuse the whole down into one mass. The till is then thrown up, and a workman, standing over the opening, grasps the crucible between the jaws of a pair of tongues and lifts it out of the furnace. The refuse is skimmed off and another workman then seizes the crucible with a pair of tongs and pours the contents into iron moulds, guiding the stream with an iron rod. During this process there is a considerable combustion of zinc, the metal burning with its characteristic blue flame. When the material is good a single fusion is sufficient, but the finer sorts undergo a second fusion with fresh calamine and charcoal.

The crude brass may show several defects in regard to its composition. It may either contain too much zinc or copper, or the reduction of the zinc may not have proceeded in a complete manner. In such cases it is possible to improve the alloy by a corresponding addition of copper, zinc ore, or charcoal, and by again fusing it. Sometimes pieces of brass or metallic zinc are also added.

B. *Manufacture of brass by fusing the metals together.* —At the first glance this would appear to be a very simple operation; it is, however, connected with many difficulties, and considerable skill is required to produce brass answering determined demands in regard to fusibility, tenacity, etc. In most factories the fusion of the metals is still effected in crucibles heated in reverberatory furnaces. For many years experiments have been made to do away with the crucibles and effect the fusion of the metals directly in special furnaces. It is evident that such a process of production would be considerably cheaper, as there would be no expense for crucibles and the consumption of fuel be considerably less. The use of a furnace in which the metals could be melted down in large quantities would have the further advantage of obtaining at one operation a large quantity of brass of the same quality.

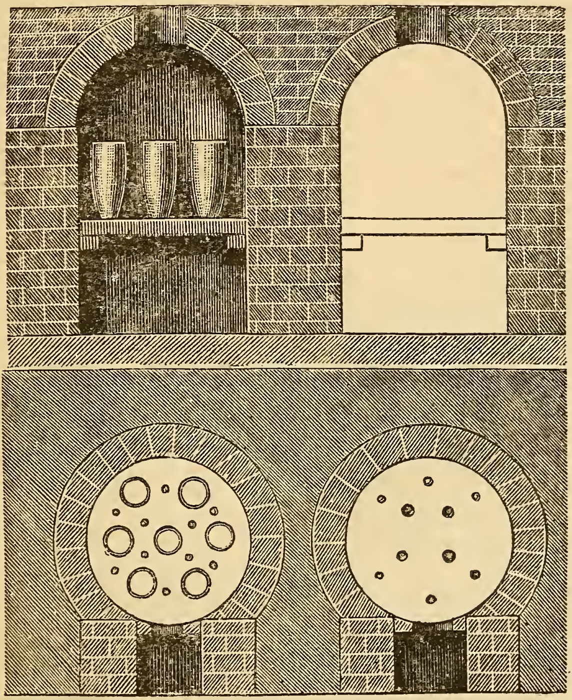
The results of experiments made in this direction have, however, been so unsatisfactory as to force a return to the older and more expensive method of fusion in crucibles. The general introduction of furnaces for melting down the brass cannot, however, be considered as entirely abandoned, as the technical difficulties in the way will, no doubt, be overcome before long. More recently experiments on a large scale have again been instituted by well-known manufacturers, which hold out a hope of final success. For the present we must, however, confine ourselves to a description of the best constructions of furnaces for crucibles.

The manner of constructing these furnaces depends chiefly on the fuel to be used (coal, coke) and on the number of crucibles to be placed in the furnace at one time. Generally speaking, the furnaces for a certain kind of fuel agree in most respects, the variations being chiefly in the arrangement of the crucibles in the furnace and the manner of distributing the flame around them.

We first give a description of a furnace especially adapted for the use of coke.

The furnace, Figs. 1 and 2, consists of a vault of refractory material and is about 3¼ feet high. On the narrowest place of the vault is an aperture through which the furnace communicates with a well-drawing chimney. The plate upon which the crucibles for melting the brass stand has seven apertures so arranged that six of them are in the periphery of a circle, while the seventh forms the centre of the circle. Between these larger apertures serving for the reception of the crucibles are smaller ones, which admit the air from below into the furnace. The bottom plate consists of a thick cast-iron plate coated with a layer of fire-clay. The six crucibles standing on the periphery of the circle have a height of 1.18 feet, with an upper diameter of 0.65 foot, which corresponds to a bottom diameter of 0.55 foot.

Figs. 1 and 2.



The crucible sitting in the centre hole is called the king crucible, and being more exposed to the heat is generally somewhat larger; it is, as a rule, 1.18 feet high with an upper diameter of 0.75 foot. The smaller crucibles hold about 92 to 97 pounds of metal and the king crucible about 132 pounds.

Fig. 3.

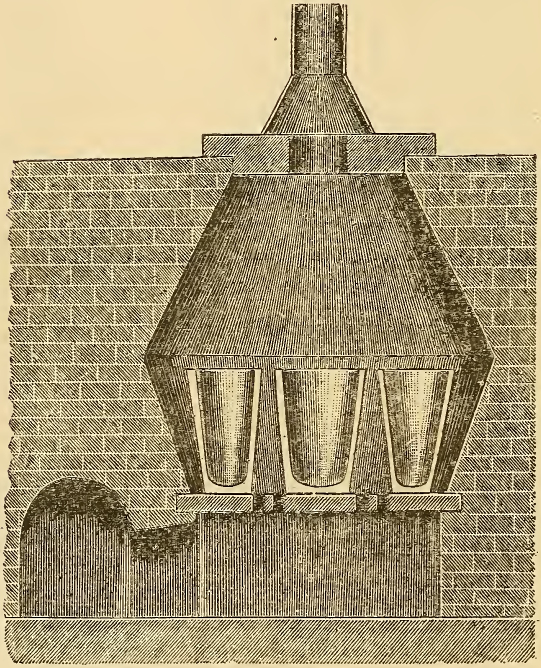
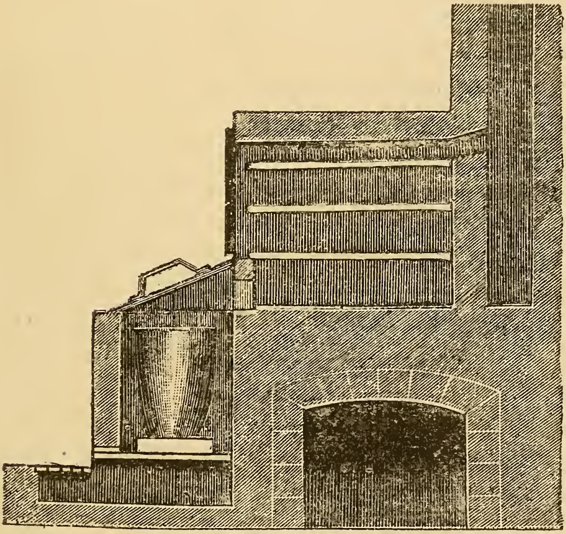


Fig. 3 shows another construction of a brass furnace. As will be seen from the illustration, the space in which the crucibles are placed has the form of two truncated cones touching each other with the basis, a shaft being thus formed in which less fuel is consumed than in a furnace having the form of a cylinder. In place of coke charcoal may be used in this furnace, if the local conditions are such as to allow of its employment without increasing the cost of the brass.

In the preparation of plate-brass the fused metal has to be cast in special moulds to solidify. It is, however, of importance that this solidification should not take place too rapidly, as otherwise the properties of the brass might be injured. To prevent too rapid cooling

Fig. 4.



the moulds serving for the reception of the fused mass are strongly heated, special furnaces having been constructed for the purpose, in which the gases escaping from the actual melting space are utilized for heating the moulds. Fig. 4 shows the construction of such a furnace in cross-section.

The crucibles in which the charge is to be melted stand upon a grate; the fuel is introduced from above, and the gases of combustion pass through a flue into a space divided into several low stories in which the moulds are placed. With the use of coke or charcoal the work is very convenient, since no smoke is developed which could possibly contain inflammable combinations. As will be seen from the above descriptions of furnaces for the use of coke or charcoal, no special provisions are required to insure a complete combustion of the fuel, it being sufficient to connect the furnace with a chimney producing a moderately strong draught. With the use of coal care must, however, be had to arrange the furnace in such a manner as to insure the complete combustion of all gaseous products evolved from the coal, as otherwise there would be a considerable loss of heat.

The arrangement of furnaces for the use of coal is modified in various ways. In one form of construction the coal is burned upon an ordinary grate, the gases of combustion passing through apertures in a vault of refractory material into a space in which the crucibles are placed. In other constructions, the fire-box is entirely separated from the melting-space, being only connected with it by flues led off at the sides through which the flame passes around the crucibles. Other constructions might be advantageously used for melting down brass. By, for instance, arranging the furnace so as to heat the crucibles by gas, the flame could be suitably regulated by a slide and with the use of a generating furnace, a number of melting furnaces could be kept going at one time. The generating furnace would, of course, have to be placed so as to form the centre of a circle on the periphery of which the separate melting furnaces are located and connected with the generating furnace by suitable flues. With, suppose, six such melting furnaces, three could be supplied with heat, while the others, after the removal of the crucibles, would be charged with fresh material.

In conclusion we will say a few words in regard to the construction of furnaces in which the fusion of the brass is effected directly upon the hearth. Generally speaking, they must be so arranged that the copper can be quickly melted down upon a flat hearth, care being had that the gases passing over the copper contain a small excess of unburnt bodies, as the presence of free oxygen in the gases might produce an oxidation of the copper, and the resulting admixture of cuprous oxide injure the quality of the brass. After the fusion of the copper it is to be strongly heated, and the zinc, together with any brass waste, both previously heated, introduced as quickly as possible. It is advisable to connect the furnace with two heating rooms, showing different temperatures. In the room showing the lowest temperature the zinc is heated as nearly as possible to its melting point, and in the hotter room the brass waste to be added to the fused mass.

By introducing, as rapidly as possible, the materials thus heated into the heated copper, a too rapid cooling off of the latter by yielding heat to the zinc need not be feared. By this precautionary measure of preparatory heating, the metal will remain thinly fluid even after the introduction of the zinc and the waste brass, and the resulting alloy will be perfectly uniform as regards fracture, hardness, and color.

The manner in which fusion is effected varies somewhat in the different works. In furnaces in which the king-crucible stands in the centre of a circle and the rest on the periphery, the work is generally carried on as follows:—

One of the crucibles is lifted from the furnace and being placed alongside of it is first charged with a small quantity of brass-waste mixed with a certain quantity of pulverized charcoal. Upon this base the mixture of copper and zinc in suitable proportions, previously weighed off for each crucible, is placed, and the whole covered with a layer of a mixture of brass-waste and pulverized charcoal. It is also advisable to cover the surface of the contents of the crucible with as high a layer of pulverized charcoal as possible, this preventing at least to some extent a too strong volatilization of the zinc. In brass foundries the waste resulting from casting and otherwise is always melted down with a new charge of the crucibles. The centre crucible, the so-called king-crucible, is generally charged last. In some foundries it is even customary to leave it entirely uncharged, it forming then so to say the inner casing of the furnace. This practice, however, cannot be recommended.

The period of the complete fusion of the charge depends on the size of the crucibles, the fuel used, and on the construction of the furnace itself, but should not be longer than from two to five hours. After placing the crucibles in the furnace, the fuel (if coke or charcoal be used) is heaped around them, or the coal placed upon the grate and ignited. In working with furnaces provided with a movable plate the latter is from time to time lifted off in order to see that the surface of the melted metal remains covered with charcoal. When by dipping a rod into the crucibles it is observed that the contents are thoroughly liquefied, the casting can be either at once proceeded with, or samples may first be taken to test the quality of the brass, and, if necessary, change its properties by additions to the fused mass.

While in the course of fusion care must be had to keep the apertures through which air is admitted to the fuel free, towards the end of the operation they are covered as much as possible in order to save fuel. It is also of importance not to force the heating of the finished alloy further than is absolutely necessary, since by strong overheating a considerable portion of the zinc volatilizes, and the alloy may acquire properties entirely different from those desired.

# IX.

## CASTING OF BRASS.

THE casting of brass requires certain precautionary measures in order to obtain homogeneous pieces as free from flaws as possible. As regards the mode of casting we especially distinguish two different methods, viz: ingot-casting and plate-casting, the former serving for casting brick-shaped pieces, which are to be remelted for further working or at once brought into the required shape, and the latter for casting plates to be rolled out into sheets.

A. *Casting of ingots.*—If the brass is to be cast in the shape of bricks or cubes or is directly to be used for casting various articles, the operation is carried on as follows: The king-crucible is generally left empty, and after the brass in the other crucibles is thoroughly melted down, is lifted from the furnace and placed in a depression in front of it filled with glowing coals. One crucible after the other is then taken from the furnace and its contents emptied into the king-crucible. As soon as it is filled the surface of the fused metal contained in it is covered with charcoal and the whole allowed to stand quietly about 15 minutes in order to bring about a uniform mixing of the masses emptied from the different crucibles. After this period, the charcoal is removed from the surface and, after vigorously stirring the contents of the crucible several times with an iron rod, the fused metal is poured into the moulds.

As will be seen from the preceding description the king-crucible answers here the purpose of a sump and may be suitably replaced by one. For this purpose another furnace, in which the sump stands free and can be heated to a bright red heat, has to be erected in front of the furnace containing the crucibles. This sump then serves for the reception of the fused brass, and by charging the king-crucible also with metal, the space occupied by it in the centre of the furnace can be advantageously utilized. By arranging several melting furnaces around the sump furnace and with a proper division of the work, only one sump is required, it being charged in rotation with the contents of the crucibles from the separate furnaces.

The moulds for casting ingots of brass are similar to those used for casting pig-iron. The patterns for the moulds are of wood and have generally the form of bricks with oblique sides. The patterns are pressed alongside each other in wet moulding sand, a small gutter being left between each two moulds through which the metal after one mould is filled runs into the other.

The object being not so much to give the ingots a beautiful appearance as to obtain them in a handy form, the sand for making the moulds need not be especially fine. The cold ingots of brass have quite a rough surface and must be freed from adhering grains of sand by rubbing.

For casting articles to be subsequently turned or worked with the file special care is required in making the mould. As a rule the ingots are remelted in a wind furnace, a certain quantity of brass or of zinc in pieces according to the quality the article to be cast is to have, being added to the fused metal. For remelting brass graphite crucibles are generally used, less dross adhering to their walls than to those of the rougher clay crucibles.

The moulds used for casting articles of brass are sometimes made of loam and must be sharply dried before use to prevent cracking. Suitable moulding sand is, however, generally preferred. The condition of the sand is of great importance for the surface of the cast article; if it be too meagre the surface is rough and requires much after work in turning or filing. Meagre sand is improved by adding a small quantity of ordinary flour paste or some sugar syrup. If the sand is too fat this property is decreased by the addition of some finely pulverized charcoal.

In order to obtain perfect castings great attention must be paid to the temperature of the fused brass. Overheated metal gives, as a rule, porous castings, and if it be too cool the mould is incompletely filled out, which with delicate articles may spoil the entire casting. The metal must be poured in an uninterrupted stream into the mould, otherwise flaws will, as a rule, be formed and the casting be useless. In conclusion it may be remarked that in making the mould, vents must be provided for the escape of the aqueous vapor evolved.

B. *Casting of plate-brass.*—For the preparation of sheet-brass or wire-brass the metal has to be cast in the form of plates of corresponding thickness. It being absolutely necessary for the metal to retain the property of ductility, special precautions must be taken in executing the casting.

Many attempts have been made to use iron moulds, but in most cases the castings turned out failures on account of the brass cooling off too rapidly. This evil might, however, be overcome by heating the moulds in a special furnace previously to casting and returning them to the furnace after casting, where by a suitable regulation of the temperature the castings could be cooled off as slowly as desired. Such furnace could be built on the same principle as the cooling furnace used in glass houses.

Loam moulds give good castings, but have the disadvantage of breaking readily, which, to be sure, might be overcome by edging the loam plates with band-iron. At present small moulds of sand are frequently used in many foundries, which must, of course, be thoroughly dried in special furnaces previously to casting. With the use of small moulds and careful work faultless plates can be readily cast, while with large moulds it frequently happens that some places of the plate are defective and have to be cut out.

In many places granite moulds are still in use, and yield, according to the statements of many manufacturers, the best results. The preparation of these moulds requires great care, the following points deserving special attention: The granite plates must be provided with a uniform coating of clay, which must always be kept in such a condition as to insure the utmost uniformity in the surface of the plates. To prevent the cracking of the coating of clay, it is covered after thorough smoothing with a thin layer of cow-dung.

The granite plates thus prepared are arranged in the following manner: The upper plate is suspended over the lower one, the space or mould between the two being limited by iron bars laid on the lower stone, which is a little longer than the upper one, and projects to the front so as to form a lip or mouth-piece for receiving the metal. The plates are bound together with iron and raised on one side so that they stand at an angle of 45°. As soon as the casting is finished and the metal is supposed to be solidified, the sheet of brass is carefully taken from the mould. With sufficient precautions such granite moulds can be used for a long time without the coating of clay becoming damaged, and the sheets turn out very uniform after the mould has once been heated by several castings. One and the same mould is frequently used continually in order to keep it warm, and if it has to stand empty for some time it is enveloped in a bad conductor, as a coarse carpet, to prevent its cooling. If the mould is damaged, it must be carefully mended and the mended places sharply dried to prevent cracking.

The sheets of brass taken from the mould are subjected to a mechanical cleansing and at the same time carefully inspected; defective sheets are remelted.

At the present time the plate-brass obtained by casting is generally worked into sheet-brass, which was formerly prepared by hammering, but now by rolling. In some cases rolling is succeeded by hammering, as, for instance, in the case of the very thin sheet brass known as Dutch metal, which is distinguished by a peculiar, clear sound it emits on being pressed together.

By the rolling process the brass becomes more brittle, and must therefore be frequently annealed, in many founderies the annealing process being repeated after each passage through the rolls. For the manufacture of sheet, brass is generally used which can be worked in the cold; for working brass only ductile in the heat, the sheets must of course pass in a hot state through the rolls.

After passing through the rolls the sheet-brass is finally subjected to a treatment, which decides whether it is to be soft and flexible or hard and elastic. For soft sheet the finished sheet-brass is again heated and quickly cooled off, while for hard and elastic sheet the annealing is omitted while the sheet is still quite thick, so that it has to pass several times through the rolls before it is finished.

For annealing the sheets a reverberatory furnace with a flat vault is used. The sheets are placed upon a grate running upon wheels and rails, so that it can be quickly pushed into the furnace or withdrawn from it. The reverberatory furnace is generally heated with wood or charcoal; if coal is to be used as fuel, it is recommended not to expose the sheets to the immediate action of the gases of the fire, they always containing a certain amount of sulphurous acid which is absorbed by the copper. Such sheet-brass, after cleansing, does not show a beautiful yellow but a red color, which is due to the copper having entered into combination with the small quantity of sulphur contained in the gases of the fire.

# X.

## CLEANSING OR PICKLING OF BRASS.

THE finished sheets have a black color, which is partially due to the formation of cupric oxide on the surface and partially to sulphur combinations formed, as previously mentioned, by heating with coal in annealing. As a rule brass is brought into commerce in a bright state, the only exception being the thicker sheets, which retain the black coating. In order to impart to the sheet its characteristic beautiful yellow color, it is subjected to a final operation termed *pickling* or *dipping*. This operation simply consists in treating the sheet with acids, which removes the layer of oxide to which the black color is due. The pickling commences by placing the sheets in a fluid consisting of 10 parts of water and 1 of sulphuric acid. The layer of oxide quickly dissolves in the fluid and the sheets show the pure yellow brass color. After this operation the sheets may be at once washed and dried and brought into commerce.

In most cases the sheets are, however, subjected to a second treatment with acids in order to impart to them a beautiful color; hence the treatment with sulphuric acid is generally termed preparatory pickling. As the actual pickle either nitric acid by itself is used or a mixture of two parts of nitric acid and one part of sulphuric acid. Pickles containing nitric acid possess the property of dissolving zinc from the brass quicker than copper, the surface of the sheet acquiring in consequence of it a warmer tone shading more or less into reddish.

By exercising great care dilute nitric acid by itself may be used as a pickle, but the sheets must be immediately washed, since if only the slightest trace of the acid remains, they acquire after some time a greenish color due to the formation of a basic cupric nitrate.

It has been observed that nitric acid containing a certain quantity of nitrous acid yields especially beautiful shades of color. To obtain them a small quantity of organic substance is added to the nitric acid or to the mixture of nitric and sulphuric acids. The most curious substances are used for the purpose, snuff, for instance, being highly recommended as especially efficacious in producing beautiful colors. The use of such substances is, however, entirely superfluous, there being a number of cheaper organic substances which, when brought together with concentrated nitric acid, evolve nitrous acid. The cheapest of these materials is dry saw-dust, the nitric acid acquiring a short time after its introduction an orange-yellow color, which is due to the products of decomposition of the nitric acid, prominent among which is nitrous acid. After taking the sheets from the pickle they are washed, best in running water, in order to remove the last traces of acid.

By quick pickling the articles are obtained bright by the removal of the layer of oxide from the smooth surface of the metal.. But sometimes a dull lustreless surface is to be imparted to the brass, which is effected by treating the articles with a boiling pickling fluid composed also of nitric and sulphuric acids. In many factories this pickle is prepared by dissolving 1 part of zinc in 3 of nitric acid and mixing the solution with 8 parts each of nitric and sulphuric acids. The solution is heated in a porcelain dish, and the articles to be pickled dipped in it 30 to 40 seconds. In dipping the brass articles large masses of red-brown vapors originating from the products of decomposition of the nitric acid are evolved which strongly attack the lungs. The operation should therefore be executed under a well-drawing chimney, or, still better, in an open space.

The pickled articles have a gray-yellow color, and in order to bring out the pure yellow color are immersed for a few seconds in pure nitric acid. They are then drawn through a weak solution of soda or potash and finally washed. The bright metal losing its beautiful color on exposure to the air in consequence of oxidation, the articles after drying must be coated with good varnish.

# XI.

## RED BRASS.

With an increase in the content of copper the color of brass changes, and its properties as regards ductility, strength, and tenacity approach more closely those of copper. On account of their color, which facilitates gilding so that only a comparatively small quantity of gold is required for the production of articles presenting a fine appearance, the compounds belonging to this group are chiefly used for articles to be gilded.

The color of red brass being more agreeable to the eye than that of ordinary brass, it is also frequently used for articles not requiring special hardness and strength, as door-knobs, escutcheons, curtain-rings, etc. It has, however, the disadvantage of turning black quicker than ordinary brass.

The content of copper in red brass amounts up to 80 per cent. and over, and to modify the properties of the alloy according to the purposes they are to serve, tin or lead, or sometimes both, are frequently added to the mixture. Red brass being frequently used for articles made by "striking up" in a die under a press or a drop-hammer, it must possess a high degree of ductility and tenacity to prevent the cracking of the articles. Red brass comes into commerce under a great many names, such as tombac, talmi-gold, etc. But all these alloys, no matter under what name they may be known, agree in containing a high percentage of copper. The manner of preparing castings and sheet being exactly the same as that described for brass, we proceed at once to give the composition of the most important alloys belonging to this group.

*Tombac.*—This alloy contains generally 84 to 85 parts of copper and 15 to 16 parts of zinc. The proportions vary, however, very much, as seen from the following table:—

| | Parts. | | |
|---|---|---|---|
| | Copper. | Zinc. | Lead. |
| Cast-tombac, German . . . | 87.00 | 13.00 | — |
| " English . . . | 86.38 | 13.62 | — |
| Tombac, German (Oker) . . | 85.00 | 15.00 | — |
| " " (Hegermühl) . | 85.30 | 14.70 | — |
| " Paris (red) . . . | 92.00 | 8.00 | — |
| " for gilding, German . | 97.80 | 2.20 | — |
| " " French . | 86.00 | 14.00 | — |
| " German (Lüdenscheid) . | 82.30 | 17.70 | — |
| " French (yellow) . . | 80.00 | 17.00 | 3.00 |
| " golden-yellow . . | 89.97 | 9.98 | 0.05 |
| " " " . . . | 82.00 | 17.50 | 0.50 |

The color of tombac varies from pure copper red to orange-yellow, according to the content of copper, though a red color is by no means a criterion as regards the content of copper, since an alloy of 49.3 parts of copper and 50.7 of zinc is redder than one of 4 parts of copper and 1 of zinc. The more copper the alloy contains the more fine-grained and ductile it generally is.

Many small articles, as candle-sticks, inkstands, etc., which are sometimes gilt, are made from a compound designated in commerce as bronze, which is, however, not bronze but only resembles it in color. Such alloys are also frequently used for casting small statues, for which they are well adapted, since they fill the moulds very uniformly. The composition of these alloys varies very much, though zinc and copper are, as a rule, the actual constituents, an admixture of tin occurring only occasionally. We give a few compositions of this (imitation) bronze :—

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Copper . . . . . . | 80 | 67 | 76 |
| Zinc . . . . . . | 20 | 33 | 24 |

*Mannheim gold or similor.*—This alloy has a beautiful golden yellow color. Its composition varies considerably.

| | Parts. | |
|---|---|---|
| | I. | II. |
| Copper . . . . . . | 83.7 | 89.8 |
| Zinc . . . . . . | 9.3 | 9.6 |
| Tin . . . . . . | 7.0 | 0.6 |

The alloy may also be obtained by melting together 69.6 parts of copper, 29.8 of brass, and 0.6 of finest tin.

Mannheim gold was formerly much used in the manufacture of buttons and pressed articles of a gold-like appearance, but it has recently been superseded by alloys which surpass it as regards beautiful color.

*Chrysochalk* (*gold-copper*).—This term is applied to several alloys resembling gold, which may consist of copper 90.5 parts, zinc 7.9, lead 1.6, or of copper 58.68, zinc 39.42, lead 1.90.

The beautiful color of this alloy soon disappears on exposure to the air, but can be preserved for some time by coating articles manufactured from it with a colorless varnish. Chrysochalk is generally used for ordinary gold imitations, as watch-chains, articles of jewelry, etc.

*Chrysorin.*—This alloy prepared by Rauschenberger, consists of 100 parts of copper and 51 of zinc. Its color resembles that of 18 to 20 carat gold, and does not tarnish on the air.

*Pinchbeck.*—The alloy known under this name was first manufactured in England, and is distinguished by its dark gold color which comes nearest to that of gold alloyed with copper. Pinchbeck being very ductile can be rolled out into very thin plates, which can be brought into any desired shape by stamping. The alloy does not readily oxidize in the air, and is, therefore, well adapted for cheap articles of jewelry, for which it is principally used. Pinchbeck answering all demands is composed—

| | Parts. | |
|---|---|---|
| | I. | II. |
| Copper | 88.8 | 93.6 |
| Zinc | 11.2 | 6.4 |

Or,

| | I. | II. |
|---|---|---|
| Brass | 1.0 | 0.7 |
| Copper | 2.0 | 1.28 |
| Zinc | — | 0.7 |

*Oreïde or oroide* (*French gold*).—This alloy is distinguished by its beautiful color, which resembles that of gold so closely that scarcely any difference can be detected on comparing the two metals. Besides its beautiful color it has other valuable properties, it being very ductile and tenacious so that it can be readily stamped into any desired shape; it also takes a high polish. It is frequently used for the manufacture of spoons, forks, etc., but being injurious to health on account of its large content of copper is not suitable for the purpose. The directions for preparing this alloy vary very much, some masses from Paris factories showing the following compositions:—

| | | | | |
|---|---|---|---|---|
| Copper | 90 | 80.5 | 68.21 | Parts. |
| Zinc | 10 | 14.5 | 13.52 | |
| Tin | | | 0.48 | |
| Iron | | | 0.24 | |

According to a special receipt orëide is prepared in the following manner: Melt 100 parts of copper and add with constant stirring 6 parts of magnesia, 3.6 of sal ammoniac, 1.8 of lime, and 9 of crude tartar. Stir again thoroughly and then add 17 parts of granulated zinc, and after mixing it with the copper by vigorous stirring, keep the alloy liquid for one hour. Then remove the cover of froth and pour out the alloy.

*Talmi or talmi-gold.*—Cheap articles of jewelry, chains, earrings, bracelets, etc., were first brought into commerce from Paris under the name of talmi-gold, which were distinguished by beautiful workmanship, a low price, and great durability. Later on, when this alloy had required considerable reputation, other alloys or rather metals, were brought into commerce under the same name, which retained their beautiful gold color, however, only as long as the articles manufactured from them were not used.

The finer quality of talmi-gold retains its pure gold color for some time and consists actually of brass or copper or tombac covered with a thin plate of gold combined with the base by rolling. The plates thus formed are then rolled out by passing through rolls, whereby the coating of gold not only acquires considerable density but adheres so firmly to the base that articles manufactured from the metal can be used for years without losing their beautiful appearance.

In modern times articles of talmi-gold are brought into market which are simply electro-plated, the coating of gold being in many cases so thin that by strong rubbing with a rough cloth the color of the base shows through. Such articles, of course, lose their gold-like appearance in a short time.

In the following we give the compositions of a few alloys used in the manufacture of articles of talmi-gold; it will be seen that the content of gold varies very much, the durability of the articles manufactured from the respective alloys being, of course, a corresponding one. The alloys I., II., and III. are genuine Paris talmi-gold; IV., V., and VI. are imitations which are electro-plated, and VII. is an alloy of a wrong composition to which the gold does not adhere.

| | I. | II. | III. | IV. | V. | VI. | VII. |
|---|---|---|---|---|---|---|---|
| Copper . | 89.88 | 90.79 | 90.00 | 90.69<br>88.16 | 87.48<br>83.13 | 93.46<br>84.55 | 86.4 |
| Zinc . . | 9.32 | 8.33 | 8.9 | 8.97<br>11.42 | 12.44<br>16.97 | 6.60<br>15.79 | 12.2 |
| Tin . . | — | — | — | — | — | — | 1.1 |
| Iron . . | — | — | — | — | — | — | 0.3 |
| Gold . . | 1.03 | 0.97 | 0.91 | 0.05<br>— | 0.03<br>— | 0.05<br>— | — |

*Tissier's metal.*—This alloy is distinguished by great hardness, and differs from the previously described compounds in containing arsenic. It has a beautiful tombac red color. Its composition is not always the same, the quantities of the component metals varying within wide limits. The alloy actually deserving the name is composed of copper 97 parts, zinc 2, arsenic 1 to 2.

According to this composition Tissier's metal may be considered a brass containing a very high percentage of copper and hardened by an addition of arsenic. It is sometimes used for axle-bearings, but can be very suitably replaced by other alloys, to be mentioned further on, which are preferable to it on account of lacking the dangerous arsenic.

*Tournay's metal.*—This alloy is much used by the Paris manufacturers of bronze articles, and on account of its great ductility can be advantageously employed for the manufacture of cheap jewelry to be made from very thin sheet. It is also well adapted for the manufacture of buttons. It is composed of copper 82.54 parts, zinc 17.46.

The preceding alloys are those which, strictly speaking, belong to the brasses, the composition of the mixtures as regards their principal constituents—copper and zinc—varying only within certain limits, and the addition of tin, lead, and iron being only made in order to change the properties of the alloys for certain purposes. Besides these alloys there are, however, some which find special application, and for that reason will be discussed separately; the alloys known as white metal, etc., and the metallic mixtures known as bronze-powders belonging to this group.

# XII.

## WHITE METAL.

The alloys known under this name contain, besides a certain proportion of copper, a large quantity of zinc, and thus have the qualitative composition of brass without, however, sharing its other properties. In consequence of the large content of zinc, the color of these alloys is not yellow, but either pure white (silver-white) or a pale, but pleasant yellow. Their ductility decreasing considerably with the increase in the content of zinc, they can only be used for cast articles, which are to be finished by the lathe or file. Their comparatively low melting point is also due to the large content of zinc. Being quite cheap, they are well adapted for casting statuettes and other small articles not exposed to the influence of the weather. In the air these alloys do not acquire the beautiful color of bronze, called patina, but a dirty brown-green.

On account of their white color these alloys are much used in the manufacture of buttons, and can be partially worked with a fly-press without, however, subjecting them to too strong a pressure.

*Birmingham platinum.*—This alloy is of a pure, nearly silver-white color, which remains constant on the air for some time. The alloy is, however, so brittle as to be only suitable for casting. Buttons are made of it by casting it in moulds giving sharp impressions, the letter, escutcheon, etc., upon the button being subsequently brought out more by careful pressing. The alloy, which is also known as platinum-lead, is composed of—

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Copper | 43 | 46.5 | 4 |
| Zinc | 57 | 53.5 | 16 |

Other alloys for white buttons consist of—

| | Parts. | |
|---|---|---|
| | I. | II. |
| Yellow brass | 32 | 32 |
| Zinc | 3 | 4 |
| Tin | 1 | 2 |

*Sorel's alloy.*—This important and valuable alloy possesses properties rendering it especially suitable for many purposes. It is chiefly remarkable for its considerable hardness, it being in this respect at least equal to good wrought-iron. Its tenacity surpasses that of the best cast-iron. In casting it shows the valuable property of being readily detached from the mould, and it can be mechanically worked with great ease, but is too brittle to be rolled out into sheets or drawn into wire. It is much used for casting small statues, which after careful bronzing are brought into commerce under the name of cast-bronze. It may also be employed in the manufacture of articles exposed to the influence of the weather, as it rusts with difficulty and finally becomes coated with a thin, firmly-adhering layer of oxide which prevents further oxidation. The following mixtures have nearly the same properties, though they vary very much as regards their composition :—

| | Parts. | |
|---|---|---|
| | I. | II. |
| Copper | 1 | 10 |
| Zinc | 98 | 80 |
| Iron | 1 | 10 |

The iron is used in the shape of cast-iron shavings, which are added to the zinc. The copper is then added and the alloy kept fluid under a cover of glowing coals for some time, in order to insure an intimate combination of the metals without a combustion of the zinc. The alloy being difficult to prepare in the above manner on account of the combustibility of the zinc, it is recommended in preparing large quantities not directly to mix the metals, but to use brass of known composition. This is melted down under a cover of charcoal and slightly overheated; the zinc is then added and finally the iron.

## XIII.

### IMITATION GOLD ALLOYS.

There are, as previously mentioned, some alloys whose color closely resembles that of gold and which are used for cheap gold-colored coatings. These alloys when in a beaten state are known as Dutch gold or leaf-metal, and are prepared in various colors as dark yellow, pale yellow, greenish-yellow, etc. The principal seats of this special industry are Vienna, Nürnberg, and Fürth, where the manufacture is carried on in connection with that of bronze powder.

The composition of the alloys, for the preparation of green leaf-metal, varies between the proportions given in the following compositions: Copper 77 to 85 parts, zinc 23 to 15.

The metals are melted in graphite crucibles, and in order to insure the uniformity of the alloy are kept liquid for some time. The mixture is then cast into half-round ingots about 23½ inches long and about ¾ inch in diameter. These ingots are rolled cold into strips about the thickness of ordinary writing paper. Each of these strips is folded together so as to form a package about 23½ inches long. This package is beaten under a hammer set in motion by a motor until the strip forms a band about 3¾ inches wide. The very thin strips obtained in this manner are cut up into pieces which are again hammered until they begin to tear on the edges, about one thousand of the thin strips being placed together for this operation.

The strips are then cut into square leaves, which are placed between parchment leaves and beaten under a rapidly-moving hammer until they are about 5¾ inches square. Each of the leaves is now cut into four squares of equal size, which are beaten between parchment leaves in the same manner as genuine gold-leaf. The beaten metal is placed in books of tissue-paper which, to prevent the leaf-metal from adhering, is previously slightly rubbed with colcathar.

Leaf-metal is much used for gilding all sorts of articles, and its beautiful color may be preserved for some time by applying a coat of thin colorless or slightly yellow varnish. By adding to the latter a small quantity of a pure color—aniline colors being well adapted for the purpose—the color of the leaf-metal can be readily changed into red, green, violet, etc.

# XIV.

## BRONZE POWDERS.

A SERIES of colors consisting of very finely triturated metallic powder occurs, as is well known, in commerce. These colors are used for various purposes, as in printing, in the manufacture of wall-papers, for coating articles of iron and plaster of Paris, and, in short, in all cases where the appearance of metal is to be given to any article. The alloys used in the preparation of these bronze powders have, as regards their quantitative composition, the greatest similarity to tombac. For colors shading strongly into white metallic mixtures with a high percentage of zinc are used, and for those approaching more a pure red alloys with a large content of copper.

The many shades of color found in commerce are, however, not produced by the employment of different compounds, but by heating the alloys converted into an impalpable powder until the desired shade is obtained by the formation of a thin layer of oxide upon the surface of each particle. In modern times bronze powders are brought into commerce showing beautiful green, blue, and violet colors, which are, however, not obtained by the formation of a layer of oxide, but by coloring the metallic powder with aniline color. The manner of preparing bronze powders has been recently much improved by the use of suitable machines for the conversion of the alloys into powder.

In metal-leaf factories the waste resulting in rolling out and hammering is used for the preparation of bronze powder. According to the old method the waste was rubbed with a honey or gum solution upon a stone until a mass consisting of fine powder combined to a dough by the honey or gum solution was formed. This dough was thrown into water, and after the solution of the agglutinant the metallic powder was dried, and subjected to oxidation by mixing it with a little fat and heating it in a pan over an open fire until the desired shade of color was obtained. At the present time this laborious and time-consuming method has been much shortened by the use of suitable machines, and of alloys prepared by melting together the metals in suitable proportions for powders which do not require to be colored by oxidation. These alloys are beaten out into thin leaves by hammers driven by steam. The leaves are then converted into powder by forcing them through the meshes of a fine iron-wire sieve with the assistance of a scratch-brush. This rubbing through is effected with a simultaneous admission of oil, and the mass running off from the sieve is brought into a grinding machine of peculiar construction—a steel-plate covered with fine blunt-pointed needles revolving over another steel-plate. In this machine the mass is reduced to a very fine powder mixed, however, with oil. The powder is first brought into water where the greater portion of the oil separates on the surface. The metallic mass lying on the bottom of the vessel is then subjected to a strong pressure, which removes nearly all the oil, the small quantity remaining exerting no injurious influence, but being rather beneficial, as it causes the powder to adhere with greater tenacity to the articles to which it is applied.

In the following we give the compositions of the alloys for some colors:—

| Color. | Parts. Copper. | Parts. Zinc. | Parts. Iron. |
|---|---|---|---|
| Yellow | 82.33 | 16.69 | 0.16 |
| Pale green | 84.32 | 15.02 | 0.63 |
| Lemon | 84.50 | 15.30 | 0.07 |
| Copper-red | 99.90 | — | — |
| Orange | 98.93 | 0.73 | — |
| Pale yellow | 90.00 | 9.60 | — |
| Crimson | 98.22 | 0.50 | 0.56 |

The better qualities of English bronze powders consist of copper 83 parts, silver 4.5, tin 8, oil 4.5, and the poorer qualities, of copper 64.8 parts, silver 4.3, tin 8.7, zinc 12.9, and oil 3.

The variety of bronze powder known under the name of "*brocade*," consists of coarser pieces prepared from the waste of metal-leaf factories by comminuting it by means of a stamping-mill, and separating the pieces of unequal size formed first by passing through a sieve and finally by a current of air. A certain kind of brocade does, however, not consist of a metallic alloy, but simply of mica rubbed to a fine powder. Some kinds of bronze powder, as previously mentioned, are colored with aniline colors. This is effected by simply pouring a dilute solution of the aniline color in strong alcohol over the powder and intimate mixing.

In the following table, originally collated for the Committee on Alloys of the U. S. Board,* the properties of the alloys of copper and zinc as described by the best authorities are exhibited in a concise manner:—

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* Report, Vol. II., 1881.

*Properties of the Alloys of*

Comparison of

| Line numbers. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Zn. | Cu. | Zn. | | | |
| 1 | | 100 | 0 | — | — | 8.874 | Red | Fibrous |
| 2 | | 100 | 0 | — | — | 8.667 | Tile-red | Earthy |
| 3 | | 100 | 0 | — | — | 8.921 | —— | —— |
| 4 | | 100 | 0 | — | — | — | —— | —— |
| 5 | | 100 | 0 | — | — | 8.952 | —— | —— |
| 6 | | 100 | 0 | — | — | — | —— | —— |
| 7 | | 100 | 0 | — | — | 8.672 | —— | —— |
| 8 | | 99.15 | 0 85 | — | — | — | —— | —— |
| 9 | | 97.80 | 2.20 | — | — | — | —— | —— |
| 10 | | 97.50 | 2.50 | 97.83 | 1.88 | 8.791 | Yellow-red | Vesicular |
| 11 | | 97.20 | 2.50 | — | — | — | —— | —— |
| 12 | | 95 | 5 | 96.07 | 3.79 | 8.825 | Yellow-red | Vesicular |
| 13 | | 93.6 | 6.4 | — | — | — | —— | —— |
| 14 | | 92.5 | 7.5 | 92 32 | 7.68 | 8.746 | Yellow-red | Vesicular |
| 15 | | 92.5 | 7.5 | — | — | — | —— | —— |
| 16 | | 92 | 8 | — | — | — | —— | —— |
| 17 | | 91 | 9 | — | — | — | —— | —— |
| 18 | $Cu_{10}Zn$ | 90.72 | 9.28 | — | — | 8.605 | Red-yellow | Coarsely crystalline |
| 19 | $Cu_{10}Zn$ | 90.65 | 9.35 | — | 9.60 | 8.834 | —— | —— |
| 20 | | 90 | 10 | 90.56 | 9.42 | 8.773 | Yellow-red | Vesicular |
| 21 | | 90 | 10 | — | — | — | —— | —— |
| 22 | $Cu_9Zn$ | 89.80 | 10.20 | — | — | 8.607 | Red-yellow | Finely crystalline |
| 23 | | 88.89 | 11.11 | — | — | — | —— | —— |
| 24 | $Cu_8Zn$ | 88.60 | 11.40 | — | — | 8.633 | Red-yellow | Finely crystalline |
| 25 | | 87.50 | 12.50 | 88.94 | 10.97 | — | Yellow-red | Vesicular |
| 26 | $Cu_7Zn$ | 87.30 | 12 70 | — | — | 8.587 | —— | Finely crystalline |
| 27 | | 86.67 | 13.33 | — | — | — | —— | —— |
| 28 | | 86.38 | 13 61 | — | — | — | —— | —— |
| 29 | | 86 | 14 | — | — | — | —— | —— |
| 30 | | 85 5 | 14 5 | — | — | 8.591 | Yellow-red | Fine fibrous |
| 31 | $Cu_6Zn$ | 85.34 | 14.66 | — | 14.90 | 8.710 | —— | —— |
| 32 | | 85 3 | 14.7 | — | — | — | —— | —— |
| 33 | | 85 | 15 | 89.80 | 10.06 | 8.656 | Red-yellow | Earthy |
| 34 | | 85 | 15 | — | — | — | —— | —— |
| 35 | | 84.6 | 15.4 | — | — | — | —— | —— |

*Copper and Zinc.*

several authorities.

| Line numbers. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston). | Order of malleability (Mallet). | Hardness (Mallet and Calvert and Johnson). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 27,800 | 8 | 30.8 | — | — | — | — | — | U. S. B. | |
| 2 | 55,104 | — | — | 1 | 22 | 15 | — | — | Ml. | |
| 3 | — | — | — | — | — | — | — | 93.16 | Ma. | |
| 4 | — | — | — | — | 30.1 | — | 81.1 | — | C. J. | |
| 5 | — | — | — | — | — | — | — | — | Mar. | Sheet copper. |
| 6 | — | — | — | — | — | — | 73.6 | 79.3 | We. | |
| 7 | 24,252 | — | — | — | — | — | — | — | We. | Mean of 9 samples. |
| 8 | — | — | — | — | — | — | — | — | Bo. | Tombac for buttons. |
| 9 | — | — | — | — | — | — | — | — | — | Red tombac of Vienna. |
| 10 | 27,240 | — | 118.9 | — | — | — | — | — | U. S. B. | |
| 11 | — | — | — | — | — | — | — | — | Bo. | Railway axles, porous. |
| 12 | 11,500 | — | 37.9 | — | — | — | — | — | U. S. B. | Defective bar. |
| 13 | — | — | — | — | — | — | — | — | Bo. | Pinchbeck. |
| 14 | — | — | — | — | — | — | — | — | U. S. B. | |
| 15 | — | — | — | — | — | — | — | — | Bo. | Bearings, Austria. |
| 16 | — | — | — | — | — | — | — | — | Bo. | Red tombac of Paris. |
| 17 | — | — | — | — | — | — | — | — | Bo. | Tombac. |
| 18 | 27,104 | 6 | — | 13 | 21 | 14 | — | — | Ml. | |
| 19 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of ingot, 8.753. |
| 20 | — | — | 169.1 | — | — | — | — | — | U. S. B. | |
| 21 | — | — | — | — | — | — | — | — | Bo. | French orëide. |
| 22 | 25 760 | 4 | — | 11 | 20 | 13 | — | — | Ml. | |
| 23 | — | — | — | — | — | — | 27.3 | 25.5 | We. | |
| 24 | 28,672 | 2 | — | 10 | 19 | 12 | — | — | Ml. | |
| 25 | — | — | — | — | — | — | — | — | U. S. B. | |
| 26 | 29,568 | 9 | — | 9 | 18 | 11 | — | — | Ml. | |
| 27 | — | — | — | — | — | — | 29.9 | 30.9 | We. | |
| 28 | — | — | — | — | — | — | — | — | Bo. | Very delicate castings. |
| 29 | — | — | — | — | — | — | — | — | Bo. | Ornaments of Hanover. |
| 30 | 31,584 | 5 | — | 8 | 17 | 10 | — | — | Bo. | French orèide. |
| 31 | — | — | — | — | — | — | — | — | Ml. | |
| 32 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of powder, 8.584. |
| 33 | — | — | 250.1 | — | — | — | — | — | Bo. | Paris jewelry. |
| 34 | — | — | — | — | — | — | — | — | U. S. B. | |
| 35 | — | — | — | — | — | — | — | — | Bo. | Tombac of Oker. |

*Properties of the Alloys of*

| Line numbers. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Zn. | Cu. | Zn. | | | |
| 1 | | 84.21 | 15.79 | — | — | — | — | — |
| 2 | | 83.99 | 17.1 | — | — | — | — | — |
| 3 | $Cu_5Zn$ | 83.02 | 16.98 | — | — | 8.415 | Red-yellow | Finely crystalline |
| 4 | $Cu_5Zn$ | 82.95 | 17.05 | — | — | 8.673 | — | — |
| 5 | | 82.54 | 17.46 | — | — | — | — | — |
| 6 | | 82.5 | 17.5 | 82.93 | 16.98 | 8.633 | Red-yellow | Earthy |
| 7 | | 82.46 | 17.54 | — | — | — | — | — |
| 8 | | 82.3 | 17.7 | — | — | — | — | — |
| 9 | | 80 | 20 | 81.91 | 17.90 | 8.598 | Yellow | Earthy |
| 10 | $Cu_4Zn$ | 79.65 | 20.35 | — | — | — | Yellow-red | Finely crystalline |
| 11 | $Cu_4Zn$ | 79.56 | 20.44 | — | — | 8.650 | — | — |
| 12 | $Cu_4Zn$ | 79.51 | 20.49 | — | 21.80 | 8.638 | — | — |
| 13 | | 77.9 | 22.1 | — | — | — | — | — |
| 14 | | 77.5 | 22.5 | 77.39 | 22.45 | 8.574 | Yellow | Earthy |
| 15 | | 75.7 | 24.3 | — | — | — | — | — |
| 16 | | 75 | 25 | 76.65 | 23.08 | 8.528 | Yellow | Earthy |
| 17 | | 74.62 | 25.38 | — | — | — | — | — |
| 18 | $Cu_3Zn$ | 74.58 | 25.42 | — | — | 8.397 | Pale yellow | Finely crystalline |
| 19 | $Cu_3Zn$ | 74.48 | 25.52 | — | — | 8.576 | — | — |
| 20 | | 72.73 | 27.27 | — | — | — | — | — |
| 21 | | 72.5 | 27.5 | 73.20 | 26.47 | 8.465 | Yellow | Earthy |
| 22 | | 72 | 28 | — | — | — | — | — |
| 23 | | 71.5 | 28.5 | — | — | — | — | — |
| 24 | | 70.1 | 29.9 | — | — | — | — | — |
| 25 | | 70 | 30 | 71.20 | 28.54 | 8.444 | Yellow | Earthy |
| 26 | | 67.74 | 32.26 | — | — | — | — | — |
| 27 | | 67.54 | 32.46 | — | — | — | — | — |
| 28 | | 67.5 | 32.5 | 69.74 | 30.06 | 8.384 | Yellow | Earthy |
| 29 | | 67.2 | 32.8 | — | — | — | — | — |
| 30 | | 66.7 | 33.3 | — | — | — | — | — |
| 31 | | 66.6 | 33.4 | — | — | — | — | — |
| 32 | $Cu_2Zn$ | 66.18 | 33.82 | — | — | 8.299 | Full yellow | Finely crystalline |
| 33 | $Cu_2Zn$ | 66.16 | 33.84 | — | — | 8.392 | — | — |
| 34 | $Cu_2Zn$ | 66.06 | 33.94 | — | — | 8.488 | — | — |
| 35 | | 66 | 34 | — | — | — | — | — |
| 36 | | 65.98 | 34.02 | — | 34.50 | 8.410 | — | — |
| 37 | | 65.4 | 34.6 | — | — | — | — | — |
| 38 | | 65.3 | 34.7 | — | — | — | — | — |
| 39 | | 65 | 35 | 66.27 | 33.50 | 8.371 | Red-yellow | Earthy |
| 40 | | 65 | 34.76 | — | — | — | — | — |
| 41 | | 63.5 | 36.5 | — | — | — | — | — |
| 42 | | 62.5 | 37.5 | 63.44 | 36.36 | 8.411 | Red-yellow | Earthy |
| 43 | | 61.25 | 38.75 | — | — | — | — | — |

*Copper and Zinc.*—Continued.

| Line numbers. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston.) | Order of malleability (Mallet). | Hardness (Mallet and Calvert and Johnson). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — | — | — | Bo. | Gold leaf. |
| 2 | — | — | — | — | — | — | — | — | Bo. | Tombac for buttons. |
| 3 | 30,688 | 11 | — | 2 | 16 | 9 | — | — | Bo. | Bronze powder. |
| 4 | — | — | — | — | 427.08 | — | 71.5 | — | Ml. | Bath metal. |
| 5 | — | — | — | — | — | — | — | — | C. J. | |
| 6 | 32.600 | — | 105.3 | — | — | — | — | — | Bo. | Alloy for jewelry. |
| 7 | — | — | — | — | — | — | 31.1 | 29.02 | U. S. B. | |
| 8 | — | — | — | — | — | — | — | — | We. | |
| 9 | 32 670 | — | 113.1 | — | — | — | — | — | Bo. | Ornaments. |
| 10 | 52,928 | 7 | — | 3 | 15 | 8 | — | — | U. S. B. | |
| 11 | — | — | — | — | 468.75 | — | 66.6 | — | Ml. | Dutch brass. |
| 12 | — | — | — | — | — | — | — | — | C. J. | |
| 13 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of powder, 8.367. |
| 14 | 35,630 | — | 97.5 | — | — | — | — | — | Bo. | Vienna gold leaf |
| 15 | — | — | — | — | — | — | — | — | U. S B. | |
| 16 | 30.520 | — | 76.7 | — | — | — | — | — | Bo. | Bristol metal. |
| 17 | — | — | — | — | — | — | — | — | U. S. B. | |
| 18 | 29,344 | 10 | — | 4 | 14 | 7 | — | — | Ml. | Rolled sheet brass. |
| 19 | — | — | — | — | 468.75 | — | 63.8 | — | C. J. | Brass of 32 copper, 12 zinc. |
| 20 | — | — | — | — | — | — | — | — | Bo. | |
| 21 | 31,580 | — | 88.7 | — | — | — | — | — | U. S. B. | |
| 22 | — | — | — | — | — | — | — | — | Bo. | Chrysorin. |
| 23 | — | — | — | — | — | — | — | — | Bo. | Tombac. |
| 24 | — | — | — | — | — | — | — | — | Bo. | Suitable for forging or leaf. |
| 25 | 30,510 | — | 77.8 | — | — | — | — | — | U. S. B. | |
| 26 | — | — | — | — | — | — | 25.8 | 25.4 | We. | |
| 27 | — | — | — | — | — | — | — | — | Bo. | Suitable for forging. |
| 28 | 28,120 | — | 49.1 | — | — | — | — | — | U. S. B. | |
| 29 | — | — | — | — | — | — | — | — | Bo. | Bristol metal. |
| 30 | — | — | — | — | — | — | — | — | Bo. | Chrysorin. |
| 31 | — | — | — | — | — | — | — | — | Bo. | Common brass. |
| 32 | 28,000 | 3 | — | 6 | 13 | 6 | — | — | Ml. | |
| 33 | — | — | — | — | — | — | — | — | Cr. | |
| 34 | — | 472 92 | — | — | — | — | 62.1 | — | C. J. | |
| 35 | — | — | — | — | — | — | — | — | Bo. | Suitable for forging. |
| 36 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of powder, 8.390. |
| 37 | — | — | — | — | — | — | — | — | Bo. | Good brass wire |
| 38 | — | — | — | — | — | — | — | — | Bo. | Mosaic gold. |
| 39 | 37 800 | — | 72.8 | — | — | — | — | — | U. S. B. | |
| 40 | — | — | — | — | — | — | — | — | Bo. | Suitable for forging. |
| 41 | — | — | — | — | — | — | — | — | Bo. | " " |
| 42 | 48,300 | — | 60.6 | — | — | — | — | — | U. S. B. | |
| 43 | — | — | — | — | — | — | — | — | Bo. | Strong solder for brass. |

*Properties of the Alloys of*

| Line numbers. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Zn. | Cu. | Zn. | | | |
| 1 | | 60.8 | 39.2 | — | — | — | —— | —— |
| 2 | | 60.16 | 39.71 | — | — | — | —— | —— |
| 3 | | 60 | 40 | 60 94 | 38.65 | 8.405 | Red-yellow | Earthy |
| 4 | | 60 | 40 | — | — | — | —— | —— |
| 5 | | 59.5 | 40.5 | — | — | — | —— | —— |
| 6 | $Cu_3Zn_2$ | 59.36 | 40 64 | — | — | 8.224 | —— | —— |
| 7 | $Cu_3Zn_2$ | 59.26 | 40.74 | — | 40 10 | 8.412 | —— | —— |
| 8 | | 58.33 | 41.77 | — | — | — | —— | —— |
| 9 | | 57.5 | 42.5 | 58.49 | 41.10 | 8.363 | Red-yellow | Earthy |
| 10 | | 55 | 45 | — | — | — | —— | —— |
| 11 | | 55 | 45 | 55.15 | 44.44 | 8.283 | Red-yellow | Earthy |
| 12 | | 54.9 | 45.1 | — | — | — | —— | —— |
| 13 | | 54 | 46 | — | — | — | —— | —— |
| 14 | | 52.5 | 47.5 | 54.86 | 44.78 | 8.301 | Red-yellow | Coarsely granular |
| 15 | | 50 | 50 | 49.66 | 50.14 | 8.291 | " | " |
| 16 | CuZn | 49.47 | 50.53 | — | — | 8.230 | Full yellow | Coarsely crystalline |
| 17 | CuZn | 49.32 | 50 68 | — | — | 7.808 | —— | —— |
| 18 | CuZn | 49.23 | 50.76 | — | 50.30 | 8.304 | —— | —— |
| 19 | | 47.5 | 52.5 | 48.95 | 50.82 | 8.216 | Pinkish-gray | Coarsely granular |
| 20 | | 45 | 55 | 47.56 | 52.28 | — | " | " |
| 21 | | 43 | 57 | — | — | — | —— | —— |
| 22 | | 42.5 | 57.5 | 43.36 | 56.22 | 8.034 | Pinkish-gray | Finely granular |
| 23 | | 40 | 60 | 41.30 | 58.12 | 8.061 | Silver-white | Vitreous conchoidal |
| 24 | $Cu_2Zn_3$ | 39.27 | 60.73 | — | 60.35 | 8 171 | —— | —— |
| 25 | | 37.5 | 62.5 | 38.36 | 61.05 | 7.982 | Silver-white | Vitreous conchoidal |
| 26 | $Cu_3Zn_5$ | 36.88 | 63.12 | — | — | 7.939 | —— | —— |
| 27 | | 35 | 65 | 36.62 | 62.78 | 7.974 | Silver-white | Vitreous conchoidal |
| 28 | $CuZn_2$ | 33.34 | 66.66 | — | — | — | —— | —— |
| 29 | $CuZn_2$ | 32.85 | 67.15 | — | — | 8.283 | Deep yellow | Coarsely crystalline |
| 30 | $CuZn_2$ | 32.74 | 67.26 | — | — | 7.859 | —— | —— |
| 31 | $CuZn_2$ | 32.66 | 67.34 | — | 64 80 | 8.048 | —— | —— |
| 32 | | 32 5 | 67 5 | 35.68 | 63.71 | 7.966 | Silver-white | Vitreous conchoidal |
| 33 | $Cu_8Zn_{17}$ | 31.52 | 68.48 | — | — | 7.721 | " | Conchoidal |
| 34 | $Cu_8Zn_{18}$ | 30.30 | 69.70 | — | — | 7.836 | " | Vitreous conchoidal |
| 35 | | 30 | 70 | 32.94 | 66.23 | 7 811 | " | " |

*Copper and Zinc.*—Continued.

| Line numbers. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston.) | Order of malleability (Mallet). | Hardness (Mallet and Calvert and Johnson). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — | — | — | Bo. | Bristol metal. |
| 2 | — | — | — | — | — | — | — | — | Bo. | Suitable for forging. |
| 3 | 41,065 | — | 49.0 | — | — | — | — | — | U. S. B. | |
| 4 | — | — | — | — | — | — | — | — | — | Muntz metal. |
| 5 | — | — | — | — | — | — | — | — | Bo. | Ship sheathing. |
| 6 | — | — | — | — | — | — | — | — | Cr. | |
| 7 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of powder, 8.329. |
| 8 | — | — | — | — | — | — | — | — | Bo. | Suitable for forging. |
| 9 | 50,450 | — | 12.1 | — | — | — | — | — | U. S. B. | |
| 10 | — | — | — | — | — | — | — | — | Bo. | Bath metal. |
| 11 | 44,280 | — | 19.5 | — | — | — | — | — | U. S. B. | |
| 12 | — | — | — | — | — | — | — | — | Bo. | Very ductile brass (Storer.) |
| 13 | — | — | — | — | — | — | — | — | Bo. | " " |
| 14 | 46,400 | — | 7.4 | — | — | — | — | — | U. S. B. | |
| 15 | 30,990 | — | 3.1 | — | — | — | — | — | U. S. B. | |
| 16 | 20,608 | 12 | — | 5 | 12 | 6 | — | — | Ml. | German brass. |
| 17 | — | — | — | — | 604.17 | — | 68.8 | — | C J. | |
| 18 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of ingot, 8.263. |
| 19 | 26,050 | — | 0.36 | — | — | — | — | — | U. S. B. | |
| 20 | 24,150 | — | 0.26 | — | — | — | — | — | U. S. B. | |
| 21 | — | — | — | — | — | — | — | — | Bo. | Escutcheons of locks. |
| 22 | 9,710 | — | 0.02 | — | — | — | — | — | U. S. B. | |
| 23 | 3,727 | — | 0.01 | — | — | — | — | — | U. S. B. | |
| 24 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of ingot, 8.039. |
| 25 | 3,087 | — | 0.02 | — | — | — | — | — | U. S. B. | |
| 26 | — | — | — | — | — | — | — | — | Cr. | |
| 27 | 2,656 | — | 0.006 | — | — | — | — | — | U. S. B. | |
| 28 | — | — | — | — | — | — | — | — | Bo. | Strong solder for brass. |
| 29 | 43.232 | 1 | — | 7 | 10 | 6 | — | — | Ml. | Watchmaker's brass. |
| 30 | — | — | — | — | Broke | — | 42.8 | — | C. J. | |
| 31 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of ingot, 7.796. |
| 32 | 2,397 | — | 0.11 | — | — | — | — | — | U. S. B. | |
| 33 | 4,704 | 0 | — | 22 | 5 | 5 | — | — | Ml. | Very brittle. |
| 34 | 4,928 | 0 | — | 23 | 6 | 5 | — | — | Ml. | Very brittle |
| 35 | 1,774 | — | 0.005 | — | — | — | — | — | U. S. B. | |

*Properties of the Alloys of*

| Line numbers. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Zn. | Cu. | Zn. | | | |
| 1 | $Cu_8Zn_{19}$ | 29.17 | 70.83 | — | — | 8.019 | Silver-gray | Conchoidal |
| 2 | $Cu_8Zn_{20}$ | 28.12 | 71.88 | — | — | 7.603 | Ash-gray | Vitreous |
| 3 | | 27.5 | 72.5 | 29.20 | 70.17 | 7.766 | Light gray | " |
| 4 | $Cu_8Zn_{21}$ | 27.10 | 72.90 | — | — | 8.058 | Silver-gray | Conchoidal |
| 5 | $Cu_8Zn_{22}$ | 26.24 | 73.76 | — | — | 7.882 | " | " |
| 6 | | 25.4 | 74.6 | — | — | — | —— | —— |
| 7 | $Cu_8Zn_{23}$ | 25.39 | 74.61 | — | — | 7.443 | Ash-gray | Finely crystalline |
| 8 | | 25 | 75 | — | — | 7.675 | Bluish-gray | Finely granular |
| 9 | $CuZn_3$ | 24.64 | 75.36 | — | — | 7.736 | —— | —— |
| 10 | $CuZn_3$ | 24.5 | 75.5 | — | — | 7.449 | Ash-gray | Finely crystalline |
| 11 | | 22.5 | 77.5 | 21.82 | 77.43 | 7.416 | Bluish-gray | Finely granular |
| 12 | | 20 | 80 | 20.81 | 77.63 | 7.418 | " | " |
| 13 | | 20 | 80 | — | — | — | —— | —— |
| 14 | $CuZn_4$ | 19.65 | 80.35 | — | — | 7.371 | Ash-gray | Finely crystalline |
| 15 | $CuZn_4$ | 19.57 | 80.43 | — | — | 7.445 | —— | —— |
| 16 | $CuZn_4$ | 19.52 | 80.48 | — | 79.30 | 7.863 | —— | —— |
| 17 | | 17.5 | 82.5 | 17.49 | 81.62 | 7.225 | Bluish gray | Finely granular |
| 18 | $CuZn_5$ | 16.33 | 83.64 | — | — | 6.605 | Very dark gray | Finely crystalline |
| 19 | $CuZn_5$ | 16.30 | 83.70 | — | — | 7.442 | —— | —— |
| 20 | | 15 | 85 | 14.19 | 85.10 | 7.163 | Bluish-gray | Finely granular |
| 21 | | 12.5 | 87.5 | 12.12 | 86.67 | 7.238 | " | " |
| 22 | $CuZn_8$ | 10.82 | 89.18 | — | 89.90 | 7.315 | —— | —— |
| 23 | | 10 | 90 | 10.30 | 88.88 | 7.253 | Bluish-gray | Finely granular |
| 24 | | 7.5 | 92.5 | 7.20 | 92.07 | 7.131 | " | " |
| 25 | | 5 | 95 | 4.35 | 94.59 | 7.108 | " | Finely crystalline |
| 26 | | 2.5 | 97.5 | 2.45 | 96.43 | 7.080 | " | Tabular. crystalline |
| 27 | | 0 | 100 | — | — | 7.143 | Bluish-white | " |
| 28 | | 0 | 100 | — | — | 6.895 | Bluish-gray | " |
| 29 | | 0 | 100 | — | — | 7.148 | —— | —— |
| 30 | | 0 | 100 | — | — | — | —— | —— |
| 31 | | 0 | 100 | — | — | — | —— | —— |

*Copper and Zinc.*—Concluded.

| Line numbers. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston.) | Order of malleability (Mallet). | Hardness (Mallet and Calvert and Johnson). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,568 | 0 | — | 21 | 7 | 5 | — | — | Ml. | Very brittle. |
| 2 | 7,168 | 0 | — | 19 | 3 | 5 | — | — | Ml. | Brittle. |
| 3 | 6,414 | — | 0.009 | — | — | — | — | — | U. S. B. | |
| 4 | 2.016 | 0 | — | 18 | 9 | 5 | — | — | Ml. | Brittle. |
| 5 | 1,792 | 0 | — | 20 | 8 | 5 | — | — | Ml. | Very brittle. |
| 6 | — | — | — | — | — | — | — | — | Bo. | Protect iron from rust. |
| 7 | 13.216 | 0 | — | 15 | 1 | 5 | — | — | Ml. | Barely malleable. |
| 8 | 9.680 | — | 0.002 | — | — | — | — | — | U. S. B. | |
| 9 | — | — | — | — | Broke | — | 53.1 | — | C. J. | |
| 10 | 11,424 | 0 | — | 16 | 2 | 4 | — | — | Ml. | Brittle. |
| 11 | 7,000 | — | 0.004 | — | — | — | — | — | U. S. B. | |
| 12 | 9,000 | — | 0.002 | — | — | — | — | — | U. S. B. | |
| 13 | — | — | — | — | — | — | — | — | Bo. | Metal for buttons. |
| 14 | 4,256 | 0 | — | 14 | 4 | 3 | — | — | Ml. | White button metal. |
| 15 | — | — | — | — | Broke | — | 58.9 | — | C. J. | |
| 16 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of ingot, 7.215. |
| 17 | 5 350 | — | 0.003 | — | — | — | — | — | U. S. B. | |
| 18 | 4,032 | 0 | — | 17 | 11 | 2 | — | — | Ml. | Brittle. |
| 19 | — | — | — | — | Broke | — | 59.5 | — | C. J. | |
| 20 | 8,500 | — | 0.004 | — | — | — | — | — | U. S. B. | |
| 21 | 12,413 | — | 0.009 | — | — | — | — | — | U. S. B. | |
| 22 | — | — | — | — | — | — | — | — | Ri. | Specific gravity of ingot, 7.299. |
| 23 | 14,450 | — | 0.10 | — | — | — | — | — | U. S. B. | |
| 24 | 10,650 | — | 8.04 | — | — | — | — | — | U. S. B. | |
| 25 | 18,065 | — | 0.84 | — | — | — | — | — | U. S. B. | |
| 26 | 11,400 | — | 2.67 | — | — | — | — | — | U. S. B. | |
| 27 | 5,400 | — | 26.51 | — | — | — | — | — | U. S. B. | |
| 28 | 34,018 | 13 | — | 12 | 23 | 1 | — | — | Ml. | Brittle. |
| 29 | — | — | — | — | — | — | 29.02 | 27.39 | Ma. | |
| 30 | — | — | — | — | — | — | 62.8 | — | C. J. | |
| 31 | — | — | — | — | — | — | 28.1 | 27.3 | We. | |

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Prof. Robert H. Thurston, who conducted the investigations of the United States Board, makes the following note on the preceding table:—

"Alloys having the name of Bolley appended are taken from Bolley's 'Essays et Recherches Chimiques,' which gives compositions and commercial names, and mentions valuable properties, such as are given in the columns of remarks, but does not give results in figures as recorded by other authorities. The same properties and the same name are accorded by Bolley to alloys of different compositions, such as those which in the column of remarks are said to be 'suitable for forging.' It might be supposed that such properties belonged to those mixtures and not to other mixtures of similar composition. It seems probable, however, that when two alloys of different mixtures of copper and zinc are found to have the same strength, color, fracture, and malleability, it will also be found that all alloys between these compositions will possess the same properties, and hence that instead of the particular alloys mentioned only suitable for forging, all the alloys between the extreme compositions mentioned also possess that quality.

"In the figures given from Mallet under the heads of 'order of ductility,' order of malleability,' 'hardness,' and 'order of fusibility,' the maximum of each of these properties is represented by 1.

"The figures given by Mallet for tenacity are confirmed by experiments of the author with a few very marked exceptions. These exceptions are chiefly the figures for copper, for zinc, and for $CuZn_2$ (32.85 copper, 67.15 zinc). The figures for $CuZn_2$, as given by Mallet, can, in the opinion of the author, only be explained on the supposition that the alloy tested was not $CuZn_2$ (32.85 copper, 67.15 zinc), but another containing a percentage of copper probably as high as 55. The figure for the specific gravity (8.283) given by Mallet indicates this to be the case as does the color. The figure for ductility would indicate even a higher percentage of copper. The name 'watchmaker's brass' in the column of remarks must be an error, as that alloy is a brittle, silver-white, and extremely weak metal.

"The figures of Calvert and Johnson and Riche, as well as those of the author, give a more regular curve than can be constructed from the figures of Mallet.

"The specific gravities in Riche's experiments were obtained both from the ingot and from powder. In some cases one, and in some cases the other, gave highest results. In the table under the head of 'specific gravity,' Riche's highest average figures are given, whether these are from the ingot or from fine powder, as probably the most nearly correct. The figures by the other method, in each case, are given in the column of remarks. The figures of Riche and Calvert and Johnson are scarcely sufficient in number to show definitely the law regulating specific gravity to composition, and the curves from their figures vary considerably. The figures of the author being much more numerous than those of earlier experimenters a much more regular curve is obtained, especially in that part of the series which includes the yellow or useful metals. The irregularity in that part of the curve which includes the bluish-gray metals is, no doubt, due to blow-holes, as the specific gravities were in all cases determined from pieces of considerable size. If they were determined from powder, it is probable that a more regular set of observations could be obtained, and that these would show a higher figure than 7.143, that obtained for cast-zinc. Matthiessen's figure for pure zinc (7.148) agrees very closely with that obtained by the author for the cast-zinc, which contained about 1 per cent. of lead.

"The figures for hardness given by Calvert and Johnson were obtained by means of an indenting tool. The figures are on a scale in which the figure for cast-iron is taken as 1000. The alloys, opposite which the word "broke" appears, were much harder than cast-iron, and the indenting tool broke them instead of making an indentation. The figures of alloys containing 17.05, 20.44, 25.52, and 33.94 per cent. of zinc have nearly the same figures for hardness, varying only from 427.08 to 472.92. This corresponds with what has been stated in regard to the similarity in strength, color, and other properties of alloys between these compositions."

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# XV.

## BRONZE IN GENERAL.

THE alloys produced by the union of copper and tin are termed "bronze" in the actual sense of the word, if the copper is present in predominating quantity, while those in which the content of tin predominates are called "white metal." In order to modify the properties of the alloys in a certain sense, both bronze and white metal are sometimes compounded with small quantities of other metals.

In this section of our work we have to deal with bronzes in the strict sense of the word. It has been previously mentioned that the term bronze is frequently erroneously applied to mixtures of metals belonging really to the brasses, so that there is actually such a confusion of terms that many whose interest it is to have an accurate knowledge of alloys do not know what bronze actually is.

The principal constituent of bronze in all cases is copper, the addition of tin only serving to modify its properties. Tin, though a very soft metal by itself, possesses the characteristic property of imparting great hardness to copper, so that genuine bronze takes a fine polish, and castings of it can be worked very clean with the file. On account of these qualities it is especially adapted for a casting material, and its properties can be so changed that it will flow freely, or give a beautiful sound, or acquire the utmost degree of hardness.

The ductility of bronze being but slight, only that containing very little tin can be converted into sheet by rolling, the operation succeeding satisfactorily at a red heat if the content of tin does not exceed 4 to 6 per cent. Bronze, as previously mentioned, being chiefly intended for casting, finds, on account of its hardness, much application in the machine industry for articles which cannot be made of iron or steel.

Bronzes consisting of absolutely pure copper and tin show definite properties according to the quantity of the metals contained in them. However, in making a chemical analysis of commercial bronze, it will almost invariably be found to contain a small quantity of other metals. A sharp distinction should, however, be made as to whether these admixtures are accidental or intentional. Besides iron, manganese, nickel, lead, and zinc, very small quantities of phosphorus, arsenic, sulphur, or antimony are sometimes found, and a small quantity of these bodies sufficing to considerably change the properties of the alloy, it is important to pay some attention to their influence. Before entering on a discussion of these properties, it may, however, be remarked that the difficulties many manufacturers find in obtaining alloys of determined qualities is due to the fact that they do not use as pure metals as possible by themselves but melt down with them certain quantities of old bronze, which, as a rule, contains zinc, iron, or other foreign metals.

A content of zinc acts upon the properties of bronze in various ways. Added to it in a very small quantity it has even a beneficial influence, the moulds being filled out sharper and the castings obtained freer from blowholes. If, however, the addition of zinc be exceeded above a certain limit, the alloy loses the characteristic properties of bronze, and especially the warm color, which passes into a more or less dull brass yellow. Besides, bronze with too large a content of zinc does not acquire on exposure to the air the beautiful green coloration termed genuine patina, but one shading into black. The addition of zinc must always be kept within very narrow limits; less than one-half per cent. of it contributes so essentially to the strength of the bronze that such an addition should be made in all cases where this property is especially desired. With an addition of up to 2 per cent. of zinc the properties of the alloy remain about the same, its elasticity being also increased to a considerable extent. With a slight increase of over 2 per cent. of zinc, the hardness as well as the tenacity of the bronze decreases to a considerable extent, and the brass-like character of the alloy soon becomes apparent.

An admixture of lead has in all cases an injurious effect upon the properties of bronze. With a content of one-half per cent. the lead begins to liquate from the bronze, which makes the castings turn out unequal and increases the oxidability of the alloy. A content of lead makes the bronze somewhat denser and more malleable, these properties being, however, of little value as the alloy is exclusively intended for casting. The peculiar patina of a velvety-black color found upon old Chinese bronzes is said to be the product of a content of lead; and it is actually a fact that all Chinese bronzes contain a certain quantity of lead.

Iron affects the properties of bronze in a similar manner as zinc, imparting great hardness to it, and for this reason is frequently added to bronzes for axle-bearings and wherever they are to show great power of resistance. A content of iron has also considerable influence upon the color and gives a peculiar white tone to the bronze. It further makes it more difficult of fusion, though the castings are faultless.

An admixture of nickel increases the hardness of bronze to a considerable extent and decreases its tenacity. On account of its costliness many declared the use of this metal as an addition to bronze impracticable. It must, however, not be forgotten that at the utmost only 1 to 1½ per cent. of it are required to impart the desired qualities to the bronze. Moreover it is not by any means the most expensive metal used as an addition to bronze, tungsten and titanium being also frequently employed for the purpose. These last-mentioned metals seem, however, to possess no special properties exerting a favorable influence upon bronze and, though the alloys have been frequently mentioned and recommended in various periodicals, they have not gained a foothold in practice, which cannot be ascribed to their costliness, because manufacturers requiring alloys completely answering certain purposes, are always willing to pay a good price for them.

An admixture of very small quantities of arsenic, antimony, and sulphur renders the bronze brittle, $\frac{1}{10}$ per cent. of either of these bodies sufficing for the purpose. Phosphorus exerting, as is well known, an injurious influence upon most metals and alloys, acts different in this respect as regards bronze, and, for this reason, the so-called phosphor-bronze will be discussed later on.

The physical properties of bronze are also materially affected by other conditions than the chemical composition, chief among which is the rapid or slow cooling off of the fused material, which exerts so powerful an influence that the product with an equal chemical composition may acquire an entirely different appearance. According to the content of tin the color of bronze varies between red and white, and with a considerable content of tin passes into steel-gray. Generally speaking, tin exerts a greater influence upon the color than zinc, the alloy with a comparatively small content of tin exhibiting no longer a red but a white color.

Alloys containing 90 to 99 per cent. of copper retain a pure red color; with 88 per cent. of copper it rapidly changes to orange-yellow, and with 85 per cent. becomes pure yellow. With a decrease of the content of copper to 50 per cent. the respective alloys show a slightly yellowish-white color. It is a remarkable fact that alloys with a content of copper of between 50 and 35 per cent. are distinguished by a pure white color, while those containing up to 65 per cent. of tin show a steel-gray color. With a still greater percentage of tin the color of the alloys again becomes pure white. Bronze of various compositions being extensively used in the construction of machines and the manufacture of ordnance, many physicists have occupied themselves with the determination of the proportions of ductility and hardness of the various alloys. But, notwithstanding the many full researches, it cannot yet be said with absolute certainty when a bronze is hardest, most tenacious, most ductile, etc., and we have only approximate numbers for these proportions, which we briefly sum up in the following:—

Alloys with 1 to 2 per cent. of tin show nearly the same ductility as pure copper; they can be worked in the cold under the hammer, but crack more readily than pure copper, this cracking showing itself especially in attempting to stretch a plate of the alloy under the hammer. The ductility decreases rapidly with an increase in the content of tin; an alloy containing 5 per cent. of tin can only be worked with the hammer at a red heat, but soon cracks when it is attempted to hammer it in the cold; alloys containing up to 15 per cent. of tin can no longer be hammered even in a warm state. The figures above given show that tin injures the ductility of the copper. Its solidity is, however, considerably increased. Alloys with about 9 per cent. of tin show, according to most statements, the greatest strength of all bronzes, and in accordance with this, gun-metal has generally a content of tin approaching that limit. According to other statements alloys with about 15 per cent. possess the greatest hardness and strength. The maximum for hardness and brittleness lies between a content of 28 to 35 per cent. of tin.

From the results of more modern researches in regard to the strength and hardness of bronzes, the following may be deducted: The hardness increases constantly until the composition of the alloy has reached 72.8 parts of copper and 27.2 of tin. With an increase in the content of tin the hardness decreases, it being in a mixture of 33.33 parts of copper and 66.66 parts of tin nearly exactly the same as that of pure copper. Above this proportion of tin the hardness decreases considerably, and with a compound of 90 parts of tin and 10 of copper is but little more than that of tin.

Alloys rich in copper undergo a peculiar molecular change by forging. By subjecting alloys containing somewhat less than 94 per cent. of copper to continued forging they become as hard as steel, but unfortunately acquire at the same time such a degree of brittleness that they can only be used for purposes where they are not exposed to strong shocks.

Though the hardening of the bronzes by forging is remarkable, there is another phenomenon yielding still more remarkable results: by quickly cooling off red-hot bronze in cold water it almost completely loses its brittleness, and can then be used for many purposes, an alloy containing 84 parts of copper and 16 of tin being most suitable for the purpose. Even a quite thick article acquires a certain flexibility through its entire thickness, which it retains after forging. If it is desired to restore an article after tempering to its original hardness, it need only be brought to a red heat and slowly cooled. According to the above the behavior of bronze in this respect is just the reverse of steel; the latter by quick cooling becoming very hard and brittle, and by slow cooling soft and malleable. The density and hardness of bronze decrease with quick cooling and increase with slow cooling, and, hence, bronze articles quickly cooled have a deeper sound, a fact well to be considered by bell-founders.

The density and hardness, as well as the power of resistance against cracking, depend on the composition of the alloy as much as on the manner of cooling the cast article.

According to practical experience the greatest strength is secured by endeavoring to obtain the crystals of the alloy as small as possible, even the material of the mould in which the casting is effected exerting a great influence upon the grain and through this upon the strength. Articles must be cast at a higher temperature in iron moulds than in sand moulds, one of 2912° F. (1600° C.) being required with the use of iron moulds, while one of 2552° F. (1400° C.) suffices with the use of sand moulds, especially for larger castings.

Alloys suddenly subjected to a high pressure, as is the case with gun-metal, must have an especially high degree of density, the density being, however, not directly proportional to the composition, as will be seen from the following table:—

| Composition. | | Density. |
|---|---|---|
| Copper. | Tin. | |
| 96.2 | 3.8 | 8.74 |
| 94.4 | 5.6 | 8.71 |
| 92.6 | 7.4 | 8.68 |
| 91.0 | 9.0 | 8.66 |
| 89.3 | 10.7 | 8.63 |
| 87.7 | 12.3 | 8.61 |
| 86.2 | 13.8 | 8.60 |
| 75.0 | 25.0 | 8.43 |
| 50.0 | 50.0 | 8.05 |

Bronze being exclusively used for casting, it is important to say a few words in regard to the temperatures at which the various alloys become fluid. According to Künzel, to whose researches we are indebted for much information regarding the properties of bronze, the various alloys show the following melting points:—

| Composition. | | Melting point, degrees F. | Melting point. degrees C. |
|---|---|---|---|
| Copper. | Tin. | | |
| 95 | 5 | 2520 | 1360 |
| 92 | 8 | 2354 | 1290 |
| 90 | 10 | 2282 | 1250 |
| 89 | 11 | 2228 | 1220 |
| 86 | 14 | 2100 | 1150 |
| 84 | 16 | 2012 | 1100 |
| 80 | 20 | 1868 | 1020 |

Articles cast of bronze contract in solidifying, as is the case with other mixtures of metals, the degree of contraction depending on the temperature of the alloy and its composition, and amounts to $\frac{1}{130}$ to $\frac{1}{77}$ of the bulk of the various mixtures.

The difficulty of obtaining perfect castings is, however, more increased by the chemical behavior of the alloys towards the oxygen of the atmosphere than by contraction. In subjecting the bronze to fusion, the tin shows greater affinity for oxygen than the copper, and hence by remelting the bronze several times, it becomes sensibly richer in copper by a portion of the tin being lost by oxidation. To prevent a change in the qualities of the alloy, a larger quantity of tin than the finished product is to contain is generally added, the volatilization of tin being equal to the excess added, so that the alloy obtained shows exactly the desired composition.

Another effect of the oxygen of the atmosphere consists in the oxides of the constituent metals of the bronze—stannic oxide and cuprous oxide—dissolving in the alloy, whereby its strength and tenacity are considerably decreased. In the manufacture of ordnance a portion of the metal required is generally obtained by melting down old cannons. The mixture of metals thus obtained containing frequently large quantities of the metallic oxides in solution, the tenacity and strength of the new alloys are considerably impaired.

The melted bronze shows another property frequently observed in other metals, especially in gold and silver: it can absorb a considerable quantity of oxygen but allows it to escape in a gaseous state on cooling. If now, as is done in most cases, the castings are rapidly cooled off, the bronze becomes so thickly fluid that the absorbed oxygen cannot escape, and the resulting castings are full of innumerable, though microscopically small, hollow spaces, which injure the density and strength of the alloy.

The absorption of oxygen, as will be seen from the above, being very injurious to the qualities of the bronze, precautions have to be taken to protect the metal from the effect of oxygen in fusing as well as in casting. The best preventative against the absorption of oxygen is to protect the alloy by a layer of glowing charcoal, and to effect a reduction of any oxides formed by vigorous stirring of the fused alloy with a stick of green wood. Though oxidation is counteracted by these means, it is not possible to remove by them the oxygen reaching the alloy from oxygenous material. Phosphorus has, however, been found an excellent agent for the deoxidation of the oxides dissolved in the metal, but it has to be added very carefully, since a small quantity of it in excess exerts great influence upon the properties of the alloy itself. In most cases an addition of $\frac{8}{1000}$ to $\frac{10}{1000}$ suffices for the reduction of the oxides in solution.

The tin oxidizing more readily it is, as a rule, advisable to fuse the copper first and then quickly introduce the tin, whereby the heat should be increased so as to keep the alloy very thinly-fluid, the union of the two metals being accelerated by these means. The melted mass should at the same time be vigorously stirred with wooden rods, which not only accelerates the mixing but also counteracts the oxidation of the tin. Even with the use of all the above-mentioned precautions, the loss in fusing and casting always amounts to several per cent. of the weight of the metals used; work where the loss is only one to two per cent. may be called excellent, as in many cases it amounts to ten per cent.

The loss of metal as well as the qualities of the castings are also considerably affected by the construction of the melting furnace. The quicker the furnace can be heated to the temperature required for reducing the alloy to a fluid state the better it is for the purpose, for even with perfect protection against the action of oxygen, changes injurious to the homogeneity of the castings take place with long-continued fusion. If a bronze be intentionally kept in a fluid state for a long time, a white alloy very rich in tin is formed in it which is clearly perceptible in the castings. The alloy is no longer homogeneous, but actually consists of a mixture of several alloys differing very much in density, power of resistance, and strength, which seriously impairs the properties of the entire mixture. This separation or liquation of the alloy into two or more compounds occurs especially in mixtures most frequently used, *i. e.*, such as contain between 5 and 20 per cent. of tin; from alloys containing a lower or higher percentage of tin, homogeneous castings are more readily obtained.

Since the liquation of an alloy rich in tin is promoted by slow cooling, the melted mass, which has a temperature of about 2552° F. must be cooled down as quickly as possible to 932° F., at which, according to experience, the alloy richest in tin solidifies. This is, however, connected with many difficulties, especially in casting large pieces, such as cannons and bells for which the perfect homogeneousness of the metal is an absolute necessity.

The behavior of the solidified alloys towards the atmosphere varies according to their chemical composition, *i. e.*, they oxidize, on exposure to the air, in a shorter or longer time, acquiring thereby a color ranging from a beautiful green to black. This layer of oxide which contributes much to the æsthetic effect produced by an article of bronze is an important factor, especially to those occupied with casting statues, etc., and will be referred to later on.

## XVI.

## MELTING AND CASTING OF BRONZE.

The quantity of bronze to be prepared at one time varies according to the article to be cast, and may amount to a few ounces or hundreds or thousands of pounds. Though the mode of preparing the bronze is the same in all cases, in the practice certain difficulties occur in casting small articles as well as large ones, which deserve attention.

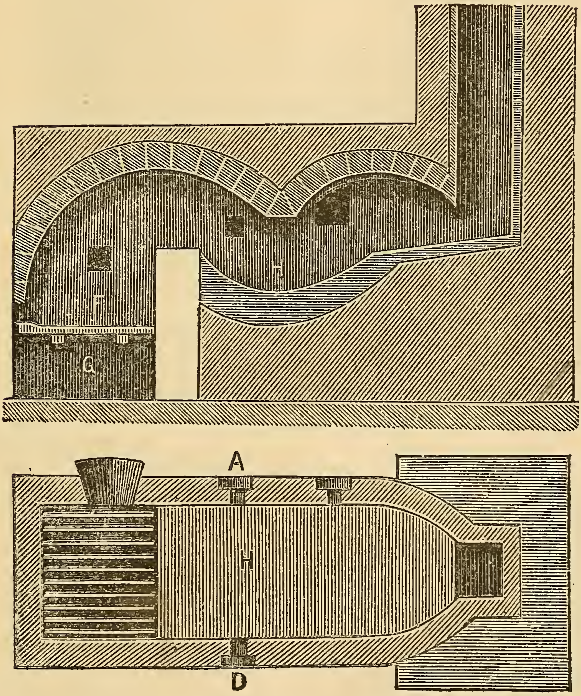
For casting small articles a finished alloy of the desired proportions of metals is generally used, it being very difficult to hit the exact composition required in preparing small quantities of bronze. The fusion, in this case, is always effected in crucibles, special care being required to prevent as much as possible oxidation of tin. The crucibles are placed in a wind-furnace and the surface of the bronze is kept carefully covered with pulverized coal, anthracite being best for the purpose on account of its great density.

Attention has already been drawn to the fact that the temperature of the fused metal exerts a considerable influence upon the quality of the casting. Experience has shown that for small articles the bronze must not be heated too strongly, as otherwise the resulting casting is blown, and one blow-hole suffices to spoil it entirely. Articles to be subjected to hammering or stretching after casting must also not be cast too hot, in order to prevent them from acquiring a too coarsely crystalline structure.

Small castings cool off rapidly, but the effect of this, especially if not uniform, is to make portions of the mass considerably harder in some parts than in others, which renders the mechanical manipulation difficult. It is therefore advisable to thoroughly heat the moulds before use, and to surround them with a bad conductor, for instance, ashes, and also cover them with a layer of the same material after finishing the casting. Moulds of cast-iron or brass are generally used for small castings, which, in order to protect them, are coated with a mass consisting of lamp-black and oil of turpentine.

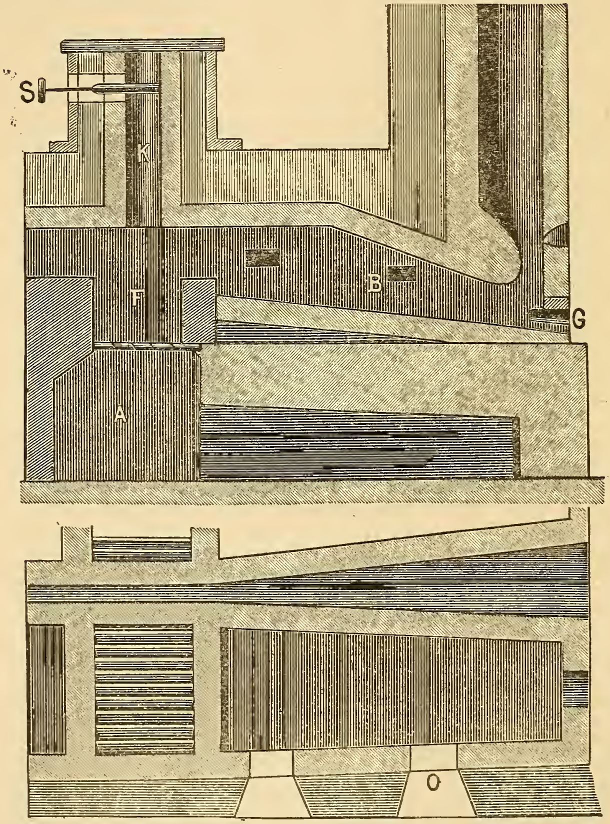
The preparation of large quantities of bronze as required for casting bells, cannons, or statues is effected in reverberatory furnaces capable of holding up to 10,000 pounds of bronze or more. The copper is first melted, and, when fluid, any old bronze to be used is added. When all is converted into a uniform mass, the tin, previously heated as much as possible, is introduced in small portions. Immediately before the introduction of the tin, the fire must be increased in order to compensate for the consequent reduction of the temperature, and to keep the metal in a thinly-fluid state. Figs. 5 and 6 show the arrangement of a reverberatory furnace

Figs. 5 and 6.



especially adapted for melting not too large a quantity of bronze. *F* is the fire-box, and *G* the ash-pit. The metals to be melted are placed upon the trough-shaped hearth *H*, while the aperture *D* serves for the introduction of the charge and for taking samples.

Figs. 7 and 8.

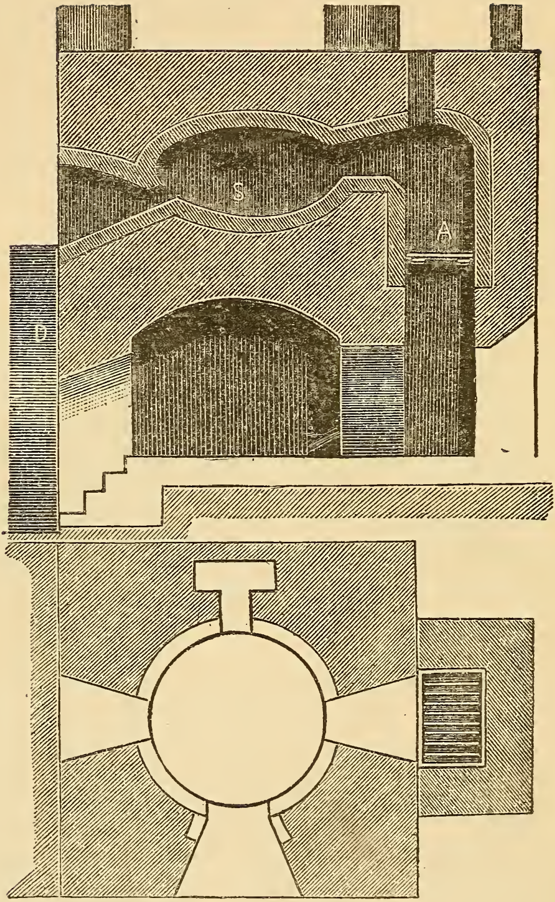


The finished bronze is run off through the aperture *D*. For large articles loam moulds are almost exclusively used, sand moulds being but seldom employed. While, as previously stated, it is advisable in casting small articles not to have the bronze too hot, for casting large works it should be very hot in order to render the production of uniform castings possible by keeping the mass in a fluid state for some time, and thus giving the gases evolved as well as the oxides a chance to rise to the surface.

Figs. 7 and 8 show the construction of a furnace especially adapted for melting a large quantity of bronze, which is to be as uniform as possible. The furnace, shown in Fig. 7 in section, and in Fig. 8 in ground-plan, has a capacity of about 16,200 pounds of bronze. Its total length is 13 feet, and it is heated with wood. *F* is the fire-box, and *A* the ash-pit, while the metals are melted in the space *B*, between *F* and *G*. *K* is the stoking-channel, which can be closed by the slide *S*. The aperture *O* serves for the introduction of the large pieces of metal, and the openings on the side for adding smaller pieces. *G* is the tap hole closed during melting by a plug of clay.

The base of the hearth in these furnaces is, as will be seen from the illustrations, trapeziform, though there are other constructions in which it is elliptical or oval or even circular, the latter form being frequently used, for instance, in casting statuary bronze. Figs. 9 and 10 show the construction of such a furnace, *S* being the hearth, *A* the fire-box, and *D* the foundry-pit in which the mould is placed. The aperture above *S* serves for the introduction of the metals, and that above *D*, which

Figs. 9 and 10.



is closed during the melting with a plug of clay, for running off the fused metal.

In a furnace of this kind up to 26,500 pounds of bronze can be melted for one casting. It is possible to construct furnaces of larger dimensions, but, on account of more uniform heating, it is recommended to use in this case several fire-places arranged on the circumference of the melting hearth.

*The different kinds of bronze.*—It will, of course, be readily understood that the composition of bronze must vary very much according to the purpose for which it is to be used. In the practice a large number of alloys is distinguished, which, according to their application, are known by various names. To retain this division would lead to the enumeration of a large number of names, and we must therefore restrict ourselves to those most frequently used, such as gun-metal, statuary bronze, speculum metal, etc.

Before proceeding with the description of the preparation of the alloys serving for these purposes, it will be convenient to briefly refer to the bronzes of pre-historic times. It is well known that bronze was extensively used by the ancients for coins, weapons, tools, and ornaments. It might be supposed, at first sight, from the castings of the ancients, that they possessed some very expeditious and simple means of making their enormous and numerous productions in this department; but upon closer inspection this conclusion appears untenable, for many analyses of their alloys have demonstrated the fact that their bronzes were not a constant composition of copper and tin, but contained frequently foreign metals, which cannot be considered as intentional additions but only as accidental contaminations. Hence the success of a bronze of good composition was, no doubt, at that time, more a matter of accident than is possible with our present knowledge in regard to alloys, and the analyses of old bronzes can only give us hints about the behavior of the metals in the presence of substances to be considered as contaminations without, however, contributing to the advancement of information in regard to the alloys. The researches made in modern times, especially as regards gun-metal, are so exhaustive in respect to the influence of the chemical composition of the alloy upon its physical qualities as to enable us to prepare alloys with any desired properties.

While the older bronzes, especially those of Greek origin, consisted almost only of copper and tin, in the older Roman coins considerable quantities of lead are frequently found, which must be considered as an intentional addition. Zinc seems to have first been intentionally added to bronze in the beginning of the present era. The exact composition of bronze has only been determined in modern times with the assistance of chemistry, the effect produced by the different elements upon the properties of the bronze, as well as the influence upon its physical qualities by rapid or slow cooling off, being now quite well understood. But that we have not yet arrived at a full knowledge of these properties is well seen from phenomena which in modern times have excited the interest of all technologists, it being only necessary to refer in this respect to phosphor-bronze and Uchatius's so-called steel-bronze.

## XVII.

## ORDNANCE OR GUN-METAL.

MORE money and labor have been spent on the study of this alloy than on any other, the governments of several of the larger countries having expended millions of dollars in experiments to find out the best alloys for the manufacture of ordnance. But that, notwithstanding all this, a final result has not yet been arrived at is best proved by the many different opinions, some diametrically opposed to each other, in regard to the value of, for instance, the previously mentioned steel-bronze.

The properties demanded from a good gun-metal follow from the use of the cannons themselves. In firing a cannon an immense pressure, amounting to over 2000 atmospheres, is suddenly developed. To resist this pressure the material must possess great tenacity, and cannons manufactured from bronze lacking this tenacity burst generally with the trial-shots, for which especially large charges of powder are used. Gun-metal must further possess a high degree of hardness, as in firing the projectile strikes once or several times against the walls of the piece, it being impossible to give the same size mathematically accurate to the calibre of the piece and that of the projectile. If the bronze be not sufficiently hard, the interior of the piece loses after a few shots its cylindrical form which is detrimental to the accuracy of the shot. Finally it must be considered that the gases evolved by the combustion of the powder attack the substance of the piece itself, and, hence, the composition of the bronze must be such that this chemical action is reduced to a minimum.

Briefly stated good gun-metal must be very tenacious, capable of resistance, hard, and indifferent towards chemical influences, conditions which vary much from each other and are difficult to combine.

In order to obtain these properties all possible additions have been made to the actual bronze (consisting of tin and copper), and analyses of ordnance metal of different centuries and various countries plainly show the efforts made to arrive at a correct composition of gun-metal by certain admixtures. In modern times the addition of foreign metals, with the exception of a small quantity of zinc or, in special cases, of phosphorus, seems to have been abandoned, the quality of the bronze being adapted to the desired purposes by suitable treatment in melting and casting. In older pieces a series of foreign metals is found, some of which, as for instance nickel and cobalt, must be considered as accidental contaminations, since the preparation of these metals in a metallic form has only been known since more recent times. Iron, if present in a considerable quantity, is, no doubt, an intentional addition, and a content of bismuth can be explained by the fact that in connection with arsenic it was formerly used as a flux in the bronze mixture.

The content of tin in bronze suitable for ordnance varies between 9 and 12 parts of it to 100 parts of copper, ordnance bronze containing more tin, showing, as a rule, greater fusibility and hardness, but less elasticity, and the resulting castings are not nearly as homogeneous. For smaller pieces alloys containing 8 parts of tin to 100 of copper are generally used, while those for larger pieces have the above composition.

So many details essential for the success of the operation are connected with the melting and casting of alloys for the manufacture of pieces of ordnance, that a special volume would be required for a complete description of the various processes. We can, therefore, only give the merest outline, and must refer those especially interested to the many treatises published on this subject. The principal requisite of an alloy answering all the demands of a good ordnance-bronze is the production of entirely homogeneous castings, which it is endeavored to attain by solidifying the alloy under conditions allowing of its uniform cooling off. The moulds are always placed in a vertical position, and the evil of the upper portions of the casting showing frequently a different composition from the lower, is counteracted by using an excess of bronze so that the finished casting has a long piece on top, the so-called "dead-head" or "sullage-piece," which is later on sawed off and remelted with a new charge. This dead-head contains the greater portion of the alloys of dissimilar composition, and also the so-called "waste" consisting of oxidized metal.

In casting ordnance old cannons are frequently melted in, the practice in the opinion of many experts producing a favorable influence upon the homogeneousness of the resulting new material. The loss of tin by oxidation is also smaller, since tin once united with copper does not oxidize as readily as in the preparation of new alloys. But in order to obtain a homogeneous product great experience is required, and after the metals are melted, samples must be taken and examined as to their qualities, so that if the composition be not correct it can be improved by a suitable addition of copper or tin or old bronze, as may be found necessary. A considerable time being, however, required for the newly added metals to form a homogeneous combination with the material already melted, great precaution is necessary to prevent the oxidation of the metals as much as possible.

The temperature at which ordnance-bronze is cast also exerts considerable influence upon its physical properties, one of about 2822° F. appearing to be the most suitable. Cannons cast at this temperature are distinguished by great homogeneousness throughout the entire mass, and besides there need to be no fear of the separation of the so-called tin-spots, one of which, if located in a place especially subjected to strong pressure in firing, suffices to render the entire piece useless in a short time.

Ordnance-bronze should be cooled off rapidly, this also decreasing the danger of the formation of tin-spots. Iron moulds are frequently used, but they must not be too cold, as otherwise the layers of bronze coming in immediate contact with the iron solidify so quickly as to prevent the mobility of the still fluid mass in the interior, which would produce an unequal tension of the molecules, in consequence of which the piece might burst with the first shot. In many ordnance-foundries sand moulds are used, there being a great diversity of opinions as to which method of casting is the most suitable. Cannons are now generally cast solid, and the cylindrical cavity is formed by boring out this solid mass. Some, however, consider it preferable to cast the piece over an iron mandrel, which is sometimes so arranged that water can circulate in it in order that the parts nearest to it may quickly solidify and become as hard as possible.

*Steel-bronze.*—The ordnance-bronze known under this name is prepared in the Austrian arsenals, the method of melting and subsequent treatment in casting being kept secret. It is only known that the bronze contains 8 per cent. of tin, and that the casting is effected in cold iron moulds. The peculiarity of the process of manufacturing ordnance from steel-bronze (also called Uchatius-bronze, after its inventor) consists in the piece after being finished to a certain extent being subjected to a peculiar mechanical treatment. The calibre of the piece is made smaller than it is finally to be, and is then gradually enlarged to the required diameter by steel-cylinders with conical points being forced through the cavity with the assistance of hydraulic presses. In consequence of this peculiar treatment the cavity is, so to say, rolled or forged, the bronze acquiring the greatest power of resistance in those places which in firing are subjected to the greatest pressure.

The following table shows the composition of ordnance-bronze of various times and different countries:—

| | Parts. | | | | | |
|---|---|---|---|---|---|---|
| | Copper. | Tin. | Lead. | Zinc. | Iron. | Brass. |
| United States . . . | 90 | 10 | — | — | — | — |
| France (modern) . | 90.09 | 9.9 | — | — | — | — |
| Prussia . . . . . . | 90.90 | 9.1 | — | — | — | — |
| England . . . . | 89.30 | 10.7 | — | — | — | — |
| France (1780) . . . | 100 | — | — | — | — | 61.0 |
| Savoy (Turin, 1771) | 100 | 12.0 | — | — | — | 6·0 |
| Russia (1819) . . | 88.61 | 10.7 | — | — | 0.69 | — |
| Lucerne (Switzerland) | 88.929 | 10.375 | 0.062 | 0.419 | 0.110 | — |
| Cochin China . . | 77.18 | 3.42 | 13.22 | 5.02 | 1.16 | — |
| | 93.19 | 5.43 | — | — | 1.38 | — |
| China . . . . . . | 71.16 | — | — | 27.36 | 1.40 | — |
| Turkey (1464) . | 89.58 | 10.15 | — | — | — | — |
| | 95.20 | 4.71 | — | — | — | — |

## XVIII.

### BELL-METAL.

THE principal requisite of good bell-metal is a pure, full sound, which is, however, only obtained with an alloy showing besides great homogeneousness and hardness, a considerable degree of strength. Experience has shown that these qualities are obtained with a composition containing from 20 to 22 per cent. of tin. The color of good bell-metal is a peculiar gray-white, differing materially from that of ordnance-bronze and statuary-bronze. The bell-founder uses the appearance of the fracture as a sign of the correct composition of the bell-metal; if the fracture be too fine the alloy is too rich in tin; if too coarse-grained it contains too little tin.

Bell-metal is brittle and cracks under the hammer, cold as well as heated. If it be repeatedly brought to a dark red heat and quickly cooled by immersion in water its brittleness is so far decreased that it can be hammered and stamped. It has been attempted to change the sound of bell-metal and improve it especially in regard to its purity. The opinion was formerly held that an addition of silver adds to the beauty of the sound, though at present it is thoroughly understood that such is not the case.

Independent of the quality of the material used the tone of a bell depends materially on its size and form; the thickness of the walls and the proportion of height to diameter are also of importance for a beautiful and pure tone. The skill of the bell-founder lies not so much in finding the right composition of the alloy, this being thoroughly understood at the present time, as in giving the bell a shape corresponding to a certain tone, which is of special importance for chimes.

The melting and casting of bell-metal is not as difficult as that of ordnance-bronze, though great analogy exists between them. The copper is first melted down, and after heating the fused mass as much as possible the tin is introduced and an intimate mixture promoted by vigorous stirring. Many bell-founders do not add all the tin at once, but at first about two-thirds of it, and when this has formed a union with the copper the other third.

It rarely happens that new materials are entirely used in preparing the bell-metal, old bells and ordnance-bronze being worked in large quantities. The composition of these should, however, be known so that the mean of the alloy be such as will yield a bell of the required quality. For this purpose it is best to melt small portions of the respective metals together in the same proportions in which they are to be fused on a large scale. From the quality of these test-pieces it will then be seen whether a change in the composition of the alloy is necessary.

It is still more preferable to ascertain by a chemical analysis the centesimal composition of the metals since the appearance of the fracture, color, and degree of brittleness give rise to errors.

It has been frequently observed that bells repeatedly remelted acquire a disagreeable tone. The principal reason for this change is found in the solution of oxide in the alloy. This evil can be overcome by deoxidizing the mixture of metals to which we will refer later on. While the composition of bell-metal for large bells is always within the above-mentioned limits, the material used for the manufacture of small tower-bells, table-bells, sleigh-bells, etc., varies very much, mixtures being frequently used which can actually not be classed as bell-metal, they being frequently only tin alloyed with a small quantity of copper and a little antimony.

Chinese tam-tams or gongs are distinguished by a strong, far-reaching sound. The alloy of which they are made is nearly of the same composition as the ordinary bell metal, the difference in sound being due to mechanical treatment. As soon as the plates intended for the manufacture of tam-tams are well solidified they are withdrawn from the mould and introduced into a furnace where they are raised to a cherry-red heat. They are then inserted between iron disks and plunged into water and allowed to cool, after which they are withdrawn, and are so tenacious that they may be worked under the hammer.

The following table shows the composition of some bell-metals :—

| | Parts. | | | | | |
|---|---|---|---|---|---|---|
| | Copper. | Tin. | Zinc. | Lead. | Silver. | Iron. |
| Normal composition . | 80 | 20 | — | — | — | — |
| | 78 | 22 | — | — | — | — |
| Alarm bell at Rouen . . | 76.1 | 22.3 | 1.6 | — | 1.6 | — |
| " " Ziegenhain | 71.48 | 33.59 | — | 4.04 | — | 0.12 |
| " " Darmstadt | 73.94 | 21.67 | — | 1.19 | 0.17 | — |
| " " Reichenhall (13th century) | 80 | 20 | — | — | — | — |
| Tam-tam . . . . . . . | 78.51 | 10.27 | — | 0.52 | 0.18 | — |
| Bells of Japanese origin | 10 | 4 | 1.5 | — | 0.5 | — |
| | 10 | 2.5 | 0.5 | 1.33 | — | — |
| | 10 | 3 | 1 | 2 | ½ | — |
| | 10 | — | — | — | — | — |

For the fabrication of small clock-bells, table-bells, sleigh-bells, etc., an alloy giving a clear and pure tone has to be used. Experience has shown that bell-metal with about 22 per cent. of tin gives the finest tone, and can therefore be suitably used for small bells. However it is an object to use as cheap an alloy as possible for these purposes by a reduction of the content of the expensive copper. The following table will suffice to show the composition of such alloys :—

| | Parts. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Copper. | Tin. | Zinc. | Lead. | Silver. | Antimony. | Bismuth. |
| House-bells . . . | 80 | 20 | — | — | — | — | — |
| " smaller | 75 | 25 | — | — | — | — | — |
| Clock-bells, German | 73 | 24.3 | 2.7 | — | — | — | — |
| " Swiss . | 74.5 | 25 | — | 0.5 | — | — | — |
| " Paris . | 72.0 | 26.56 | — | — | 1.44 | — | — |
| Sleigh-bells . . . | 84.5 | 15.42 | — | — | — | 0.1 | — |
| White-table bells . | 17 | 800 | — | — | — | — | 5 |
| " " . | — | 7 | — | — | — | 1 | — |

*Algiers metal* (*metal d'Alger*).—This metal has a nearly pure white color and takes a beautiful polish. It can scarcely be classed with bell-metal, its composition having nothing in common with it. It is composed of copper 5 parts, tin 94.5, and antimony 0.5. The antimony is very likely added to give greater hardness.

Large bells are cast in loam moulds. The figures or designs with which the bell is to be ornamented are placed in the mould, the portions which have been left imperfect in casting being mended after the cast bell is cold. Small bells are generally cast in sand moulds, though recently iron moulds are frequently used.

*Silver bell-metal.*—This alloy suitable for small bells is distinguished by a beautiful silver-clear tone, and a nearly white color. It is composed of:

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Copper . . . . . | 40 | 41.5 | 41.6 |
| Tin . . . . . . | 60 | 58.5 | 58.4 |

# XIX.

# BRONZES FOR VARIOUS PURPOSES.

As previously stated the properties of bronze may be varied within very wide limits according to the purpose for which they are to be used. In the following a few of the most important bronzes used in the various branches of industry are given. To enter on a detailed description of all these alloys is scarcely practicable, since many manufacturers preparing bronzes for their special purposes use alloys which, as regards their centesimal composition (in respect to copper and tin), show considerable variations, and sometimes contain other metals as additions, which, according to the assertions of the manufacturers, impart to them exactly the properties desired.

According to the purposes for which the bronzes are to be used they may be designated, besides those already mentioned, as machine bronze (for bearings and pieces subject to severe friction), coin and medal bronze, and ormolu. The last alloy is chiefly used for small articles of art, and is by many classed among statuary bronze, but incorrectly so, because the latter, as will be explained later on, cannot be termed a bronze in the actual sense of the word. Besides the above-mentioned varieties of bronze, there remains to be mentioned the speculum metal, which was formerly much used for mirrors of optical instruments, but at the present its application is limited, these mirrors being now made by a cheaper process and at the same time of greater power.

*Medal and coin-bronze.*—A bronze suitable for these purposes must have a certain degree of ductility, be able to receive a true impression, and wear well. In many countries the baser coin is now made of a bronze-like alloy instead of pure copper as formerly, it being better calculated to resist the injuries it is likely to receive in circulation. The bronze used in casting medals contains a variable proportion of tin, ranging generally from 4 to 10 per cent., according to the depth of the impression. Bronzes containing about 8 per cent. of tin are distinguished by great hardness, but can be rendered sufficiently soft for stamping by heating to a red heat and tempering. This variety of bronze is chiefly used for medals which, besides being distinguished by artistic execution, are to have considerable durability. If the impression is to be quite deep or if the medals are to be stamped several times they must be repeatedly annealed.

An addition of a very small quantity of lead and zinc has a favorable effect upon the metal to be used for medals. It renders it softer, so that it can be worked with greater ease, and its color and fusibility are also improved.

The baser coin of many countries (France, Switzerland, Belgium, Italy, etc.) consists of a bronze of variable composition. The copper coin manufactured in France since 1852 consists, for instance, of copper 95 parts, tin 4, and zinc 1. This alloy has stood the test of time, coins stamped in 1852 still showing the impression in all its details, which is sufficient proof of its durability. Coin-bronze as made by the Greeks and Romans contained from 96 parts of copper and 4 of tin to 98 parts of copper and 2 of tin. Chaudet has shown that the first of these alloys can be used for fine work, obtaining medals of this composition of very perfect polish while sufficiently hard to wear well.

Many medals, as is well known, do not show the color of bronze, but a pleasant brown color subsequently produced by oxidation. A bronze which, on account of its pale-red color, is especially adapted for figures stamped in relief upon medals consists of a mixture rich in copper, which at the same time is very flexible, so that medals with figures in high relief can be stamped without an expense of great power. This bronze consists of copper 97 parts, tin 2, and lead 1.

Medals whose size does not exceed a certain limit are at present stamped from sheet rolled out to the required thickness, and the disks thus obtained stamped with the impression; this method is also used in making coins. For large medals with impressions in very high relief plates are prepared by casting, the model of the medal being used in order to obtain plates already somewhat raised or depressed on the respective places. As soon as the pieces cast in sand are solidified, they are thrown into cold water to give them the required degree of softness. After subjecting them to one or two pressures in the stamping-press, they must be again annealed in order to prevent cracking of the edges.

*Ormolu* (*Or moulu*).—This alloy is much used for small statues, candlesticks, inkstands, etc., but serves also for purely artistic purposes. It also finds a very interesting application in the manufacture of articles coated with enamel. The enamel is placed in shallow cavities chiselled in the surface of the bronze and fused by heating the latter. Enamel of various colors can be used, each color being terminated by the edges of the cavities, and the articles after heating appear coated with the tightly-adhering enamel. Such work is termed *email cloisonné.* It became known in Europe through Chinese articles, but at present the European product by far surpasses the Chinese.

Below we give the composition of a few bronzes which can be classed with ormolu; they are much used in the manufacture of small articles of art, which manufacture is carried on to an enormous extent in Paris and Vienna.

*Actual ormolu.*—This bronze is distinguished by a pure golden-yellow color, and requires but very little gold for gilding. It is much used for the finest bronze articles of luxury. It is composed of copper 58.3 parts, tin 16.7, zinc 25.3.

*Bronze for small castings.*—For articles to be prepared in large quantities, it is desirable to have a bronze which becomes very thinly fluid in the heat and fills out the moulds. Cast-iron moulds are generally used, and the articles, as a rule, turning out very clean, can be at once brought into commerce after slightly mending the parts which have been left imperfect in casting. A bronze of excellent quality for this purpose is composed of copper 94.12 parts, tin 5.88.

*Gold-bronze.*—For many articles which are to present a beautiful appearance without being too expensive, it is scarcely practicable to provide them with a coating of genuine gold. An effort must, therefore, be made to impart to the alloy to be used a color resembling as closely as possible that of gold. A mixture possessing these properties in a high degree is composed of copper 90.5 parts, tin 6.5, and zinc 3.0. This alloy retains its beautiful gold color on exposure to the air, but loses it rapidly if exposed to both air and water. Articles manufactured from it, if kept in a room, retain their color, and in the course of time act like all genuine bronzes, *i. e.*, they become covered with the characteristic green coating known as genuine patina, which is so highly valued on account of bringing out the beauty of the contours.

*Bronze to be gilded.*—Every kind of bronze can be gilded, the gold adhering with great tenacity. An example of this is furnished in the equestrian statue of the Emperor Marcus Aurelius, standing in front of the capitol at Rome, which still shows traces of the gold with which it was at one time entirely coated. In making castings to be subsequently gilded, it is advisable to use an alloy which is distinguished by a beautiful gold color, such alloy, as previously mentioned, requiring the smallest possible quantity of gold. An alloy answering the purpose is composed of copper 58.3 parts, tin 16.7, zinc 25.3.

In many places, especially in Paris, much jewelry is made of bronze. The articles being generally turned out by pressing and finally gilded, the bronze used must have a certain degree of ductility and allow of being readily gilded. A mixture answering these demands, and of which the greater portion of the Paris bronze jewelry is made, consists of copper 8 parts, tin 7.

*Bronze which can be rolled.*—A bronze containing 4.5 to 7 parts of tin to 100 parts of copper can be readily rolled out to sheets at a red heat. Such bronze-sheets are at the present time frequently substituted for copper-sheathing of vessels, as they are more durable.

*Machine-bronze.*—In this collective term are included a great number of alloys with very variable properties, and which have actually nothing in common except that they are used for certain parts of machines. Many of these mixtures of metals—for some of them can scarcely be called bronzes—must be as hard as possible in order to resist wear, others must possess great strength so as not to yield under shocks or pressure, while still others must have the property of showing, even under a heavy load, but little frictional resistance when in contact with other metals.

Bronzes of ordinary composition differ but little as regards their properties from other cheaper metals and mixtures of metals, and, on account of their higher price, are but little used in the manufacture of parts of machines, red brass being more frequently employed. The so-called white metal, which is distinguished by great hardness and comparative cheapness, finds, however, much application for bearings. The white metals most frequently used in the manufacture of machines consist of alloys very rich in tin, containing besides this metal antimony and a small quantity of copper.

*Alloys for bearings.*—The alloys for bearings of heavy axles, especially such as revolve rapidly, for instance bearings of railroad wheels, are, as a rule, very rich in copper (between 80 and 90 per cent.), and must, therefore, be classed among the bronzes. The alloys richest in copper can be forged in the heat, while those with a smaller content of copper lack this valuable property. In the annexed table the composition of a few important alloys belonging to this group and the purposes for which they are generally used are given. We would, however, remark that nearly every large machine-shop uses alloys of varying composition for the same purposes. This variation can only be explained by the difference in the quality of the metals worked, for it is evident from what has already been said in regard to the influence of small quantities of foreign metals upon the quality of the alloys, that a machine-shop having only copper containing a small quantity of iron at its disposal, will use a different composition from one working copper free from iron.

The same holds good as regards all other contaminations, and it would be a great achievement if the metals serving for the preparation of the alloys could be procured chemically pure at a low price. The result would be a considerable decrease in the number of alloys used for certain purposes, and the same mixtures would be employed for the same purposes in all factories.

### *Metals for bearings.*

| | Parts. | | |
|---|---|---|---|
| | Copper. | Zinc. | Tin. |
| For locomotive axles | 86 | 14 | — |
| “ “ “ | 82 | 8 | 10 |
| “ railroad car axles | 82 | 18 | — |
| “ “ “ | 84 | 16 | — |
| “ “ “ | 75 | 2 | 20 |
| “ various axles | 73.7 | 2.1 | 14.2 |
| “ “ “ (medium hard) | 69.55 | 5.88 | 21.77 |
| “ “ “ (hard) | 82 | 2 | 16 |
| “ “ “ (very hard) | 88.8 | 11.2 | — |

### *Machine metals for various purposes.*

| | Parts. | | | |
|---|---|---|---|---|
| | Copper. | Zinc. | Tin. | Lead. |
| For cog-wheels | 91.3 | 8.7 | — | — |
| “ punches | 83.3 | 16.7 | — | — |
| “ steam-whistles | 80 | 2 | 17 | — |
| “ “ “ | 81 | 2 | 16 | — |
| “ cocks | 88 | 2 | 10 | — |
| “ boxes for wagon wheels | 87.7 | 2.6 | 9.7 | — |
| “ stuffing boxes | 86.2 | 3.6 | 10.2 | — |
| “ mechanical instruments | 81.2 | 5.1 | 12.8 | — |
| “ files | 64.4 | 10 | 17.6 | 8.6 |
| “ “ | 61.5 | 7.7 | 30.8 | — |
| “ weights | 90 | 2 | 8 | — |
| “ castings to be gilded | 79.1 | 7.8 | 13.1 | — |
| “ “ “ “ | 77.2 | 7 | 15.8 | — |
| “ shovels (malleable) | 50 | 16.4 | 33.6 | — |
| “ “ | 3 | 2 | 1 | — |
| “ buttons (white) | 57.9 | 36.8 | 5.3 | — |
| “ sheet for pressed articles | 63.88 | 30.55 | 5.55 | — |
| “ small castings | 94.12 | — | 5.88 | — |
| “ “ “ | 90 | 10 | — | — |
| “ piston rings | 84 | 8.3 | 2.9 | 4.3 |
| “ pump barrels | 88 | 2 | 10 | — |
| “ eccentric straps | 90 | 2 | 8 | — |

*Bronze for articles exposed to shocks and very great friction.*—Copper 83 parts, tin 15, zinc 1.5, lead 0.5.

*Bronze for valve-balls and other constituent parts to which other parts are to be soldered with hard solder.*—Copper 87 parts, tin 12, antimony 1. This alloy is flexible and of a red, granular fracture.

*Bronze resisting the action of the air.*—For this purpose Bath recommends a mixture of 576 parts of copper, 48 of brass, and 59 of tin.

A bronze for the same purpose can, however, also be obtained by mixing together 26 parts of copper and 2 of tin.

*A beautiful bronze,* which can be used for most purposes as a substitute for brass and also as hard solder for copper, is obtained, according to Eisler, by mixing together 16 parts of copper and 1 of tin. It is golden-yellow, can be hammered and stretched, is harder and more plastic than brass and copper, nearly as hard as wrought-iron, and runs more easily and thinner than brass.

*Chinese bronzes.*—Some bronzes exhibited at the last Paris Exhibition attracted special attention, not only on account of their artistic beauty, but also on account of the unusually deep bronze color, which, in many specimens, presented a beautiful dead-black appearance. The color, which was doubtless intended to contrast with the silver of the filigree work, was proved to belong to the substance proper of the bronze and not to have been artificially produced by an application upon its surface. Analyses of the different specimens of the bronze gave the following results :—

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Tin | 4.36 | 5.52 | 7.27 |
| Copper | 82.72 | 72.09 | 72.32 |
| Lead | 9.9 | 20.31 | 14.59 |
| Iron | 0.55 | 1.73 | 0.28 |
| Zinc | 1.86 | 0.67 | 6.00 |
| Arsenic | — | trace | trace |

These alloys contain a much larger proportion of lead than is found in ordinary bronze; and it is noticeable that the quantity of lead augments precisely with the intensity of the bronze color, proving, as before stated, that the latter is due to the special composition of the bronze.

Some of the specimens contain a considerable proportion of zinc, but the presence of this metal, instead of improving the appearance, seemed rather to counterbalance the effect of the lead.

In imitation of the Chinese bronze some alloys were made of the following composition :—

| | I. | II. |
|---|---|---|
| Tin | 5.5 parts. | 5.0 parts. |
| Copper | 72.5 " | 83.0 " |
| Lead | 20.0 " | 10.0 " |
| Iron | 1.5 " | — " |
| Zinc | 0.5 " | 2.0 " |

No. I. produced an alloy exceedingly difficult to work, and, without giving any superior results as regards color, furnished castings which were extremely brittle.

No. II., on the contrary, gave an alloy exactly resembling the Chinese bronze. Its fracture and polish were identical, and when heated in a muffle it quickly assumed the peculiar dead-black appearance so greatly admired in the Chinese specimens.

Hitherto it has been found difficult, if not impossible, to obtain this depth of color with bronzes of modern art, since the surface scales off when heated under similar conditions as No. II.

*Japanese bronzes.*—An analysis of Japanese bronzes made by M. E. J. Maumené gave the following results:—

| | | | | |
|---|---|---|---|---|
| Copper | 86.38 | 80.91 | 88.70 | 92.07 |
| Tin | 1.94 | 7.55 | 2.58 | 1.04 |
| Antimony | 1.61 | 0.44 | 0.10 | 1.04 |
| Lead | 5.68 | 5.33 | 3.54 | 1.04 |
| Zinc | 3.36 | 3.08 | 3.71 | 2.65 |
| Iron | 0.67 | 1.43 | 1.07 | 3.64 |
| Manganese | 0.67 | trace | 1.07 | 3.64 |
| Silicic acid | 0.10 | 0.16 | 0.09 | 0.04 |
| Sulphur | 0.10 | 0.31 | 0.09 | 0.04 |
| Waste | 0.26 | 0.79 | 0.21 | 0.56 |

All these alloys show a granulated texture, are blistered on the interior surface, and sound on the exterior surface. In the presence of an abundance of antimony their color is sensibly violet, and red in the presence of iron. The specimens were cast thin, from 0.195 to 0.468 inch, and the mould was well filled.

*Old Peruvian bronze.*—An old chisel, weighing about 7 ounces, found in Quito, and which had evidently been used for working trachyte,* showed according to Boussingault the following composition: Copper 95.0 parts, tin 4.5, lead 0.2, iron 0.3, silver traces.

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* A nearly compact, feldspathic, volcanic rock, breaking with a rough surface, and often containing crystals of glassy feldspar, with sometimes hornblende and mica.

A chisel brought by Humboldt to Europe from a silver mine worked by the Incas consists of copper 94 per cent., tin 6 per cent. Charlon ascribes the hardness of the tools used by the Peruvians in mining, which consisted of copper 94 per cent. and tin 6 per cent., to the presence of a small quantity of silicium.

*A Turkish bronze basin* examined by Fleck was composed of copper 78.54 parts, tin 20.27, lead 0.54, iron 0.19.

*An antique bronze weapon* in the form of a chisel, which was found near Bremen, was composed of copper 85.412 parts, tin 6.846, iron 0.346.

## XX.

## SPECULUM METAL.

ALLOYS, composed of two-thirds copper and one-third tin, take a beautiful polish and can be used as mirrors. At the present time such alloys are only used in the construction of mirrors for optical instruments, especially for large telescopes, though they are being gradually displaced by glass mirrors.

Good speculum metal should be perfectly white, without a tinge of yellow, have a fine-grained fracture, and be sound and uniform, and sufficiently tough to bear the grinding and polishing without danger of disintegration. A composition answering all purposes must contain at least 65 to 66 per cent. of copper. The specula made by Mudge contained from 32 parts of copper and 16 of tin to 32 of copper and 14.5 of tin. A little tin is lost in fusion. It has been frequently attempted to increase the hardness of speculum metal by additions of arsenic, antimony, and nickel. With the exception of nickel these additions have, however, an injurious effect, the specula readily losing their high lustre, this being especially the case with larger quantities of arsenic.

It would seem that the actual speculum-metal is a combination of the formula $Cu_4Sn$, and has the following centesimal composition:—

| | |
|---|---|
| Copper | 66.6 |
| Tin | 33.4 |
| | 100.0 |

According to David Ross the best proportions are: copper 126.4, tin 58.9, *i. e.*, atomic proportions. He adds the molten tin to the fused copper at the lowest safe temperature, stirring carefully, and securing a uniform alloy by remelting.

The so-called tin-spots which sometimes separate when ordnance-bronze is incorrectly treated form an alloy similar in composition to speculum metal; it has, however, not a pure white color, such as is found in those containing 31.5 of tin. By increasing the content of copper, the color shades gradually into yellow, and with a larger content of tin into blue. It is dangerous to increase the content of tin too much, as besides the change in color the alloy becomes brittle and cannot be further worked. The following table shows the composition of some alloys used for speculum-metal. We would, however, remark that the standard alloy is undoubtedly the best for the purpose:—

| | Parts. | | | | |
|---|---|---|---|---|---|
| | Copper. | Tin. | Zinc. | Arsenic. | Other metals. |
| Standard alloy . | 68.21 | 31.79 | — | — | |
| Otto's . . . . . | 68.5 | 31.5 | — | — | |
| Richardson's . . | 65.3 | 30 | 0.7 | 2 | 2 silver. |
| Little's . . . . | 65 | 30.8 | 2.3 | 1.9 | |
| Sallit's . . . . | 64.6 | 31.3 | — | — | 4.1 nickel. |
| Chinese speculum metal . . . . | 80.83 | — | — | — | 8.5 antimony. |
| Old Roman . . . | 63.9 | 19.05 | — | — | 17.29 lead. |

# XXI.

## PHOSPHOR-BRONZE.

In the actual sense of the word phosphor-bronze cannot be considered an alloy containing a certain quantity of copper, but it is rather a bronze subjected to a peculiar treatment with the use of combinations of phosphorus. Many excellent phosphor-bronzes contain but a very small quantity of phosphorus, which exerts no essential influence upon the qualities of the alloy. In such alloys the phosphorus has exerted its influence during the preparation.

It has been previously mentioned that bronze frequently contains a considerable quantity of cuprous oxide in solution, which is formed by direct oxidation of the copper during fusion, and that the admixture of this oxide injures to a great extent the strength of the alloy. If now the melted bronze be treated with a substance exerting a powerful reducing action, as, for instance, phosphorus, a complete reduction of the cuprous oxide takes place, the pure bronze acquiring thereby a surprisingly high degree of strength and power of resistance. If exactly the quantity of phosphorus required for the complete reduction of the oxide has been used, no phosphorus will be found in the alloy, but the latter must nevertheless be called phosphor-bronze. Hence it will readily be seen that phosphor-bronze is not a special alloy, but that every kind of bronze can be converted into it. With the use of combinations of phosphorus phosphor-bronze is, therefore, deoxidized bronze.

Phosphor-bronze has long been known to chemists, but its valuable qualities as a material to be used in construction were first made known by Montefiori, Levi, and Künzel, who discovered the alloy in 1871. Besides reducing any oxides dissolved in the alloy, the phosphorus exerts another very material influence upon its properties. The ordinary bronzes consist of mixtures in which the copper actually forms the only crystallized constituent, the tin crystallizing with great difficulty, and the alloy in consequence of this dissimilar condition of the two metals is not as solid as it would be if both constituents were crystallized. The presence of phosphorus is useful in giving the tin a crystalline character, which enables it to alloy itself more completely and strongly with the copper, the result being a more homogeneous mixture.

If so large a content of phosphorus be added that it can be authenticated in the finished phosphor-bronze, the latter must be considered as an alloy of crystallized phosphor-tin with copper. By increasing the content of phosphorus still more, a portion of the copper also combines with the phosphorus, and the bronze then contains, besides copper and tin, combinations of crystallized copper-phosphide with phosphide of tin. The strength and tenacity of the bronze do not suffer by a greater addition of phosphorus, but its hardness is considerably increased, so that many phosphor-bronzes are equal in this respect to the best steel, and some even surpass it in general properties.

The content of phosphorus is imparted to the bronze by an addition of copper-phosphide or phosphide of tin, both these phosphor-metals being sometimes used at the same time. They must be especially prepared, the best processes being briefly as follows:—

*Copper-phosphide* is prepared by heating a mixture of 4 parts of super-phosphate of lime, 2 parts of granulated copper, and 1 part of finely-pulverized coal in a crucible at not too high a temperature. The melted copper-phosphide, which contains 14 per cent. of phosphorus, separates on the bottom of the crucible.

According to another method copper-phosphide is prepared by adding phosphorus to copper-sulphide solution and boiling, adding sulphur as the sulphide is precipitated. The precipitate is carefully dried, melted, and cast into ingots. When of good quality and in proper condition it is quite black.

*Phosphide of tin* is prepared in the following manner: Place a bar of zinc in an aqueous solution of chloride of tin, collect the sponge-like tin separated and bring it moist into a crucible, upon the bottom of which sticks of phosphorus have been placed. Press the tin tightly into the crucible and expose it to a gentle heat. Continue the heating until flames of burning phosphorus are no longer observed on the crucible. After the operation is finished a coarsely-crystalline mass of a tin-white color, consisting of pure phosphide of tin, is found upon the bottom of the crucible.

Phosphor-bronze is prepared by melting the alloy to be converted into it in the usual manner, and adding small pieces of copper phosphide and phosphide of tin.

The properties of correctly prepared phosphor-bronze are as follows: Its melting point is nearly the same as that of ordinary bronze. In cooling it shows, however, the phenomenon of passing directly from the liquid into the solid state without first becoming thickly fluid. In a melted state it retains a perfectly bright surface, while that of ordinary bronze is always covered with a thin film of oxide.

If phosphor-bronze be subjected to continued melting no loss of tin takes place, but the content of phosphorus decreases slightly.

The chief properties of phosphor-bronze are its extraordinary tenacity and strength; in a cold state it can be rolled, stretched, and hammered. Its strength is double that of the best ordinary bronze. It is especially used for articles which are to show great strength and power of resisting external influences, for instance, the action of sea-water.

Bronze with a content of tin of about 4 per cent. is especially suitable for the manufacture of sheet; with up to 5 per cent. of tin it can be used in a forged state for gun-barrels and ordnance. Beautiful fire-arms of such bronze were exhibited at the last Vienna Exhibition.

Bronzes with a content of tin between 7 and 10 per cent. have the greatest hardness and are especially adapted for the manufacture of axle-bearings, cylinders for steam fire-engines, cog-wheels, and generally for parts of machines requiring great strength and hardness. Phosphor-bronze possesses the property of acquiring, by exposure to the air for a short time, a beautiful, tightly-adhering patina, and can, therefore, be suitably used for cast-works of art. According to the purpose for which the bronze is to be used from 0.25 to 2.5 per cent. of phosphorus is added. In the following a few analyses of different kinds of phosphor-bronze are given :—

| | I. | II. | III. |
|---|---|---|---|
| Copper | 90.34 | 90.86 | 94.71 |
| Tin | 8.90 | 8.56 | 4.39 |
| Phosphorus | 0.76 | 0.196 | 0.053 |

The following are Kirkaldy's figures for tenacity and ductility of phosphor-bronze wire of No. 16 Birmingham gauge.

*Phosphor-bronze wire No.* 16.

| Materials. | Load at fracture. | | | | Elongation. Length 5 in. | No twists before breaking. | |
|---|---|---|---|---|---|---|---|
| | Unannealed. | | Annealed. | | | | |
| | Per sq. mm. | Per sq. in. | Per sq. mm. | Per sq. in. | Per cent. | Unannealed. | Annealed. |
| Phosphor-bronze of several proportions. | 72.3 kil | 46 tons | 34.7 kil. | 22 tons | 37.5 | 6.7 | 80 |
| | 85.1 " | 54 " | 33.6 " | 21.3 " | 34.1 | 22.3 | 52 |
| | 85.2 " | 54.1 " | 37.5 " | 23.8 " | 42.4 | 13.0 | 124 |
| | 97.7 " | 62.1 " | 42.8 " | 27.2 " | 44.9 | 17.3 | 53 |
| | 112.2 " | 71.2 " | 41.7 " | 26.5 " | 46.6 | 17.3 | 66 |
| | 106.3 " | 67.6 " | 45.4 " | 28.9 " | 42.8 | 15.0 | 60 |

*Cast phosphor-bronze.*

| Reduction of section. | Elastic limit. | | Ultimate resistance. | |
|---|---|---|---|---|
| Per cent. | Per sq. mm. | Per sq. in. | Per sq. mm. | Per sq. in. |
| 8.4 | 16.65 kil. | 10.6 tons | 37.0 kil. | 23.5 tons |
| 1.5 | 17.38 " | 11.05 " | 32.5 " | 20.6 " |
| 33.4 | 11.6 " | 7.2 " | 31.3 " | 19.9 " |

According to Thurston five sorts of phosphor-bronze are considered to answer all requirements.

0. Ordinary phosphor-bronze of 2 per cent. of phosphorus.
1. Good phosphor-bronze of 2½ per cent. of phosphorus.

These two numbers are in all cases superior to ordinary bronze and steel.

2. Superior phosphor-bronze of 3 per cent. of phosphorus.

3. Extra phosphor-bronze of 3½ per cent. of phosphorus.
4. Maximum phosphor-bronze of 4 per cent. of phosphorus.

These three, according to Delalot, are superior to any other bronzes. Above No. 4 phosphor-bronze is useless, below No. 0 it is inferior to common bronze and steel. Nos. 3 and 4 are comparatively unoxidizable.

*Bronze for telephone lines.*—E. Van der Ven* has instituted a careful investigation on wires of phosphor-bronze and silicon-bronze. The wires experimented with contained, according to chemical analysis made for him by M. Van Eyndhoven, in the case of the phosphor-bronze: Copper 95.5 per cent., phosphorus 2.6 per cent., with small quantities of tin, manganese, and silicic acid; in the silicon bronze: Copper 92.2 per cent., silicium 0.91 per cent., together with small quantities of tin, manganese, and antimony.

The practical results of Dr. Van der Ven's researches are that phosphor-bronze has about 30 per cent. of the conducting power of copper, silicon-bronze about 70, while the steel as used in wires has only about 10.5 per cent. Comparing their tenacity, as also very carefully determined by him, with that of steel, he finds that a wire of the latter material, of 2 millimetres diameter, with quadruple security and the conventional sag of 0.7 millimetre, can have a stretch from pole to pole of 130 metres, while the stretch, under the same conditions of a wire 1 millimetre in diameter would for phosphor-

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* Musée Teyler, and Electrotech. Zeitsch. 1883.

bronze be 106 metres, for silicon-bronze 91 metres. These alloys, with a diameter of 1.18, and of 0.77 millimetres respectively, have the same electrical resistance as the steel wire of 2 millimetres resistance. The relatively short stretch which in general increases the expense of construction and maintenance is less costly in cities, where at short distances the roofs of buildings offer points of suspension for telephone wires. It is thus self-evident that the bronze wires are preferable to those of steel, whose resistance demands a much larger section; the more, since the network of lines suspended in the air cannot be counted among the ornaments of a large city. To this result may be added the statements made by M. Bede, at the Paris Electrical Congress, concerning the practicability of the use of phosphor-bronze wire. A phosphor-bronze wire of 0.8 millimetre (costing, too, the same as steel of 0.2 mm.) would, on account of its high elasticity, coil up, before it has fallen 4 metres from its original position, so rapidly that on breaking it would ordinarily not strike the ground, and hence would be less dangerous. On account of non-oxidation there is no loss of diameter.

## XXII.

### STATUARY BRONZE.

For casting statues the actual bronze can be advantageously used, and many antique statues are composed of this material. But in modern times a mixture of metals is used which besides copper and tin—the constituents of actual bronze—contains a quantity of zinc, the alloy thus formed being actually an intermediary between genuine bronze and brass. The reason for the use of such mixtures must partially be sought in their cheapness as compared with genuine bronze, and partially in the purpose for which the metal is to be used. A statuary bronze which thoroughly answers the purpose must become thinly fluid in fusing, fill the moulds out sharply, allow of being readily worked with the file, and must acquire a beautiful green color, the patina, on exposure to the air for a short time.

But the actual bronze, even if highly heated, does not become sufficiently thinly fluid to accurately fill out the moulds, and has the further disadvantage of yielding homogeneous castings with difficulty. Brass by itself is also too thickly fluid, and lacks the requisite hardness to allow of the fine mending of those parts which have been left imperfect in casting.

Alloys containing zinc and tin, besides copper, can, however, be so prepared that they become very thinly fluid, and yield fine castings which can be readily worked with the file and chisel. The most suitable proportions seem to be a content of zinc of from 10 to 18 per cent. and one of tin of from 2 to 4 per cent. In regard to hardness statuary bronze is a mean between genuine bronze and brass, it being harder and tougher than the latter, but is surpassed in these properties by the former.

Statuary bronze being chiefly used for artistic purposes, its color is of great importance. By small variations in the content of tin or zinc, which must, however, be always kept between the indicated limits, the color may be shaded from orange yellow to pale yellow. With an excessive content of tin the alloy becomes brittle and difficult to chisel, and by increasing the content of zinc the warm tone of color is lost, and the bronze does not acquire, on exposure to the air, a fine patina.

Though the alloys best adapted for statues are definitely known at the present time, it happens sometimes that many large castings do not exhibit the right qualities. Their color is either defective or they do not acquire a beautiful patina or are difficult to chisel. These evils may be due either to the use of impure metals or to the treatment of the alloy in melting. On account of the large content of zinc there is a considerable loss in melting, amounting even with the most careful work to at least 3 per cent., and sometimes reaching 10 per cent., and it is evident that in consequence of this loss the alloy will show an entirely different composition from what it should have according to the quantity of metal used in its preparation.

The color of the alloys, as mentioned above, quickly changes by variations in their compositions. The following table gives a series of alloys of different colors suitable for statuary bronze:—

| Copper. | Zinc. | Tin. | Color. |
|---|---|---|---|
| 84.42 | 11.28 | 4.30 | red-yellow. |
| 84.00 | 11.00 | 5.00 | orange-red. |
| 83.05 | 13.03 | 3.92 | " |
| 83.00 | 12.00 | 5.00 | " |
| 81.05 | 15.32 | 3.63 | orange-yellow. |
| 81.00 | 15.00 | 4.00 | " |
| 78.09 | 18.47 | 3.44 | " |
| 73.58 | 23.27 | 3.15 | " |
| 73.00 | 23.00 | 4.00 | pale orange. |
| 70.36 | 26.88 | 2.76 | pale yellow. |
| 70.00 | 27.00 | 3.00 | " |
| 65.95 | 31.56 | 2.49 | " |

According to d'Arcet the best bronze for statues consists of copper 78.5 parts, zinc 17.2, tin 2.9, and lead 1.4, or of copper 164 parts, zinc 36, tin 6, and lead 3.

In the following table will be found the composition of a few celebrated statues:—

| | Parts. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Copper. | Zinc. | Tin. | Lead. | Iron. | Nickel. | Antimony. |
| Column Vendome (Paris) . | 89.20 | 0.50 | 10.20 | 0.10 | — | — | — |
| Column of July (Paris) . | 91.40 | 5.60 | 1.60 | 1.40 | — | — | — |
| Henry IV. (Paris) . . . . | 89.02 | 4.20 | 5.70 | 0.48 | — | — | — |
| Keller's Louis XIV. . . . | 91.40 | 5.53 | 1.70 | 1.37 | — | — | — |
| Napoleon I. . . . . . . . | 75.00 | 20.00 | 3.00 | 2.00 | — | — | — |
| The Shepherd, Potsdam Palace . . . . . . . . | 88.68 | 1.28 | 9.20 | 0.77 | — | — | — |
| Bacchus, Potsdam Palace . | 89.34 | 1.63 | 7.50 | 1.21 | 0.18 | — | — |
| Germanicus, Potsdam . . | 89.78 | 2.35 | 6.16 | 1.33 | — | 0.27 | — |
| Augsburg bronze . . . . | 89.43 | — | 8.17 | 1.05 | 0.34 | 0.19 | — |
| " " . . . . | 94.74 | 0.54 | 1.64 | 0.24 | — | 0.71 | 0.84 |
| Munich bronze . . . . . | 77.03 | 19.12 | 0.91 | 2.29 | 0.12 | 0.43 | — |
| " " . . . . . | 92.88 | 0.44 | 4.18 | 2.31 | 0.15 | — | — |

*Melting and casting of statuary bronze.*—On account of the oxidability of the bronze used for statues, certain precautionary measures must be observed in melting in order to reduce the loss to a minimum. For melting small quantities crucibles are used, but for casting large statues reverberatory furnaces, the principal arrangement of which has been described on pp. 174–76.

The operation is commenced by heating the furnace to a red heat, and then quickly introducing the copper. The latter being melted, it is covered with a layer of coal and the previously-heated zinc added. Immediately after the introduction of the latter the tin is added, and the fused mass frequently stirred with wooden poles in order to prevent, by the products of distillation evolved from the wood, the oxidation of the metals and to promote the homogeneity of the alloy.

Before using the metal for casting, many founders draw it in a very thinly fluid state into a pan or kettle standing in front of the tap-hole, and allow it to stand for some time in order to separate on the surface any oxide still contained in the alloy, which otherwise would injure the purity of the casting. After the layer of oxide is removed, the clay-plug closing the discharge-aperture in the bottom of the pan is removed and the metal allowed to run into the mould placed in the pit directly in front of the furnace.

Loam-moulds can only be used for large castings, and it being impossible to previously heat them, the fused metal is introduced from below and gradually rises to the top. When it runs from the apertures in the top of the mould and from the vent-holes the mould has been successfully filled.

The following table* is a list of about 140 different alloys of copper and tin, giving some of their mechanical and physical properties :—

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* Prepared originally for United States Board; Committee on Metallic Alloys. Report, Vol. I. 1879, p. 390.

## *Properties of the Alloys of*

### Comparison of

| Number. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Sn. | Cu. | Sn. | | | |
| 1 | — | 100 | 0 | — | — | 8.791*a*<br>8.874*b* | Copper-red | Fibrous |
| 2 | — | 100.00 | 0.00 | — | — | 8.667 | Tile-red | Earthy |
| 3 | — | 100.00 | 0.00 | — | — | 8.921 | — | — |
| 4 | — | 100.00 | 0.00 | — | — | — | — | — |
| 5 | — | 100.00 | 0.00 | — | — | 8.794 | — | — |
| 6 | — | 100.00 | 0.00 | — | — | 8.921 | — | — |
| 7 | — | 100.00 | 0.00 | — | — | 8.952 | — | — |
| 8 | — | 100.00 | 0.00 | — | — | — | — | — |
| 9 | — | 100.00 | 0.00 | — | — | 8.672 | — | — |
| 10 | — | 98.59 | 1.41 | — | — | — | — | — |
| 11 | $SnCu_{96}$ | 98.10 | 1.90 | 97.89 | 1.90 | 8.564 | Red | Vesicular |
| 12 | — | 98.04 | 1.96 | — | — | — | — | — |
| 13 | — | 98.00 | 2.00 | — | — | — | — | — |
| 14 | — | 97.50 | 2.50 | — | — | 8.511 | Red | Vesicular |
| 15 | — | 96.97 | 3.03 | — | — | — | — | — |
| 16 | $SnCu_{48}$ | 96.27 | 3.73 | 96.06 | 3.76 | 8.649 | Reddish-yellow | Vesicular |
| 17 | — | 96.00 | 4.00 | — | — | 8.947 | — | — |
| 18 | — | 95.00 | 5.00 | — | — | — | Golden-yellow | — |
| 19 | — | 94.10 | 5.90 | — | — | — | — | — |
| 20 | — | 94.00 | 6.00 | — | — | 8.939 | — | — |
| 21 | — | 93.98 | 6.02 | — | — | — | — | — |
| 22 | $SnCu_{25}$ | 93.17 | 6.83 | — | — | 8.820 | — | — |
| 23 | $SnCu_{24}$ | 92.80 | 7.20 | — | — | 8.694 | Reddish-yellow | Vesicular |
| 24 | — | 92.50 | 7.50 | — | — | 8.684 | " | " |
| 25 | — | 92.00 | 8.00 | — | — | — | — | — |
| 26 | — | 91.75 | 8.25 | — | — | — | — | — |
| 27 | — | 91.74 | 8.26 | — | — | — | — | — |

*Copper and Tin.*

several authorities.

| Number. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston). | Hardness (Mallet and Calvert and Johnson). | Order of malleability (Mallet). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 27,800 | — | 30.8 | — | — | — | — | — | U. S. B. | *a.* Specific gravity of bar.<br>*b.* Specific gravity of turnings from ingot. |
| 2 | 55,104 | 1 | — | 10 | 2 | 16 | — | — | M. | |
| 3 | — | — | — | — | — | — | — | 93.16 | Ma. | |
| 4 | — | — | — | 301 | — | — | 81.1 | — | C. J. | |
| 5 | — | — | — | — | — | — | — | — | Cr. | |
| 6 | — | — | — | — | — | — | — | — | Mar. | Cast copper. |
| 7 | — | — | — | — | — | — | — | — | Mar. | Sheet copper. |
| 8 | — | — | — | — | — | — | 73.6 | 79.3 | We. | |
| 9 | 24,252 | — | — | — | — | — | — | — | Na. | Mean of 9 samples. |
| 10 | — | — | 100.1 | — | — | — | — | 62.46 | Ma. | |
| 11 | — | — | — | — | — | — | — | — | U. S. B. | Defective bar. |
| 12 | — | — | — | — | — | — | — | — | Bo. | Can be forged like copper. |
| 13 | — | — | — | — | — | — | — | — | La. | Ramrods for guns. |
| 14 | — | — | — | — | — | — | — | — | U. S. B. | Defective bar. |
| 15 | — | — | — | — | — | — | — | — | W. | Resists action of hydrochloric acid. |
| 16 | 32,000 | — | 70.3 | — | — | — | — | — | U. S. B. | |
| 17 | — | — | — | — | — | — | — | — | Ri. | Annealed and compressed. |
| 18 | — | — | — | — | — | — | — | — | W. | Hard, malleable. |
| 19 | — | — | — | — | — | — | — | — | Bo. | Pieces of machines. |
| 20 | — | — | — | — | — | — | — | — | Ri. | Specific gravity after repeated tempering. |
| 21 | — | — | — | — | — | — | — | 19.68 | Ma. | |
| 22 | — | — | — | 602.8 | — | — | — | — | C. J. | |
| 23 | 28,540 | — | 21.9 | — | — | — | — | — | U. S. B. | |
| 24 | 27,900 | — | 43.2 | — | — | — | — | — | U. S. B. | |
| 25 | — | — | — | — | — | — | — | — | Bo. | Bronze for medals. |
| 26 | — | — | — | — | — | — | — | — | W. | Shows separation of metals when examined with a lens. |
| 27 | — | — | — | — | — | — | — | — | Bo. | English ordnance. |

*Properties of the Alloys of*

| Number. | Atomic formula. | Composition of original mixture. |  | Composition by analysis. |  | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
|  |  | Cu. | Sn. | Cu. | Sn. |  |  |  |
| 28 | — | 91.70 | 8.30 | — | — | — | — | — |
| 29 | — | 91.66 | 8.33 | — | — | — | — | — |
| 30 | $SnCu_{20}$ | 91. 9 | 8.51 | — | — | 8.793 | — | — |
| 31 | — | 91.30 | 8.70 | — | — | — | — | — |
| 32 | — | 90.91 | 9.09 | — | — | — | — | — |
| 33 | — | 90.90 | 9.10 | — | — | — | — | — |
| 34 | — | 90.73 | 9.27 | — | — | — | — | — |
| 35 | — | 90.10 | 9.90 | — | — | — | — | — |
| 36 | — | 90 00 | 10.00 | 90.27 | 9.58 | 8.669 | Grayish-yellow | Earthy |
| 37 | — | 90.00 | 10.00 | — | — | 8.875 | — | — |
| 38 | — | 90.00 | 10.00 | — | — | 8.935 | — | — |
| 39 | — | 90.00 | 10.00 | — | — | — | — | — |
| 40 | — | 89.30 | 10.70 | — | — | — | — | — |
| 41 | — | 89.29 | 10.71 | — | — | 8.953 | — | — |
| 42 | — | 89.29 | 10.71 | — | — | 8.313 | — | — |
| 43 | — | 89.29 | 10.71 | — | — | 8.353 | — | — |
| 44 | — | 89 23 | 10.77 | — | — | — | — | — |
| 45 | $SnCu_{15}$ | 89.00 | 11.00 | — | — | 8.84 | — | — |
| 46 | $SnCu_{15}$ | 88 97 | 11.03 | — | — | 8.825 | — | — |
| 47 | — | 88.89 | 11.11 | — | — | 8.523 | — | — |
| 48 | — | 88.39 | 11.61 | — | — | — | — | — |
| 49 | — | 88.00 | 12.00 | — | — | — | — | — |
| 50 | — | 87 65 | 12.35 | — | — | — | — | — |
| 51 | — | 87.50 | 12.50 | — | — | 8 648 | Grayish-yellow | Earthy |
| 52 | — | 86.80 | 12.40 | — | — | — | — | — |
| 53 | $SnCu_{12}$ | 86.57 | 13.43 | 87.15 | 12.73 | 8.681*a*<br>8.943*b* | Mottled-white and yellow | Finely vesicular |
| 54 | — | 86.21 | 13.79 | — | — | 8.87 | — | — |
| 55 | — | 86.00 | 14.00 | — | — | — | — | — |
| 56 | — | 85.71 | 14.29 | — | — | — | — | — |
| 57 | — | 85.09 | 14.91 | — | — | — | — | — |
| 58 | $SnCu_{10}$ | 84.33 | 15.67 | — | — | 8.87 | — | — |
| 59 | — | 84.30 | 15.68 | — | — | 8.832 | — | — |
| 60 | — | 84.29 | 15.71 | — | — | 8.561 | Reddish-yellow, 1 | Finely crystalline |

*Copper and Tin.*—Continued.

| Number. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston.) | Hardness (Mallet and Calvert and Johnson). | Order of malleability (Mallet). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 28 | — | — | — | — | — | — | — | — | Bo. | Ordnance metal. |
| 29 | — | — | — | — | — | — | — | — | Bo. | 8-pounder guns. |
| 30 | — | — | — | 639.58 | — | — | — | — | C. J. | |
| 31 | — | — | — | — | — | — | — | — | Bo. | Toothed wheels. |
| 32 | 32,093 | — | — | — | — | — | — | — | Mus. | Prussian ordnance. |
| 33 | — | — | — | — | — | — | — | — | Bo. | Ordnance metal. |
| 34 | — | — | — | — | — | — | — | — | Bo. | French ordnance. |
| 35 | — | — | — | — | — | — | — | — | Bo. | |
| 36 | 26,860 | — | 18.0 | — | — | — | — | — | U. S. B. | Compressed ordnance bronze. |
| 37 | — | — | — | — | — | — | — | — | De. | After repeated compression. |
| 38 | — | — | — | — | — | — | — | — | Ri. | Railroad car bearings. |
| 39 | — | — | — | — | — | — | — | — | Bo. | Ordnance metal |
| 40 | — | — | — | — | — | — | — | — | Bo. | Small bar cast in iron mould. |
| 41 | 37 688 | — | — | — | — | — | — | — | Wa. | Small bar cast in clay mould. |
| 42 | 25,783 | — | — | — | — | — | — | — | Wa. | Mean of 12 gun-heads. |
| 43 | 26,011 | — | — | — | — | — | — | — | Wa. | Ordnance metal. |
| 44 | — | — | — | — | — | — | — | — | Bo. | |
| 45 | — | — | — | — | — | — | — | — | Ri. | |
| 46 | — | — | — | 772 92 | — | — | — | — | C. J. | Mean of 83 gun-heads. |
| 47 | — | — | — | — | — | — | — | — | Wa. | |
| 48 | — | — | — | — | — | — | — | 12.10 | Ma. | Gun-metal. |
| 49 | — | — | — | — | — | — | — | — | La. | |
| 50 | — | — | — | — | — | — | — | 10.15 | Ma. | |
| 51 | 31,100 | — | 7.3 | — | — | — | — | — | U. S B. | |
| 52 | — | — | — | — | — | — | — | — | W. | |
| 53 | 29,430 | — | 13.09 | — | — | — | — | — | U. S. B | *a*. Specific gravity of bar.<br>*b*. Specific gravity of fine turnings. |
| 54 | — | — | — | — | — | — | — | — | W. | Densest of all alloys (?) (Riche). |
| 55 | — | — | — | — | — | — | — | — | W. | Axle-tree bed, Seraing locomotive. |
| 56 | 44,071 | — | — | — | — | — | — | — | Mus. | |
| 57 | — | — | — | — | — | — | — | 8.82 | Ma. | |
| 58 | — | — | — | — | — | — | — | — | Ri. | |
| 59 | — | — | — | 916.66 | — | — | — | — | C. J. | |
| 60 | 36,064 | 2 | — | 8 | 6 | 15 | — | — | Ml. | |

*Properties of the Alloys of*

| Number. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Sn. | Cu. | Sn. | | | |
| 61 | — | 84.00 | 16.00 | — | — | — | — | — |
| 62 | — | 83.30 | 16.70 | — | — | — | — | — |
| 63 | $SnCu_9$ | 82.81 | 17.19 | — | — | 8.462 | Reddish-yellow, 2 | Finely crystalline |
| 64 | — | 82.50 | 17.50 | — | — | 8.792 | Reddish-gray | " |
| 65 | — | 82.00 | 18.00 | — | — | 8.927 | — | — |
| 66 | $SnCu_8$ | 81.15 | 18.85 | — | — | 8.86 | — | — |
| 67 | $SnCu_8$ | 81.10 | 18.90 | — | — | 8.459 | Yellowish-red, 2 | Finely crystalline |
| 68 | — | — | — | 80.43 | 19.57 | 8.953 | — | — |
| 69 | — | 80.00 | 20.00 | — | — | 8.7 | — | — |
| 70 | — | 80.00 | 20.00 | — | — | — | — | — |
| 71 | — | 80.00 | 20.00 | — | — | 8.850 | — | — |
| 72 | — | 80.00 | 20.00 | — | — | 8.955 | — | — |
| 73 | — | 80.00 | 20.00 | 80.95 | 18.84 | 8.740 | Reddish-gray | Finely granular |
| 74 | — | 79.20 | 20.80 | — | — | 8.927 | — | — |
| 75 | $SnCu_7$ | 79.02 | 20.98 | — | — | 8.90 | — | — |
| 76 | $SnCu_7$ | 78.97 | 21.03 | — | — | 8.728 | Yellowish-red, 1 | Vitreous conchoidal |
| 77 | — | 78.00 | 22.00 | — | — | — | — | — |
| 78 | — | 77.50 | 22.50 | — | — | 8.917 | Pinkish-gray | Finely granular |
| 79 | $SnCu_6$ | 76.32 | 23.68 | 76.64 | 23.24 | 8.565 | — | Smooth |
| 80 | $SnCu_6$ | 76.31 | 23.69 | — | — | 8.91 | — | — |
| 81 | $SnCu_6$ | 76.29 | 23.71 | — | — | 8.750 | Bluish-red | Vitreous |
| 82 | — | 76.20 | 23.80 | — | — | 9.1(?) | — | — |
| 83 | — | 75.20 | 24.80 | — | — | — | — | — |
| 84 | — | 75.00 | 25.00 | — | — | — | — | — |
| 85 | $SnCu_5$ | 72.91 | 27.09 | — | — | 8.87 | Reddish-white | — |
| 86 | $SnCu_5$ | 72.90 | 27.10 | — | — | 8.965 | — | — |
| 87 | $SnCu_5$ | 72.80 | 27.20 | — | — | 8.575 | Bluish-red | Conchoidal |
| 88 | — | 72.50 | 27.50 | — | — | 8.925 | Reddish-white | " |
| 89 | — | 70.00 | 30.00 | 69.84 | 29.89 | 8.932 | White | " |
| 90 | — | 68.82 | 31.18 | — | — | — | — | — |
| 91 | $SnCu_4$ | 68.28 | 31.72 | — | — | 8.80 | — | — |
| 92 | $SnCu_4$ | 68.27 | 31.73 | — | — | 8.948 | — | — |
| 93 | $SnCu_4$ | 68.25 | 31.75 | 68.58 | 31.26 | 8.938 | White | Conchoidal |
| 94 | $SnCu_4$ | 68.21 | 31.79 | — | — | 8.400 | Ash-gray | " |
| 95 | — | 68.21 | 31.79 | — | — | — | — | — |
| 96 | — | 67.50 | 32.50 | — | — | 8.907 | White | Conchoidal |

*Copper and Tin.*—Continued.

| Number. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston.) | Hardness (Mallet and Calvert and Johnson). | Order of malleability (Mallet). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 61 | — | — | — | — | — | — | — | — | Bo. | Carriage wheel boxes. |
| 62 | — | — | — | — | — | — | — | — | Bo. | Jeweler's punches. |
| 63 | 34,018 | 3 | — | 5 | 7 | 14 | — | — | Ml. | |
| 64 | 36.200 | — | 0.32 | — | — | — | — | — | U. S. B. | Strongest of series. |
| 65 | — | — | — | — | — | — | — | — | R. | Annealed and tempered. |
| 66 | — | — | — | — | — | — | — | — | Ri. | |
| 67 | 39,648 | 4 | — | 4 | 10 | 13 | — | — | Ml. | |
| 68 | — | — | — | — | — | — | — | — | Th. | Chinese gong. |
| 69 | — | — | — | — | — | — | — | — | Bo. | Bells of Reichenhall, 300 y'rs old. |
| 70 | 35,739 | — | — | — | — | — | — | — | Mus. | |
| 71 | — | — | — | — | — | — | — | — | Ri. | Annealed and tempered. |
| 72 | — | — | — | — | — | — | — | — | Ri. | After repeated compression. |
| 73 | 32,980 | — | 0.40 | — | — | — | — | — | U. S. B. | |
| 74 | — | — | — | — | — | — | — | — | Ri. | Annealed and tempered. |
| 75 | — | — | — | — | — | — | — | — | Ri. | |
| 76 | 30,464 | 5 | — | 3 | 11 | 12 | — | — | Ml. | |
| 77 | — | — | — | — | — | — | — | — | Bo. | Best bell-metal. |
| 78 | 24,650 | — | 0.03 | — | — | — | — | — | U. S. B. | |
| 79 | 22,010 | — | 0.02 | — | — | — | — | — | U. S. B. | |
| 80 | — | — | — | — | — | — | — | — | Ri. | |
| 81 | 21,728 | 0 | — | 2 | 12 | 11 | — | — | Ml. | |
| 82 | — | — | — | — | — | — | — | — | Bo. | Church bell in Reichenhall, 600 years old. |
| 83 | — | — | — | — | — | — | — | — | Bo. | Swiss clock-bells, brittle. |
| 84 | — | — | — | — | — | — | — | — | W. | |
| 85 | — | — | — | — | — | — | — | — | Ri. | |
| 86 | — | — | — | Broke | — | — | — | — | C. J. | |
| 87 | 10.976 | 0 | — | 1 | 13 | 10 | 20.7 | — | Ml. | |
| 88 | 6,493 | — | 0.003 | — | — | — | — | — | U. S. B. | |
| 89 | 5,585 | — | 0.008 | — | — | — | — | — | U. S. B. | |
| 90 | — | — | — | — | — | — | — | — | Bo. | Mirror of telescope. |
| 91 | — | — | — | — | — | — | — | — | Ri. | |
| 92 | — | — | — | Broke | — | — | — | — | C. J. | |
| 93 | 1.620 | — | — | — | — | — | 15.5 | — | U. S. B. | |
| 94 | 1,568 | 0 | — | 6 | 14 | 9 | — | — | Ml. | |
| 95 | — | — | — | — | — | — | — | — | Bo. | Mirror metal. |
| 96 | 2,536 | — | 0.009 | — | — | — | — | — | U. S. B. | |

*Properties of the Alloys of*

| Number. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Sn. | Cu. | Sn. | | | |
| 97 | — | 66 67 | 33.33 | — | — | — | Steel-gray | — |
| 98 | — | 66.67 | 33 33 | — | — | — | — | — |
| 99 | — | 65.00 | 35.00 | 65.34 | 34.47 | 8.947 | Bluish-gray | — |
| 100 | — | 62.50 | 37.50 | — | — | 8.956 | Dark gray | Radiated crystalline |
| 101 | $SnCu_3$ | 61.79 | 38.21 | — | — | 8.954 | — | — |
| 102 | $SnCu_3$ | 61.79 | 38.21 | — | — | 8.96 | — | — |
| 103 | $SnCu_3$ | 61.71 | 38.29 | — | — | 8.970 | Dark gray | Rough, stony |
| 104 | $SnCu_3$ | 61.69 | 38.31 | — | — | 8.539 | " | Tabular crystalline |
| 105 | — | 60.00 | 40.00 | — | — | — | — | — |
| 106 | — | 57.50 | 42.50 | — | — | 8.781 | Light gray | Stony |
| 107 | $Sn_5Cu_{12}$ | 56.32 | 43.68 | 56.70 | 43.17 | 8.682 | " | " |
| 108 | — | 52.50 | 47.50 | — | — | 8.643 | " | " |
| 109 | $SnCu_2$ | 51.84 | 48.16 | — | — | 8 57 | — | — |
| 110 | $SnCu_2$ | — | — | — | — | 8.512 | — | — |
| 111 | $SnCu_2$ | 51.83 | 48.17 | — | — | 8 533 | — | — |
| 112 | $SnCu_2$ | 51.80 | 48.20 | 51.62 | 48.09 | 8.560 | Light gray | — |
| 113 | $SnCu_2$ | 51.75 | 48.25 | — | — | 8.416 | Grayish-white | Vitreous conchoidal |
| 114 | — | 50.00 | 50.00 | — | — | — | — | — |
| 115 | — | 50.00 | 50.00 | — | — | 8.79 | Bluish-white | — |
| 116 | $Sn_7Cu_2$ | 47.95 | 52.05 | 47.61 | 52.14 | 8.442 | Grayish-white | Fine grain |
| 117 | — | 47.50 | 52.50 | — | — | 8.446 | " | Crystal |
| 118 | $Sn_2Cu_3$ | 44.67 | 55.33 | — | — | 8.30 | " | — |
| 119 | $Sn_3Cu_3$ | 44.63 | 55.37 | 44.52 | 55.28 | 8.312 | Grayish-white | Crystal |
| 120 | — | 42.50 | 57.50 | — | — | 8.437 | " | " |
| 121 | $Sn_3Cu_4$ | 41 74 | 58.26 | 42.38 | 57.30 | 8.302 | " | " |
| 122 | — | 40.00 | 60 00 | — | — | — | — | — |
| 123 | $Sn_5Cu_6$ | 39.20 | 60.80 | 38.37 | 61.32 | 8.182 | Grayish-white | Crystal |
| 124 | — | 37.50 | 62.50 | — | — | 8.101 | " | " |
| 125 | $SnCu$ | 34.99 | 65.01 | — | — | 8 12 | — | — |
| 126 | $SnCu$ | 34.98 | 65.02 | — | — | 7.992 | — | — |
| 127 | $SnCu$ | — | — | — | — | 8.072 | — | — |
| 128 | $SnCu$ | 34.95 | 65.05 | 34.22 | 65.80 | 8.013 | Grayish-white | Crystal |
| 129 | $SnCu$ | 34.92 | 65.08 | — | — | 8.056 | " | Tabular crystalline |
| 130 | — | 33.33 | 66.67 | — | — | — | White | — |
| 131 | — | 32.50 | 67.50 | — | — | 7.931 | Grayish-white | Crystal |
| 132 | $Sn_4Cu_3$ | 28.72 | 71.28 | 25.85 | 73.80 | 7.918 | " | " |
| 133 | — | 27.50 | 72 50 | — | — | 7.915 | " | " |
| 134 | — | 25.00 | 75.00 | — | — | 7.813 | Bluish-white | " |

*Copper and Tin.*—Continued.

| Number. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston). | Hardness (Mallet and Calvert and Johnson). | Order of malleability (Mallet). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 97 | — | — | — | — | — | — | — | — | W. | Hard, uniform. |
| 98 | 1,017 | — | — | — | — | — | — | — | Mus | |
| 99 | 2,201 | — | 0.002 | — | — | — | — | — | U. S. B. | |
| 100 | 1,561 | — | 0.001 | — | — | — | — | — | U. S. B. | |
| 101 | — | — | — | Broke | — | — | 49.4 | — | C. J. | |
| 102 | — | — | — | — | — | — | — | — | Ri. | |
| 103 | 688 | — | 0.003 | — | — | — | — | — | U. S. B. | Greatest density, weakest. |
| 104 | 1,120 | 0 | — | 7 | 16 | 8 | — | — | Ml. | |
| 105 | — | — | — | — | — | — | — | — | Bo. | White bell-metal. |
| 106 | 1,377 | — | 0.001 | — | — | — | — | — | U. S. B. | |
| 107 | 1,455 | — | 0.003 | — | — | — | — | — | U. S. B. | |
| 108 | — | — | 0.001 | — | — | — | — | — | U. S. B. | Weakest under transverse stress. |
| 109 | — | — | — | — | — | — | — | — | Ri. | |
| 110 | — | — | — | — | — | — | — | — | Cr. | |
| 111 | — | — | — | Broke | — | — | 42.8 | — | C. J. | |
| 112 | 2,555 | — | 0.003 | — | — | — | — | — | U. S. B. | Remarkable for liquation. |
| 113 | 3,808 | 0 | — | 9 | 15 | 7 | — | — | Ml. | |
| 114 | 725 | — | — | — | — | — | — | — | Mus. | |
| 115 | — | — | — | — | — | — | — | — | W. | Very slightly malleable. |
| 116 | 1,525 | — | 0.003 | — | — | — | — | — | U. S. B. | |
| 117 | 2,407 | — | 0.003 | — | — | — | — | — | U. S. B. | |
| 118 | — | — | — | — | — | — | — | — | Ri. | |
| 119 | 3,010 | — | 0.003 | — | — | — | — | — | U. S. B. | |
| 120 | 2,098 | — | 0.006 | — | — | — | — | — | U. S. B. | |
| 121 | 3,910 | — | 0.007 | — | — | — | — | — | U. S. B. | |
| 122 | — | — | — | — | — | — | — | — | Bo. | White bell-metal. |
| 123 | 2,820 | — | 0.005 | — | — | — | — | — | U. S. B. | |
| 124 | 2,400 | — | 0.004 | — | — | — | — | — | U. S. B. | |
| 125 | — | — | — | — | — | — | — | — | Ri. | |
| 126 | — | — | — | Broke | — | — | 41.5 | — | C. J. | |
| 127 | — | — | — | — | — | — | — | — | Cr. | |
| 128 | 3,371 | — | 0.005 | — | — | — | — | — | U. S. B. | |
| 129 | 3,136 | 0 | — | 11 | 9 | 6 | — | — | Ml. | |
| 130 | — | — | — | — | — | — | — | — | W. | Brittle; uniform. |
| 131 | 2,322 | — | 0.014 | — | — | — | — | — | U. S. B. | |
| 132 | 1,648 | — | 0.011 | — | — | — | — | — | T. | |
| 133 | 4,380 | — | 0.018 | — | — | — | — | — | T. | |
| 134 | — | — | — | — | — | — | — | — | W. | |

*Properties of the Alloys of*

| Number. | Atomic formula. | Composition of original mixture. | | Composition by analysis. | | Specific gravity. | Color. | Fracture. |
|---|---|---|---|---|---|---|---|---|
| | | Cu. | Sn. | Cu. | Sn. | | | |
| 135 | $Sn_5Cu_3$ | 24.38 | 75.62 | 23.35 | 76.29 | 7.835 | Grayish-white | Finely crystalline |
| 136 | — | 22.50 | 77.50 | — | — | 7.774 | " | " |
| 137 | — | 21.74 | 78.26 | 21.38 | 77.63 | 7.53 | Whitish | — |
| 138 | $Sn_2Cu$ | 21.21 | 78.79 | — | — | 7.738 | — | — |
| 139 | $Sn_2Cu$ | 21.21 | 78.79 | — | — | 7.74 | — | — |
| 140 | $Sn_2Cu$ | 21.18 | 78.82 | 20.25 | 79.63 | 7.770 | Grayish-white | Crystal |
| 141 | $Sn_2Cu$ | 21.15 | 78.85 | — | — | 7.387 | " | Coarse, crystal |
| 142 | $Sn_5Cu_2$ | 17.68 | 82.32 | — | — | 7.652 | — | — |
| 143 | — | 17.50 | 82.50 | — | — | 7.690 | Grayish-white | Crystal |
| 144 | — | 16.40 | 83.60 | — | — | — | — | — |
| 145 | $Sn_3Cu$ | 15.21 | 84.79 | — | — | 7.53 | — | — |
| 146 | $Sn_3Cu$ | 15.21 | 84.79 | — | — | 7.606 | — | — |
| 147 | $Sn_3Cu$ | 15.19 | 84.81 | 15.08 | 84.62 | 7.657 | Grayish-white | Crystal |
| 148 | $Sn_3Cu$ | 15.17 | 84.83 | — | — | 7.447 | " | Coarsely crystalline |
| 149 | — | 12.50 | 87.50 | — | — | 7.543 | " | Crystal |
| 150 | $Sn_4Cu$ | 11.86 | 88.14 | — | — | 7.558 | — | — |
| 151 | $Sn_4Cu$ | 11.84 | 88.16 | 11.49 | 88.47 | 7.552 | Grayish-white | Crystal |
| 152 | $Sn_4Cu$ | 11.84 | 88.16 | — | — | 7.59 | — | — |
| 153 | $Sn_4Cu$ | 11.82 | 88.18 | — | — | 7.472 | Grayish-white | Coarsely crystalline |
| 154 | $Sn_5Cu$ | 9.73 | 90.27 | — | — | 7.517 | — | — |
| 155 | $Sn_5Cu$ | 9.73 | 90.27 | — | — | 7.52 | — | — |
| 156 | $Sn_5Cu$ | 9.70 | 90.30 | 8.57 | 91.39 | 7.487 | Grayish-white | Granular |
| 157 | $Sn_5Cu$ | 9.68 | 90.32 | — | — | 7.442 | " | Earthy |
| 158 | — | 9.09 | 90.91 | — | — | 7.472 | — | — |
| 159 | — | 7.50 | 92.50 | — | — | 7.417 | Grayish-white | Granular |
| 160 | — | 6.43 | 93.57 | — | — | — | — | — |
| 161 | $Sn_{12}Cu$ | 4.29 | 95.71 | 3.72 | 96.31 | 7.360 | Grayish-white | Granular |
| 162 | — | 2.50 | 97.50 | — | — | 7.342 | " | Fibrous |
| 163 | $Sn_{48}Cu$ | 1.11 | 98.89 | 0.74 | 99.02 | 7.305 | " | " |
| 164 | $Sn_{96}Cu$ | 0.56 | 99.44 | 0.32 | 99.46 | 7.299 | " | " |
| 165 | Sn | 0 | 100.00 | — | — | 7.293 | " | " |
| 166 | — | 0 | 100.00 | — | — | 7.291 | White | " |
| 167 | — | 0 | 100.00 | — | — | 7.297 | — | — |
| 168 | — | 0 | 100.00 | — | — | 7.294 | — | — |
| 169 | — | 0 | 100.00 | — | — | 7.305 | — | — |
| 170 | — | 0 | 100.00 | — | — | — | — | — |
| 171 | — | 0 | 100.00 | — | — | — | — | — |

*Copper and Tin.*—Concluded.

| Number. | Tenacity, pounds per square inch. | Order of ductility (Mallet). | Relative ductility (Thurston). | Hardness (Mallet and Calvert and Johnson). | Order of malleability (Mallet). | Order of fusibility (Mallet). | Conductivity for heat, silver = 100. | Conductivity for electricity, silver = 100. | Authority. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 135 | 6,775 | — | 0.03 | — | — | — | — | — | T. | |
| 136 | 5,000 | — | 0.12 | — | — | — | — | — | T. | |
| 137 | — | — | — | — | — | — | — | — | W. | Yellow, greenish-white, shining. |
| 138 | — | — | — | 135.42 | — | — | 43.1 | — | C. J. | |
| 139 | — | — | — | — | — | — | — | — | Ri. | |
| 140 | 4,337 | — | 0.06 | — | — | | — | — | T. | |
| 141 | 8,736 | 0 | — | 12 | 8 | 5 | — | — | Ml. | |
| 142 | — | — | — | — | — | — | — | — | Cr. | |
| 143 | 2,816 | — | 0.20 | — | — | — | — | — | T. | |
| 144 | — | — | — | — | — | — | — | 12.76 | Ma. | |
| 145 | — | — | — | — | — | — | — | — | Ri. | |
| 146 | — | — | — | 104.17 | — | — | 42.3 | — | C. J. | |
| 147 | 6,520 | — | 0.92 | — | — | — | — | — | T. | |
| 148 | 6,944 | 0 | — | 13 | 15 | 4 | — | — | Ml. | |
| 149 | 3,798 | — | 4.71 | — | — | — | — | — | T. | |
| 150 | — | — | — | 95.81 | — | — | 40.6 | — | C. J. | |
| 151 | 6,380 | — | 7.08 | — | — | — | — | — | T. | |
| 152 | — | — | — | — | — | — | — | — | Ri. | |
| 153 | 6,944 | 8 | — | 14 | 4 | 3 | — | — | Ml. | |
| 154 | — | — | — | 83.33 | — | — | 39.6 | — | C. J. | |
| 155 | — | — | — | — | — | — | — | — | Ri. | |
| 156 | 6,450 | — | 23.47 | — | — | — | — | — | T. | |
| 157 | 3,360 | 6 | — | 15 | 3 | 2 | — | — | Ml. | |
| 158 | — | — | — | — | — | — | — | — | W. | Slightly malleable. |
| 159 | 6,096 | — | 40.06 | — | — | — | — | — | U. S. B. | |
| 160 | — | — | — | — | — | — | — | 12.03 | Ma. | |
| 161 | 4,780 | — | 56.77 | — | — | — | — | — | U. S. B. | |
| 162 | 5,600 | — | 121.9 | — | — | — | — | — | U. S. B | |
| 163 | 3,650 | — | 133.9 | — | — | — | — | — | U. S. B. | |
| 164 | 4.475 | — | 208.8 | — | — | — | — | — | U. S. B. | |
| 165 | 3,500 | — | 219.8 | — | — | — | — | — | U. S. B. | |
| 166 | 6.040 | 7 | — | 16 | 1 | 1 | — | — | Ml. | |
| 167 | 2,122 | — | — | — | — | — | — | — | Wa. | |
| 168 | — | — | — | — | — | — | — | 11 45 | Ma. | |
| 169 | — | — | — | — | — | — | — | — | Cr. | |
| 170 | — | — | — | 27 | — | — | 42.2 | — | C. J. | |
| 171 | — | — | — | — | — | — | 15.2 | 17.0 | We. | |

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*Note on the table.*—In the preceding table the figures of order of ductility, hardness, and fusibility are taken from Mallet's experiments on a series of 16 alloys, the figure 1 representing the maximum and 16 the minimum of the property. The ductility of the brittle metals is represented by Mallet as 0.

The relative ductility given in the table of the alloys experimented on by the U. S. Board is the proportionate extension of the exterior fibres of the pieces tested by torsion as determined by the autograph strain diagrams.

It will be seen that the order of ductility differs widely from that given by Mallet.

The figures of relative hardness, on the authority of Calvert and Johnson, are those obtained by them by means of an indenting tool. The figures are on a scale in which cast-iron is rated at 1000. The word "broke" in this column indicates the fact that the alloy opposite which it occurs broke under the indenting tool, showing that the relative hardness could not be measured, but was considerably greater than that of cast-iron.

The figures of specific gravity show a fair agreement among the several authorities in the alloys containing more than 35 per cent. of tin, except those given by Mallet, which are in general very much lower than those by all the other authorities. In the alloys containing less than 35 per cent. of tin there is a wide variation among all the different authorities, Mallet's figures, however, being generally lower than the others. Several of the figures of specific gravity have been selected from Riche's results of experiments on the effects of annealing, tempering, and compression, which show that the latter especially tends to increase the specific gravity of all the alloys containing less than 20 per cent. tin to about 8.95. This result is due merely to the closing up of the blow-holes, thus diminishing the porosity. The specific gravity of 8.953 was obtained by Major Wade by casting a small bar in a cold iron mould from the same metal which gave a specific gravity of only 8.313 when cast in the form of a small bar in a clay mould. The former result is exceptionally high, and indicates the probability that every circumstance of the melting, pouring, casting, and cooling was favorable to the exclusion of the gas which forms blow-holes and to the formation of a perfectly compact metal.

The figures of tenacity given by Mallet, Muschenbroek, and Wade agree with those found in the experiments as closely as could be expected from the very variable strengths of alloys of the same composition which have been found by all experimenters.

Mallet's figure for copper, 24.6 tons or 55,104 pounds, is certainly much too high for cast copper; the piece which he tested was probably rolled or perhaps drawn into wire. Haswell's Pocket Book gives the following as the tensile strength of copper; the names of the authorities are not given :—

| | Pounds per square inch. |
|---|---|
| Copper, wrought | 34,000 |
| Copper, rolled | 36,000 |
| Copper, cast (American) | 24,250 |
| Copper, wire | 61,200 |
| Copper, bolt | 36,800 |

The strength of gun-bronze, as found in the guns, is not given in the table, which is designed to compare the various authorities on the tenacities of the alloys only as cast under ordinary conditions, and not when compressed, rolled, or cast under pressure.

# XXIII.

## NICKEL ALLOYS.

*Nickel and copper.*—Nickel and copper unite in a wide range of proportions, the color of the alloys varying from copper-red to the blue-white of the nickel, according to the proportions of the respective metals. With a content of 0.10 per cent. of nickel the alloy is very ductile, of a light copper-red color, and moderate strength; with 0.15 per cent. the ductility is still considerable, while the color changes to a very pale red; a content of 0.25 per cent. of nickel gives a nearly white alloy, and 0.30 per cent. a silver-white metal. The beautiful white color and considerable hardness acquired by copper by an addition of nickel make the alloy especially suitable for coinage, and it is used for this purpose in Switzerland, Belgium, and the United States. Both the Belgian and United States coins now contain copper 75, nickel 25.

The use of alloys consisting of copper and nickel alone is limited, those consisting of copper, nickel, and zinc being more frequently employed. C. Morfit prepares a beautiful alloy of nickel and copper by mixing 33 parts of nickel and 34 parts of copper with some borax, and fusing in a graphite crucible. To the melted mass he adds with constant stirring 33 parts more of copper, and casts the resulting alloy in small sticks.

*Berthier's* alloy consists of copper 0.682 part, nickel 0.318. It is fusible, ductile, strong, bluish-white, slightly magnetic, and somewhat crystalline near the surface.

*Nickel, copper, and zinc alloys.*—These alloys form the mixtures of metals known as German silver, packfong, *argent neuf*, etc. They may in a measure be considered as brass, which, by an addition of nickel, has acquired a white color and considerable hardness.

Generally speaking, German silver is superior to brass as regards hardness, strength, and power of resisting chemical influences, the latter property making it especially valuable for certain purposes. In respect to its preparation it is, however, a very subtle mixture, and exceedingly small quantities of foreign metals exert a considerable influence upon the physical properties of the alloy.

A content of arsenic is most injurious in this respect. Even a very small percentage of it renders the alloy so brittle that it can scarcely be worked, and turns it in a short time into a brownish color.

The greater portion of nickel is at present obtained from an ore known as copper nickel or arsenical nickel and from certain cobalt ores. Both ores, however, always contain considerable quantities of arsenic, which it is impossible to remove entirely by the ordinary mode of smelting. This content of arsenic prevented for a long time the general introduction of nickel alloys in practice, and it became necessary entirely to abandon the method of preparing nickel by the dry method. It is now prepared by the wet method in order to obtain protoxide of nickel entirely free from arsenic. This protoxide is then made into small cubes with starch-paste and heated at a very high temperature. By this treatment it is reduced to metal, the pure nickel remaining behind in the form of a quite dense metallic sponge, which is, however, not fused, but simply slagged, nickel belonging to the metals very difficult to fuse. It may here be mentioned that for making alloys, it is really better to have the nickel, not as a compact fused mass, but in the form of a sponge, the latter combining with greater ease with the other metals.

Nickel ores are also reduced by fluxing with chalk and fluospar if arseniated, or by roasting and then reducing with charcoal and sulphur to the state of sulphide, and then by double decomposition with carbonate of soda obtaining the carbonate, which is finally reduced with charcoal.

Nickel and cobalt are closely allied as regards their chemical properties and frequently occur together, so that the nickel found in commerce often contains a considerable quantity of cobalt, which passes into the alloy without, however, exerting an injurious influence. The same may be said of iron, also chemically closely allied to nickel, a content of it even increasing the tenacity and hardness of the nickel alloys and imparting to them a whiter color. But, on the other hand, it makes them more difficult to work and renders them somewhat brittle. The genuine packfong, the original nickel alloy introduced from China, contains sometimes as much as three per cent. of iron. European manufacturers also frequently add a small quantity of iron to German silver, if a high degree of hardness is required for certain purposes.

Some skill is, however, required to effect an actual combination of the alloy with the iron. By adding the iron directly to the fused alloy it does not combine with it, and forms upon the surface of the fused mass a layer consisting of copper, nickel, and the added iron. An alloy of iron and copper dissolves, however, readily in the German silver, and an intimate union of all the metals can be easily effected by melting together equal portions of copper and steel and adding pieces of this alloy to the fused German silver.

An addition of silver to German silver does not affect its properties injuriously, nor an addition of a few per cent. of lead, which makes the alloy more fusible, somewhat cheaper, and improves its color. It is, however, remarkable that only a very small addition of lead renders the alloy quite brittle.

By an addition of tin German silver acquires considerable hardness and a beautiful sound. An alloy of this kind containing a suitable quantity of tin could be used as speculum-metal and bell-metal. But the previously given compositions for these purposes being very suitable and much cheaper, tin alloys containing nickel are not used in practice.

As regards the properties of nickel alloys they may be summed up as follows: The color of the mixture is always white, the degree of whiteness depending on the quantity of the separate metals used in the respective composition. The most beautiful color is shown by an alloy of 4 parts of copper and 3 of nickel, but unfortunately this alloy is scarcely available for practical purposes, it being extremely difficult to fuse, and so hard that it can scarcely be worked. An alloy containing 75 parts of copper and 25 of nickel does no longer show a pure white color, but one with a yellowish tinge, which is clearly perceptible by holding a polished piece of such an alloy alongside a piece of silver. Hence the better qualities of German silver must in all cases contain more than one-fourth of nickel. In using a small quantity of nickel it has been attempted to remove the yellowish color by an addition of silver; but without success. The Swiss coins are made of such an alloy, and, as is well known, show a decidedly yellowish cast.

In most factories the articles made of German silver are plated with silver by the electric current and exhibit the color of chemically pure silver, which they retain for a shorter or longer time according to the thickness of the deposit.

The mechanical manipulation of German silver is attended with some difficulties, the plates, which for the purpose of preparing sheet must be obtained by casting, being strongly crystalline and readily cracking under the hammer.

Generally small plates about 7¾ to 12 inches long, 4¾ to 7¾ inches wide, and ⅓ inch thick are prepared by casting. These plates are slightly rolled and hammered, being annealed after each mechanical manipulation. By this treatment they gradually lose the crystalline structure, and when this has entirely disappeared can be further worked with ease, and rolled and stamped into any desired form, most articles (spoons, forks, etc.) being prepared by the latter method. Like alloys of the precious metals German silver has the property of retaining its metallic color and lustre on being brought in contact with air and water, and it is not affected even by dilute acids such as are frequently found in food (lactic acid, acetic acid, etc.).

Nickel alloys possessing strong electric properties are used in the manufacture of positive elements for thermo-electric piles; they are especially adapted for the purpose on account of their high melting point. A thermo-electric pile, one portion of which consists of a nickel alloy, can be heated to a strong red heat without fear of the alloy melting.

*German silver or argentan.*—Alloys of nickel, copper, and zinc are recognized in commerce under all sorts of names, but in order to avoid confusion we will retain the term German silver or argentan, which is most in use. Factories which produce this alloy are found in almost all large cities, though Germany and England are the chief seats of the industry. The composition of the alloys used by the various factories differs considerably, as may be seen from the following figures:—

| | |
|---|---|
| Copper | 50 to 66 parts. |
| Zinc | 19 " 31 " |
| Nickel | 13 " 18 " |

For the fabrication of spoons, forks, cups, candlesticks, etc., alloys consisting of copper 50 parts, nickel 25, and zinc 25 are most suitable, as they show a beautiful white blue color which does not tarnish.

German silver is sometimes so brittle that a spoon allowed to fall upon the floor will break; this fragility is due, of course, to an incorrect composition. It is impossible to give a definite composition for German silver, inasmuch as it varies according to the manipulation the article manufactured from the alloy is to undergo. The following table of analyses of different kinds of German silver shows how the qualities of the alloys change with the percentage of metals contained in them. Immaterial admixtures of foreign metals have been omitted in the compilation, only those belonging to the composition of the alloy being given:—

| German silver. | Parts. | | | Quality. |
|---|---|---|---|---|
| | Copper. | Zinc. | Nickel. | |
| English . . . . | 8 | 3.5 | 4 | finest quality. |
| " . . . . | 8 | 3.5 | 6 | very beautiful, but very refractory. |
| " . . . . | 8 | 6.5 | 3 | ordinary, readily fusible. |
| German . . . . | 52 | 26 | 22 | prime quality. |
| " . . . . | 59 | 30 | 11 | second " |
| " . . . . | 63 | 31 | 6 | third " |

The following analyses give interesting particulars concerning various kinds of alloys for German silver:—

| German silver. | Parts. | | | | |
|---|---|---|---|---|---|
| | Copper. | Zinc. | Nickel. | Lead. | Iron. |
| French for sheet | 50 | 31.3 | 18.7 | — | — |
| | 50 | 30 | 20 | — | — |
| | 58.3 | 25 | 16.7 | — | — |
| Vienna | 50 | 25 | 25 | — | — |
| | 55.6 | 22 | 22 | — | — |
| | 60 | 20 | 20 | — | — |
| Berlin | 54 | 28 | 18 | — | — |
| | 55.5 | 29.1 | 17.5 | — | — |
| English | 63.34 | 17.01 | 19.13 | — | — |
| | 62.40 | 22.15 | 15.05 | — | — |
| | 62.63 | 26.05 | 10.85 | — | — |
| | 57.40 | 25 | 13 | — | 3.00 |
| Chinese | 26.3 | 36.8 | 36.8 | — | — |
| | 43.8 | 40.6 | 15.6 | — | — |
| | 45.7 | 36.9 | 17.9 | — | — |
| | 40.4 | 25.4 | 31.6 | — | 2.60 |
| For casting | 48.5 | 24.3 | 24.3 | 2.9 | — |
| | 54.5 | 21.8 | 21.8 | 1.9 | — |
| | 58.3 | 19.4 | 19.4 | 2.9 | — |
| | 57.8 | 27.1 | 14.3 | 0.8 | — |
| | 57.0 | 20.0 | 20.0 | 3.0 | — |
| Sheffield— | | | | | |
| Common (yellow) | 59.30 | 25.90 | 14.80 | — | — |
| Silver-white | 55.20 | 24.10 | 20.70 | — | — |
| Electrum (bluish) | 51.60 | 22.60 | 25.80 | — | — |
| Hard (can be worked cold) | 45.70 | 20.00 | 31.30 | — | — |
| Fricke's— | | | | | |
| Bluish-yellow (hard) | 55.50 | 39.00 | 5.50 | — | — |
| Pale yellow (ductile) | 62.50 | 31.20 | 6.30 | — | — |
| Silvery (hard) | 50.00 | 18.80 | 31.20 | — | — |
| " (harder) | 59.00 | 30.00 | 10.00 | — | — |
| Common formula | 55.00 | 25.00 | 20.00 | — | — |

Many varieties of German silver contain different quantities of iron, manganese, tin, or very frequently lead to change the qualities of the alloy or to cheapen it. All these additions, however, exert rather an injurious than beneficial influence, and especially lessen the power of resistance against the action of dilute acids, which is one of the most valuable properties of this alloy.

An addition of lead makes German silver more fusible; one of tin acts in a certain sense as in bronze, making the alloy denser and more sonorous, and causing it to take a better polish. An addition of iron or manganese increases the white color of the alloy, but it becomes at the same time more refractory and inclines towards brittleness.

## XXIV.

## MANUFACTURE OF GERMAN SILVER ON A LARGE SCALE.

In the manufacture of German silver, the purity of the metals used is of greater importance than in the preparation of any of the alloys previously described. The nickel found at present in commerce is generally sufficiently pure to be used without further preparation, the chief contamination being cobalt, which, as previously mentioned, exerts little influence upon the properties of the alloy. Copper is frequently contaminated with iron, lead, arsenic, and antimony, and, in such case, is only fit for the preparation of German silver of second or third quality. Zinc also contains certain contaminations injurious to the qualities of the alloy.

In consideration of the great influence the contaminations of the metals exerts upon the properties of German silver, great care must be exercised in buying the metals, as it is advisable to subject them to a chemical analysis. But, notwithstanding that such an analysis is inexpensive at the present time, many manufacturers still prefer the empirical method of preparing small samples of the alloy from the metals to be used, and, by subjecting them to certain tests, judge as to the availability of the respective metals. The conclusions drawn from such tests are, however, frequently unreliable.

The test is generally executed by alloying the metals in the proportions in which they are to be used and casting the test-alloy into thin and flat sticks. These sticks are then fastened in a vise, and the projecting end is quickly bent by pounding with a hammer, the place where the stick is held by the vise being carefully observed, as in nearly all cases it breaks there first. If a stick can be bent backward and forward several times without breaking, it is a proof of the good quality of the metals, and the alloy composed of them can be subjected to every mechanical manipulation. The presence of foreign metals is indicated by the breaking of the stick if bent but once, and if the breaking takes place at any other than a right angle the metals are not available for the finer qualities of German silver.

Manufacturers are generally of the opinion that in this case the nickel is of pure quality, but this opinion is correct only when based upon the assumption that pure copper and zinc have been used in the preparation of the test-alloy.

The manufacture of German silver is generally carried on according to two methods, which, from the countries where they have been perfected, are termed the *German* and the *English* process. Both yield German silver of excellent quality, and, as will be seen from the descriptions of the two methods, differ chiefly in the manner in which the various operations in melting down the alloys are executed.

*German process.*—The alloy is prepared in the following manner: The zinc and nickel to be used for a certain quantity of copper are divided into three equal portions. Now place upon the bottom of a graphite crucible, capable of holding at the utmost 22 pounds of the alloy, a layer of copper, upon this a layer of zinc and nickel, upon this again a layer of copper, and continue in this manner until all the copper is in the crucible, retaining, however, one-third each of the nickel and zinc.

The crucible is now covered with a layer of charcoal powder to prevent volatilization and oxidation of zinc, and the contents melted down as quickly as possible in a wind-furnace connected with a high chimney, quite a high temperature being required for the fusion of the alloy.

When the contents of the crucible are supposed to be liquefied, they are examined by dipping in an iron rod, and, if the whole is found to be thoroughly melted, an intimate mixture of the metals is effected by vigorous stirring with the rod.

The zinc and nickel retained are now added in portions to the melted contents of the crucible, the mass being vigorously stirred after each addition, and a sharp fire kept up to prevent the alloy from cooling off too much by the newly introduced metals. After the introduction of the last portion, an additional piece of zinc is generally thrown into the crucible to compensate for the loss of zinc by volatilization, and besides experience has shown that a small excess of zinc renders the alloy more thinly fluid, which materially facilitates the work in the subsequent casting. If the alloy is to be rolled out into thin sheets, it is recommended to keep the finished alloy liquid for some time longer before proceeding to casting. In doing this, however, it is necessary constantly to keep the surface of the melted metal covered with charcoal to prevent volatilization of zinc.

The casting of the alloy is effected in various ways. It is either at once cast into plates, which are subsequently rolled out into sheets, or into very thin sticks, which after cooling are remelted and finally cast into plates. On account of the greater consumption of fuel and labor, the last method is somewhat more expensive than direct casting, but it has the advantage of the alloy becoming more homogeneous by remelting, and besides it can be worked with greater ease. Only with the use of very pure metals is it advisable to cast the alloy at once into plates.

Considerable skill is required for casting the alloy, it being necessary to run it into the moulds at as high a temperature as possible and in an uninterrupted stream. An interruption of the stream can be at once detected by the fact that the plate is not uniform.

The moulds used in casting plates consist of two iron plates, one smooth and the other with a ledge corresponding to the thickness of the plate to be cast, which varies from 0.50 to 0.59 inch. On account of the great contraction of the alloy in solidifying, the distance between the two plates must be somewhat greater. In order to obtain castings of greater homogeneousness, it is recommended to run the melted metals from below into the moulds. This is effected by providing the lower plate with a lip or mouth-piece, in which is placed a clay-funnel connected with a pipe rising somewhat above the mould. After the plates are tightly screwed together, the mould is highly heated and the casting proceeded with. The metal is heated as intensely as possible, and after being freed from all contaminations floating on the surface, is allowed to run in a steady, thin stream into the mould. When the metal appears on the upper end of the mould and the funnel remains filled, the casting is finished. After allowing the filled mould to stand quietly for about half an hour the solidified plate is removed. To prevent the alloy from adhering to the sides of the mould, these are previously to casting coated with a layer of fine lamp-black. The principal difficulty in casting plates of German silver is to obtain them perfectly homogeneous and free from blow-holes, which is best effected by bringing the melted metal as hot as possible into the mould. On account of the difficulty of executing the casting so quickly that the contents of the crucible do not cool off, it is recommended to fill only one mould at a time, and replace the crucible in the furnace in order to keep the contents at the highest temperature possible.

The plates of German silver thus obtained have to be carefully examined as to whether they are perfectly homogeneous. Imperfect plates must be thrown out and remelted. The perfect plates are rolled out into sheets from which the articles to be manufactured are punched out and then further worked.

*English process.*—The English method of preparing the alloy differs somewhat from the German, especially in the manner in which the metals are melted together, no portion of the zinc or nickel being retained, but the entire quantity of metal is melted at one time. Good graphite crucibles are used, which are placed in a furnace capable of producing a high temperature. The metals are used in the form of small pieces. The charge of each crucible generally consists of 8¼ pounds of tin, ½ pound of zinc, and, according to the quality of the alloy to be produced, 2 to 3 pounds of nickel. The metals are intimately mixed and quickly introduced into the red-hot crucibles. Their surface is immediately covered with a thick layer of coal-dust and the mixture fused as quickly as possible. After ascertaining by stirring with an iron rod that the mass is liquefied, a previously prepared alloy of 1 part by weight of zinc and ½ part of copper is added, the quantity for the above charge varying between 1⅗ and 2 pounds. When this alloy is melted and the entire contents of the crucible forms a homogeneous whole, 2 pounds of zinc are finally added. The mass being kept constantly covered with coal-dust is now heated as strongly as possible, and when thinly fluid a sample is taken to test its qualities.

The alloy always contains a certain amount of oxide, and, if a large quantity of it is present, the casting will be badly blown. To ascertain how the alloy will act in casting, a test casting is made, and, if the fracture of this shows blow-holes, the oxides will have to be reduced. This is effected by throwing pitch into a stoneware pipe pushed through the contents of the crucible to the bottom. The products of dry distillation evolved from the pitch effect a reduction of the oxides, which is accelerated by stirring coal dust into the melted metal. When the reduction of oxides is supposed to be finished, a strong heat is given, and, after the coal mechanically mixed with the alloy has collected upon the surface, the purified metal is cast in manner similar to that described under the German process. Instead of coating the moulds with lamp-black alone, many manufacturers use a mixture of lamp-black and oil of turpentine. Moulds thus treated must, however, be sharply dried to volatilize the oil of turpentine, as otherwise the vapors evolved from the oil of turpentine in casting might readily cause the formation of blow-holes.

The casting of the plates finishes the chemical portion of the process, and the perfect plates are mechanically worked in the same manner as indicated under the German process. Articles of German silver have to be soldered with a solder whose color approaches as nearly as possible that of the alloy. An excellent composition for this purpose is prepared by melting 5 to 6 parts of German silver together with 4 parts of zinc. It is, however, better directly to prepare the alloy which is to serve as solder by melting together copper 35 parts, zinc 57, and nickel 8.

The alloy is prepared in the same manner as German silver, and after being cast in thin plates pulverized while hot. If the alloy is too tough and can only be pulverized with difficulty it contains too little zinc, while too great brittleness indicates too small a quantity of nickel. In both cases the alloy must be improved by remelting and adding the necessary quantity of the respective metals.

The alloys of German silver are principally used for the manufacture of tableware, as cups, dishes, forks, spoons, etc., but on account of their beautiful color and solidity, they are also used for articles of art, and are more and more substituted for genuine silver. For fine mechanical work German silver surpasses all other alloys, it having, besides considerable strength and power of resistance, the valuable property of not changing its appearance in contact with dry air and of expanding but little on heating.

*Alfénide, Argiroide, and allied alloys.*—The alloys brought into commerce under these and many other names consist in most cases of a mixture of metals closely resembling German silver, but they are always plated with pure silver by the galvanic current, the thickness of the plating depending on the price of the respective articles. In many cases the composition used in the manufacture of these articles is a very ordinary quality of German silver, which by itself would present a mean appearance, but is hid from the buyer by the silver plating.

In modern times alloys have been frequently recommended which differ from the actual nickel alloys as represented by German silver in containing tin and aluminium, which makes them more fusible and more easily worked than German silver. Thus far these alloys have not been generally introduced in practice, and besides they are dearer than German silver.

We give in the following several alloys recommended as substitutes for German silver.

*Alfénide.*—According to Rochet, this alloy is composed of 59.1 parts of copper, 30.2 of zinc, 9.7 of nickel, and 1.0 of iron. According to this, it is actually nothing but an ordinary quality of German silver. It is said to be well adapted for electro-silver plating spoons, forks, and other articles with a smooth surface, but it does not succeed so well for decorated pieces.

*Toucas's alloy* is composed of copper 5 parts, nickel 4, antimony, tin, lead, zinc, and iron, of each 1. The metals are melted together in a crucible. This alloy has the advantage of being complex, if it does not possess other qualities than similar compounds. According to the inventor, it has nearly the color of silver, may be worked like it, and is laminated by the ordinary processes. It is resisting, malleable, susceptible of a fine polish, with a lustre of platinum, and can be perfectly silvered. For objects which are to be spun, hammered, or chased the above alloy is very convenient, but for cast and adjusted pieces it is preferable to increase the proportion of zinc in order to increase the fluidity of the metal. This compound is employed for ornaments, jewelry, etc.

According to Trabuk, of Nimes, a beautiful white alloy, which resists the action of vegetable acids, and may serve as a substitute for German silver, is obtained by melting together 875 parts of tin, 55 of nickel, 50 of antimony, and 20 of bismuth. Into a crucible of suitable size introduce first $\frac{1}{3}$ of the tin and all the nickel, antimony, and bismuth, and after covering these metals with the second $\frac{1}{3}$ of tin, cover the whole with a layer of charcoal powder to prevent oxidation. The lid is then placed upon the crucible and the latter heated to a bright red heat. After ascertaining by stirring with a red hot iron rod that all the nickel is fused, the last third of tin is added, without, however, removing the layer of charcoal; the mass is then stirred until it is perfectly homogeneous, and cast into ingots.

## XXV.

### ALLOYS OF TIN, WITH LITTLE COPPER AND ADDITIONS OF ANTIMONY, ETC.

Tin by itself is a very soft metal, and in a pure state finds but little application in the industries, but in the form of alloys its use is constantly increasing. These alloys show different properties according to the metals with which the tin is combined, and form one of the most important and valuable groups, as they include metal for bearings, type-metal, britannia metal, etc.

The tin alloys most frequently used contain copper, zinc, or antimony; others less frequently employed contain iron or lead, and some for special purposes bismuth.

The effect produced by the different metals upon the properties of the tin varies very much, but, generally speaking, it may be said, that the melting point is raised, while the great ductility of the tin is decreased, but its hardness and resisting power are very much increased.

An addition of copper makes the tin considerably harder, the properties of the alloys thus formed approaching those of genuine bronze. Alloys containing, besides tin and copper, certain quantities of zinc, possess the same constituents as brass, and it depends on the quantity of the metals whether the properties of the alloy actually approach those of brass, or whether they have a more bronze-like character.

Antimony possessing the special property of hardening soft metals, the tin and antimony alloys always show a certain degree of hardness, but unfortunately become also so brittle that they can only be used for castings, as stretching them under the hammer or by rolling is very difficult and frequently impossible.

Alloys of tin and lead were formerly much used in the manufacture of pots, dishes, plates, etc., but at the present time their application is limited. Alloys of tin with bismuth and other metals are distinguished by a very low melting point, frequently below that of boiling water; such alloys are only used for special purposes.

The most important alloys of tin are those known as white metal and britannia metal. In a certain sense a few other alloys might be classed among the tin alloys, but as the other metals are present in a preponderating quantity, it seems more suitable to discuss them under the name of the metal present in largest quantity, or which at least imparts to the alloy its characteristic properties.

*White metals.*—The so-called white metals contain varying quantities of tin, copper, and antimony. Sometimes the latter is replaced by zinc, the composition in this case approaching more or less that of statuary bronze. A simultaneous use of zinc and antimony occurs but seldom; there are further some alloys which contain iron or lead besides the mentioned metals. A combination of many metals to one and the same alloy does not seem especially practical, since our knowledge of the alloys has scarcely reached such a point as to enable us to determine with absolute certainty how three metals in various proportions of mixture behave towards each other, and we are still less able to state with accuracy the behavior of alloys in the preparation of which four, five, or even six metals are used. Besides practical experience has shown such alloys to be frequently of no value, and are simply recommended by some persons in order to make a market for a new product.

The so-called white metals serve almost exclusively for bearings, some compositions used for the same purpose having been already given on page 142 *et seq.* In mechanics a very exact line is drawn between the various kinds of bearings, and they can be chiefly divided into two large groups: red-brass bearings and white-metal bearings. The red-brass bearings are distinguished by great hardness and power of resistance, and are principally used for bearings of heavily loaded and rapidly revolving axles. For bearings of axles of large, heavy fly-wheels revolving at great speed bearings of red brass are also preferable to white metal, though they are more expensive.

White metals are cheaper than red-brass alloys and have a lower melting point, so that a worn-out bearing can be readily remelted and replaced by a new one, while with red brass these operations are connected with much more trouble and expense. White-metal bearings possess still another property which makes them almost indispensable for certain purposes. If, for instance, the shaft resting in the bearing does not run perfectly quietly, the consequence of the use of a red-brass bearing will be that either the axle or the bearing, according to whether the one is harder than the other, is subjected to great wear, and this will in a short time increase to such an extent that the axle in revolving will swerve considerably. By using, however, for these purposes white-metal bearings of a sufficient degree of softness, the harder axle by pressing into the softer bearing runs more quietly for a longer time than if the latter consists of red-brass. The bearing, of course, wears out as quickly, but this is of little importance since the expense of replacing it is comparatively small.

White-metal bearings contain a preponderating quantity of tin; the degree of hardness of such alloys depends chiefly on the content of copper, those containing certain quantities of it being, as a rule, the strongest and most capable of resistance. The tin can, however, be also considerably hardened by the use of antimony, and such bearings are frequently used at the present time, they being much cheaper than those containing copper, though they are not so strong and generally quite brittle, so that they frequently break.

In the annexed table will be found the compositions of the more frequently used compounds for bearings. From the many receipts given those have been selected which differ in regard to hardness and wear. As will be seen, iron is only used in rare cases, and the compositions containing lead find but little application, experience having shown that the strength of the alloy is considerably decreased by an addition of lead.

In modern times bearings of soft metal are frequently replaced by such as consist of a metal whose hardness is almost equal to that of which the axle is made, phosphor-bronze being often used for this purpose, as it can be readily obtained so hard as to equal in that respect an axle of wrought or cast-steel. The metal is then used in a very thin layer, and serves, so to say, to fill out the small interspaces formed by wear on the axle and bearing, the latter consisting simply of an alloy of tin and lead. Such bearings, though very durable, are rather expensive, and can only be used for large machines. For small machines bearings of white metal are generally preferred, and, if the axles are not too heavily loaded, do excellent service.

*White metals for bearings.*

| | Parts. | | | | | |
|---|---|---|---|---|---|---|
| | Tin. | Anti-mony. | Zinc. | Iron. | Lead. | Copper. |
| German for light loads | 85 | 10 | — | — | — | 5 |
| " " | 82 | 11 | — | — | — | 7 |
| " " | 80 | 12 | — | — | — | 8 |
| " " | 76 | 17 | — | — | — | 7 |
| " " | 3 | 1 | 5 | — | 3 | 1 |
| " heavy loads | 90 | 8 | — | — | — | 2 |
| " " | 86.81 | 7.62 | — | — | — | 5.57 |
| English for heavy loads | 17.47 | — | 76.14 | — | — | 5.62 |
| " medium loads | 76.7 | 15.5 | — | — | — | 7.8 |
| " " | 72.0 | 26.0 | — | — | — | 2.0 |
| For mills . . . | 15 | — | 40 | — | 42 | 3 |
| " . . . | — | 1 | 5 | — | 5 | — |
| " . . . | — | 1 | 10 | — | 2 | — |
| For heavy axles . . | 72.7 | 18.2 | — | — | — | 9.1 |
| " " . . | 38 | 6 | 47 | — | 4 | 1 |
| For rapidly revolving axles | 17 | 77 | — | — | — | 6 |
| Bearings of great hardness | 5 | — | — | 70 | — | 2.5 |
| " " " | 12 | 82 | 2 | — | — | 4 |
| " (cheap) . . | 2 | 2 | 88 | — | — | 8 |
| " " . . | 1.5 | 1.5 | 90 | — | — | 7 |
| For railroads— | | | | | | |
| Prussia . . . | 91 | 6 | — | — | — | 3 |
| " . . . | 85 | 10 | — | — | — | 5 |
| " . . . | 80 | 12 | — | — | — | 8 |
| Prussian and Hanoverian railroads approved under the heaviest pressure | 86.81 | 7.62 | — | — | — | 5.57 |
| Bavaria, durable cold running . . . | 90 | 8 | — | — | — | 2 |
| Austria government railroad . . . . | 90 | 7 | — | — | — | 3 |
| Distributing slide valves | 83.2 | 11.2 | — | — | — | 5.6 |
| Railroad cars and larger machines . . . | — | 16 | — | — | 84 | — |
| Railroad cars, harder and stronger | 20 | 20 | — | — | 60 | — |
| | — | 12 | — | 8 | 80 | — |

*Babbitt's anti-attrition metal* is made by melting separately 4 parts of copper, 12 of Banca tin, 8 of regulus of antimony, and adding 12 parts of tin after fusion. The antimony is added to the first portion of tin, and the copper is introduced after taking the melting pot away from the fire and before pouring into the mould. The charge is kept from oxidation by a surface coating of powdered charcoal. The "lining metal" consists of this "hardening" fused with twice its weight of tin, thus making 3.7 parts copper, 7.4 parts antimony, and 88.9 tin. The bearing to be lined is cast with a shallow recess to receive the Babbitt metal. The portion to be tinned is washed with alcohol and powdered with sal ammoniac, and those surfaces which are not to receive the lining metal are to be covered with a clay wash. It is then warmed sufficiently to volatilize a part of the sal ammoniac and tinned. The lining is next cast in between a former, which takes the place of the journal, and the bearing.

Founders often prefer to melt the copper first in a plumbago crucible, then to dry the zinc carefully, and immerse the whole in the barely fluid copper.

*Kingston's metal*, formerly much used for bearings, is made by melting 9 parts of copper with 24 of tin, remelting, and adding 108 parts of tin, and finally 9 of mercury.

*Fenton's alloy for axle-boxes for locomotives and wagons* consists of zinc 80 parts, copper 5½, tin 14½. This alloy may be recommended as regards cheapness and lightness. Experiments have shown that boxes of this alloy require but half as much oil for lubricating as others. The components can be melted in an ordinary iron pot, and the alloy is less difficult to work than brass.

*Dewrance's patent bearing for locomotives* consists of copper 4 parts, tin 6, antimony 8. A locomotive of the Liverpool-Manchester railroad ran over 4500 miles without the bearing requiring repair.

*Alloy for anti-friction brasses.*—Zinc 80 parts, tin 14, copper 5, nickel 1.

*Alloy for metal stopcocks which deposits no verdigris.*—Zinc 72 parts, tin 21, copper 7.

*English white metal.*—Tin 53 parts, lead 33, copper 2.4, zinc 1, antimony 10.6. The specific gravity of this alloy is 7.22 and it melts at 290° F.

*A composition of white metal* for machines recommended by Jacoby consists of copper 5 parts, tin 85, and antimony 10.

*Hoyle's patent alloy for pivot bearings* consists of tin 24 parts, lead 22, and antimony 6. It is claimed to stand friction without heating longer than any other composition.

In the factory of H. Roose, of Breslau, the following alloys are used for white metal bearings:—

| | Parts. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Tin | 18 | 18 | — | — |
| Lead | 3 | — | 8 | 8 |
| Copper | 1 | 1 | 1 | — |
| Antimony | — | 3 | 1 | 1 |

# XXVI.

## ALLOYS OF COPPER WITH OTHER METALS.

*Cupro-manganese.*—The alloys of copper with manganese have a beautiful, silvery color, considerable ductility, great hardness and tenacity, and are more fusible than ordinary bronze. They are distinguished by the special property of filling the moulds very exactly and without the formation of blow-holes. These alloys are very suitable for many purposes for which bronze is used and are not more expensive, but the preparation of large quantities of them is rendered difficult by the fact that up to the present time manganese is not prepared on a large scale, so that it becomes necessary for the preparation of alloys first to reduce that metal from its combinations. Moreover, manganese oxidizing more readily than other metals, it is difficult to obtain entirely homogeneous alloys.

This evil has more recently been partially overcome, as a very pure combination of manganese, which is readily reduced to metal, can be prepared with great ease and at a low price. It is well known that chlorine used in bleacheries, paper-mills, etc., is prepared with the assistance of pyrolusite (black ore of manganese). The manganiferous liquid resulting as a by-product is of little value, but pure oxide of manganese can be readily gained from it, which can be used in the preparation of cupro-manganese. It would be most convenient to use pyrolusite, which is the most frequently occurring ore of manganese, for the preparation of cupro-manganese, but as it always contains considerable quantities of foreign metals, which are reduced together with the manganese and enter with it into the alloys, it is evident that it would be very difficult to prepare cupro-manganese answering certain demands.

For preparing the alloy the copper is used in the form of fine grains, obtained by pouring melted copper into cold water. These copper grains are mixed with charcoal and the dry oxide of manganese, and the mixture is introduced into a crucible capable of holding about 66 pounds. The charge is kept from oxidation by a thick surface coating of powdered charcoal. The crucible is placed in a wind-furnace and exposed to a strong white heat, at which the oxide of manganese is completely reduced to manganese, which at once combines to an alloy with the copper. To prevent the access of air to the fusing mass as much as possible, it is advisable to cover the crucible with a lid provided in the centre with an aperture for the escape of the carbonic oxide formed during the reduction.

When the reduction is supposed to be complete and the metals fused, the lid is removed and the contents of the crucible stirred with an iron rod to make the alloy as homogeneous as possible. It is then poured out and rapidly solidifies to a mass resembling in appearance good German silver. As by repeated remelting of the cupro-manganese a considerable quantity of the manganese is reconverted into oxide, it is recommended to cast articles to be prepared from the alloy directly from the crucible in which the reduction has been effected. This is the more important as the crucible is strongly attacked by the cupro-manganese and will stand but a few operations. The most suitable varieties of cupro-manganese are those with a content of manganese varying between 10 and 30 per cent. They have a beautiful white color, are hard, tougher than copper, and can be worked under the hammer as well as by rolls.

Pure cupro-manganese may in many cases be used as a substitute for bronze, especially where great hardness is not especially demanded. It may, however, also be used as an initial point of many alloys containing besides cupro-manganese tin or zinc, which are cheaper than the pure alloy. They must always be prepared by first melting the respective metals under a surface coating of powdered charcoal, heating the fused metal as strongly as possible and introducing the cupro-manganese in small pieces.

Of the alloys prepared with the assistance of cupro-manganese that containing zinc may become of importance in the industry, as its properties nearly resemble those of German silver, and like it is capable of resisting to a considerable extent the influence of chemical agents. Alloys consisting of copper, manganese, and tin resemble in their character metals for bearings and can be advantageously used for that purpose.

Alloys of cupro-manganese especially valuable for technical purposes have the following composition :—

| | Parts. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Copper | 77 | 60 | 65 | 60 |
| Manganese | 25 | 25 | 20 | 20 |
| Zinc | — | 15 | 5 | — |
| Tin | — | — | — | 10 |
| Nickel | — | — | 10 | 10 |

*Alloys of copper and iron.*—These alloys are at the present time but little used in the industries, but it seems that formerly they were frequently prepared for the purpose of imparting considerable hardness to copper. Copper and iron unite in any proportions at high temperatures if the heat is sufficiently prolonged. The alloys possess considerable strength and great hardness, but these qualities are only found in such as have a certain composition; with a constant increase of the content of iron the solidity decreases while the hardness increases. A copper and iron alloy which with considerable strength possesses also great hardness is composed of copper 66 parts, iron 34.

It may here be remarked that the alloys of copper with iron acquire on exposure to the air a disagreeable color shading into black and are therefore not adapted for articles of art.

*Alloys of copper and lead.*—An addition of lead to copper renders it softer and more ductile. Alloys of copper and lead are subject to separation or liquation, the lead separating out and leaving the copper in a porous mass, especially if the alloy is not quickly solidified. In preparing the alloys the copper is melted down under a cover of charcoal dust, the fire is then made as hot as possible and the lead quickly introduced into the overheated copper. As soon as all is melted, stir several times with an iron rod to make the alloy homogeneous and quickly pour the liquid mass into cold metallic moulds. On account of the above-mentioned liquation it is difficult to obtain faultless large castings of these alloys, and hence they are cast into thin plates, which are subsequently rolled out into sheets. The alloy forms a metal of gray color, brittle, and of feeble affinity. An alloy of copper 4 parts and lead 1 is sometimes used for large type.

*Alloys of copper and arsenic.*—Arsenic imparts to copper a very beautiful white color and great hardness and brittleness. Before German silver was known these alloys were sometimes used for the manufacture of cast articles which were not to come in contact with iron. On exposure to the air these alloys retain their white color only for a short time and acquire a brownish tinge. On account of this, as well as the poisonous character of arsenic and the difficulty of working them, these alloys are very little used at the present time.

The alloy is best prepared by pressing a mixture of 70 parts of copper in the form of fine shavings and 30 parts of arsenic into a crucible and melting the mixture under a surface coating of glass in a furnace of good draught.

*Alloys of copper and cobalt.*—These alloys show a red color and a fracture resembling that of pure copper. They are distinguished by great ductility and tenacity, and can be forged and stretched in the heat, but cannot be hardened. They are prepared by melting together copper and cobalt in a crucible under a cover of boric acid and charcoal. An alloy cast in grains, which is attracted by a magnet, is composed of cobalt 48.20 per cent., nickel 1, copper 50.26, and iron 0.46. It is red, while an alloy containing equal proportions of nickel and copper shows a white color. Alloys with 1 to 6 per cent. of cobalt can be as readily forged, stretched, and rolled in the heat as copper, but are considerably tougher. An alloy with 5 per cent. of cobalt shows especially valuable properties; it is non-oxidizable and ductile like copper, elastic and tough like iron, and will no doubt be applied to many purposes.

*Copper and silicon*, with or without tin, may be alloyed to form "silicon bronze." Weiller's alloy is made by the introduction of sodium to reduce silica in the crucible. The inventor recommends the following proportions: fluo-silicate of potash 450 parts by weight, glass in powder 600, chloride of sodium 250, carbonate of soda 75, carbonate of lime 60, and dried chloride of calcium 500. The mixture of these substances is heated in a plumbago retort to a temperature a little below the point when they begin to react on one another, and it is then placed in a copper or bronze bath, when the combination of silicium takes place.

Silicon acts upon copper in almost exactly the same manner that phosphorus does, except that it appears to be a more natural alloy, and a flux or reducing agent to the oxide of copper that is produced when copper is in a melted condition, and it is thereby more active in clarifying, refining, hardening, and strengthening copper and its alloys. In this respect it is more vigorous and pronounced than phosphorus.

The qualities that particularly recommend silicon-bronze are great strength and tenacity, high electrical conductivity, and resistance to corrosion. It is, therefore, logically the best metal extant for electric-light, telephone, and telegraph wire. It can be made stronger than steel and yet may possess two or three times its conductivity.

The early specimens of silicon-bronze wire for telegraph purposes had a conductivity of 97 per cent., and a resistance to rupture of about 28½ tons to the square inch; that for telephone purposes having a conductivity of 32 per cent. and a resistance to rupture of 47½ tons to the square inch.

Quite recently there has been developed a new type of telegraph wire, possessing less conductivity than the former, but having considerably higher tensile strength, which allows the wire to be more tightly strained, while the posts may be placed at a greater distance apart. This new wire has a conductivity of 80 per cent. and a tensile strength varying from 35 to 37 tons to the square inch. At the same time the character of the telephone wire has also been changed, raising its conductivity to 42 per cent. and its tensile strength to 52 tons. These wires are almost exclusively used for telephone lines at Prague, Trieste, Lemberg, and other European cities. The line at Trieste, in particular, has stood the test of violent storms completely, which is due to the small diameter of the conductor. A similar experience has been made at Rheims, where, in one case, a line having a span of more than a thousand feet was exposed to the action of the wind blowing directly across it.

Its power of resisting snow has been equally well established. Thus, on an Austrian railway the engineer at the head of the telegraph department personally examined the wires during a violent storm of damp snow, followed by a sharp frost, at a point where the line crosses hilly ground at a height of about 2000 feet above the sea. The wires were well covered with snow and sagged considerably more than usual. In several instances by shaking the wire the snow was detached, when the conductors immediately assumed their normal deflections after the snow had melted. The Austrian railway company above mentioned has numerous lines on which the distance between posts varies from 328 to 720 feet across flat country; in hilly districts the distance ranges from 160 to 500 feet.

During the last few years the "Italian General Telephone Company" has employed these silicon-bronze wires with spans as large as one thousand feet without any accident having occurred. In Vienna telephone posts are frequently placed at the same distance apart, and carry as many as 78 parallel wires.

# XXVII.

## ALLOYS OF ALUMINIUM AND COPPER.

As stated in the general review of the metals aluminium is distinguished by a beautiful silvery color and great strength; but it is especially valuable on account of its very small specific gravity, which is about that of glass.

Among the alloys of aluminium that with copper is of special importance, but before entering on a description of it we will briefly mention the behavior of aluminium towards the other metals. The properties of its alloys with the precious metals, gold and silver, approach nearest to those of the metal present in largest quantity. An alloy of aluminium 90 parts and gold 10 equals in hardness a corresponding alloy of gold and silver and shows a beautiful yellow color. It can be readily worked under the hammer and rolled out to sheet. An alloy of aluminium with 5 parts of silver does not differ in its properties from pure aluminium, except that it is somewhat harder and takes a finer polish. It is used in making balances for chemists. With a content of iron of over 5 per cent. the aluminium becomes more refractory and at the same time brittle. The introduction of 0.1 per cent. of bismuth makes the metal so brittle that it can no longer be worked; it breaks even if worked directly after annealing. The presence of a small quantity of silicium gives to aluminium a strong crystalline structure, the crystallization being clearly perceptible on the surface by a peculiar net-like appearance of the metal. A content of 0.08 per cent. of aluminium is said greatly to improve steel.

*Aluminium-bronze.*—The alloys of aluminium with copper show very different properties according to the quantity of aluminium they contain. Alloys containing but little copper cannot be used for industrial purposes. With 60 to 70 per cent. of aluminium they are very brittle, glass-hard, and beautifully crystalline. With 50 per cent. the alloy is quite soft, but under 30 per cent. of aluminium the hardness returns.

The usual alloys are those of 1, 2, 5, and 10 per cent. of aluminium. The 5 per cent. bronze is golden in color, polishes well, casts beautifully, is very malleable cold or hot, and has great strength, especially after hammering. The 7.5 per cent. bronze is to be recommended as superior to the 5 per cent. bronze. It has a peculiar greenish-gold color, which makes it very suitable for decoration. All these good qualities are possessed by the 10 per cent. bronze. It is bright golden, keeps its polish in the air, may be easily engraved, shows an elasticity much greater than steel, and can be soldered with hard solder. When it is made by a simple mixing of ingredients, it is brittle and does not acquire its best qualities until after having been cast several times. After three or four meltings it reaches a maximum, at which point it may be melted several times without sensible change. It gives good castings of all sizes and runs in sand-moulds very uniformly. Thin castings come out very sharp, but if a casting is thin and suddenly thickens, small off-shoots must be made at the thick place, into which the metal can run and then soak back into the casting as it cools and shrinks, thus avoiding cavities by shrinkage at the thick part. Its specific gravity is 7.68, about that of soft iron. Its strength when hammered is equal to the best steel. It may be forged at about the same heat as cast-steel and then hammered until it is almost cold without breaking or ripping. Tempering makes it soft and malleable. It does not foul a file and may be drawn into wire. Any part of a machine which is usually made of steel can be replaced by this bronze.

The melting point of aluminium-bronze varies slightly with the content of aluminium, the higher grades melting at a somewhat lower temperature than the lower. The 10 per cent. bronze melts at about 1700° F., a little higher than ordinary bronze or brass.

Aluminium-bronze shrinks about twice as much as brass, and hence due allowance has to be made for this in the mould and pattern. As the metal solidifies rapidly, it is necessary to pour it quickly and to make the gates amply large so that there will be no "freezing" in the "gates" before the casting is properly fed. To obviate the shrinkage as much as possible, the metal is allowed to enter the mould at a temperature not higher than will admit of it running freely. When there is a heavy mass of metal in the shape of an envelope surrounding a core, the contraction upon solidification will cause the metal to split unless the core is made to yield equally with the contraction. Baked sand-moulds are preferable to green sand except for small castings.

One of the chief difficulties met with in the casting of aluminium-bronze is to avoid oxidation in transferring the metal from the crucible or ladle to the mould. If any of the film of oxide which floats on the surface should get into the casting during the pouring, it will appear there like so much dirt and is apt to cause trouble. The ordinary "skim-gate" will prevent this in the case of small castings, but with large masses the metal is first poured into a receiver, which is connected with and is part of the pouring "gate," but is prevented from entering the mould by means of a plug which closes up the mouth of the "gate." To illustrate this more clearly imagine the pouring "gate" shaped like a funnel into which the metal is first poured. It is prevented from running into the mould by the plug already mentioned. As soon as the dirt has risen to the top, the plug is withdrawn, and consequently nothing but the clear metal at the bottom enters the mould. For castings over 50 pounds the metal is poured from a large ladle through a hole in the bottom. Ample facilities should be made for the escape of gases.

Both aluminium and copper volatilize only at extremely high temperatures, and consequently aluminium-bronze can be remelted without any appreciable change in the strength or quality of the metal whatever.

Aluminium bronze forges similarly to the best Swedish iron, but at a much lower temperature. It works best at a cherry red; if this is much exceeded, the metal becomes hot, short, and is easily crushed. The temperature for rolling is a bright red heat, and it is a curious fact that if the metal were forged at the temperature it is rolled, it would be crushed to pieces. If the temperature in the ordinary muffle in which it is heated be allowed to rise too high, the bronze will frequently fall apart by its own weight. When in the rolls it acts very much like yellow Muntz metal. As it loses its heat much more rapidly than copper or iron, it has to be annealed frequently between rollings.

The following examples of rolling are given by the "Cowle's Electric Smelting and Aluminium Company:" A billet of 10 per cent. bronze about 18″ x 1¼″ x 1¼″ was rolled in a Belgian train to quarter-inch rod, at one annealing. The 5 per cent. bronze is harder to roll hot than the 10 per cent., but in cold rolling just the reverse is true; a piece of 5 per cent. sheeting, 8 inches wide, has been reduced 8 gauge numbers when rolled cold at one annealing; while a 10 per cent. sheet could not be reduced more than half that number. The billets for rolling can be best prepared by casting in iron moulds previously rubbed with a mixture of plumbago, pipe-clay, and lard oil. The metal chills very quickly and very smooth castings can be produced, the smoothness depending considerably on the speed of pouring. With care the 5 and 10 per cent. bronzes can be easily drawn into wire. It is preferable, however, to roll the 5 per cent. to quarter inch rods and the 10 per cent. to a less diameter, and anneal them. The metal thus prepared is much tougher and less liable to break in drawing. The dies must be very hard, or the ordinary wire, and especially the higher grades, are apt to cut them. The speed of the draw blocks must be less than for iron, brass, copper, German silver, or soft steel, and the reduction must be more gradually effected.

Aluminium bronze is, in every respect, considered the best bronze yet known. Its high cost alone prevents its extensive use in the arts, but since the perfection of Cowle's electric furnace, described on page 47, and the erection of several other factories, among which the one in Germany, at Hamelingen near Bremen, is designed to produce aluminium, magnesium and kindred metals by process of electric smelting, the cost of manufacture has been greatly reduced.

The following results were obtained at the South Boston Iron Works, with pieces of the Cowle's Company alloys, February, 1886:—

| Aluminium bronze. | Tensile strength, pounds per square inch. | Elastic limit. | Elongation, per cent. |
|---|---|---|---|
| 10 per cent. bronze . . | 91,463 | — | $1\frac{1}{2}$ |
| 10 " " . . | 92,441 | 59,815 | $2\frac{1}{2}$ |
| 10 " " . . | 96,434 | 85,034 | 1 |
| 9 " " . . | 77,062 | 51,774 | 9 |
| 9 " " . . | 71,698 | 44,025 | 9 |
| $8\frac{1}{2}$ " " . . | 72,019 | — | $28\frac{1}{2}$ |
| $7\frac{1}{2}$ " " . . | 60,716 | 45;537 | 6 |

The following tests were made at the Washington Navy Yard of pieces very nearly half an inch in diameter and two inches between shoulders :—

| Aluminium bronze. | Tensile strength, pounds per square inch. | Elastic limit. | Elongation, per cent. |
|---|---|---|---|
| 10 per cent. bronze . . | 114,514 | — | 0.45 |
| 10 " " . . | 95,366 | 69,749 | 0.05 |
| 10 " " . . | 109,823 | 79,894 | 0.05 |

According to Thurston, the alloys of aluminium and copper may be made by fusing together the oxides with metallic copper and enough carbon and flux to reduce them. The oxides as well as the other materials should be as finely divided as possible, and the carbon introduced in excess.

A number of remarkable and useful alloys are made by mixing aluminium bronzes with nickel in various proportions. These compositions are said to be very ductile and to have a tenacity of from 75,000 to over 100,000 lbs. per square inch with about 30 per cent. elongation. Tests made by Kirkaldy on alloys of a similar nature made by the "Webster Crown Metal Company," England, give results ranging from 82,000 to over 100,000.

According to J. Webster, for preparing the bronze two alloys are used, which are designated as aluminium alloy (A) and nickel alloy (B). A consists of 15 parts of aluminium and 85 of tin, and B of 17 parts of nickel, 17 of copper, and 66 of tin. The metals are melted together in the usual manner with the use of a flux under a cover of common salt and chloride of potash. The two alloys are then melted together with copper. It has been found that the bronze is the harder and better, the more it contains of the two alloys and *vice versa.* The following is given as the best proportion: Copper, 88 parts, and 8 parts of each of A and B. When the copper is melted the alloys are added, and melted, being stirred with a wooden or clay rod (an iron rod must not be used under any conditions), until the mass is homogeneous, which is recognized by a test-ingot. A second quality of aluminium bronze, which is cheaper than the preceding, is composed of 92 parts of copper, and 4 parts each of the alloys A and B.

The addition of a few per cent. of aluminium to common brass greatly increases its tenacity and resistance to corrosion. Alloys containing copper, zinc, and aluminium between the following limits,

| | |
|---|---|
| Copper . . . . . | 67 to 71 per cent. |
| Zinc . . . . . | 27½ " 30 " |
| Aluminium . . . . | 1¼ " 3 " |

and combined in different proportions, give tenacities from a little above 30,000 to over 65,000 lbs. per square inch. Alloys with much less copper and more zinc —55.8 to 57 per cent. copper and 42 to 43 per cent. zinc—approach nearer 70,000 lbs., and a specimen composed of copper 67.4 per cent., zinc 26.8, and aluminium 5.8 broke at over 95,000 lbs. tenacity per square inch.

There is at present one great drawback to the use of aluminium-bronzes for small manufactured articles—the difficulty of soldering. In a pamphlet issued by the "Cowle's Electric Smelting and Aluminium Company" the following directions are given :—

*Brazing.*—Aluminium-bronze will braze as well as any other metal, using one-quarter brass solder (zinc 50 per cent., copper 50 per cent.) and three-quarters borax.

*Soldering.*—To solder aluminium-bronze with ordinary soft (pewter) solder: Cleanse well the parts to be joined free from dirt and grease. Then place the parts to be soldered in a strong solution of sulphate of copper, and place in the bath a rod of soft iron touching the parts to be joined. After a while a copper-like surface will be seen on the metal. Remove from bath, rinse quite clean, and brighten the surfaces. These surfaces can then be tinned by using a fluid consisting of zinc dissolved in hydrochloric acid in the ordinary way with common soft solder.

Mierzinski recommends ordinary hard solder, and says that Hulot uses an alloy of the usual half-and-half lead-tin solder with 12.5, 25, or 50 per cent. of zinc amalgam.

Aluminium-bronze for jewelry may be soldered by using the following composition :—

*Hard solder for* 10 *per cent. aluminium-bronze.*—Gold 88.88 per cent., silver 4.68, copper 6.44.

*Middling hard solder for* 10 *per cent. aluminium-bronze.*—Gold 54.40 per cent., silver 27.60, copper 18.

*Soft solder for aluminium-bronze.*—Brass (copper 70 per cent., tin 30 per cent.) 14.30 per cent., gold 14.30, silver 57.10, copper 14.30.

*Alloy of aluminium and chromium.*—With chromium, aluminium forms a beautiful alloy, which can be prepared by a tedious operation in the form of crystalline needles. It has no technical application, and is here simply mentioned for the sake of completeness.

*Alloy of aluminium and tin.*—An alloy, the use of which it is claimed overcomes the difficulties of working and welding aluminium, is formed by melting together 100 parts of aluminium with 10 of tin. The alloy is whiter than aluminium and but little heavier, its specific gravity being 2.85. By most substances it is less attacked than pure aluminium, and it can be welded and soldered like brass without any special preparation.

*Aluminium and iron.*—Ostberg, a Swedish inventor, has lately devised an ingenious process of making castings (clean and sharp) of wrought-iron, or, as they are called, mitis castings, by taking advantage of the observation which he made that the addition of an extremely small quantity of aluminium to wrought-iron, kept at a white heat in a crucible, forms a combination which has a much lower point of fusion than wrought-iron.

In making mitis castings a very small quantity, about $\frac{5}{1000}$ of 1 per cent., of aluminium, in the form of a 7 or 8 per cent. aluminium alloys of cast-iron, is added to the charge (about 60 pounds) of wrought-iron in the crucible the moment this has been melted. The fusing point is at once lowered some 500° F., and the charge, now an alloy of iron and aluminium, becomes extremely fluid and can be cast in the finest moulds, while the great difference between its temperature and its fusing point gives all the time necessary for manipulating it without danger of its solidifying. The extreme fluidity of the charge allows the ready escape of the gases, which otherwise would make a porous casting, and the result appears to be a remarkably fine, solid, and tough casting of wrought-iron.

These mitis castings are said to be from 30 to 50 per cent. stronger than the iron from which they are made, but though aluminium undoubtedly greatly increases the strength of most of the metals with which it alloys, it is not credited with the increase of strength in this case, for it is said that after hammering the mitis metal loses its increase in strength and returns to the fibrous appearance and to the strength of the original iron.

## XXVIII.

## TIN-ALLOYS.

As will be seen from the preceding alloys tin is much used in the preparation of mixtures of metals, and although soft in itself, it has the property of hardening many other soft metals. Tin by itself is actually only used for tinning iron, etc.; for casting it is in most cases used in the form of an alloy.

*Alloys of tin and lead.*—Tin and lead alloy freely in all proportions, and the two metals are frequently found associated in nature. The alloys are easily made, and they generally impart more resistance to the lead without sensibly impairing the qualities of the tin. It would not be impossible to ascertain the proportion of lead in the alloy by the behavior of the latter under a chisel, a punch, and by the streak it leaves upon paper. Lead added to tin increases its malleability and ductility, but diminishes its tenacity. Difficult to break even after successive bendings, tin becomes more brittle when alloyed with lead. The fracture is then more marked than that of lead, whatever may be the proportions in the alloy, the latter metal being more easily separated than tin, but requiring, however, to be torn asunder. The strongest alloy of tin and lead is produced by alloying tin 3 parts and lead 1, the density of this alloy being 8. According to Watson, the densities of alloys of tin and lead are as follows:—

| | | |
|---|---|---|
| 0 | 1 | 11.3 |
| 10 | 1 | 7.2 |
| 32 | 1 | 7.3 |
| 16 | 1 | 7.4 |
| 8 | 1 | 7.6 |
| 4 | 1 | 7.8 |
| 2 | 1 | 8.2 |
| 1 | 1 | 8.8 |

Alloys of tin and lead were formerly much used in the manufacture of domestic utensils. They are, however, not suitable for this purpose on account of the solubility and poisonous properties of the lead. Under no circumstances should an alloy of tin and lead used in the manufacture of domestic utensils contain more than 10 to 15 per cent. of lead. Such an alloy is not sensibly attacked by vinegar and fruit acids. But unfortunately there are cases in which the so-called tin contains as much as one-third of its weight of lead.

Alloys containing from 10 to 15 per cent. of lead have a beautiful white color, are considerably harder than pure tin and much cheaper. Many alloys of tin and lead have an especially lustrous appearance and are used for stage-jewelry and mirrors for reflecting the light of lamps, etc. An especially lustrous alloy is known under the name of *Fahlun brilliants.* It is used for stage-jewelry and consists of tin 29 parts, lead 19. The alloy is poured into moulds faceted in the same manner as diamonds. Seen in an artificial light, the pieces of metal thus cast are so brilliant as to produce the effect of diamonds. Other alloys of tin and lead of some importance are those used in the manufacture of toys (tin soldiers). They must fill the moulds well and be cheap, and, consequently, as much as 50 per cent. of lead is used. With the use of sharp iron or brass moulds such an alloy yields good castings. Toys can also be prepared from type-metal, which is even cheaper than alloys of tin and lead, but has the disadvantage of readily breaking on sharply bending the articles.

In the following table the melting points of alloys of tin and lead as determined by Messrs. Parkes and Martin are given :—

| Composition. | | Melting points. Degrees F. |
|---|---|---|
| Tin. | Lead. | |
| 4 | 4 | 372° |
| 6 | 4 | 336 |
| 8 | 4 | 340 |
| 10 | 4 | 348 |
| 12 | 4 | 336 |
| 14 | 4 | 362 |
| 16 | 4 | 367 |
| 18 | 4 | 372 |
| 20 | 4 | 378 |
| 22 | 4 | 380 |
| 24 | 4 | 382 |
| 4 | 4 | 392 |
| 4 | 6 | 412 |
| 4 | 8 | 442 |
| 4 | 10 | 470 |
| 4 | 12 | 482 |
| 4 | 14 | 490 |
| 4 | 16 | 498 |
| 4 | 18 | 505 |
| 4 | 20 | 512 |
| 4 | 22 | 517 |
| 4 | 24 | 519 |
| 4 | 26 | 523 |
| 4 | 28 | 527° |
| 4 | 30 | 530 |
| 4 | 32 | 532 |
| 4 | 34 | 535 |
| 4 | 36 | 538 |
| 4 | 38 | 540 |
| 4 | 40 | 542 |
| 4 | 42 | 544 |
| 4 | 44 | 546 |
| 4 | 46 | 548 |
| 4 | 48 | 550 |
| 4 | 50 | 551 |
| 4 | 52 | 552 |
| 4 | 54 | 554 |
| 4 | 56 | 555 |
| 4 | 58 | 556 |
| 4 | 60 | 557 |
| 4 | 62 | 557 |
| 4 | 64 | 557 |
| 4 | 66 | 557 |
| 4 | 68 | 557 |
| 4 | 70 | 558 |

For baths used by cutlers and others in tempering and heating steel articles, Parkes and Martin propose the following alloys :—

| No. | Use. | Composition. | | Melting points. Degrees F. |
|---|---|---|---|---|
| | | Lead. | Tin. | |
| 1 | Lancets . . . . . . . | 7 | 4 | 420° |
| 2 | Other surgical instruments | 7½ | 4 | 430 |
| 3 | Razors . . . . . . . | 8 | 4 | 442 |
| 4 | Pen-knives . . . . . . | 8½ | 4 | 450 |
| 5 | Knives, scalpels, etc. . | 10 | 4 | 470 |
| 6 | Chisels, garden knives . | 14 | 4 | 490 |
| 7 | Hatchets . . . . . . . | 19 | 4 | 509 |
| 8 | Table knives . . . . | 30 | 4 | 530 |
| 9 | Swords, watch springs . | 48 | 4 | 550 |
| 10 | Large springs, small saws | 50 | 4 | 558 |
| 11 | Hand saws . . . . . . | Oil boiling | | 600 |
| 12 | Articles of low temper . | 1 | 4 | 612 |

# XXIX.

## BRITANNIA METAL.

THE alloy known under this name consists principally of tin alloyed with antimony. Many varieties contain only these two metals and may be considered tin hardened by antimony. Other alloys, also called Britannia metal, contain, however, in addition, certain quantities of copper, sometimes lead, and occasionally, though rarely, bismuth.

The Pewterers' Company of England, which has been an incorporated society ever since the reign of Edward IV. (1474), in 1772 attempted to regulate the quality of pewter wares by permitting enough lead to bring the density of pewter from $\frac{1835}{1820}$ to $\frac{1985}{1820}$, that of tin. Persons who departed from this regulation were liable to expulsion from the guild, but it has been so greatly disregarded as to have very little effect in keeping up the standard of pewter.

Britannia metal has always a silvery color with a bluish tinge, and, on account of its hardness, takes a fine polish, which it retains on exposure to the air. Though it is quite hard, in strength it only slightly surpasses tin. Good Britannia metal shows a fine-grained, jagged fracture; if the fracture be quite coarse and strongly crystalline the alloy contains too much antimony, and, as a rule, is too brittle to be worked to advantage.

Even with a correct composition the brittleness of Britannia metal is such that in rolling it out to sheet the edges generally become full of cracks. A content of iron or zinc increases this brittleness to a considerable extent, and, in preparing an alloy to be rolled out into sheet or to be used for stamped articles, great care must be had to have the metals to be used, entirely free from iron or zinc. A content of copper increases the ductility of Britannia metal but decreases its fusibility, which is one of its most valuable properties, and besides gives to the color a strong yellowish cast. An addition of lead is of advantage especially to metal to be principally used for castings, it becoming more fusible thereby and filling out the moulds better, but its color acquires a strong brownish cast, and articles manufactured from it lose their lustre on exposure to the air much more quickly than those containing no lead.

A large content of antimony, to be sure, imparts great hardness and a permanent brilliant lustre to Britannia metal, but it also decreases its ductility. And, moreover, the antimony possessing poisonous properties its use must be restricted, especially if the alloy is to be employed in the manufacture of domestic utensils, such as coffee and tea pots, etc. It need scarcely be said that for sanitary reasons the antimony must be free from arsenic, and besides a very small content of it renders the alloy extremely brittle, and articles manufactured from it tarnish quickly, especially on exposure to moist air. Alloys consisting of tin and antimony alone would seem to deserve the preference, and a composition of tin 90 parts, antimony 10, can be especially recommended as regards resistance to chemical influences and facility of working.

For most purposes, not requiring a special degree of hardness, this alloy is the most suitable, it being readily fusible and filling the moulds out well. For articles subjected to constant wear a harder alloy is required.

The following table shows the composition of several varieties of Britannia metal :—

| Britannia metal. | Parts. | | | | | |
|---|---|---|---|---|---|---|
| | Tin. | Antimony. | Copper. | Zinc. | Lead. | Bismuth. |
| English . . . . . . | 81.90 | 16.25 | 1.84 | — | — | — |
| " . . . . . . | 90.62 | 7.81 | 1.46 | — | — | — |
| " . . . . . . | 90.1 | 6.3 | 3.1 | 0.5 | — | — |
| " . . . . . . | 85.4 | 9.66 | 0.81 | 3.06 | — | — |
| Pewter . . . . . . | 81.2 | 5.7 | 1.60 | — | 1.15 | — |
| " . . . . . . | 89.3 | 7.6 | 1.8 | — | 1.8 | — |
| " . . . . . . | 83.30 | 6.60 | 1.60 | 3.06 | — | 1.60 |
| Tutania . . . . . . | 91.4 | — | 0.7 | 0.3 | 7.6 | — |
| Queen's metal . . . | 88.5 | 7.1 | 3.5 | 0.9 | — | — |
| German . . . . . . | 72 | 24 | 4 | — | — | — |
| " . . . . . . | 84 | 9 | 2 | 5 | — | — |
| " (cast) . . . | 20 | 64 | 10 | 6 | — | — |
| Malleable (cast) . . | 48 | — | 3 | 48 | — | 1 |
| Birmingham (sheet) . | 90.60 | 7.80 | 1.50 | — | — | — |
| " (cast) . | 90.71 | 9.20 | 0.09 | — | — | — |
| Karmarsch's . . . | 85.0 | 5.0 | 3.60 | 1.40 | — | 1.60 |
| Koeller's . . . . | 85.70 | 10.40 | 1.00 | — | — | 1.80 |
| Wagner's (fine) . . | 85.64 | 9.66 | 0.81 | 3.06 | — | 0.83 |

Britannia wares made in Sheffield are often composed of block tin 3½ parts, antimony 28, copper 8, brass 8.

Dr. Karl Karmarsch, who has thoroughly studied the properties of Britannia metals, says that the specific gravity of the alloys is 7.339 for laminated sheets, and 7.361 for casting. He explains this anomaly by the fact that the molecules, under the action of the rollers, have a tendency to become separated, their softness and malleability not being great enough to allow of a regular and uniform compression. This is not an isolated fact. M. LeBrun has also found a lower specific gravity for certain alloys of copper and zinc which had been laminated or hammered.

Britannia metal is prepared by first melting the copper by itself, then adding a portion of the tin and the entire quantity of the antimony. The fire can then be quickly moderated, because the new alloy has a much lower melting point than copper.

The last quantity of tin is finally added, and the alloy uninterruptedly stirred for some time to make it thoroughly homogeneous.

Britannia metal can be brought into determined shapes by pressing and rolling, which will be referred to later on, but it being always to some extent brittle, it is preferred to prepare many articles by direct casting. To obtain clean and beautiful casting, requiring but little after manipulation, it is best to use brass moulds. Before casting the moulds have to be strongly heated and the interior lined with a special coating to prevent the alloy from adhering. This is effected by means of a mixture of lamp-black and oil of turpentine, or by lamp-black alone, and, though the first process is the more simple and convenient, the latter is preferable, especially for casting fine articles. The moulds can be so coated as to be beautiful and uniform by using an ordinary lamp, similar to a spirit lamp, filled with oil of turpentine. By holding the cold mould over the dull flame of such a lamp, it becomes coated with a delicate film of a velvety black soot which, while it preserves all the fine lines of the mould, prevents the alloy from adhering.

Instead of lamp-black, some manufacturers use finely elutriated reddle or red chalk mixed to a uniform mass with water. With moulds having many small and at the same time deep turns, it is difficult perfectly to coat the inside with the protecting mass, and the coating with lamp-black is decidedly to be preferred.

With ordinary moulds it is, of course, impossible to cast an article which is to have a certain shape, in one piece. The different parts are consequently cast separately, and subsequently put together with a solder of a color as nearly like that of the metal as possible. Such articles can, however, be also cast in one piece. We will take, for example, an article frequently made of Britannia metal: a coffee-pot, whose shape is such that it must consist of several pieces. To cast it in one piece, the mould must be so constructed that it can be completely removed from the finished casting.

The separate parts of the mould having been coated with lamp-black, or reddle, are put together, and the whole heated nearly to the temperature of the melted Britannia metal. The latter is then poured into the mould until it seems entirely filled. After waiting until it may be supposed that a sufficiently thick layer of metal is solidified the mould is quickly turned over to allow the still liquid portion of the metal to run out.

In order to obtain castings of the right condition, this mode of procedure requires considerable practical skill, it being necessary to hit the exact moment at which the layer of metal has acquired the required thickness, and before succeeding the operator may be prepared to meet with many failures. But by noting by means of a watch the time allowed to pass between pouring the metal into the mould, and pouring the still liquid portion out, the exact time required for the formation of a sufficiently thick layer will soon be learned.

The inside of the articles obtained by the above mode of casting is sometimes roughly crystalline. This is due to the metal beginning to crystallize, and the corners and edges of the small crystals being exposed by pouring out the liquid portion of the metal. Care must therefore be had to use for such casting an alloy giving a fine-grained mass. The interior of the articles, as far as accessible, can also be smoothed, while the article is still in the mould, with a burnishing stone or burnisher.

For articles to be made by stamping or other mechanical process, the alloy resulting from melting the metals together is ladled into cast-iron boxes, and the slabs thus made are subsequently rolled into sheet. Spherical vessels are usually "spun up" in halves, which are then united by soldering, and smaller articles are generally pressed in moulds by a stamping press of very simple construction.

Cast or stamped Britannia metal has always an unsightly gray white appearance, the innumerable small crystals of which the surface of the articles is composed preventing a complete reflection of the light. The articles must, therefore, be polished, which is effected with a burnisher, or, if their shape permits, upon the lathe by means of wooden disks covered with leather rubbed with emery.

A great many articles of Britannia metal are at the present time silvered by the galvanic process, the same as other objects of German silver, which are so well manufactured in England, Germany, and this country, that it is difficult to distinguish them from pure silver.

In some cases the Britannia metal is covered, by galvanism, with a deposit of tombac.

*Biddery metal.*—The name of this alloy is derived from Biddery, a city of the East Indies. It may be classed among the alloys known under the collective term of Britannia metal, but differs from it in containing lead instead of antimony.

Genuine Indian Biddery metal, which is frequently imitated in England, consists of—

| | Parts. | |
|---|---|---|
| | I. | II. |
| Copper | 3.5 | 11.4 |
| Zinc | 93.4 | 84.3 |
| Tin | — | 1.4 |
| Lead | 3.1 | 2.9 |

According to Dr. Hamilton, who had occasion to witness the operation, 123.6 parts of zinc, 4.6 of copper, and 4.14 of lead, together with a mixture of resin and wax to prevent oxidation, are melted together in a crucible. The fused metal is poured into clay moulds and the articles finished with the lathe. The Indian artists impart to the articles a beautiful velvety-black color by treatment with a solution of sulphate of copper, and decorate the surface in a very peculiar and original manner. By means of a graver, lines forming frequently very artistic designs are cut into the surface. The lines are then inlaid with fine gold and silver wire, pressed in by means of a burnishing stone, after which the articles are carefully polished. The beauty of the black coating being somewhat marred by the manipulation is restored by treating the articles with a solution of sulphate of copper, sal ammoniac, and saltpetre, and finally polishing with very fine polishing agents.

The finished articles have a peculiar appearance, the gold and silver designs upon a velvety-blackground presenting frequently a striking resemblance to an embroidery executed in gold and silver threads upon black velvet.

There are several other alloys somewhat resembling Britannia metal which are known under various names. Of these we mention :—

*Ashberry metal.*—It is composed of—

| | Parts. | |
|---|---|---|
| | I. | II. |
| Copper | 2.0 | 3.0 |
| Tin | 80.0 | 79.0 |
| Antimony | 14.0 | 15.0 |
| Zinc | 1.0 | 2.0 |
| Nickel | 2.0 | 1.0 |
| Aluminium | 1.0 | — |

*Minofor metal.*—This alloy is composed of—

| | Parts. | |
|---|---|---|
| | I. | II. |
| Copper | 3.26 | 4 |
| Tin | 67.53 | 66 |
| Antimony | 17.00 | 20 |
| Zinc | 8.94 | 9 |
| Iron | — | 1 |

This alloy, as well as the Ashberry metal, is employed for making forks and spoons, coffee-pots, tea-pots, and all similar articles generally made of ordinary Britannia metal, composed of 9 parts of tin and 1 of antimony.

Britannia metal in fact surpasses both the Ashberry and Minofor metals in beauty, but the latter are harder.

*English metal* is a more complex alloy and is composed of: Tin 88 parts, pure copper 2, brass (copper 75, zinc 25), 2, nickel 2, bismuth 1, antimony 8, tungsten 2.

# XXX.

## LEAD ALLOYS.

On account of its softness and slight solidity lead in a pure state is but little used except for pipes, foil, and for certain chemical purposes. Some of its alloys are, however, of great importance, and are generally used, notwithstanding many efforts to replace them, especially for typographical purposes. An addition of other metals generally makes the lead harder and more or less injures its ductility. An addition of copper imparts to the alloy greater hardness without impairing its ductility to a great extent, and if the content of copper be small such an alloy can be drawn to pipes or rolled out to thin sheet.

A content of arsenic, antimony, and tin increases the hardness of lead, but considerably impairs its ductility. The affinity of zinc and iron for lead being very small it is difficult to prepare alloys with them. The most important alloys of lead are type-metal and shot-metal; the first, generally, an alloy of lead with antimony, and the latter, one with arsenic.

*Type-metal.*—An alloy to serve for type-metal must allow of being readily cast, fill the moulds sharply, and at the same time be as hard as possible. Though it is difficult entirely to satisfy these demands an alloy consisting of lead and antimony answers the purpose best. Antimony increases the hardness of lead and renders it very brittle if present in too large a proportion. An alloy of lead 76 parts, and antimony 24, appears to be the point of saturation of the two metals. More fusible than the average fusibility of the two component metals, ductile and considerably harder than lead, this alloy expands in cooling, and to this property is due its employment for the manufacture of type. But the above compound does not answer perfectly well, especially for small type. When too soft it gets out of shape, when too hard it cuts the paper; and it happens very often that the founder passes to one or the other extreme. When the alloy is melted in contact with the air antimony is oxidized much before lead, and this accounts for the difficulty of obtaining an exact composition. It is a constant subject of study for type-founders to arrive at a fusible and homogeneous metal with much expansion, resisting as much as possible, and, at the same time, soft enough to be repaired and to bear the action of the press without being soon put out of shape.

The alloy of equal proportions is dry, porous, and brittle. These defects increase in the same ratio as the proportion of antimony. On the other hand they disappear when the lead takes the place of antimony. An alloy of lead 4 parts and antimony 1 is compact, much harder than lead, and remains malleable.

An alloy of antimony 1 part and lead 8 possesses much tenacity and a specific gravity greater than the proportional specific gravity of the two metals. It is more malleable than the preceding alloy and retains a certain hardness. The hardness imparted by antimony, the increase of tenacity, and that of the specific gravity are very perceptible up to the alloy of antimony 1 part and lead 16.

At present a great many receipts for type metal are known, in the preparation of which other metals besides lead and antimony are used for the purpose of rendering the alloy more fusible (additions of bismuth as imparting to them greater power of resistance, copper and iron having been recommended for the purpose). By such admixtures the fusibility of the alloys is, however, impaired, and the manufacture of the types becomes much more difficult than with an alloy of lead and antimony alone. In the following table some alloys suitable for casting type are given :—

| Metals. | Parts. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. |
| Lead . . . . | 3 | 5 | 10 | 10 | 70 | 60 | 55 | 55 | 100 | 6 |
| Antimony . . | 1 | 1 | 1 | 2 | 18 | 20 | 25 | 30 | 30 | — |
| Copper . . . | — | — | — | — | 2 | — | — | — | 8 | 4 |
| Bismuth . . | — | — | — | 1 | — | — | — | — | 2 | — |
| Zinc . . . . | — | — | — | — | — | — | — | — | — | 90 |
| Tin . . . . | — | — | — | — | 10 | 20 | 20 | 15 | 20 | — |
| Nickel . . . | — | — | — | — | — | — | — | — | 8 | — |

The manufacture of the types from the alloy is seldom effected by cold stamping in steel moulds, the process being very expensive; hence they are generally cast. According to the old process the types are cast piece by piece by means of a small casting ladle, but for types with a large face and much detail, the motion of the hand is barely sufficient to give the momentum required to throw the metal into the matrix and produce a clean, sharp impression. A machine is then used, which may be compared to a small forcing-pump, by which the mould is filled with the fluid metal; but from the greater difficulty of allowing the air to escape such types are in general considerably more unsound in the shaft or body, so that an equal bulk of them only weigh about three-fourths as much as types cast in the ordinary way by hand, and which for general purposes is preferable and more economical.

Some other variations are resorted to in type-founding; sometimes the mould is filled twice, at other times the faces of the types are *dabbed* (the *cliché* process), many of the large types and ornaments are stereotyped and either soldered to metal bodies or fixed by nails to wooden blocks. The music type and ornamental borders and dashes display much curious power of combination. *Plates for engraving music* are generally made of tin 5 to 7.5 parts, antimony 5 to 2.5.

*Ehrhardt's type-metal* is composed of zinc 89 parts, tin 4, lead 3, copper 4; or zinc 93 parts, tin 3, lead 3, copper 2.

Type-metal being easily cast may also be used for candlesticks, statuettes, etc., sand moulds being generally employed for the purpose, though for decorated articles metallic moulds thoroughly rubbed inside with oil can be advantageously used.

*An alloy for keys of flutes and similar parts of instruments* consists of lead 2 parts, antimony 1.

*Shot-metal.*—The mixture of metal used for the manufacture of shot consists of lead and arsenic. The latter, as previously mentioned, possesses the property of hardening lead, the alloy being at the same time more fusible than pure lead. Shot, as we know, is prepared by letting fall from an elevated place drops of lead into water, and an addition of a very small quantity of arsenic to the lead helps its solidification and gives to the shot a more spherical shape.

On account of the poisonous properties of the arsenious vapors certain precautions have to be observed in preparing the alloy. In a cast-iron pot provided with a well-fitting lid the lead is first melted and then covered with a layer of charcoal dust. Only after this is done should the arsenic or arsenious combination to be used be introduced. In many shot-factories this precaution is omitted, which, however, deserves censure, as everything should be done to protect the workmen from the injurious effects of the poisonous arsenious vapors. If the metal is covered with a layer of charcoal dust, the vapors cannot reach the air as easily as when the bright metal is in direct contact with the air. White arsenic (arsenious acid) is generally used as an addition to the lead, though in some cases red arsenic (realgar or red orpiment) is employed. Immediately after the introduction of the arsenic the mass is vigorously stirred with a wooden rod, and the pot is then covered with the lid, which is luted around the edges with moist clay.

A strong fire is now kept up to render the contents of the pot thinly fluid. After about three hours the lid is removed and the charcoal and oxides floating upon the surface being carefully lifted off, the alloy is poured with ladles into moulds. This alloy serves for the preparation of the actual shot-lead, which is prepared by melting lead and adding a certain quantity of the alloy of lead and arsenic. It is in all cases preferable first to prepare the arsenious alloy in the manner prescribed, it being otherwise difficult intimately and homogeneously to combine the lead with the comparatively small quantity of arsenic required for shot-metal.

In working by the preceding process generally 1000 parts of lead are alloyed with 20 of arsenic, and equal parts of this alloy and of lead are subsequently melted together. For the direct preparation of the alloy of lead and arsenic for shot 2.4 parts of arsenious acid are used for 600 parts of refined lead, or 3.0 parts of arsenic to 700 parts of lead. As will be seen the quantity of arsenic is exceedingly small, and should in no case exceed that actually required for hardening the lead and rendering it easy to cast. The quantity considered necessary for this varies much in different countries. While, for instance, in England 10 parts of arsenic are allowed for 1100 parts of lead, in France 3 to 8 parts are considered sufficient for 1000 parts of lead.

This variation in the proportions of arsenic used for hardening the lead is readily accounted for by the difference in the qualities of the lead used; the purer and softer the lead the greater the quantity of arsenic required. But under no circumstances should good shot-metal contain more than from $\frac{}{1000}$ to $\frac{10}{1000}$ of the weight of lead used.

Both a too small or too large content of arsenic is injurious ; if the lead contains too little arsenic, the resulting shot has the shape of tears, and the interior is frequently full of cavities, while with too much arsenic the drops are lenticular. As even with much experience it is quite difficult to hit at once the right proportion, it is advisable, before melting together large quantities of lead and arsenic, first to make tests with small quantities. From the shape of the shot obtained from these samples it can be readily judged whether the proportions are right or in what respect they have to be changed.

Many manufacturers of shot, it would seem, vary the compositions of the alloys used by them, for, besides lead and arsenic, other metals are frequently found in shot, especially antimony and copper, though the latter only in exceedingly small quantities. The content of antimony is, however, larger, reaching in many cases 2 per cent. of the total weight, and from this it would appear that the manufacturers endeavor to replace the arsenic by antimony.

*Casting of shot.*—According to the old method, shot is prepared by allowing the melted metal to fall in drops from a tower of considerable height. This method is said to have originated with a plumber of Bristol, England, named Watts, who, about the year 1782, dreamed that he was out in a shower of rain, that the clouds rained lead instead of water, and the drops of lead were perfectly spherical. He determined to try the experiment, and, accordingly, poured some melted lead from the tower of St. Mary Redcliffe Church into some water below; the plan succeeded and he sold the invention for a large sum of money.

For the carrying out of this invention shot-towers and shot-wells have been constructed. At the top of the tower melted lead is poured into a colander and the drops are received into a vessel of water below. The surface of the lead becomes covered with a spongy crust of oxide called *cream*, which is used to coat over the bottom of the colander to prevent the lead from running too rapidly through the holes, whereby they would form oblong spheroids instead of spheres. The colanders are hollow hemispheres of sheet-iron, the holes in them differing according to the size of the shot. They must be at a distance of at least three times the diameter of the shot from each other, as otherwise it might happen that two or more drops of lead would, while falling down, unite to one mass, which, of course, would be useless and have to be remelted.

The water serving for the reception of the drops must be frequently changed to prevent it from becoming too hot or boiling. By some it is recommended to pour a layer of oil upon the surface of the water, the shot retaining thereby its spherical shape better than when dropping directly into the water. To prevent the shot, when taken from the water, from losing its metallic appearance by oxidation, a small quantity (about 0.25 per cent.) of sodium sulphide is dissolved in the water serving for the reception of the shot, by means of which the drops falling into it are at once coated with a thin film of sulphide of lead of a lustrous, metallic, gray-black color, which is permanent even in moist air.

In more recent times the formation of shot by centrifugal power has been introduced, which does away with the expensive towers. The melted lead is poured in a thin stream upon a rapidly revolving metal disk, surrounded at some distance by a screen against which the shot is thrown. The moment the melted lead falls upon the metal disk it is divided by the centrifugal force into drops, the size of which depends on the rapidity with which the disk revolves. The drops are hurled in a tangential direction from the disk and are stopped by the above-mentioned screen.

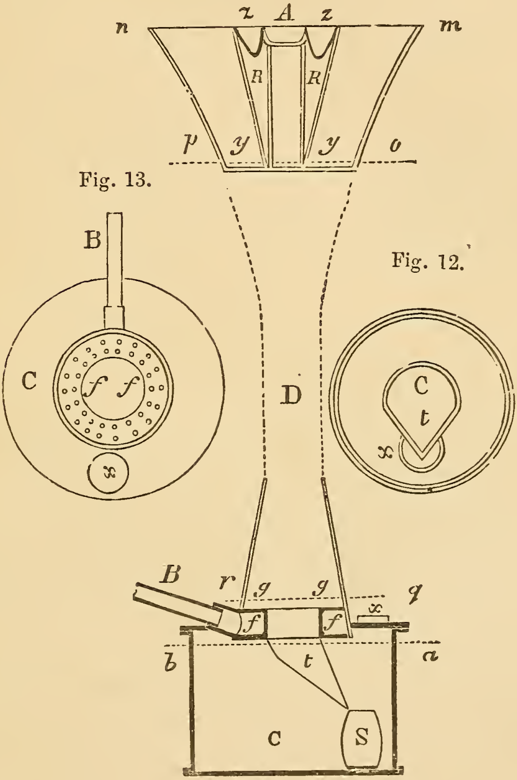
David Smith, of New York, has invented and put into practice a new mode of manufacturing drop-shot. The chief feature of this invention consists in causing the fused metal to fall through an ascending current of air, which shall travel at such a velocity that the dropping metal shall come in contact with more particles of air in a short tower than it would in falling through the highest towers before in use. Fig. 11 is a vertical sectional elevation of a sheet-metal cylinder set up as a tower within a building, and may be about 20 inches internal diameter and 50 feet high or less. This tower, although mentioned in Smith's patent, is now dispensed with in the middle of the height, so that only an open space remains. Fig. 12 is a plan at the line *a b;* Fig. 13 is a plan at the line *q r;* Fig. 14 is a section at *o p;* and Fig. 15 is a section at *m n*, Fig. 11.

*C* is a water cistern beneath the tower. *B* is a pipe from the blowing apparatus leading into the annular chamber *f;* the upper surface *g* is perforated as shown in Fig. 13 to dispense the ascending air. The outer side

Fig. 11.

Fig. 13.

Fig. 12.



of this annular ring *f* forms the base of a frustum of a cone, forming the tower *D*, passing the blast through the frame *y y*, Fig. 14; and in Fig. 11 is shown to support a cylindrical standard *R*, the upper central portion of which receives the pouring pan *A*. This pan is charged with each separate size of shot. Round the pouring pan *A* is a circular waste-trough *z*. The object of this arrangement is that the fluid-metal, running through the pouring pan *A* into the ascending current of air, will be operated upon in the same manner as if it fell through stagnant air of great height. The shot falls through the open centre of the ring *f* into the water cistern *C*, where a shoat *t* carries it into the tub *S*, which when full may be removed through *x*, an aperture in the cover of the cistern.

Fig. 14.

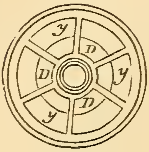
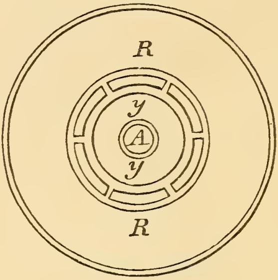


Fig. 15.



*Sorting the shot.*—Even with the most careful work it happens that drops of unequal size or cornered masses are found among the shot, and the latter, after being taken from the water and dried, must be sorted. This was formerly effected by hand in the following manner: A slab of polished iron is tilted at a certain angle, and the shot are strewed along the upper part of the inclined plane thus formed. The perfect shot proceed rapidly in straight lines and fall into a bin placed to receive them, about a foot away from the bottom of the slab. The misshapen shot, on the contrary, travel with a slower zigzag motion and fall without any bound into a bin placed immediately at the end of the incline. The perfect shot are then subjected to another sorting by passing them through sieves with meshes of exactly the same size as the apertures in the casting colanders.

The finished shot, which are now of dead silvery-white color, are polished and made dark in an iron barrel or *rumble* containing a quantity of powdered plumbago. They are then tied up in canvas bags and are ready for sale.

At present the shot are, however, generally sorted by means of sorting drums consisting of inclined cylinders perforated with holes whose diameter corresponds to that of the shot. The forward motion of the shot in these drums is effected by means of an Archimedes screw.

Large shot are at the present time also frequently prepared by casting in moulds like bullets, or by stamping them from thin plates of the alloy. In both cases the resulting shot shows a seam which is removed by bringing the shot together with very fine quartz sand into revolving drums. By the action of the sand the seams are ground off, and a perfectly spherical shape imparted to the shot.

*Alloys of lead and iron.*—Lead, as previously stated, has no affinity for iron. A piece of lead thrown into a bath of melted iron becomes oxidized, or is separated and found at the bottom of the bath after the cast-iron has been run out. As soon as the lead is introduced into the melted cast-iron, a certain agitation appears on the surface, and even through the whole bath, and the cast-iron seems more fluid. When thin or large pieces are to be cast, the founders, who are aware of this phenomenon, often throw a certain quantity of lead into the melted cast-iron in order to prevent it from congealing too soon against the sides of the casting ladle.

This want of affinity of lead for iron, and conversely, is made use of for separating iron from other metals, such as silver, for instance. Thus, if lead is added in sufficient quantity to a fused alloy of cast-iron and silver, it will combine with the silver, and the iron will float on the surface of the bath.

All the authors who have occupied themselves with the question of alloys agree upon the impossibility of alloying lead and iron.

*Alloys of lead and other metals.*—Lead, as seen from the preceding sections, is much used in the preparation of alloys which have been already partially mentioned under the respective mixtures of metals. Lead is also frequently alloyed with cadmium and bismuth, and forms an important constituent of the so-called soft-solder. In speaking of these compounds, the lead alloys not yet mentioned will be referred to. Only type-metal and shot-metal can be considered as lead alloys, *i. e.*, alloys of which lead forms the greater portion.

# XXXI.

## CADMIUM ALLOYS.

Cadmium shares with bismuth the property of strongly reducing the melting points of alloys, there being some whose melting point is so low that they can be liquefied in hot water. But while the bismuth alloys are nearly all brittle, many alloys of cadmium possess considerable ductility, and can be worked under the hammer as well as between rolls. They act, however, very differently in this respect, there being alloys which are very ductile, and others again, though containing besides cadmium the same metals only in different proportions, which are very brittle.

An alloy consisting, for instance, of cadmium and silver shows this phenomenon in the most remarkable manner. By melting together one part of cadmium and one to two parts of silver a very ductile alloy is obtained which can be rolled out to a very thin sheet. By taking, however, two parts of cadmium to one of silver, the resulting alloy is so brittle as to break into pieces under the hammer.

As cadmium imparts to the alloys a very low melting point, it is frequently used in the preparation of very fusible solders, for casting articles not to be exposed to a high temperature, and, in dentistry, for compounds for filling hollow teeth.

Alloys of cadmium contain generally tin, lead, bismuth, and sometimes mercury, the latter being chiefly added to lower the melting point still more. Alloys of cadmium and mercury alone (cadmium amalgams) are solid and malleable, hence the addition of mercury does not impair their solidity.

*Lipowitz's alloy.*—This alloy is composed of cadmium 3 parts, tin 4, bismuth 15, lead 8. It is best prepared by heating the comminuted metals in a crucible and stirring, as soon as fusion begins, with a stick of hard wood. This stirring is of importance in order to prevent the metals, whose specific gravity varies considerably, from depositing themselves in layers. This alloy softens at 140° F., and melts completely at 158° F.

Lipowitz's metal has a silvery-white color, a lustre like polished silver, and can be bent short, hammered, and turned. It, therefore, possesses properties adapting it for many purposes where a beautiful appearance is of special importance, but on account of the considerable content of cadmium and bismuth, the alloy is rather expensive and finds but limited application. Castings of small animals, insects, lizards, etc. have been prepared with it, which in regard to sharpness were equal to the best galvano-plastic products. Plaster of Paris is poured over the animal to be cast, and after sharply drying the whole the animal is withdrawn from the mould and the latter filled up with Lipowitz's metal. The mould is then placed in a vessel containing water, and by heating the latter to the boiling point the metal is melted and deposits itself in the finest impressions of the mould.

The alloy is very suitable for soldering tin, lead, Britannia metal, etc., and on account of its silver-white color is especially adapted for soldering Britannia metal and nickel. But the costliness of the alloy prevents its general use for this purpose, and cheaper alloys having nearly the same properties as Lipowitz's metal have been prepared.

*Cadmium alloy* (*melting point* 170° *F.*).—Cadmium 2 parts, tin 3, lead 11, bismuth 16.

*Cadmium alloy* (*melting point* 167° *F.*).—Cadmium 10 parts, tin 3, lead 8, bismuth 8.

*Cadmium alloys* (*melting point* 203° *F.*).—The following compositions have all the same melting point (203° F.).

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Cadmium | 1 | 1 | 1 |
| Tin | 2 | 3 | 1 |
| Bismuth | 3 | 5 | 2 |

*Very fusible alloy.*—An alloy with a melting point of 150° F. is composed of:—

| | Parts. | | |
|---|---|---|---|
| Tin | 1 | or | 4 |
| Lead | 2 | " | 3 |
| Bismuth | 4 | " | 15 |
| Cadmium | 1 | " | 3 |

*Wood's alloy or metal* melts between 140° and 161.5° F. It is composed of lead 4 parts, tin 2, bismuth 5 to 8, cadmium 1 to 2. In color it resembles platinum and is malleable to a certain extent.

*Cadmium alloy* (*melting point* 179.5° *F.*).—Cadmium 1 part, lead 6, bismuth 7. This alloy, like the preceding, can be used for soldering in hot water.

*Cadmium alloy* (*melting point* 300° *F.*).—Cadmium 2 parts, tin 4, lead 2. This alloy yields an excellent soft solder, with a melting point about 86°, below that consisting of lead and tin alone.

*Cliché metal.*—An alloy consisting of lead 50 parts, tin 36, and cadmium 22½, is especially adapted for the preparation of clichés, since with as low a melting point as the cliché metals (of bismuth alloys) generally used, it combines the valuable property of greater hardness. With a cliché from this alloy a large number of sharp impressions are obtained.

According to Hauer's researches, given below, the melting points of fusible alloys are relative to the composition:—

| *Atomic weights.* | *Melting points.* |
|---|---|
| $Cd_1Sn_1PbBi$ | 155.1° F. |
| $Cd_2Sn_2Pb_2Bi_2$ | 155.1 |
| $Cd_3Sn_4Pb_4Bi_4$ | 153.5 |
| $Cd_4Sn_5Pb_5Bi_5$ | 150.0 |
| *Mixing proportion.* | |
| 1Cd6Pb7Bi | 190.4 |
| 1Cd2Bi3Pb | 193.0 |
| 2Cd4Bi7Pb | 203.0 |

The alloys of cadmium with mercury (cadmium amalgam) will be discussed in speaking of the amalgams, and those containing gold, which are used by goldworkers for certain purposes, will be referred to under gold alloys.

It has been stated that cadmium alloys are not reliable in regard to their melting points, and that, on account of the volatility of cadmium, the alloy becomes the more difficult to fuse the oftener it is remelted. A glance at the above figures shows plainly that cadmium cannot volatilize at those temperatures, and, further, a series of experiments made especially for the purpose has shown that the respective alloys can be remelted as often as desired without their melting points undergoing any sensible change. It may, however, happen that the originally homogeneous alloy may liquate into several with differently high melting points if a large quantity be allowed to stand in a melted state for a long time. This evil can, however, be readily prevented by not keeping the alloy in a fluid state until this liquation takes place (it requires many hours), and if it does take place by vigorous stirring of the melted alloy.

# XXXII.

## BISMUTH ALLOYS.

LIKE cadmium bismuth possesses the property of lowering the melting points of metals, and is, therefore, frequently used in the preparation of fusible alloys, which would be still more extensively used than at present if bismuth could be obtained in abundance and at a small cost. The alloys are now chiefly used in the preparation of delicate clichés, very fusible solders, and in the manufacture of safety-valves of a peculiar construction for steam boilers.

The behavior of bismuth towards other useful metals is given by Guettier as follows:—

*Alloys of bismuth and copper.*—These alloys are easily effected notwithstanding the difference in the points of fusion of the two metals. They are brittle and of a pale-red color whatever the proportions employed. Their specific gravity is sensibly equal to the average of the two metals.

*Alloys of bismuth and zinc.*—These alloys are seldom made and produce a metal more brittle, presenting a larger crystallization with less adherence than zinc or bismuth taken singly. On that account they are useless in the arts.

*Alloys of bismuth and tin.*—The combinations of bismuth and tin take place easily and in all proportions. A very small quantity of bismuth imparts to tin more hardness, sonorousness, lustre, and fusibility. On that account and for certain applications a little bismuth is added to tin to increase its hardness. However, bismuth being easily oxidized and often containing arsenic, the alloys of tin and bismuth would be dangerous for the manufacture of domestic utensils such as culinary vessels, pots, etc.

The alloys of tin and bismuth are more fusible than each of the metals taken separately. An alloy of equal parts of the two metals is fusible between 212° to 302° F. When tin is alloyed with as little as 5 per cent. of bismuth, its oxide acquires the peculiar yellowish-gray color of the bismuth oxide. According to Rudberg, melted bismuth begins to solidify at 507° F., and tin at 550° F. For the alloys of the two metals the "constant point" is 289° F.

*Alloys of bismuth and lead.*—These two metals are immediately alloyed by simple fusion with merely the ordinary precautions. The alloys are malleable and ductile as long as the proportion of bismuth does not exceed that of lead. Their fracture is lamellar, and their specific gravity greater than the mean specific gravity of either metal taken singly. An alloy of equal parts of bismuth and lead has a specific gravity equal to 10.71. It is white, lustrous, sensibly harder than lead, and more malleable. The ductility and malleability diminish with an increased proportion of bismuth, while they increase with the excess of lead in the alloy. An alloy of bismuth 1 part, and lead 2 is very ductile, and may be laminated into thin sheets without cracks. According to Berthier, its point of fusion is 331° F.

*Alloys of bismuth and iron.*—Authorities disagree as to the possibility of combining bismuth and iron. The presence of bismuth in iron renders the metal brittle.

It will be seen, from the preceding data, that the alloys of bismuth are not at present of importance in the arts excepting the fusible alloys made of bismuth and certain white metals, such as tin, lead, etc., and a few others.

*Alloys of bismuth with antimony.*—The alloys of these two metals alone are grayish, brittle, and lamellar. In order to remove the brittleness varying quantities of tin and lead are added, whereby their fusibility rather increases than decreases. Alloys containing the above metals are much used in the preparation of Britannia and Queen's metal, but they are also employed for some special purposes of which the following are examples:—

*Cliché metal.*—This alloy is composed of tin 48 parts, lead 32½, bismuth 9, and antimony 10.5. It is especially suitable for *dabbing* rollers for printing cotton goods, and, possessing a considerable degree of hardness, it wears well.

*For filling out defective places in metallic castings,* the following alloy can be used to advantage: bismuth 1 part, antimony 3, lead 8.

*Alloys of bismuth, tin, and lead.*—The compounds obtained by alloying these metals have a somewhat higher melting point than the cadmium alloys. They have, however, been known for a long time, and are used for various purposes.

*Newton's metal* consists of bismuth 8 parts, lead 5, tin 3. It melts at 202° F.

*Rose's alloys* consist of:—

| | I. | II. | |
|---|---|---|---|
| Bismuth | 2 | 8 | Parts. |
| Tin | 1 | 3 | |
| Lead | 1 | 8 | |

The first of these alloys melts at 200.75° F., and the other at 174.2° F. These alloys were formerly used in the preparation of the so-called safety-plates which were inserted in the top of steam boilers. The composition of these plates was such that they became fluid at a determined temperature corresponding to a certain steam pressure in the interior of the boiler, thus giving the steam a chance to escape through the aperture formed. Such plates acted as a sort of safety-valve, and were intended to prevent the explosion of the boiler with too high a tension of the steam.

At the present time their use has, however, been almost entirely abandoned, it having been found that boilers provided with these plates would explode, without a previous melting of the plates. A chemical and physical examination has shown that, by long-continued heating of the plates, alloys are formed whose melting points are much higher than those of the compositions originally used. The following table gives the compositions of some alloys which are said to melt, if the pressure of the steam exceeds that indicated:—

| Bismuth. | Lead. | Tin. | Melting point. Degrees F. | Corresponding pressure of steam in atmospheres. |
|---|---|---|---|---|
| 8 | 5 | 3 | 212° | 1 |
| 8 | 8 | 4 | 235.9 | 1½ |
| 8 | 8 | 8 | 253.9 | 2 |
| 8 | 10 | 8 | 266 | 2½ |
| 8 | 12 | 8 | 270.3 | 3 |
| 8 | 16 | 14 | 289.5 | 3½ |
| 8 | 16 | 12 | 300.6 | 4 |
| 8 | 22 | 24 | 308.8 | 5 |
| 8 | 32 | 36 | 320.3 | 6 |
| 8 | 32 | 28 | 331.7 | 7 |
| 8 | 30 | 24 | 341.6 | 8 |

*Onion's fusible alloy* consists of lead 3 parts, tin 2, bismuth 5. It melts at 197° F.

*Darcet's fusible alloys.* Mr. Darcet gives the following proportions for fusible alloys:—

| No. | Parts. | | | Remarks. |
|---|---|---|---|---|
| | Bismuth. | Lead. | Tin. | |
| 1 | 7 | 2 | 4 | Softens at 212° F., without melting. |
| 2 | 8 | 2 | 6 | Softens at 212° F., easily oxidized. |
| 3 | 8 | 2 | 4 | Softens more or less at 212° F. No. 4 becoming softer than either No. 3 or No. 5. |
| 4 | 16 | 4 | 7 | |
| 5 | 9 | 2 | 4 | |
| 6 | 16 | 5 | 7 | Becomes nearly fluid at 212° F. |
| 7 | 8 | 3 | 4 | Becomes quite liquid at 212° F. |
| 8 | 8 | 4 | 4 | Becomes very liquid at 212° F. |
| 9 | 8 | 7 | 1 | Becomes soft at 212° F., but does not melt. |
| 10 | 16 | 15 | 1 | Neither liquid nor soft at 212° F. |
| 11 | 8 | 5 | 3 | Melts at 205° F. |
| 12 | 8 | 6 | 2 | Melts at 205° F. |
| 13 | 16 | 9 | 7 | Becomes very liquid at 212° F. |

These alloys are generally harsh, but may be cut. Their fracture is a dead blackish-gray. They are rapidly tarnished in the air, and more so in boiling water in which they become covered with a wrinkled pellicle which falls as a black powder.

*Bismuth alloys for delicate castings.*—For the preparation of castings of delicate articles, and taking impressions from dies, medals, etc., bismuth alloys of the following compositions have been recommended:—

| | Parts. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Bismuth | 6 | 5 | 2 | 8 |
| Tin | 3 | 2 | 1 | 3 |
| Lead | 13 | 3 | 1 | 5 |

On cooling, these alloys expand strongly, and, consequently, fill out the finest depressions and elevations.

*Bismuth alloy for cementing glass.*—Most cements in use are dissolved by petroleum, or, at least, softened.

The following alloy, which melts at 212° F., is, however, not attacked by petroleum, and is therefore well adapted for fastening the metal parts upon glass lamps: Lead 3 parts, tin 2, bismuth 2.5.

The following table, made by Messrs. Parkes and Martin, indicates the various points of fusion of the fusible combinations of bismuth, lead, and tin:—

| Parts. | | | Temperature of fusion. Degrees F. | Parts. | | | Temperature of fusion. Degrees F. |
|---|---|---|---|---|---|---|---|
| Bismuth. | Lead. | Tin. | | Bismuth. | Lead. | Tin. | |
| 8 | 5 | 3 | 202° | 8 | 16 | 24 | 316° |
| 8 | 6 | 3 | 208 | 8 | 18 | 24 | 312 |
| 8 | 8 | 3 | 226 | 8 | 20 | 24 | 310 |
| 8 | 8 | 4 | 236 | 8 | 22 | 24 | 308 |
| 8 | 8 | 6 | 243 | 8 | 24 | 24 | 310 |
| 8 | 8 | 8 | 254 | 8 | 26 | 24 | 320 |
| 8 | 10 | 8 | 266 | 8 | 28 | 24 | 330 |
| 8 | 12 | 8 | 270 | 8 | 30 | 24 | 342 |
| 8 | 16 | 8 | 300 | 8 | 32 | 24 | 352 |
| 8 | 16 | 10 | 304 | 8 | 32 | 28 | 332 |
| 8 | 16 | 12 | 294 | 8 | 32 | 30 | 328 |
| 8 | 16 | 14 | 290 | 8 | 32 | 32 | 320 |
| 8 | 16 | 16 | 292 | 8 | 32 | 34 | 318 |
| 8 | 16 | 18 | 298 | 8 | 32 | 36 | 320 |
| 8 | 16 | 20 | 304 | 8 | 32 | 38 | 322 |
| 8 | 16 | 22 | 312 | 8 | 32 | 40 | 324 |

These alloys are valuable baths for tempering small steel tools. They give a very exact temperature, which may be adjusted to the purpose intended. They are used, according to Thurston,* by placing the article on the surface of the unmelted alloy and gradually heating until fusion occurs and they fall below the surface, at

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* Brasses, Bronzes, and other Alloys, p. 196.

which moment their temperature is right; they are then removed and quickly cooled in water. It is not easy, even if possible at all, to give as uniform a temperature by the ordinary processes of heating or to obtain the exact heat desired, and the quality of the tool is not so easy of adjustment by any other method.

*Alloys of lead and bismuth* have also been tried. They are too easily oxidized and are difficult to make on account of the separation of the lead. An alloy of equal parts of bismuth and lead possesses a tenacity from fifteen to twenty times that of lead.

*Alloys of bismuth and tin* succeed better; those which are best known are—

| Bismuth. | Tin. | Melts at about |
|---|---|---|
| 50 parts | 50 parts | 310° F. |
| 33 " | 67 " | 325 |
| 10 " | 80 " | 480 |

The first alloy (equal parts bismuth and tin) is called "cutlanego," of which the oxide makes a white enamel.

*New fusible alloy.*—"La Nation" gives the formula for a new alloy which is suitable for many applications in the arts. It melts at about 158° F., and, consequently, at a much lower temperature than that at which the so-called "magic spoon" melts in a cup of hot tea. It is composed of bismuth 48 parts, cadmium 13, lead 19, tin 26. The alloy resists great pressure.

*Bismuth-bronze.*—Webster's bismuth-bronze is made of various proportions. According to the statement of its discoverer its composition and qualities are as follows: For a hard alloy take 1 part of bismuth and 16 of tin, both by weight, and, having melted them, mix them thoroughly. For a hard bismuth-bronze take 69 parts of copper, 21 of spelter, 9 of nickel, and 1 of the above hard alloy of bismuth and tin. This bismuth-bronze is a hard, tough, sonorous, metallic alloy, which is proposed for use in the manufacture of screw propeller blades, shafts, tubes, and other appliances employed partially or constantly in sea-water. In consequence of its toughness it is thought to be well suited for telegraph wires and similar purposes where much stress is borne by the wires. From its sonorous quality it is well adapted for piano wires. For domestic utensils and articles exposed to atmospheric influences use bismuth 1 part, aluminium 1, and tin 15, melted together to form the separate or preliminary alloy, which is added in the proportion of 1 per cent. to the above-described alloy of copper, spelter, and nickel. This bronze forms a bright and hard alloy suited for the manufacture of utensils or articles exposed to oxidation.

# XXXIII.

## SILVER ALLOYS.

Pure silver possesses but little hardness, and articles manufactured from it would wear off considerably. For this reason silver-ware is never made of the pure article, but always of alloys with other metals, excepting certain chemical utensils which must be of pure silver, as alloys would be attacked by the substances to be manipulated in them.

The alloys of silver present a real interest only when they are made with gold, copper, or aluminium. With the other metals, with very few exceptions, they are of no use in the arts. The alloys of silver and gold and silver and copper are those employed for articles of luxury and for coinage. The alloys of silver, gold, and copper are used for the same purpose. An alloy of silver, copper, and tin is made into a solder for plated-ware and false jewelry. In modern times alloys containing silver and nickel, or silver, nickel, and zinc, are much used for table utensils, they having a beautiful white appearance and being much cheaper than alloys of copper and silver, which were formerly exclusively used for the purpose.

*Alloys of silver and aluminium.*—These alloys have previously been briefly referred to. Aluminium and silver form beautiful white alloys considerably harder than pure aluminium and taking a very high polish. These alloys have the advantage over copper alloys of being unchangeable on exposure to the air and retaining their white color. It has, therefore, been proposed to alloy coins with aluminium instead of with copper, which would render them much more durable, but the results of experiments made on a large scale were not satisfactory.

The alloys of aluminium and silver show very varying physical properties according to the content of aluminium. An alloy consisting of 100 parts of aluminium and 5 of silver differs but little from pure aluminium, but is considerably harder and takes a beautiful polish. An alloy of aluminium 169 parts and silver 5 possesses considerable elasticity, and is recommended for fine watch springs and dessert knives. An alloy of equal parts of aluminium and silver shows a hardness equal to that of bronze.

*Tiers-argent* (*one-third silver*).—This alloy is chiefly prepared in Paris factories for the manufacture of various utensils, and as indicated by its name consists of silver 33.33 parts and aluminium 66.66. The advantages of this alloy over silver consist in the lower price (90 francs per kilogramme) and greater hardness; it is also stamped and engraved with greater ease than the alloys of copper and silver.

*Alloys of silver and zinc.*—Silver and zinc have great affinity for each other, and consequently are readily alloyed. The alloys are prepared by throwing the required quantity of zinc previously wrapped in paper into the melted and strongly-heated silver, stirring thoroughly with an iron rod and pouring the fused mass at once into moulds. Alloys of silver and zinc can be obtained both ductile and flexible. An alloy consisting of zinc 2 parts and silver 1 has nearly the color of pure silver and is quite ductile. With a larger proportion of zinc it becomes, however, brittle. In preparing the alloy a small quantity of zinc volatilizes, and hence somewhat more has to be taken than the finished product is to contain.

Alloys of silver and zinc have many valuable properties, especially that of retaining their white color and being more fusible than alloys of silver with copper. It has therefore been proposed to use them for coinage and especially for small coins. Comparative experiments have, however, shown that for coins it is best to use alloys which besides silver and zinc contain copper, the following composition being especially recommended for the purpose: Silver 835 parts, copper 93, zinc 72.

The alloy is readily rolled into a sheet of suitable thickness, and should it become brittle its ductility can be restored by annealing.

*Alloys of silver, copper, and nickel.*—Nickel by itself makes silver very hard and brittle, such alloys being difficult to work into utensils. But by adding some copper the alloys can be cast, rolled, and fused, and the articles manufactured from them are harder than those from silver and copper alloys. Alloys of silver, nickel, and copper are much used by French manufacturers for articles formerly prepared from standard silver. These compositions may be considered as an argentan whose properties have been improved by a content of silver.

*Argent-Ruolz.*—The articles manufactured by Ruolz, of Paris, from the so-called Ruolz silver, or *argent français*, have the appearance of pure silver, but are much cheaper and harder. According to the quality of the articles, different alloys are used, a few such compositions being given as follows:—

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Silver | 33 | 40 | 20 |
| Copper | 37 to 42 | 30 to 40 | 45 to 55 |
| Nickel | 25 to 30 | 20 to 30 | 25 to 35 |

C. D. Abel, of London, has patented in England several alloys containing silver and nickel. They are divided into two classes, the first consisting of alloys of silver, copper, and nickel, with or without an addition of manganese. The alloys of this class can be composed according to the following proportions:—

| | Per cent. | | |
|---|---|---|---|
| | A. | B. | C. |
| Silver . . . . . | 33 | 40 | 20 |
| Nickel . . . . | 25 to 30 | 20 to 30 | 25 to 35 |
| Copper . . . . | 37 to 42 | 30 to 40 | 45 to 55 |

The second group of these alloys consists of silver, copper, nickel, and zinc, with or without manganese, and is composed of the following proportions:—

| | Parts. | | |
|---|---|---|---|
| | D. | E. | F. |
| Silver . . . . | 333 | 340 | 400 |
| Copper . . . . | 418 | 420 | 446 |
| Zinc . . . . | 163 | 160 | 108 |
| Nickel . . . . | 86 | 80 | 46 |

Of the above-mentioned alloys A, D, and E are especially intended for rolled, pressed, or drawn silver articles, C for casting, and F for jewelry. The content of silver in these alloys varies from 20 to 40 per cent., according to the purposes for which they are to be used—the proportion of nickel being the less, the greater that of silver.

For the alloys of the first group the patentee uses the purest copper found in commerce and purified nickel, the purification of the latter being effected in the following manner: The ordinary impure nickel of commerce is dissolved in nitric acid or in dilute sulphuric acid, the solution in the latter case being promoted by connecting the nickel with the positive pole of a galvanic battery. The solution is treated with chlorine and the ferric oxide precipitated by boiling with calcium carbonate. The solution is subsequently precipitated with soda, the precipitate re-dissolved in hydrochloric acid, the solution diluted with a large quantity of water, saturated with chlorine, and then treated with barium carbonate and allowed to cool. From the fluid separated from the precipitate the nickel is subsequently precipitated by the galvanic method and then reduced.

Nickel-speiss can be treated by the dry method by melting 100 parts of it with 20 of saltpetre and 100 of feldspar, whereby the cobalt forms a blue glass. The residue is roasted, washed, and dissolved in sulphuric acid, the resulting fluid being treated in the same manner as above. But no matter how the nickel may have been purified, it is of advantage before preparing the alloys to remelt it in a crucible together with yellow or red prussiate of potash, 50 parts of yellow or 25 to 30 of red prussiate of potash being used for 1000 parts of nickel. Frequently this method alone suffices for the purification of the commercial nickel, which by these means is obtained in well-fluxed, homogeneous pieces of any desired size.

The nickel purified in the above or any other manner is melted with the copper and an addition of charcoal and yellow, or, better, red prussiate of potash, which, when used as flux, is claimed to impart special properties to the alloys. In preparing an alloy which is to contain the highest content of silver and the smallest of copper, it is of advantage to add some manganese to prevent oxidation as much as possible, since the addition of nickel, if exceeded above a certain proportion, would impair the quality of the alloy. For this purpose sufficient oxide of manganese previously glowed with charcoal in a closed crucible is added to the mixture of copper and nickel before melting, so that a preliminary alloy, consisting of 80 to 90 parts of copper and nickel and 10 to 20 parts of manganese, is obtained—borax, red or yellow prussiate of potash, and charcoal, being used as flux. The manganese readily combines with the copper and the nickel and silver form with them a ductile alloy readily worked.

For the preparation of the alloys D, E, and F, the patentee employs the purest commercial copper and zinc and nickel purified by one of the methods above described. He first melts the copper and zinc together in the right proportions and adds to the alloy thus obtained the nickel by remelting, using the above-mentioned fluxing agents. For an alloy with a large percentage of silver, manganese is added in the same manner as above described.

The preliminary alloys thus obtained are subsequently melted together with the necessary quantity of silver, either yellow or red prussiate of potash, charcoal or borax, together with phosphorus, being added. For the production of an alloy of phosphorus and copper the use of copper phosphide deserves the preference. Its content of phosphorus being previously determined by an analysis, it is added to the argentiferous alloy in such a quantity that the content of phosphorus of the latter amounts to ½ to 2 per cent. The phosphide of copper is best prepared by heating 8 parts of comminuted copper with 1 part of a mixture of 40 parts of charcoal and 27 of super-phosphate of lime. The final silver alloys can also be at once fused with this mixture of charcoal and super-phosphate of lime previously heated to a slight red heat, using 1000 parts of the alloy to 100 of the mixture. By this process the content of phosphorus in the alloys will be the greater the longer the heating has been continued. The introduction of phosphorus makes the alloys more fusible and more homogeneous, and at the same time imparts to them a white color. To retain these advantages and to restore to the alloy its ductility lost by the addition of phosphorus, the latter is almost entirely removed, after homogeneous ingots have been obtained, by heating the alloy with charcoal powder in a closed crucible for several hours.

*Alloys of silver, copper, nickel, and zinc.*—These alloys have been used for the preparation of small coins, especially in Switzerland. The coins while wearing well, however, soon lose their original beautiful white color and acquire a disagreeable yellowish shade resembling the color of poor brass. For coinage these alloys have the further disadvantage of the silver contained in them, being only regained by a very tedious process.

*Mousset's silver alloy.*—Copper 59.06 parts, silver

27.56, zinc 9.57, nickel 3.42. Color, yellowish with a reddish tinge, but white upon the fractured surface.

*Alloys for Swiss fractional coins.*

| | 20 centimes. | 10 centimes. | 5 centimes. |
|---|---|---|---|
| | Parts. | Parts. | Parts. |
| Silver | 15 | 10 | 5 |
| Copper | 50 | 55 | 60 |
| Nickel | 25 | 25 | 25 |
| Zinc | 10 | 10 | 10 |

The argent-Ruoz sometimes contains also certain quantities of zinc. The following alloys can be rolled into sheet or drawn out into wire :—

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Silver | 33.3 | 34 | 40 |
| Copper | 41.8 | 42 | 44.6 |
| Nickel | 8.6 | 8 | 4.6 |
| Zinc | 16.3 | 18 | 10.8 |

*Alloys of silver and arsenic.*—These alloys may be formed by direct fusion, and the silver will retain a certain proportion of arsenic even when the temperature is very high. The compound made of 86 parts of silver to 14 of arsenic is of a dead grayish-white color, brittle, and acquires a metallic lustre by friction. It is very fusible. An alloy composed of silver 49 parts, copper 49, and arsenic 2, is very ductile and has a beautiful white color. It was formerly used for the manufacture of table-ware, for which it is, however, not suitable on account of the poisonous properties of the arsenic.

*Alloys of silver, copper, and cadmium.*—Cadmium imparts to silver alloys great flexibility and ductility without impairing their white color. Some of the more important alloys of this group are composed of—

| | Parts. | | | | | | |
|---|---|---|---|---|---|---|---|
| | I. | II. | III. | IV. | V. | VI. | VII. |
| Silver | 980 | 950 | 900 | 860 | 666 | 667 | 500 |
| Copper | 15 | 15 | 18 | 20 | 25 | 50 | 50 |
| Cadmium | 5 | 35 | 82 | 180 | 309 | 284 | 450 |

In preparing these alloys the great volatility of cadmium must be taken into consideration. The silver and copper are, as a rule, first alloyed; the cadmium wrapped in paper is then brought into the fused mass, the whole quickly stirred and at once poured into moulds. By this mode of procedure volatilization of cadmium is best prevented.

Silver is also used in the preparation of other alloys, especially in connection with platinum, which will be referred to later on. No true alloys of silver and iron have been made, only more or less intimate mixtures, where silver appears in the shape of drops or filaments. The alloys of silver with cobalt and chromium are generally very hard and brittle and thus far have found no application in the industries.

*Alloys of silver and copper.*—These alloys are more used than any other compounds of silver, and in most countries form the legal composition of coins and silverware. Silver and copper are easily alloyed in all proportions, the combination taking place with expansion and its specific gravity being less than that calculated from the proportions of the component metals. The copper imparts to silver greater hardness, strength, and tenacity, the alloys acquiring at the same time a beautiful sound. The presence of copper does not modify the color of silver so long as the proportion of copper does not exceed 40 to 50 per cent.; a greater proportion imparts to the alloy a yellowish tint similar to that of brass, and if the compound contains from 65 to 70 per cent. of copper the color is reddish, approaching that of pure copper.

The alloys of copper and silver, though easily affected by the ordinary process of fusion, are, nevertheless, subject to the defect of separation, or "liquation" which necessitates certain precautions when running the metal into moulds. When such an alloy is run into a cold ingot mould, the centre of the ingot is at a lower degree of fineness than the portion nearer the mould; and even in the monetary alloys all the portions are not of the same degree of fineness.

Formerly the silver used for coinage frequently contained small quantities of gold, and for this reason nearly all the older coins are treated in the mints by the wet method to regain the gold.

At the present time the fineness of all coins is determined by thousandths, the standard varying according to the size of the coins, and the laws of the different countries, from $\frac{900}{1000}$ to $\frac{750}{1000}$. In the following table the composition of the silver coins of various countries is given :—

| Country. | Coins. | Fineness. |
|---|---|---|
| Austria | Pieces of 3 and 2 guldens | 900 |
| Belgium | 5 franc-piece | 897 |
| “ | 2 “ “ | 835 |
| Brazil | Milreis, pieces of 500 and 200 reis | 916 |
| Denmark | Dobbelt rigsdaler, rigsdaler, halvdaler | 875 |
| “ | Mark ($\frac{1}{6}$ rigsdaler) | 500 |
| East Indies | Pieces of 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$ rupees | 916.66 |
| Egypt | Pieces of 20, 10, and 5 piastres | $833\frac{1}{8}$ |
| “ | Pieces of 1 piastre | 755 |
| “ | Pieces of $\frac{1}{2}$ and $\frac{1}{4}$ piastre | 750 |
| France | Pieces of 5, 2, and 1 franc, and 50 and 20 centimes | 835 |
| Germany | Mark piece | 900 |
| Great Britain | Crown, half-crown, and shilling | 925 |
| Greece | Pieces of 5, 1, $\frac{1}{2}$, and $\frac{1}{4}$ drachme | 900 |
| Holland | Pieces of $2\frac{1}{2}$, 1, and $\frac{1}{2}$ gulden | 945 |
| Italy | Pieces of 5, 2, 1, $\frac{1}{2}$, and $\frac{1}{4}$ lira | 835 |
| Mexico | Peso (average by U. S. Mint assay) | 901 |
| “ | Peso of Maximilian (average by U. S. Mint assay) | $902\frac{1}{2}$ |
| Norway | Pieces of 1, $\frac{1}{2}$, $\frac{1}{5}$, $\frac{1}{10}$ specie daler | 875 |
| Portugal | Pieces of 500 reis (by U. S. Mint assay) | 912 |
| Prussia | Thaler pieces | 900 |
| “ | Old Thalers before 1857 | 750 |
| Russia | Pieces of 1, $\frac{1}{2}$, and $\frac{1}{4}$ ruble | 768.5 |
| “ | Pieces of $\frac{1}{5}$, $\frac{1}{10}$, and $\frac{1}{20}$ ruble | 750 |
| Spain | Dollar of 5 pesetas | 900 |
| “ | Peseta (present, by U. S. Mint assay) | 835 |
| Sweden | Riksdaler, crown, and $\frac{1}{2}$ riksdaler | 750 |
| Switzerland | Pieces of 2, 1, and $\frac{1}{2}$ francs | 800 |
| Turkey | Pieces of 20, 10, 5, and 2 piastres | 830 |
| United States | Half dollar, quarter dollar, dime, half dime, and three cent piece | 900 |

The fineness of silver used in the manufacture of silver-ware varies from $\frac{750}{1000}$ to $\frac{950}{1000}$, as shown by the following table :—

| Countries. | Fineness. |
|---|---|
| Prussia, Saxony, Brunswick | 780 |
| Austria, Bavaria | 812 |
| England | 925 |
| France, Italy, Belgium | 950<br>800 |

Silver alloyed with copper in the preceding proportions has, in the form of wire or sheet, a hardness equal to that of cold-forged copper. By continued mechanical manipulation the hardness increases, however, and may be made equal to that of wrought-iron. Silver is also sometimes used for casting small articles of art, but it is difficult to obtain castings entirely free from blow-holes. This evil can, however, be readily prevented by adding to the alloy a small quantity of zinc, about 1 per cent. The resulting castings will be homogeneous, and free from blow-holes, while the ductility of the alloy is not in the least impaired by such a small percentage of zinc.

In consequence of the frequent annealing required in working articles of silver, they gradually acquire a steel-gray color which is due to the oxidation of copper. Hence the finished articles must be subjected to a special manipulation called "blanching." This is effected by boiling the articles in a fluid consisting of 40 parts of water and one part of sulphuric acid. The oxide of copper readily dissolves in the mixture, leaving the surface of the article coated with a layer of chemically pure silver.

*Gray silver* (*Japanese silver*).—In Japan an alloy of equal parts of silver and copper is prepared which acquires a beautiful gray color by boiling in a solution of alum to which sulphate of copper and verdigris are added. The so-called "mokum," an alloy also introduced from Japan, is prepared by placing thin plates of gold, silver, copper, and of the above alloy upon each other, and stretching under the hammer. The cross sections of the resulting thin plates show the colors of the various metals, and have a peculiar striped appearance. Mokum is chiefly used for decorations upon gold and silver articles.

*Imitation silver alloys.*—There is a large number of imitation silver alloys which are used as substitutes for many purposes. In the following a few of them together with their properties are given:—

*Warne's metal.*—Tin 10 parts, nickel 7, bismuth 7, cobalt 3. White, fine-grained, quite difficult to fuse.

*Minargent.*—This alloy, which has a very beautiful white color, is composed of copper 1000 parts, nickel 700, tungsten 50, aluminium 10.

*A beautiful white alloy closely resembling silver* is manufactured in Paris, which, according to an analysis by Prof. Rochleder, of the Prague University, is composed of copper 69.8 parts, nickel 19.8, zinc 5.5, and cadmium 4.7.

*Delalot's alloy.*—This white, silver-like alloy is claimed to possess properties adapting it as a substitute for several alloys now in use. It consists of 80 parts of pure copper, 2 of manganese, 18 of zinc, and 1 of phosphate of lime. First melt the copper, then add gradually the manganese, and when this is thoroughly dissolved the phosphate of lime. Remove the scoria and about te minutes before casting add the zinc. To promote the fusion of the manganese $\frac{1}{2}$ part of calcium fluoride, $\frac{1}{2}$ part of borax, and 1 part of charcoal may be added.

*Tournu-Leonard's alloy.*—This alloy, which closely resembles silver, is prepared in the following manner: 200 parts of fine tin are introduced into a crucible heated to a red heat. When the metal is melted add 64 parts of bell-metal, previously comminuted to the size of lentils. Add only small portions at one time, and stir the mixture with an iron rod to effect the solution as quickly as possible. Finally add 300 parts more of tin, stir thoroughly, and pour the alloy into moulds of copper or sand. By the content of copper in the bell-metal, the tin is sufficiently hardened to allow of the alloy being worked into table-ware, plates for printing music, and even into jewelry.

*Clark's patent alloy* consists of shot-copper 1 ounce, nickel 3 dwts. 18 grains, spelter 1 dwt. 22 grains, tin 12 grains, cobalt 12 grains.

*Pirsch-Baudoin's alloy.*—This alloy resembling silver is composed of copper 71 parts, nickel 16.5, cobalt (in the form of oxide) 1.75, tin 2.5, and zinc 7. Some aluminium (about $\frac{1}{2}$ per cent.) may also be added. Prepare first an alloy of all the nickel, an equal quantity of the copper and the zinc; then melt this alloy together with the iron, the remainder of the copper, the cobalt, and some charcoal powder under a surface covering of charcoal powder in a graphite crucible at a strong heat. Allow the melted mass to cool and then add the zinc, previously alloyed with copper, at a temperature just sufficient for its fusion. Now take the crucible from the fire, stir the contents with a wooden stick, add the tin previously wrapped in paper, stir the mass once more, and pour out into moulds. But a small quantity of zinc remains in the alloy, the greater portion of it volatilizing during fusion.

# XXXIV.

## GOLD ALLOYS.

GOLD has been known and used by every nation, both uncivilized and civilized, from the earliest period down to our time. It is found among the old Egyptian monuments, and semi-barbarous nations have used it in the form of dust as the principal medium of exchange. When America was discovered by Columbus gold was well known to its inhabitants; the Chinese have used it from time immemorial; the Medes and Persians were remarkable, even more than other Asiatics, for their love of gold; jewels of costly description were employed to indicate the rank of the wearer, and this custom is still continued in the East at the present time. To show the sacred value the Egyptians in ancient times placed on gold, it was represented by a circle with a dot in the middle, this circle amongst that nation being the symbol of divinity and perfection.

Gold is one of the metals which most readily enter into combination with other metals. But this property is without importance when we consider the inutility of the majority of the compounds and the necessity of not debasing its value or impairing its properties. Moreover, it is certain that excepting its alloys with copper, silver, iron, and platinum, the latter two being without actual utility, gold loses part of its ductility, resistance, and cohesion, when it is combined with other metals such as zinc, tin, lead, etc. Therefore, it is entirely useless to experiment on those alloys where gold loses not only a part of its money value but also those valuable properties which participated in making it a noble metal.

The principal alloys of gold used at the present time are those with copper or silver, or, in rare cases, with both these metals.

*Gold and copper* have great mutual affinity and may be alloyed in all proportions. The alloys are harder and more fusible than gold alone. Copper diminishes the ductility of gold when it enters into the combination in a proportion over 10 to 12 per cent. The specific gravity of an alloy of gold and copper is less than the average of the two metals. The color of the alloy varies between dark yellow and red, according to the quantity of copper. Pure copper must be used in the preparation of the alloys, as the impure metal alters the malleability of gold and may render it brittle.

*Gold and silver* may be easily mixed together, but do not appear to form true combinations. These compounds are more fusible than gold and are generally greenish-white, more ductile, harder, more sonorous and elastic than gold or silver considered singly. One-twentieth of silver is sufficient to modify the color of gold. Silver, like copper, increases the firmness of gold, and on that account it is employed at various degrees of fineness for jewelry work. These alloys are known by jewellers under the names of *yellow gold*, *green gold*, and *pale gold*, according to the proportion of silver.

As previously mentioned the alloys of gold with other metals are of no practical utility and need only be briefly referred to. Gold alloyed with iron forms pale gray masses, brittle and somewhat magnetic. An alloy holding $\frac{1}{6}$ of iron is employed in jewelry under the name of *gray gold*.

Lead shows a peculiar behavior towards gold. Both metals are very soft and ductile, but when alloyed they form an exceedingly brittle metal of a pale yellow color, strongly crystalline, and hard as glass. According to Berthier, one-half of one-thousandth of lead alloyed to gold is sufficient to render the latter metal entirely brittle and without ductility.

Arsenic or antimony alloyed with gold gives a brittle, very crystalline, alloy of a white or gray color. Accidental admixtures of arsenic or antimony can, however, be removed in a simple manner, it being only necessary to keep the metal in a melted state for some time, whereby the arsenic and antimony volatilize, the pure gold remaining behind.

*Alloys of gold and palladium.*—Alloys of gold, copper, silver, and palladium have a brownish-red color and are as hard as iron. They are sometimes used for bearings of the arbors in fine watches, as they cause but little friction (less than the jewels used for the same purpose) and never rust on exposure to the air. The composition used in the Swiss and English watch factories consists of gold 18 parts, copper 13, silver 11, palladium 6.

*Alloy of aluminium and gold.*—This alloy, which is also known as *Nürnberg gold,* is frequently used in the manufacture of cheap gold-ware, it being well adapted for the purpose as its color exactly resembles that of pure gold and remains unchanged in the air. The composition of most articles of Nürnberg gold is according to the following proportions: Copper 90 parts, gold 2.5, aluminium 7.5.

An addition of cadmium to an alloy of gold and silver imparts to it a beautiful green color; these alloys will be referred to in speaking of colored gold.

## XXXV.

## PREPARATION OF GOLD ALLOYS.

THE preparation of alloys varies according to the purpose for which they are to be used, this difference being especially apparent in the moulds employed for casting. The manufacturers of gold articles rarely use moulds for shaping the articles excepting such as have considerable thickness, as seal-rings, medals with especially high relief, etc. The casting of such articles is generally effected in moulds of very fine sand or finely pulverized and elutriated cuttle-fish.

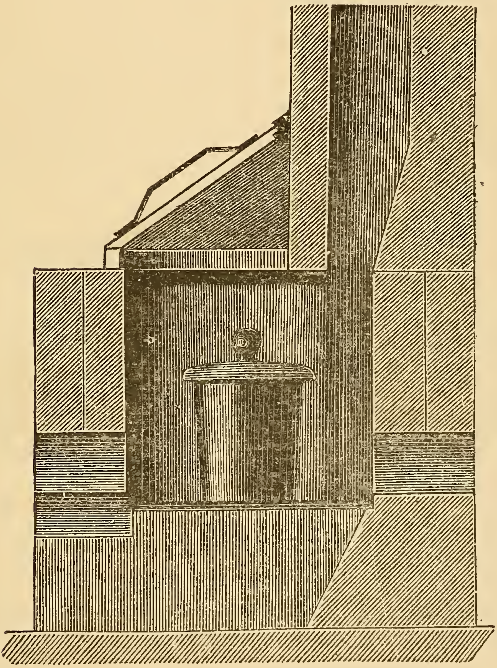
For coinage the gold is always cast into ingots or bars, iron moulds being generally used for the purpose. The bars are either rolled out to sheet or drawn into wire, the larger part of jewelry being also manufactured from such sheet or wire. The shape of the iron moulds used for casting varies according to the shape the ingot is to have; for ingots to be drawn out into wire it is best to use cylindrical tubes open on top and closed on the lower end by an iron plug. The gold contracting strongly in solidifying can be removed from the tubes without difficulty.

Ingots to be used for the preparation of gold plates are best cast in the form of four-sided prisms, casting ladles with a corresponding bowl being used for the purpose. For casting very thin plates upright ladles covered with a level plate are also used.

The melting of the metals constituting the alloys is always effected in graphite crucibles, the gold being in all cases first melted, and as it does not oxidize even at a red heat a protecting cover is not required. The gold being entirely melted, it is heated as strongly as the furnace will permit, and the other metals previously converted into small pieces are then introduced. On account of the great density of gold as compared with that of the other metals, the mixture of the metals is promoted by stirring with an iron rod sharpened on the point and made previously red hot. The crucible is then quickly withdrawn and its contents poured into a suitable ingot mould, previously warmed and greased to prevent adhesion. The warming of the mould is quite indispensable, but if made too hot the metal on being turned into it will spit and fly about, and besides incurring great loss of gold dangerous results might thereby happen to the person in charge. The same remark applies when the ingot mould is cold. It is hot enough when it will just stand touching with the hand for a second or so.

The melting point of gold being very high, the furnace used should have a good draught. In some mints which alloy daily large quantities of gold and silver, furnaces heated by gas are used.

Fig. 16.



The furnace used by most manufacturers of gold-ware is, however, the wind-furnace, one admirably suited for the purpose being shown in Fig. 16. The crucible and fuel are introduced through an oblique iron door lined inside with fire-clay. These furnaces can also be used for the preparation of granulated gold, frequently used by gold-workers in the manufacture of jewelry. For this purpose thin sheet gold or wire is cut with scissors into small pieces, which are enveloped in charcoal dust in a graphite crucible and heated in the furnace. The pieces of gold melt to small balls of corresponding dimensions, which, after being freed from adhering foreign bodies by washing, are separated into sizes by passing through a sieve.

When it is desired to produce very tough gold use as flux a tablespoonful of charcoal and one of sal ammoniac, adding it to the gold just before melting; the sal ammoniac burns away while toughening the gold. The employment of the mixture of sal ammoniac will bring the ingots of gold up bright and clear; it will also prevent them from splitting or cracking when rolled and in subsequent working.

In remelting scrap-gold from the work-shop and old gold, care should be taken that they are not too much contaminated by solder and free from organic matter, wax, etc. The solder used in soldering goldware contains tin, lead, bismuth, and sometimes zinc, and the presence of these metals has an injurious effect upon the ductility of the gold. It is recommended to separate much contaminated gold from the foreign metals by the wet process, and alloy the resulting chemically pure gold.

In most countries there are legally fixed standards for gold alloys. Generally such alloys are considered as consisting of so many carats to the unit, the pound, or half pound being divided into 24 carats, each of which contains 12 grains. What is termed 18 carat gold is a unit of 24 carats of alloy containing 18 carats gold and 6 of copper. Since the introduction of the decimal system in many countries the fineness of gold alloys has been determined by thousandths, the fineness of the alloys being officially expressed in this manner. Notwithstanding the simplicity of the system, many manufacturers still hold to the old method and calculate according to carats and grains. To save calculation the conversion of carats and grains into thousandths is given in the following table:—

| | | | |
|---|---|---|---|
| 1 grain = | 3.47 | 7 carats = | 291.666 |
| 2 “ | 6.95 | 8 “ | 333.333 |
| 3 “ | 10.42 | 9 “ | 374.999 |
| 4 “ | 13.89 | 10 “ | 416.667 |
| 5 “ | 17.36 | 11 “ | 458.630 |
| 6 “ | 20.84 | 12 “ | 500.000 |
| 7 “ | 24.31 | 13 “ | 541.667 |
| 8 “ | 27.78 | 14 “ | 583.333 |
| 9 “ | 31.25 | 15 “ | 624.555 |
| 10 “ | 34.73 | 16 “ | 666.667 |
| 11 “ | 38.19 | 17 “ | 707.333 |
| 12 “ | 41.67 | 18 “ | 750.000 |
| 1 carat = | 41.667 | 19 “ | 791.666 |
| 2 “ | 83.334 | 20 “ | 833.333 |
| 3 “ | 125.001 | 21 “ | 874.999 |
| 4 “ | 166.667 | 22 “ | 916.666 |
| 5 “ | 208.333 | 23 “ | 958.333 |
| 6 “ | 250.000 | 24 “ | 1000.000 |

## XXXVI.

### USE OF GOLD ALLOYS.

Gold alloys are principally used for coinage and ornamental articles. They are further employed in the manufacture of genuine gold-leaf, in the preparation of genuine *Leonis* wires (which consist of silver coated with gold), and in filling teeth.

*Standard gold.*—The alloy used at present in all countries for gold coins consists of gold and copper. Many coins contain a small quantity of silver, but this is due to a contamination of the copper with this metal, many copper ores containing silver, but in such small quantities that the separation of the two metals would not pay. As coins are subjected to considerable wear through frequently passing from hand to hand, the amount of loss occasioned thereby is worthy of some little consideration. Of course, this amount will be in proportion to the length of time the coins have been in circulation. To provide against this the English government allows a sovereign to be a legal tender till it is reduced not below 122.5 grains, the difference between this and the full standard weight of 123.147 grains being the remedy allowed by English law for abrasion or loss by wear. The depreciation of a coin depends upon its hardness, wearing much more when soft, and also upon the rapidity of circulation. In most countries the fineness of gold coins is fixed by law, and though, as will be seen from the following table, the differences are slight, commerce would be greatly facilitated if all countries would adopt a universal standard of fineness.

| | | |
|---|---|---|
| Ducats, Hungarian | 989 | thousandths. |
| " Austrian | 986 | " |
| " Dutch | 982 | " |
| English sovereigns | 916 | " |
| Prussian Friedrichsd'or | 902 | " |
| German gold coins | 900 | " |
| Austrian crowns | | |
| French gold coins | | |
| Belgian | | |
| Italian | | |
| Swiss | | |
| Spanish | | |
| Greek | | |
| United States | | |
| Chinese | | |
| Older German gold coins (pistoles) | 895 | " |

In the manufacture of jewelry alloys of gold with copper, or with silver, or with both metals are used. The alloy with copper alone is termed *red,* while if silver is used it is termed *white,* and if both metals are alloyed with gold the caratation is termed *mixed.* In most countries there are legally fixed standards for gold jewelry. In England 16, 18, and 22 carat gold is stamped, or, as it is termed *Hall marked,* in France 18, 20, and 22 carat, in Germany 8, 14, and 18 carat, and, also, under the term *joujou* gold, a 6 carat gold used for jewelry to be electro-gilt. Though this is intended as a protection to the buyer, the price of the articles does not depend alone on the quantity of gold used, but to a great extent on the labor expended on its production, and, therefore, these legal regulations are, in many cases, illusive.

In the following table the gold alloys legally fixed by the various governments are given, but we would remark that for certain ornamental articles distinguished by their color some deviation, though within certain limits, is permitted:—

| Fineness. | Parts. | | | Color. |
|---|---|---|---|---|
| | Gold. | Silver. | Copper. | |
| 583 | 14 | 6 | 4 | yellow. |
| 583 | 14 | 3 | 7 | dark yellow. |
| 583 | 14 | 1 | 9 | very red. |
| 666 | 16 | 4.66 | 3.33 | yellow. |
| 666 | 16 | 1.60 | 6.40 | red. |
| 750 | 18 | 3.50 | 2.50 | yellow. |
| 750 | 18 | 2.50 | 3.50 | red. |

*Gold alloys which can be legally used in various countries.*

| | | Fineness. |
|---|---|---|
| England | . . . . . . . . | 750 |
| France | highest standard . . . . | 920 |
| Belgium | second " . . . . | 840 |
| Italy | third " . . . . | 750 |
| Austria, No. I. | . . . . . . . | 326 |
| " No. II. | . . . . . . . | 545 |
| " No. III. | . . . . . . . | 767 |

*Pforzheim gold-ware.*

| | Fineness. |
|---|---|
| Ordinary ware (joujou) . . . . . | 130 to 250 |
| Finer quality . . . . . | 563 |
| Finest quality . . . . . | 583 to 750 |

| | Gold. Parts. | Silver. Parts. | Copper. Parts. |
|---|---|---|---|
| Elastic gold alloy (spring gold) | 2.66 | 2.66 | 5.33 |
| Japanese blue gold (Shakdo) | 1 to 10 | — | 90 to 99 |

The last-mentioned alloy has the property of acquiring a permanent color, shading from dark blue into black.

The following table shows the proportions of various metals incorporated in the gold alloys used by jewelers:—

| Carats. | Parts. | | |
|---|---|---|---|
| | Copper. | Silver. | Gold. |
| 23 . . . | ½ | ½ | 23 |
| 22 . . . | 1 | 1 | 22 |
| 20 . . . | 2 | 2 | 20 |
| 18 . . . | 3 | 3 | 18 |
| 15 . . . | 6 | 3 | 15 |
| 13 . . . | 8 | 3 | 13 |
| 12 . . . | 8½ | 3½ | 12 |
| 10 . . . | 10 | 4 | 10 |
| 9 . . . | 10½ | 4½ | 9 |
| 8 . . . | 10½ | 5½ | 8 |
| 7 . . . | 9 | 8 | 7 |

*Colored gold.*—As previously remarked the color of gold alloys varies according to the proportions of copper or silver used. Manufacturers of jewelry and other gold-ware make extensive use of the various colors of alloys, one article being frequently composed of several pieces of different colors. The appended table gives the composition of the alloys most frequently used, with their specific colors:—

| Parts. | | | | | Color. |
|---|---|---|---|---|---|
| Gold. | Silver. | Copper. | Steel. | Cadmium. | |
| 2 to 6 | 1.0 | — | — | — | green. |
| 75.0 | 16.6 | — | — | 8.4 | “ |
| 74.6 | 11.4 | 9.7 | — | 4.3 | “ |
| 75.0 | 12.5 | — | — | 12.5 | “ |
| 1.0 | 2.0 | — | — | — | pale yellow. |
| 4.0 | 3.0 | 1.0 | — | — | dark yellow. |
| 14.7 | 7.0 | 6.0 | — | — | “ |
| 14.7 | 9.0 | 4.0 | — | — | “ |
| 3.0 | 1.0 | 1.0 | — | — | pale red. |
| 10.0 | 1.0 | 4.0 | — | — | “ |
| 1.0 | — | 1.0 | — | — | dark red. |
| 1.0 | — | 2.0 | — | — | “ |
| 30.0 | 3.0 | — | 2.0 | — | gray. |
| 4.0 | — | — | 1.0 | — | “ |
| 29.0 | 11.0 | — | — | — | “ |
| 1 to 3 | — | — | 1 | — | blue. |

The alloys containing cadmium, given in the above table, are malleable and ductile and can be used for plating. To prepare them the constituent parts must be carefully melted together in a covered crucible lined with coal dust. The resulting alloy is then remelted with charcoal or powdered resin and borax in a graphite crucible. If, notwithstanding these precautions, a considerable portion of the cadmium volatilizes the alloy must be again remelted with an excess of cadmium to bring it up to the required percentage.

In modern times certain alloys of gold are also prepared by the galvanic process, and articles showing various colors are now manufactured by this method. It is generally done by immersing the article of gold in a diluted bath of chloride of gold in which is a plate of silver connected with the positive pole of a battery:

silver separates upon the gold, a certain alloy being formed which is used as a basis for further coloring. When the desired color has made its appearance the plate of silver is replaced by one of colored gold, whose color corresponds to the shade the article is to have.

In many factories it is customary to color the finished gold articles, *i. e.*, to impart to them, by treatment with agents capable of dissolving copper, a color approaching that of chemically pure gold. By this operation the alloy of gold and copper is decomposed on the surface of the article, the copper being dissolved out. By allowing the surface of the article to remain in contact with the bath for some time the copper is entirely dissolved, a layer of pure gold with its characteristic color remaining behind. By allowing the bath to act for a shorter time only a portion of the copper is dissolved, and, by skilful manipulation, the various shades between red and yellow can be imparted to the articles.

# XXXVII.

## ALLOYS OF PLATINUM AND PLATINUM METALS.

PLATINUM alloys readily with all metals. Many of these alloys possess properties making them extremely useful for certain purposes and they are frequently used in the manufacture of artificial teeth, measuring scales, and articles subject to especially strong mechanical action. (Alloys of platinum and iridium are used for cylinders in which the touch-hole of cannon is to be bored.) Pure platinum, as well as its alloys, with iridium and palladium, being indifferent to most chemical agents is much used in the manufacture of standard weights and scales. The so-called platinum vessels used in the laboratories of chemists, in manufactories of sulphuric acid and other chemical products, consist generally of platinum alloyed with one of its allied metals.

The platinum occurring in nature is never pure, but generally contains a number of other metals, those most frequently associated with it being silver, gold, iron, palladium, osmium, iridium, ruthenium, rhodium, further small quantities of nickel, cobalt, etc. The enumeration of these metals occurring in combination with platinum explains why the latter metal combines so readily with others, the native platinum occurring in nature being actually not such in the true sense of the word, but a platinum alloy.

The platinum melting only at a very high temperature, a furnace of peculiar construction heated with oxyhydrogen gas is required for the preparation of the alloys. The melting point of the latter is, however, frequently so low as to allow of their being melted in ordinary furnaces. In the following we will briefly describe a platinum furnace exhibited by the French government at the last Paris Exhibition, which is used for melting the platinum required in the manufacture of standard meters.

This furnace, or, more correctly, melting apparatus, consists of an oblong bowl of lime with a cavity capable of holding 440 pounds of melted platinum. Upon this bowl a lid of lime can be lowered by means of a lever mechanism. In this lid are so-called Daniell's cocks, used for ordinary oxy-hydrogen blow-pipes. The products of combustion escape through apertures in the periphery of the bowl. The oxy-hydrogen gas used in this apparatus does not consist of oxygen and hydrogen, but of oxygen and illuminating gas.

For the preparation of platinum alloys on a small scale an apparatus resembling the above in its main features may be used. A bowl holding several pounds of platinum can be fashioned from chalk over a wooden mould, and is, before use, converted into caustic lime by heating to a white heat. An ordinary oxy-hydrogen blow-pipe is used, the compressed oxygen and hydrogen being contained in strong vessels, or in bags of strong canvas made gas-proof by several coats of caoutchouc varnish. In preparing alloys of platinum with base metals in such a bowl, it must be taken into consideration that the latter are at once oxidized by the smallest excess of oxygen, and hence care must be had to set the cocks of the oxy-hydrogen blow-pipe so that the flame receives a small excess of hydrogen. In preparing the alloys the quantity of platinum required is first brought into flux, and then the other metals are added all at once through an aperture in the lid of the bowl which otherwise is closed with a lime-plate.

Immediately after the introduction of the metals into the fused platinum, the flame can be modified or in some cases entirely extinguished, the alloys having, as a rule, a much lower melting point than that of platinum. The melted alloy is cast in ingots or cylindrical bars in moulds of lime. The ingots are especially adapted for rolling out into sheet, while the bars are more suitable for wire.

*Alloys of platinum and iridium.*—Pure platinum is a very soft metal, being scarcely harder than gold. The solidity of platinum articles found in commerce is nearly always due to the presence of a certain quantity of iridium, and for the manufacture of vessels alloys of the two metals are used. They are much harder and more tenacious than pure platinum and more capable of resisting chemical agents, an alloy of 90 parts of platinum and 10 of iridium not being attacked even by nitro-muriatic acid. Vessels prepared from this alloy when used become very lightly coated with pure iridium, and are then indifferent to mechanical and most chemical influences. On account of their great ductility these alloys can be rolled out cold to a very thin sheet and drawn to very fine wire.

The other alloys of platinum with platinum metals have found no technical application up to the present time, though the alloy with palladium could certainly be advantageously used for many purposes on account of its strength and ductility. Among the alloys of platinum with other precious metals there are several which are used to some extent in various branches of the metal industry, and they are prepared either by themselves (platinum with gold, or platinum with silver) or with addition of tin, nickel, copper, etc.

*Alloys of platinum and gold.*—The two metals may be alloyed in all proportions, but on account of the refractory nature of the platinum the combination takes place only at a very high temperature. A very small quantity of platinum suffices to change the properties of gold to a considerable extent. With a very small percentage the color becomes sensibly lighter than that of pure gold, and the alloys show a high degree of elasticity, which they nearly lose, however, if the content of platinum exceeds 20 per cent. The melting point of the alloys is very high, and those with 70 per cent. platinum can be fused only in the flame of oxy-hydrogen gas. The application of alloys of platinum and gold is limited ; one containing from 5 to 10 per cent. of platinum is used in the form of sheet and wire in the manufacture of artificial teeth.

*Alloys of platinum and silver.*—By an addition of platinum the hardness of silver is increased and its pure white color changed to gray, an alloy containing but a few per cent. of platinum showing a much darker color than pure silver. Alloys with 17 to 35 per cent. of platinum are prepared and known as *platine au titre.* Their use is limited, they being chiefly employed in dentistry. The alloys are difficult to produce on account of the separation of the platinum, which is due to its superior specific gravity.

*Alloys of platinum, gold, silver, and palladium.*—The alloys composed of these metals are especially prepared for dental purposes, and the compositions of those found in commerce vary very much. They are best prepared with the assistance of oxyhydrogen gas, though it is possible to fuse them in an ordinary furnace. The readily fusible metals are first melted, and after increasing the fire as much as possible the platinum metals are added. In the following the compositions of a few of these alloys are given :—

*Platinor.*—The alloy known under this name in commerce has a beautiful golden-yellow color (hence its name) without containing any gold. It consists of varying quantities of platinum, silver, copper, zinc, and nickel, the variations in the percentage of copper and zinc being very likely due to the fact that the two metals are not used directly, but in the form of brass. The use of the latter has the advantage of making the alloy more homogeneous and preventing, to some extent, the loss of zinc. An alloy with a color closely resembling that of pure gold and quite constant in the air may be made as follows: Melt 1 part of silver with 5 of copper, add to the melted mass 2 parts of brass, then 1 of nickel, and, after raising the temperature to the highest point the furnace is capable of producing, 2 parts of platinum, which is best used in the form of a very fine powder, the so-called platinum-black.

*Platinum-bronze.*—This alloy deserves attention, it possessing properties not to be found to the same extent in other alloys, and besides it is not very expensive. Platinum-bronzes are indifferent to the action of air and water, and, once polished, retain their bright lustre for a long time. Up to the present time they have only been used for tableware and articles of luxury, and occasionally, on account of their sonorousness, for bells. Besides tin, platinum-bronze always contains platinum and some compositions, a certain quantity of silver, which, however, can be replaced by a corresponding quantity of brass, without impairing the resistance against atmospheric influences. The following table gives the composition of some varieties of platinum-bronze:—

| Uses. | Parts. | | | | |
|---|---|---|---|---|---|
| | Nickel. | Platinum. | Tin. | Silver. | Brass. |
| For table utensils . . . | 100 | 1 | 10 | — | — |
| " bells . . . . . . . | 100 | 1 | 20 | 2 | — |
| " articles of luxury . | 100 | 0.5 | 15 | — | — |
| " tubes for spy-glasses | 100 | 20 | 20 | — | — |
| " ornaments . . . . | 60 | 10 | — | — | 120 |

*Alloys of platinum with the base metals.*—Among the alloys of platinum with the base metals only those with copper and iron are of importance. The other metals also form alloys with platinum, which, however, are not suitable for technical purposes. The alloys with iron are also of secondary interest, since platinum-iron and platinum-steel have not found the general application in the industries which was at one time prophesied by many. It may, however, be said that a certain addition of platinum imparts to steel many excellent properties, an alloy consisting of 1 part of platinum and 70 of steel being, for instance, on account of its great hardness, very suitable for the manufacture of cutting tools. For knives with especially sharp edges, an alloy containing only one-half per cent. of platinum is claimed to be the most suitable.

With pure iron platinum forms a steel-gray mass very difficult to fuse, and so hard as to be scarcely scratched by the best file. Berthier has tried alloys made of 1 part of platinum with from 4 to 10 parts of iron. The fracture of the alloy was gray and granular, and it was possible to flatten the metal with a hammer before breaking it.

*Alloys of platinum and copper.*—These alloys possessing with great ductility and tenacity a very beautiful color, can be advantageously used for some technical purposes. The color of the copper is modified by the presence of a comparatively small quantity of platinum, copper containing but 4 per cent. of it showing a rose color, which, in the presence of more platinum, soon changes to golden-yellow.

The alloys of copper with platinum are very ductile, malleable, and easily worked. By adding zinc a mixture of metals is obtained which, as regards color and durability of lustre, is equal to gold, and, for this reason, is used in the manufacture of ornaments. The properties of the alloys vary very much according to the quantity of metals they contain, and, hence, they are adapted for many technical purposes.

*Golden-yellow alloys of platinum and copper.*—Alloys so composed that their color approaches that of pure gold are suitable for the manufacture of jewelry and other ornaments, and as regards the price of the metals can be prepared for about twice the cost of silver. With an equally beautiful color they surpass gold, on account of their much lower price, and, especially, their durability.

The composition of the alloys used in the manufacture of ornaments varies within very wide limits. The following are, however, the most important:—

| | Parts. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Platinum | 2 | 20 | 7 | 3 |
| Copper | 5 | — | 16 | 13 |
| Zinc | — | — | 1 | |
| Silver | 1 | 20 | — | |
| Brass | 2 | 240 | — | |
| Nickel | 1 | 120 | — | |

The alloy No. IV., which is known as Cooper's gold, is especially adapted for ornamental articles, it having a color which cannot be distinguished from that of 18 carat gold, even by a close comparison. It can be drawn out to the finest wire, and rolled out to very thin sheet.

Other alloys suitable for ornaments, on account of their gold-like appearance, are composed of—

| | Parts. | | | |
|---|---|---|---|---|
| | I. | II. | III. | IV. |
| Platinum | 15 | 16 | 7 | 6 |
| Copper | 10 | 7 | 16 | 26 |
| Zinc | 1 | 1 | 1 | — |

The success in preparing these alloys depends, however, on using metals entirely free from iron, experiments having shown that the $\frac{8}{1000}$ part of the weight of the alloy of iron suffices to render it sensibly brittle. If any of the constituent metals contains iron, the alloy, though showing a beautiful color, will be too hard, and besides so brittle as to make it impossible to draw it out into fine wire or roll it out to thin sheet.

Cooper has thoroughly examined the properties of platinum alloys, and to his researches we are indebted for some important compositions which he has termed mirror-metal and pen-metal, they being especially suitable for these purposes.

*Cooper's mirror-metal.*—Copper 35 parts, platinum 6, zinc 2, tin 16.5, arsenic 1. This alloy being entirely indifferent to the action of the weather, and taking a beautiful polish on account of its hardness, is especially adapted for the manufacture of mirrors for optical instruments.

*Cooper's pen-metal.*—The preceding alloy is also very suitable for the manufacture of pens, but is too expensive to compete successfully with steel. An alloy frequently used for the preparation of pen-metal consists of: Copper 1 or 12 parts, platinum 4 or 50, silver 3 or 36.

Their great hardness and resistance against atmospheric influences make Cooper's pen alloys very suitable for the manufacture of mathematical and other instruments of precision. It can, for instance, scarcely be calculated how long a chronometer, whose train of wheels is constructed of such an alloy, can run before it shows any irregularity attributable to wear.

*Palladium alloys.*—Palladium occurs associated with platinum and is obtained as a by-product in refining platinum. Pure palladium is but little used. It is sometimes employed in the preparation of mirrors by the galvanic process or of semicircular protractors for fine mathematical instruments. The pure metal is, however, more frequently used in the preparation of alloys which are chiefly employed in dentistry and in the manufacture of fine watches. The most important of these alloys are the silver alloys and the so-called palladium bearing-metal.

*Alloys of palladium and silver.*—This alloy, which is almost exclusively used for dental purposes, consists of 9 parts of palladium and 1 part of silver. It does not oxidize, and is, therefore, very suitable for plates for artificial teeth. The following alloy is still more frequently used: Platinum 10 parts, palladium 8, gold 6.

*Palladium bearing-metal.*—This alloy is uncommonly hard, and is said to produce less friction upon arbors of hard steel than the bearings of jewels generally used for fine watches. The alloy has the following composition: Palladium 24 parts, gold 72, silver 44, copper 92.

The alloys of the other platinum metals are but little used, especially on account of their rarity and costliness. The alloys of platinum and iridium are only used for special scientific purposes, for instance, for standard scales, etc. Iridium as well as rhodium possesses the property of imparting great hardness to steel, but the rhodium and iridium steel found in commerce contain, in many cases, not a trace of either. The alloy of iridium with osmium is distinguished by great hardness and resistance, and has, therefore, been recommended for pivots, for fine instruments, and points for ships' compasses.

*Phosphor-iridium.*—For preparing larger pieces of iridium than found in nature for making points for the Mackinnon stylographic pen, Mr. John Holland, of Cincinnati, has devised the following ingenious process: The ore is heated in a Hessian crucible to a white heat, and, after adding phosphorus, the heating is continued for a few minutes. In this manner a perfect fusion of the metal is obtained, which can be poured out and cast into any desired shape. The material is about as hard as the natural grains of iridium, and, in fact, seems to have all the properties of the metal itself.

Phosphor-iridium, as this metal may be called, possesses some very remarkable properties. It is as hard, if not harder, than iridosmine, from which it is prepared. It is somewhat lighter, owing to its percentage of phosphorus and increase of volume. It is homogeneous and easy to polish and forms some alloys impossible to prepare in any other manner. It combines with small quantities of silver and forms with it the most flexible and resisting alloy of silver. With gold or tin no alloy has thus far been obtained. Added in small quantities to copper it furnishes a metal possessing very small resistance to friction and is especially adapted for articles subjected to great pressure. This alloy seems to possess more than any other metal the power of retaining lubricants. With iron, nickel, cobalt, and platinum phosphor-iridium forms combinations in all proportions which are of great importance. With iron an alloy is obtained which retains the properties of phosphor-iridium, although its hardness decreases with a larger addition of iron. The alloy is slightly magnetic, and is not attacked by acids and alkalies, and the best file produces no effect upon it even if it contains as much as 50 per cent. of iron. With more than 50 per cent. of iron the power of resistance decreases gradually, and the nature of the metal approaches that of iron.

# XXXVIII.

## ALLOYS OF MERCURY AND OTHER METALS OR AMALGAMS.

Mercury, as is well known, is the only metal which is liquid at an ordinary temperature. It freezes at 40° F., forming a ductile, malleable mass and boils at 662° F., forming a colorless vapor; it volatilizes, however, even at ordinary temperatures. Compounded with other metals it forms alloys whose properties vary very much according to the metals used. In most cases the amalgams are at first liquid and after some time acquire a crystallized form, whereby the mercury in excess is separated.

The amalgams offer an excellent means of studying the behavior of the metals towards each other, the examination being facilitated by the low temperature at which these combinations are formed. If a metal be dissolved in mercury, and the latter be present in excess, a crystalline combination will in a short time be observed to separate from the originally liquid mass. This crystalline combination forms the actual amalgam and is composed of proportions which can be expressed according to determined atomic weights, and can be readily obtained by removing the excess of mercury by pressure.

Many amalgams require considerable time to pass into the crystalline state, and are at first so soft that they can be kneaded in the hand like wax, but harden completely in time. They are especially adapted and much used for filling hollow teeth.

Before the action of the galvanic current upon solutions of metals was known, amalgams were of great importance for gilding and silvering, which was effected by coating the article to be gilt or silvered with the amalgam and volatilizing the mercury by the application of heat, whereby the gold and silver remained behind as a coherent coat (fire gilding).

The affinity of metals for mercury varies very much; while many metals combine with it with great ease; others do so only with great difficulty, and their union with the mercury can only be accomplished in a roundabout manner.

Though the amalgams are of considerable theoretical interest and of great importance for a general knowledge of alloys, only a limited number of them are used in the industries, which will be somewhat more closely described in the following:—

*Gold amalgam.*—Gold and mercury alloy freely, and the amalgam can be prepared by the direct union of the two metals. If the gold to be used has been obtained by the chemical process (by the reduction of salts of gold) it dissolves with difficulty in the mercury, it being in a finely divided state, and the finer particles apt to float upon the surface of the mercury. If, however, the gold is reduced in the form of larger crystals, the solution takes place in a comparatively short time. Such small gold crystals can be readily obtained by dissolving chloride of gold in amyl alcohol and heating the solution to boiling, whereby the gold is separated in the form of very small, lustrous crystals.

In gaining gold from auriferous sand, gold amalgam is prepared in large masses, and by subsequent heating in iron retorts the combination is destroyed, the mercury volatilizing, while the pure gold remains behind. Gold forms with mercury a chemical combination of the formula $Au_4Hg$, which shows great tendency towards crystallization, which, in preparing the amalgam, must be prevented as much as possible, it being difficult to apply a crystalline amalgam to the articles to be gilded.

An amalgam suitable for fire gilding is best prepared as follows: Heat in a graphite crucible, rubbed inside with chalk to prevent adhesion, the gold to be alloyed to a red heat. It is not absolutely necessary to use chemically pure gold, but it should be at least 22 carat fine, and preferably alloyed with silver instead of copper. Gold amalgam containing copper becomes stone hard in a short time, and a small content of it impairs its uniform application to the metals to be gilded. It is best to use the gold in the form of thin sheets, which is cut into small pieces by means of scissors, and brought into the crucible. When the gold is heated to a red heat, introduce about the eighth or ninth part of the weight of the gold of mercury previously heated to boiling. Stir constantly with an iron rod, and after a few minutes remove the crucible from the fire. If the finished amalgam were allowed to cool in the crucible, it would become strongly crystalline and be unsuitable for fine gilding. To prevent this it is at once poured into a larger vessel cooled by water. By keeping this amalgam for some time, crystallization takes place nevertheless, the amalgam separating from the mercury in excess, and it is therefore advisable to prepare it fresh a short time before use. Crystalline amalgam can be restored by heating it in a crucible with an excess of mercury.

In preparing the amalgam, as well as in using it for gilding, a wind-furnace connected with a well-drawing chimney has to be used, as otherwise the vapors evolved from the mercury exert an injurious effect upon the health of the workmen.

*Amalgam of silver.*—The properties of silver amalgam are nearly the same in most respects as those of gold amalgam, it having, however, a still greater tendency towards crystallization. Only pure silver can be used for its preparation, a content of copper producing the same injurious effect as in gold amalgam. Silver amalgam is best prepared by using pulverulent silver obtained by the reduction of silver solution. It may be prepared by bringing a solution of nitrate of silver in 10 to 15 parts of water into a bottle, adding a few small pieces of sheet zinc and vigorously shaking a few minutes. The silver separating in the form of a very fine black-gray powder need only be washed and dried to be suitable for the preparation of amalgam. This finely divided powder can be directly dissolved in the mercury, though it requires some time. The object is more quickly attained by heating the mercury nearly to boiling in a crucible, then throwing in the pulverulent silver and quickly combining the mass by vigorous stirring with an iron rod.

Silver amalgam can also be prepared without the use of heat, it being only necessary to compound a concentrated solution of nitrate of silver (1 part of nitrate of silver in 3 of distilled water) with four times the quantity of mercury and combine the liquids by shaking. The silver is reduced from the nitrate by the mercury and dissolves immediately in the excess of it. If the amalgam is to be used for fire-silvering, the presence of the small quantity of nitrate of mercury adhering to it is of no consequence, and it can be at once applied.

*Fire-gilding.*—Fire-gilding or fire-silvering is always effected with a pure amalgam, *i. e.*, such as is freed as much as possible from an excess of mercury. For this purpose the amalgam is tied in a bag of strong chamois-leather and subjected to a gradually increasing pressure, whereby the mercury is forced through the pores of the leather while the amalgam remains in the bag. The pressed-out mercury contains a considerable quantity of gold or silver in solution and is used in the preparation of fresh amalgam.

Fire-gilding or silvering is, of course, only applicable to articles of metals which, without melting, will stand a temperature near that of the boiling point of mercury. The amalgam adhering only to absolutely bright metals, the articles before gilding are subjected to a preparatory operation. This consists in heating them to a glowing heat, whereby the grease, dust, etc., adhering to the surface are burnt, and the metal becomes covered with a layer of oxide. The articles are then dipped in a mixture of 3 parts of nitric acid and 1 of sulphuric acid, whereby the oxide is rapidly dissolved and the metal acquires a bright surface. Articles to be heavily gilded must remain for some time in the acid mixture, a rougher surface being required for the adherence of a larger quantity of amalgam.

The pickled articles are then rinsed in water without touching them with the hands, and, to prevent oxidation, placed in water until they are to be *amalgamated*, which consists in covering the bright articles with a layer of metallic mercury. This so-called amalgamating water is prepared by dissolving 100 parts by weight of mercury in 110 parts by weight of strong nitric acid and compounding the solution with 25 parts by weight of water. This amalgamating water is applied to the metal by means of a brush of fine brass wire. By the action of the metal upon the mercury salt the latter is reduced to metallic mercury in the form of very small drops, whereby the articles acquire a white color.

The articles being thoroughly amalgamated, the amalgam is quickly and uniformly applied with a stiff scratch-brush and the articles placed upon glowing coals, whereby the mercury evaporizes while the gold or silver remains behind in a coherent layer. While heating the articles must, however, be frequently taken out and defective places provided with amalgam. This process is very injurious to health; the mercury volatilized by the heat insinuates itself into the body of the workmen notwithstanding the greatest care, and those who are so fortunate as to escape for a time absolute disease are constantly liable to salivation from its effects. Though fire-gilding is the most durable, it is more and more abandoned and electro-plating substituted for it.

Many articles are not finished by one gilding, and have to be subjected to the same process twice and frequently three times, whereby the layer of gold becomes, of course, thicker. By suitable treatment during the heating and by burning off the so-called gilder's wax various shades can be given to the gilding. But, as these operations belong to another branch of industry, we cannot enter upon a further description of them.

*Amalgams of the platinum metals.*—Though the platinum metals can be combined with mercury, the amalgams obtained are thus far not used in the industries, the plating of articles with platinum or allied metals being entirely effected by means of galvanism.

*Amalgam of copper.*—On account of its peculiar properties amalgam of copper finds quite an extensive use in several branches of industry.

It crystallizes with great ease, and on solidifying becomes so hard that it can be polished like gold. It can also be worked under the hammer and between rolls, be stamped, and retains its metallic lustre for some time on exposure to the air, but tarnishes quickly and turns black on being brought in contact with air containing sulphuretted hydrogen. A peculiar property of amalgam of copper is that it becomes soft on being placed in boiling water, and so flexible that it can be used for moulding the most delicate articles. In a few hours it again solidifies to a fine-grained mass which is quite malleable.

Copper amalgam, on account of its peculiar properties, was formerly recommended for filling hollow teeth, but is no longer used for that purpose, there being other amalgams just as suitable and free from poisonous copper. An important application of copper amalgam is for cementing metal, it being only necessary to apply it to the metals to be cemented, which must be bright and previously heated to from 176° to 194° F., and press them together; they will be joined as tightly as if soldered.

Many directions have been given for preparing amalgam of copper, but it is effected with the greatest ease as follows: Place strips of zinc in a solution of sulphate of copper and shake vigorously. The copper thus obtained in the form of a delicate powder is washed, and, while still moist, treated in a rubbing-dish with a solution of mercurous nitrate. Hot water is then poured over the copper, the dish kept warm, and the mercury added. The contents of the dish are then kneaded with a pestle until the pulverulent copper combines with the mercury to a plastic mass; the longer the kneading is continued the more homogeneous the mass will be. The best proportions to use are 3 parts of copper and 7 of mercury.

When the amalgam has the proper consistency, the water is poured off and the soft amalgam moulded in the shape in which it is to be preserved. For the purpose of cementing it is recommended to roll it into small cylinders about $\frac{1}{8}$ inch in diameter and $\frac{3}{4}$ to $1\frac{1}{2}$ inches long.

A composition of 25 parts of copper in fine powder, obtained by precipitation from solutions of the oxide by hydrogen, or of the sulphate by zinc, washed with sulphuric acid and amalgamated with 7 parts of mercury, after being well washed and dried, is moderately hard, takes a good polish, and makes a fine solder for low temperatures. It will adhere to glass.

An imitation of gold, which, on account of its golden-yellow color and capability for taking a fine polish, is suitable for the manufacture of cheap jewelry, consists of copper 86.4 parts, mercury 13.6. The color of the alloy being, however, very easily affected by sulphuretted hydrogen, it is recommended to provide the articles with a thin coating of pure gold by the galvanic method.

*Dronier's malleable bronze* is made by adding 1 per cent. of mercury to the tin when hot, and this amalgam is carefully introduced into the melted copper.

*Amalgam of tin.*—This amalgam was formerly of much greater importance for the manufacture of mirrors and looking-glasses than it is at the present time, when mirrors coated with a thin layer of silver surpass those coated with amalgam in beauty and cheapness. The great affinity of tin for mercury renders the preparation of the amalgam easy; all that is necessary is to combine the tin, which is best used in the form of fine shavings or of foil with the mercury. According to the quantity of mercury rubbed together with the tin, an amalgam solidifying in a shorter or longer time is obtained.

*Amalgam of tin for filling teeth.*—This amalgam is prepared by intimately rubbing together 1 part of tin with 4 of mercury, removing the excess of mercury by pressing in a leather bag and kneading or rubbing for some time. It is obtained in a flexible mass which hardens in a few days.

*Amalgam for mirrors and looking-glasses.*—The amalgam which serves for silvering mirrors is a complete saturation of the two metals. It is, however, not prepared by itself, but directly upon the plate of glass which is to form the mirror. The operation is as follows: The glass plate having been thoroughly cleansed from all grease and dirt with putty-powder and wood ash, the workman proceeds to lay a sheet of tin foil of larger dimensions than the plate to be silvered smoothly upon the silvering table, pressing out with a cloth dabber all wrinkles and places likely to form air-bubbles. A small quantity of mercury is then poured upon it and uniformly distributed by means of a fine woollen cloth. When the surface is uniformly covered more mercury is added so as to attain a height of 2 or 3 lines; the coating of oxide is removed with a wooden rod and a brilliant surface produced. The plate of glass is then pushed slowly forward from the side with the longest edge foremost, and dipping below the surface of the mercury so as completely to exclude the air. In this way the glass is brought into contact with the metals and a brilliant surface produced. The plate may now be said to be floating on a bed of mercury. To get rid of the excess of metal the mirror is loaded with weights and the table inclined 10° or 12°, when the excess of mercury drains off. A further portion is got rid of by setting the plate up on edge, and in the course of three or four weeks a dry, permanent coating of tin amalgam is left upon the plate.

If curved glass plates are to be converted into mirrors, the amalgam is prepared by itself, and after spreading it as uniformly as possible upon the glass the latter is heated until the amalgam melts.

This method of silvering has many objections: the vapor of mercury is poisonous to the workmen; the plates are liable to fracture from the heavy load placed upon them, and when set up on edge drops of mercury sometimes trickle down, carrying the amalgam with them, thus rendering it necessary to resilver the whole mirror. Moreover, the amalgam is liable to spoil by crystallization or carriage. For these reasons this process has been almost entirely abandoned and that of silvering by precipitation substituted for it.

*Amalgam for electric machines.*—This amalgam, known as Kienmayer's, consists of mercury 2 parts, tin 1, and zinc 1. It is best prepared by heating the mercury in a rubbing dish and combining with it the metals previously converted into fine shavings by constant kneading. To prevent the amalgam from becoming crystalline a small quantity of tallow is finally added and the kneading continued until the tallow is also completely combined with the amalgam. The finished amalgam must be kept in a well-stoppered glass vessel and should be used within a few months, as in time it becomes crystalline.

*Amalgam for tinning.*—Small articles of iron, for instance pins, can be tinned by making them first bright by pickling in an acid, dipping in melted tin amalgam, blanching in dilute acid, drying and polishing.

*Amalgam of zinc.*—Zinc amalgamates readily with mercury, it being only necessary to heat the latter to the boiling point and introduce the zinc in small pieces. Zinc amalgam is not directly employed, but is largely used in the zinc anodes of galvanic batteries. For this purpose it is, however, prepared upon the zinc plate itself by heating the latter to about 482° to 500° F., and, after quickly and uniformly coating it by means of a brush with a solution of chloride of zinc and ammonia, dipping at once into mercury. Amalgamation takes place at once, and the plates thus amalgamated give currents of greater constancy and intensity than ordinary zinc plates.

*Amalgam of cadmium.*—Cadmium readily combines with mercury to an amalgam which easily becomes crystalline. For the preparation of the actual cadmium amalgam, whose composition is $Cd_5\ Hg_8$, proceed in the same manner as already described for other amalgams. Heat the mercury nearly to boiling in a crucible and introduce the cadmium in the form of thin sheet. Cadmium amalgam remains soft for some time and becomes crystalline only after a considerable period. The mass obtained by heating is, therefore, allowed to stand in the crucible until the excess of mercury separates out or it can be separated in the ordinary manner by pressing in a leather bag.

Pure cadmium amalgam forms a tin-white or silver-white mass which softens on being moderately heated and can be kneaded like wax. It is used for filling hollow teeth either by itself or compounded with other metals which make it still better for the purpose. An addition of tin or bismuth makes it more pliant in the heat, and for this reason the mass used for filling teeth is at present frequently composed of amalgams containing several metals. A few such compositions are given in the following. Those containing lead are, however, not recommended, as lead has poisonous properties and is attacked even in the form of an amalgam by organic acids :—

*Amalgams for filling teeth.*

| | Parts. | | | | |
|---|---|---|---|---|---|
| | I. | II. | III. | IV. | V. |
| Cadmium | 25.99 | 21.74 | 1 | 1 to 2 | 3 |
| Mercury | 74.01 | 78.26 | — | — | — |
| Tin | — | — | 2 | 2 | 4 |
| Lead | — | — | — | 7 to 8 | 15 |

Amalgam No. I. corresponds to the centesimal composition of the above-mentioned combination of cadmium and mercury and is well adapted for filling teeth, it acquiring in time such hardness that it can be worked with the lathe or file, and, of course, becomes hard in the mouth. Cadmium amalgams being very ductile can, moreover, be used for many other purposes. An amalgam of equal parts of cadmium and mercury is extremely plastic and can be stretched under the hammer like pure gold. It is silver-white and constant in the air.

*Evans's metallic cement.*—This alloy is obtained by dissolving a cadmium amalgam consisting of 25.99 parts of cadmium and 74.01 of mercury in an excess of mercury, slightly pressing the solution in a leather bag and thoroughly kneading. By kneading, especially if the amalgam be previously heated to about 97° F., Evans's metallic cement is rendered very plastic and like softened wax can be brought into any desired form. On cooling it acquires considerable hardness, which is, however, not equal to that of pure cadmium amalgam.

*Amalgams of the "fusible alloys."*—The fusible alloys already mentioned in speaking of the alloys of cadmium and bismuth possess the property of melting in an amalgamated state at a still lower temperature than by themselves. By adding a suitable quantity of mercury to them they can be converted into masses well adapted for filling teeth or for cementing metals.

*Amalgam of Lipowitz's metal.*—This amalgam (compare p. 298) is prepared as follows: Melt in a dish cadmium 3 parts, tin 4, bismuth 15, and lead 8, and add to the melted alloy mercury 2 parts, previously heated to about 212° F. Amalgamation takes place readily and smoothly. After the introduction of the mercury the dish is immediately taken from the fire and the liquid mass stirred until it solidifies. While Lipowitz's alloy becomes soft at 140° F. and melts at 158° F., the amalgam melts at about 143.5° F. It is very suitable for the production of impressions of objects of natural history, direct impressions of leaves and other delicate parts of plants being obtained, which, as regards sharpness, are equal to the best plaster of Paris casts, and, on account of the silver-white color, fine lustre, and constancy of the amalgam, present a very neat appearance. The amalgam can also be used for the manufacture of small, hollow statuettes and busts, which can be readily gilt or bronzed by the galvanic process.

The manufacture of small statuettes is readily effected by preparing a hollow mould of plaster of Paris, and, after uniformly heating it to about 140° F., pouring in the melted amalgam. The mould is then swung to and fro, this being continued until the amalgam is solidified.

After cooling the mould is taken apart and the seams trimmed with a sharp knife. Some experience being required to swing the mould so that all parts are uniformly moistened with the amalgam, it may happen that defective casts are at first obtained; in such case the amalgam is simply remelted and the operation commenced anew. With some skill the operator will soon succeed in applying a uniform layer to the sides of the mould and preparing casts with very thin sides. The operation may also be modified by placing the mould upon a rapidly revolving disk and pouring in the melted amalgam in a thin stream. By the centrifugul force developed the melted metal is hurled against the sides of the mould, and in this manner statuettes of considerable size can be cast.

*Amalgam of iron.*—Iron possessing but little affinity for mercury it is impossible directly to combine the two metals. The amalgam may, however, be prepared by rubbing together very finely divided iron with mercuric chloride and water and a few drops of metallic mercury. Pure amalgam of iron forms lustrous white crystals, which, however, soon lose their lustre on exposure to the air and become coated with rust. By lying in the air the iron contained in the amalgam is in a short time converted into ferric oxide, which floats upon the metallic mercury.

Though scientifically of interest amalgam of iron is only used in the industries in rare cases where iron is to fire-gilt, and then is produced upon the article to be gilded itself. For this purpose the article previously made bright by pickling is boiled in a mixture of mercury 12 parts, zinc 1, copperas 2, water 12, hydrochloric acid 1.5. The mercury dissolved in the solution separates upon the iron article, a thin lustrous layer of iron amalgam being formed upon the surface to which the amalgam of gold can be readily and uniformly applied without further preparation. The subsequent treatment of the gilded article is the same as described under fire-gilding.

*Amalgam of bismuth.*—By introducing mercury into melted bismuth a combination of the two metals is readily effected. The resulting amalgam being very thinly fluid can be advantageously used for filling out very delicate moulds. Other amalgams are also rendered more thinly fluid by an addition of bismuth amalgam, a few examples of which have already been given under cadmium amalgams, and such combinations, being cheaper than pure bismuth amalgam, are frequently used.

Bismuth amalgams can be used for nearly all purposes for which cadmium amalgams are employed. On account of their lustre, which is at least equal to that of silver, they are preferred for certain purposes, such as for silvering glass globes and the preparation of anatomical specimens.

*Amalgams for silvering glass globes, etc.*—Glass globes can be readily silvered by either of the following compositions:—

| | Parts. | | |
|---|---|---|---|
| | I. | II. | III. |
| Bismuth | 2 | 2 | 2 |
| Lead | 2 | 2 | 2 |
| Tin | 2 | 2 | 2 |
| Mercury | 2 | 4 | 18 |

First melt the lead and tin and then add the bismuth. After removing the drosses pour the mercury into the compound and stir vigorously. Leaves of Dutch gold are sometimes introduced into the mixture according to the color to be imparted to the globes. For silvering the globes heat them carefully to the melting point of the amalgam. Then pour a small quantity of the amalgam into the cavity of the globe and swing it to and fro until its entire surface appears covered.

*Amalgam of bismuth for anatomical preparations.*—Colored wax was formerly exclusively used by anatomists for injecting vessels. A bismuth amalgam, being of a silvery-white color, is, however, preferable, and by becoming hard on cooling contributes essentially to the solidity of the preparation. The amalgam used for the purpose melts at 169° F. and remains liquid at 140° F., the latter property rendering its use especially suitable for larger preparations. It is composed of: Bismuth 10 parts, lead 3.2, tin 3.5, mercury 2. For use, heat the amalgam in a dish in a water-bath to 212° F., which insures it being forced by the injection-pump into the finest ramifications of the vessels.

*Amalgam of sodium.*—By itself this amalgam is not used, it quickly decomposing on exposure to the air into caustic soda and mercury. It can, however, be used in the preparation of many amalgams which cannot be made by the direct method. By bringing, for instance, amalgam of sodium together with a solution of a metallic chloride, the respective metal is generally separated from the chlorine combination by the sodium, and the moment it is liberated unites with the mercury to an amalgam while the sodium combines with the chlorine. The presence of a very small quantity of sodium amalgam exerts, moreover, a very favorable effect upon the formation of amalgams, and by its use in the process of amalgamation for gaining gold and silver considerable time is saved and the amalgamation more complete.

Sodium amalgam can be prepared by melting sodium under petroleum and introducing the mercury through a very narrow glass tube. Both metals combine at once with the emission of a peculiar noise, and the amalgam solidifies to a silver-white mass, which, to prevent the oxidation of the sodium, must, however, be kept under petroleum until it is to be used.

By introducing sodium amalgam into a solution of chloride of ammonium it swells to many times its former bulk, rises to the surface of the fluid, and is converted into amalgam of ammonium, which is, however, very unstable, being decomposed into ammonia, hydrogen, and metallic mercury on exposure to the air.

*Makenzie's amalgam.*—This amalgam, which is solid at an ordinary temperature and becomes liquid by simple friction, may be prepared as follows: Melt 2 parts of bismuth and 4 of lead in separate crucibles, then throw the melted metals into two other crucibles, each containing 1 part of mercury. When cold these alloys or amalgams are solid, but will melt when rubbed one against the other.

*Other amalgams.*—Besides the amalgams described in the preceding section, there are a number of others, each metal, as previously mentioned, being capable of forming an amalgam. It is, however, not necessary to enter further into this subject, as none besides those mentioned are of any technical value.

The preparation of all these amalgams is effected in the same manner. Introduce into the solution of the pure chloride of the respective metal a corresponding quantity of sodium amalgam. The sodium combines at once with the chlorine, while the liberated metal forms an amalgam with the mercury.

The amalgams of many metals have not as yet been thoroughly examined, and some of them, as, for instance, the amalgams of nickel, cobalt, and chromium, may yet be called to take an important part in the practice of the industrial arts.

# XXXIX.

## MISCELLANEOUS ALLOYS.

This section contains alloys we have not been able to classify in the preceding series. The following receipts for alloys are taken from "Industrie Blätter," edited by E. Jacobsen.

We will first mention a *mixture especially adapted for serving as a protective cover in remelting metallic alloys.* It is composed of borax, calcined soda, calcined alum, and fluor spar, each 1 part.

*Iron* is frequently added to *copper-zinc alloys,* but an addition of more than 2.5 per cent. is not admissible, all above that remaining unfixed and in excess in the crucible. Alloys of copper and zinc with a content of iron always show a more reddish-yellow color than pure alloys of copper and zinc. In preparing *speculum metal* iron does excellent service. Such an alloy consists of iron 10 parts, nickel 36, copper 18, tin 18, and zinc 18. This is one of the best compositions for concave mirrors and analogous works. The metal closely resembles platinum, takes an excellent polish, and with a corresponding power of resistance possesses great hardness. Another alloy for *speculum metal* is composed of 32 parts of copper, 15.5 of tin, 2 of nickel; some arsenic may be advantageously added to this alloy. There are a number of alloys known as speculum metal, but when closely examined under the microscope they show crystals which impair the beauty of the mirrors.

*Alloy for spoons.*—A beautiful alloy closely resembling silver is obtained by melting together 50 parts of copper, 25 of nickel, and 25 of zinc.

*Alloy resembling German silver* consists of copper 58 parts, zinc 27, nickel 12, tin 2, aluminium 0.5, and bismuth 0.5. The separate metals are first melted by themselves and then combined by vigorous stirring. This metal retains its polish for a long time.

*Alloy resembling silver.*—Copper 70 parts, manganese 30, zinc 20 to 25.

*Non-oxidizable alloy.*—Iron 10 parts, nickel 36, copper 18, tin 18, zinc 18. This metal has a white color, with a slightly reddish tinge.

*Calin.*—This term is applied to an alloy for metallic foils used by the Chinese for lining tea-chests. It is composed of lead 126 parts, tin 17.5, and copper 1.25, besides a trace of zinc.

*Alloy for moulds for pressed glass.*—An alloy suitable for this purpose is obtained according to C. H. Knoop, of Dresden, by melting together 100 parts of iron with 10 to 25 parts of nickel.

*New method of preparing alloys.*—The alloys consist of heavy metals and the sulphides of the alkali metals or metals of the alkaline earths. Preferably sulphide of strontium is alloyed with copper in order to obtain a product of a constant gold-like color. For this purpose zinc is melted together with 8 to 15 per cent. of calcined strontium sulphate and the resulting alloy allowed to cool. To this alloy a varying quantity of copper is added, according to the color and power of resistance required. As much of the zinc as may be desired can be expelled by subsequent cupellation.

*Alloys of indium and gallium.*—L. de Boisbaudran, the discoverer of gallium, has experimented with alloys of indium and gallium. They are distinguished by not having a fixed melting point, but soften gradually, like fats. In this semi-liquid condition they form a mixture of melted and crystalline metal. L. de Boisbaudran has prepared the following alloys:—

1. Indium 227 parts, gallium 69.9 parts. This alloy is white, granular, and can be readily cut with the knife; it begins to melt at 132.8° F., and is viscid at 167° F.

2. Iridium 113.5 parts, gallium 69.9. This alloy forms a white coherent mass, but is still softer than the first alloy. It is hard at 60.8° F., semi-liquid at 113° F., and liquid at from 140° to 176° F.

3. Iridium 113.5 parts, gallium 139.8. White; soft. It hardens at 60.8° F.; is butyraceous at 64.4° F.; liquid from 140° to 176° F.

4. Indium 113.5 parts, gallium 279.6. This alloy is white, commences to melt at 62° F., is semi-liquid at 95° F., and liquid at 122° F.

*Platinoid.*—This alloy, invented by H. Martino, is a kind of German silver with an addition of 1 to 2 per cent. of tungsten. The latter, in the form of phosphor-tungsten, is first melted together with a certain quantity of copper, the nickel is next added, then the zinc, and finally the remainder of copper. In order to remove the phosphorus and a portion of the tungsten, both of which separate as dross, the resulting compound is several times remelted. Finally an alloy of a beautiful white color is obtained, which, when polished, closely resembles silver, and retains its lustre for a long time. Platinoid has the properties of German silver in a pre-eminent degree. It shows great resistance, which changes but little with the temperature, and is about 1½ times greater than that of German silver. To determine the dependence of the resistance on the temperature, platinoid wire was wound upon a bobbin provided with a thread, and uniformly heated in an oil-bath. The experiments gave the following table, in which the resistance at 0° C. is placed = 1.

| Temperature. | Resistance. | Temperature. | Resistance. |
|---|---|---|---|
| 0° C. . . . | 1.0000 | 60° C. . . . | 1.0126 |
| 10 . . . | 1.0024 | 70 . . . | 1.0134 |
| 20 . . . | 1.0044 | 80 . . . | 1.0166 |
| 30 . . . | 1.0066 | 90 . . . | 1.0188 |
| 40 . . . | 1.0075 | 100 . . . | 1.0209 |
| 50 . . . | 1.0097 | | |

This shows an average increase of resistance of 0.0209 for 1° C. between 0° and 100° C.; another experiment with wire gave an average of 0.022 for 1° C. According to experiments by Matthiessen and the more recent ones by Erno, the increase in the resistance of copper is 0.38 per cent. and of German silver 0.044 per cent. Hence platinoid is in this respect far superior to other wire in use.

*Steel composition.*—Steel shavings 60 parts, copper 22.5, mercury 20, tin 15, lead 7.5, and zinc 15, are gradually introduced and dissolved in 860 parts of nitric acid. The resulting reddish-brown paste is dried, melted together with twenty times its weight of zinc, and the mass cast in ingots. After cooling, the alloy is remelted with a corresponding addition of tin, according to whether it is to be softer or harder.

*Malleable ferro-cobalt and ferro-nickel.*—For the direct gaining of malleable ferro-cobalt or ferro-nickel, the "Fonderie de nickel et méteaux blancs" of Paris claims to utilize either the ores themselves or to prepare first an especially suitable initial product for the final result by melting together corresponding quantities of nickel or cobalt and chromium ores. In melting together the ores the degree of heat at which the liquation of the iron would take place must, however, not be attained. This product of melting, or the raw materials themselves, are melted together in a suitable crucible with potassium ferrocyanide and peroxide of manganese. In running off, a small quantity of aluminium is added. According to the condition desired for the final product, and according to the original content of iron of the ores, a larger or smaller quantity of cast-iron or wrought-iron can be added from the start, whereby a more or less soft and malleable product is obtained. If, for instance, an alloy of 70 per cent. of nickel and 30 per cent. of iron, with a very small content of sulphur, be used, 71.9 parts of fused nickel, 12 of peroxide of manganese, 16 of potassium ferrocyanide, and 0.1 of aluminium are taken for the mass to be melted together. If, however, nickel ore containing only about 25 per cent. of pure nickel with 64 per cent. of iron, and 11 per cent. of other admixtures, be used, the melting material is best composed of about 82 parts of fused nickel, 8 of peroxide of manganese, and 10 of potassium ferrocyanide. The alloys thus obtained are claimed to excel in perfect malleability, and completely to retain this property when remelted, so that, on the one hand, malleable ingots are at once produced, and, on the other, all waste and defective castings can be again utilized.

*Bronze resisting acids.*—Débié gives the following receipt: Copper 15 parts, zinc 2.34, lead 1.82, antimony 1. This alloy melted in a crucible can be worked in the ordinary manner, and is claimed to answer as substitute for lead for lining vessels used in the manufacture of sulphuric acid, etc.

*Zinc-iron* being very brittle is used little as an alloy, but on account of its brilliant light promises to become of considerable value for pyrotechnics. Theoretically it is also interesting as an alloy of a very volatile with a non-volatile metal, and, further, it offers the readiest means of obtaining zinc in a finely divided state for purposes where the presence of iron is not objectionable. The best method of preparing the alloy is as follows: Heat 1 to 2 pounds of zinc in a clay crucible to the melting point, then throw 3 to 3.5 ounces of anhydrous sodium ferrous chloride upon the surface of the melted zinc and immediately cover the crucible. A very vigorous reaction takes place during the formation of the alloy mixed with zinc chloride ($Zn + FeCl_2 + Fe$). The excess of the zinc alloys with the reduced iron forms the exceedingly brittle zinc-iron which can be readily pulverized.

*An alloy which expands on cooling* is prepared from lead 9 parts, antimony 2, and bismuth 2. It is very suitable for filling up small holes and defective places in cast-iron.

*Spence's metal.*—This compound is an English invention and is named after the inventor. Strictly speaking, it is not a metal, but a compound obtained by dissolving metallic sulphides in melted sulphur, which is found to be capable of receiving into solution nearly all the sulphides of the metals. For most purposes Mr. Spence employs in the production of his "metal" the sulphides of iron, lead, and zinc, in varying proportions, according to the quality of the product desired, which will depend on the uses for which it is designed. On cooling the mixture solidifies, forming a homogeneous, tenacious mass, having ordinarily a specific gravity of 3.37 to 3.7. It is said to be exceedingly useful in the laboratory for making the air-tight connections between glass tubes by means of caoutchouc and a water or mercury jacket where rigidity is no disadvantage. The fusing point is so low that it may be run into the outer tube on to the caoutchouc, which it grips, on cooling, like a vise and makes it perfectly tight. It melts at 320° F., expands on cooling, is claimed to be capable of resisting well the disintegrating action of the atmosphere, is attacked by but few acids, and by them but slowly; or by alkalies; is insoluble in water and may receive a high polish. It makes clean, full castings, taking very perfect impressions; it is cheap and easily worked. It has been used as solder for gas-pipes and as a joint material in place of lead.

*Lutecine or Paris metal.*—Copper 800 parts, nickel 160, tin 20, cobalt 10, iron 5, and zinc 5.

*Alloys for small patterns in foundries.*

I. Tin 7.5 parts, lead 2.5.
II. Zinc 75 parts, tin 25.
III. Tin 30 parts, lead 70.

The last of these alloys is for patterns which will not be in frequent use and which may be mended, bent, etc. The first gives harder and stiffer patterns; the second is harder than tin and more tenacious than zinc, while at the same time it preserves a certain ductility.

*Alloys for calico-printing rollers.*—Hauvel considers a semi-hard bronze of the following composition the best material for the rollers: Copper 86 parts, tin 14, zinc 2.

Rendel, on the other hand, found an English roller material composed of: Copper 5.6 parts, zinc 78.3, tin 15.8. Though this compound gives a hard, fine-grained alloy, it is likely very readily attacked by the colors used in printing.

According to analyses by J. Dépierre and P. Spiral, the composition of the scrapers (sometimes called doctors or ductors) intended to remove the surplus of colors from the rollers is as follows:—

| | Copper. | Zinc. | Tin. |
|---|---|---|---|
| Yellow French scrapers . . | 78.75 | 12.50 | 8.75 |
| " English scrapers . . | 80.50 | 10.50 | 8.00 |
| " German scrapers . . | 85.80 | 9.80 | 4.90 |

According to the researches of the above-named scientists, three groups are to be distinguished: 1. Copper with 95 to 100 per cent. of copper; 2. Brass with about 60 per cent. of copper and 40 per cent. of zinc; and 3. Alloys. In the annexed table I. the physical properties of the examined pieces are given, whereby it has, however, to be remarked that in rollers for printing calico, where the hardness of the metal is of considerable importance, the chemical composition alone does not express the characteristics of the metal, they depending also on the manner of hardening and tempering.

Table II. shows the chemical composition of the samples.

Besides red copper the alloys containing 25 to 30 per cent. of zinc and 75 to 70 per cent. of copper are especially suitable for rollers. Even as small a content of lead as 0.5 per cent. exerts an injurious influence, and the samples containing lead showed blow-holes. The presence of phosphorus could not be detected in any of the samples, but Messrs. Dépierre and Spiral are of the opinion that rolls of copper, containing 1 to 2 per cent. of phosphorus, would yield excellent results as regards resistance against chemical influences, as well as hardness, fineness of grain, homogeneousness and durability. An addition of 1 per cent. of phosphorus might also be recommended for varieties of brass containing 30 to 35 per cent. of zinc.

*Table I.*

| Sample. | Color. | Class. | Density. | Grain. | Hardness. | Remarks. |
|---|---|---|---|---|---|---|
| 1 | red | 1 | 8.82 | coarse | hard | — |
| 2 | " | 1 | 8.83 | fine | " | — |
| 3 | " | 1 | 8.82 | coarse | very soft | — |
| 4 | " | 1 | 8.83 | very fine | medium | — |
| 5 | yellow | 3 | 8.40 | coarse | hard | blow-holes. |
| 6 | " | 2 | 8.25 | very fine, homogeneous | " | — |
| 7 | " | 3 | 8.58 | fine, not homogeneous | very brittle | — |
| 8 | red | 1 | 8.88 | very fine | hard | burnt. |
| 9 | " | 1 | 8.80 | coarse | soft | suitable for printing. |
| 10 | yellow | 2 | 8.15 | very fine | hard | very unequal. |
| 11 | " | 3 | 8.45 | coarse, homogeneous | " | — |
| 12 | " | 3 | 8.50 | fine, not very homogeneous | very brittle | many blow-holes (1835). |
| 13 | red | 1 | — | — | — | very good. |
| 14 | " | 1 | 8.90 | fine | hard | bad. |
| 15 | yellow | 3 | 8.35 | " | " | very good. |
| 16 | " | 3 | 8.20 | " | " | blow-holes. |
| 17 | " | 2 | 8.10 | fine, homogeneous | " | very bad. |
| 18 | red | 1 | 8.90 | fine | " | good. |
| 19 | — | — | — | — | — | — |
| 20 | yellow | 2 | 8.20 | coarse, not very homogeneous | soft | — |
| 21 | " | 2 | 8.15 | fine, homogeneous | hard | — |
| 22 | " | 2 | 8.22 | middling | soft | — |
| 23 | red | 1 | 8.85 | fine | hard | — |
| 24 | yellow | 2 | — | — | — | — |
| 25 | gray-yellow | 3 | — | — | — | attacked by colors. |

*Table II.*

| No. of the samples. | | Copper. | Tin. | Lead. | Zinc. | Remarks. |
|---|---|---|---|---|---|---|
| Copper. | 3 | 99.11 | 0.05 | 0.12 | 0.57 | |
| | 4 | 99.16 | 0.02 | 0.12 | 0.58 | some aluminium. |
| | 8 | 99.13 | 0 03 | 0.19 | 0.45 | some aluminium and sulphur. |
| | 9 | 99 03 | 0.03 | 0.12 | 0.60 | " " " |
| | 1 | 99.93 | traces | 0.14 | 0.67 | " " " |
| | 2 | 99 67 | " | 0.07 | — | " " " |
| | 14 | 99.40 | " | 0.48 | — | |
| | 18 | 99.84 | " | traces | — | |
| | 23 | 99.52 | " | — | — | |
| Brass. | 6 | 60.33 | 0.03 | 0.68 | 38.68 | all contain traces of arsenic and iron. |
| | 10 | 61.70 | 0.08 | 0.64 | 37 51 | |
| | 20 | 64.41 | 0.21 | 2.86 | 31.88 | |
| | 22 | 68.60 | — | 0.39 | 30.53 | |
| | 21 | 58.25 | — | 0.43 | 41.02 | |
| | 17 | 77.68 | traces | 0.42 | 41.41 | |
| Alloys. | 11 | 74.51 | 2.80 | 2.18 | 19.85 | |
| | 12 | 76.96 | 2.55 | 1.88 | 17.83 | |
| | 7 | 77.63 | 2.58 | 1.94 | 17.16 | |
| | 5 | 74.12 | 2.37 | 2.22 | 20.59 | |
| | 15 | 79.42 | 4.17 | 1.23 | 14.49 | |
| | 16 | 72.15 | 3.27 | 1.71 | 22.16 | |
| | 24 | 70.40 | — | 0.60 | 28.0 | |
| | 25 | 15.0 | — | — | 84.0 | |

*Alloy for silvering.*—This alloy consists of tin 80 parts, lead 18, silver 2; or tin 90 parts, lead 9, silver 1. Melt the tin, and when the bath is lustrous white add the granulated lead and stir the mixture with a pine stick; then add the silver and stir again. Increase the fire for a short time until the surface of the bath assumes a light yellow color, then stir thoroughly and cast the alloy into bars. The operation of silvering is executed as follows:—

The article, for instance a knife blade, is dipped in a solution of hydrochloric or sulphuric acid, rinsed in clean water, dried, rubbed with a piece of soft leather or dry sponge, and then exposed in a muffle five minutes to a temperature of 158° to 176° F. The effect of this treatment is to render the surface of the iron or steel porous. With iron not very good and coarsely porous the silvering process is difficult to execute. With steel, however, the process is easy; the article heated to about 140° F. is dipped into the alloy melted in a crucible over a moderate fire. The bath, which must be completely liquid, is stirred with a pine or poplar stick. The surface of the bath should show a fine silver-white color. One to two minutes dipping suffices for a knife blade. When taken from the bath the article is dipped into cold water, or, if necessary, hardened and tempered in the usual manner. It is then rubbed dry and polished without heating.

Articles thus treated have the appearance of silver and also possess the sound of silver, and resist oxidation in the air. To protect them from the action of acid liquids they are first dipped in an amalgam bath of 69 parts of mercury, 39 parts of tin, and 1 part of silver; then, while hot, in melted silver, and electroplated with silver. This method of silvering is claimed to be very durable and not costly.

*Robertson alloy for filling teeth.*—Gold 1 part, silver 3, tin 2. First melt the gold and silver in a crucible, and at the moment of fusion add the tin. The alloy, when cold, may be finely pulverized. Equal quantities of the powder and mercury are kneaded together in the palm of the hand to form a paste for filling teeth.

*American sleigh-bells.*—These bells excelling in beauty, fine tone, and small specific gravity are manufactured by fusing together 10 parts of nickel and 60 of copper. When this alloy has become cold, add 10 parts of zinc and two-fifths part of aluminium, fuse the mass and allow it to cool; then remelt it with the addition of two-fifths part of mercury and 60 parts of melted copper.

*Alloy for casting small articles.*—Fuse a mixture of 79 per cent. of cast-iron, 19.50 of tin, and 1.50 of lead. This alloy has a beautiful appearance, fills the mould completely, and is therefore well adapted for casting small articles. It is malleable to a certain extent.

*Arnold's iron alloy.*—A compact and malleable iron alloy capable of a fine polish is obtained by melting together 100 parts of crude cast-iron, 1 of soda, 1 of copper, $\frac{1}{2}$ of tin, $\frac{1}{2}$ of antimony, and 5 of zinc. The material is claimed to be especially adapted for ship's screws, it resisting the corrosive action of sea-water remarkably well. By omitting the soda and decreasing the quantity of zinc a softer kind of iron is obtained, and a harder material by using a greater quantity of soda and zinc and decreasing the proportion of copper.

*Lemarquand's non-oxidizable alloy.*—Copper 750 parts, nickel 140, black oxide of cobalt 20, tin in sticks 18, zinc 72. The metals must be pure.

*Marlie's non-oxidizable alloy.*—Iron 10 parts, nickel 35, brass 25, tin 20, zinc 10. Articles prepared from this alloy are heated to a white heat and dipped into a mixture of sulphuric acid 60 parts, nitric acid 10, hydrochloric acid 5, and water 25.

# SOLDERING.

## XL.

### SOLDERS IN GENERAL.

THE so-called solders are alloys in the true sense of the word, but being used for special purposes will have to be separately described. Soldering is the process of uniting the edges or surfaces of metals by means of a more fusible metal which, being melted upon each surface, serves, partly by chemical attraction and partly by cohesive force, to bind them together. There is a great variety of solders known by the names of *hard*, *soft*, *spelter*, *silver*, *white*, *gold*, *copper*, *tin*, *plumbers'*, and many others; they may, however, be broadly distinguished as *hard solders* and *soft solders*. The former fuse only at a red heat, and are therefore only suitable for metals and alloys which will stand that temperature; the soft solders fuse at a comparatively low temperature, and may consequently be used for nearly all metals. Nearly all the principal metals take part in the composition of solder. The metals to be united may be either the same or dissimilar, but the uniting metal must always have an affinity for both, and should agree with them as nearly as possible in hardness and malleability. When this is the case, as when zinc solder is used to unite two pieces of brass, or of copper, or one piece of each, or when lead or pewter is united with soft solder, the work may be bent or rolled almost as freely as if it had not been soldered. But when copper or brass is united by soft solder, the joint is very liable to be broken by accidental violence or the blow of a hammer. In all soldering processes the following conditions must be observed: 1. The surfaces to be united must be bright, smooth, and chemically clean. 2. The contact of air must be excluded during the soldering, because it is apt to oxidize one or other of the surfaces and thus to prevent the formation of an alloy at the points of union. This latter object is effected by means of fluxes, which will be referred to later on.

The process called *autogenous soldering* takes place by the fusion of the two edges of metals themselves without interposing another metallic alloy as a bond of union. The process is possible with the majority of metals and alloys, even the refractory ones, and though it does not actually belong here, the subject being alloys, it will be briefly described. The union of the metals is accomplished by directing a jet of burning oxyhydrogen gas from a small movable beak upon the two surfaces or edges to be soldered together. Metals thus joined together are much less apt to crack asunder at the line of union by differences of temperature, flexibility, etc., than when the common soldering process is employed. This method of soldering is especially of great advantage in chemical works for joining the edges of sheet lead for sulphuric acid chambers and concentrating pans, because any solder containing tin would soon corrode.

All soldered work should be kept under motionless restraint for a period, as any movement of the parts during the transition of the solder from the fluid to the solid state disturbs its crystallization and the strict unity of the several parts. In hard soldering it is frequently necessary to bind the work together in their respective position; this is done with soft iron *binding wire*, which for delicate jewelry work is exceedingly fine, and for stronger work is $\frac{1}{20}$ or $\frac{1}{30}$ inch in diameter; it is passed around the work in loops, the ends of which are twisted together with the pliers.

In soft soldering the binding wire is scarcely ever used, as, from the moderate and local application of the heat, the hands may in general be freely used in retaining most of the work in position during the process. Thick work is handled with pliers or tongues whilst being soft soldered, and the two surfaces to be united are often treated much like glue joints, if we conceive the wood to be replaced by metal and the glue by solder, they being frequently coated or tinned whilst separated, and then rubbed together to distribute and exclude the greater part of the solder.

## XLI.

## SOFT SOLDERS.

The soft solders serve chiefly for soldering tin-plate, sheet-zinc, and kitchen utensils of sheet-brass. Their melting points lie between 284° and 464° F. For special purposes the two previously mentioned alloys of cadmium and bismuth, with as low a melting point as 140° F., would be very suitable, but their costliness prevents their general use.

Pure tin is the simplest of all soft solders, and is frequently used for soldering fine utensils of tin. Absolutely pure tin should, however, only be used, as the presence of foreign metals, especially that of iron, considerably increases the melting point. Tin solder is generally employed in the form of semi-cylindrical bars or very thin prisms. For soldering very delicate work tin-foil of very pure tin is frequently used. The surfaces being thoroughly cleansed, and, if necessary, nicely fitted together with a file, a piece of tin-foil is placed between them. They are then firmly bound together with binding wire and heated in the flame of a lamp or a Bunsen burner, or in the fire until the tin melts and unites with both surfaces. Joints carefully made may be united in this way so neatly as to be invisible.

The soft solder most frequently used consists of 2 parts of tin and 1 of lead. A cheaper solder is formed by increasing the proportion of lead; 1½ tin to 1 lead is the most fusible solder, unless bismuth be added. The following table gives the composition of some of these solders with their points of fusion:—

| No. | Parts. | | Melts at degrees F. | No. | Parts. | | Melts at degrees F. |
|---|---|---|---|---|---|---|---|
| | Tin. | Lead. | | | Tin. | Lead. | |
| 1 | 1 | 25 | 558° | 7 | 1½ | 1 | 334° |
| 2 | 1 | 10 | 541 | 8 | 2 | 1 | 340 |
| 3 | 1 | 5 | 511 | 9 | 3 | 1 | 356 |
| 4 | 1 | 3 | 482 | 10 | 4 | 1 | 365 |
| 5 | 1 | 2 | 441 | 11 | 5 | 1 | 378 |
| 6 | 1 | 1 | 370 | 12 | 6 | 1 | 381 |

For ordinary plumber's work the solders from 4 to 8 are used with tallow as a flux. For lead and tin-pipes No. 8 is used with a mixture of resin and sweet-oil as a flux. For Britannia metal No. 8 is used with chloride of zinc or resin as a flux. It can also be used for soldering cast-iron and steel, with common resin or sal ammoniac as a flux. The same solder can also be used for copper and many of its alloys, such as brass, gun-metal, etc., sal ammoniac, chloride of zinc, or resin being used as a flux. The solder No. 5 is what is called in England *plumbers' sealed solder*, which is assayed and stamped by an officer of the "Plumbers' Company."

The preparation of soft solder is very simple. The tin is first melted, a porcelain or stoneware vessel being best adapted for the purpose, as with the use of iron vessels there is danger of the absorption of iron by the solder. The tin being completely melted the lead is added, and the two metals are thoroughly combined by stirring. The finished alloy is then poured into suitable moulds.

Many manufacturers simply pour the finished solder in a fine stream upon a stone-slab, and subsequently break the sheet thus obtained into small pieces. It is, however, recommended to cast the solder in moulds, as it is more handy for working in this shape, and besides its consumption can be better controlled. The most suitable shape is that of thin bars about 7¾ by 1½ inches and ⅛ to ¼ inch thick.

Experts judge the quality of a solder by the appearance of the surface of the cast pieces, and attach special value to its being radiated-crystalline, which is technically called the "*flower*," and should have a stronger lustre than the dull ground of a dead silver color. If, as it sometimes happens, the solder shows a uniform gray-white color, it contains too little tin and it is best to remelt it with an addition of a small quantity of tin.

*Bismuth solder* is composed of bismuth 1 part, tin 1, and lead 1. It melts at 284° F. As will be seen from the composition it is much dearer than ordinary solder on account of the content of bismuth. It is, however, well adapted for certain purposes, as it is very thinly fluid and considerably harder than ordinary solder.

As previously mentioned every readily fusible metallic composition can be used for soldering and consequently the fusible alloys of cadmium and of bismuth might be classed with the soft solders. They are, however, only used in exceptional cases on account of their costliness.

## XLII.

## HARD SOLDERS.

UNDER this name very different alloys are used, their composition depending principally on that of the metals or alloys to be soldered. Though hard solders are found in commerce, many large manufacturers prefer to make their own solders in order to have them entirely suitable for the purpose they are intended for. According to the metals or alloys for which they are to be used, hard solders are divided into brass-solder for soldering brass, copper, etc., argentan-solder for German silver, gold and silver solders for gold and silver, etc., and this division will be retained here.

*Brass-solder* is the most fusible of all hard solders and is prepared according to various proportions. It is generally made by melting a good quality of brass together with a determined quantity of pure zinc, or sometimes adding some tin to the mixture. Such solders are composed of brass 8 parts, zinc 1. A somewhat more refractory composition consists of brass 6 parts, zinc 1, and tin 1. And a still more refractory one of brass 6 parts, zinc 1, tin 1, copper 1. The latter solder is the so-called hard brass-solder and is used for soldering iron and copper. In speaking of the respective alloys attention was drawn to the fact that with an increase in the content of tin the color of the brass passes from golden yellow more and more into gray, and that the ductility decreases at a corresponding rate. Varieties of brass very rich in tin are no longer ductile, but possess a considerable degree of brittleness. By adding to such compositions tin, their hardness and brittleness are still further increased, and mixtures are thus obtained which, according to their peculiar color, are designated as *yellow*, *half-yellow* or *half-white*, and *white* solder.

Regarding the quantity of metals to be added to the brass it has to be taken into consideration that solders containing much tin, though quite thinly fluid, acquire such a degree of brittleness as to break in most cases on bending the soldered place.

In making solders, great care should be taken to secure uniformity of composition; they are often found in commerce in a granulated form or cast in ingots. The most suitable mode of their preparation is as follows: Perfectly homogeneous sheet-brass is used, it being preferable to cast brass, as by rolling it has acquired greater homogeneousness. To prepare the brass for the manufacture of solders directly by melting together copper and zinc, is not advisable, as the unavoidable loss of zinc during the operation can never be exactly determined. By using finished brass it can, however, be readily melted down and compounded, if necessary, with zinc, without any sensible volatilization of the latter.

The brass is first melted in a crucible at as strong a heat as possible, and when thoroughly fused the entire quantity of zinc to be used in the manufacture of the solder, and which has previously been strongly heated, is added. The contents of the crucible are then vigorously stirred and after a few minutes poured out. The granulation of the solder is effected by pouring the melted metal from the crucible or ladle through a wet broom or from a considerable height into cold water. The size of the grains thus obtained varies within wide limits, and in order to obtain a uniform product the grains have to be passed through different-sized sieves and all excessively large pieces remelted.

According to another method, the melted metal is poured into a shallow vessel filled with cold water in which lies a large cannon ball so as partially to project from the fluid. The metal falling in a fine stream upon the cannon ball flies into small pieces of nearly uniform size, which fall into the water where they quickly harden.

The finest and most beautiful product is, however, obtained in the following manner: At some distance above the level of the water serving for the collection of the grains a horizontal pipe is arranged which is connected either with a powerful forcing-pump or a water reservoir situated at a higher level. Before pouring out the melted metal the cock on the pipe is opened so that the jet of water issuing from the pipe is thrown in a horizontal direction over the vessel containing the water; upon this jet of water the stream of melted metal is poured. The greater the force with which the water is hurled from the pipe the greater also the force with which the stream of melted metal is divided, and by this means it is possible, within certain limits, to obtain grains of a determined size. As will be seen from the above description the scattering of the stream of melted metal is based upon the same principle as that employed in diffusing fragrant liquids in the air.

Casting being finished the grains of solder deposited on the bottom of the vessel are collected and quickly dried to prevent them from becoming covered with a layer of oxide, which would exert a disturbing influence in soldering.

The following table shows the centesimal composition of various kinds of solder which have stood a practical test for various purposes:—

| | Copper. | Zinc. | Tin. | Lead. |
|---|---|---|---|---|
| Very refractory . . . . | 57.94 | 42.06 | — | — |
| " " . . . . | 58.33 | 41.67 | — | — |
| Refractory . . . . | 50.00 | 50.00 | — | — |
| Readily fusible . . . | 33.34 | 66.66 | — | — |
| Half-white, readily fusible . | 44.00 | 49.90 | 3.30 | 1.20 |
| White . . . . . . | 57.44 | 27.98 | 14 58 | — |
| Malleable solder . . . | 72.00 | 18.00 | 4.00 | — |
| Hard solder according to Volk | 53.30 | 46.70 | — | — |

Since these solders, as previously mentioned, are generally prepared by melting together brass and zinc we give in the following table the proportions of brass (in sheet) and zinc required for the purpose.

| | Parts. | | |
|---|---|---|---|
| | Brass. | Zinc. | Tin. |
| Very refractory . . . . | 85.42 | 12.58 | — |
| " " . . . . | 7.00 | 1.00 | — |
| Refractory . . . . . | 3.00 | 1.00 | — |
| " . . . . . | 4.00 | 1.00 | — |
| Readily fusible . . . . | 5.00 | 2.00 | — |
| " " . . . . | 5.00 | 4.00 | — |
| Half-white . . . . . | 12.00 | 5.00 | 1.00 |
| " " . . . . . | 44.00 | 20.00 | 2.00 |
| White . . . . . . | 40.00 | 2.00 | 8.00 |
| " . . . . . . | 22.00 | 2.00 | 4.00 |
| " . . . . . . | 18.00 | 12.00 | 30.00 |
| Very ductile . . . . . | 78.25 | 17.25 | — |
| For girdlers . . . . . | 81.12 | 18.88 | — |

*Prechtl's brass-solders.*

| | Parts. | | | |
|---|---|---|---|---|
| | Copper. | Zinc. | Tin. | Lead. |
| Yellow, refractory . . | 53.30 | 43.10 | 1.30 | 0.30 |
| Half-white, readily fusible | 44.00 | 49.90 | 3.30 | 1.20 |
| White . . . . . | 57.44 | 27.98 | 14.58 | — |

Brass-solders containing lead are very rarely used at the present time, those containing besides copper, zinc, and perhaps a small quantity of tin being generally preferred.

*Argentan-solder.*—The metallic mixture to which this term is applied, not only serves for soldering articles of argentan or German silver, but, on account of its refractory character and considerable tenacity, is generally used for soldering articles where the joints are to be especially solid; it is very frequently employed for soldering fine articles of steel and iron.

As regards its centesimal composition, argentan-solder is a variety of German silver especially rich in zinc, which must show considerable brittleness, so that it can be mechanically converted into a fine powder. The proportions according to which the solder is composed vary, and depend chiefly on the composition of the articles of German silver to be soldered with it. Manufacturers of German silver articles especially rich in nickel, and consequently more difficult to fuse, use, as a rule, a somewhat more refractory solder than those manufacturing alloys which contain but little nickel, and which are consequently more fusible.

As argentan-solder is not only employed for soldering German silver, but also for articles of steel, efforts have been made to prepare compositions answering all demands, of which the following have stood a practical test:—

*a. Readily fusible argentan-solder.*—Copper 35 parts, zinc 57, nickel 8.

*b. Less fusible argentan-solder* (especially adapted for iron and steel).—Copper 38 parts, zinc 50, nickel 12. The alloys are melted in the same manner as German silver and cast in thin plates, which, while still hot, are broken into pieces and converted into as fine a powder as possible in an iron mortar previously heated. If the alloy is readily converted into powder, it contains too much zinc, or if with difficulty, too little zinc. But in either case it does not possess the properties of argentan-solder of the proper proportions, and nothing is left but to remelt it. Hence it is recommended first to ascertain by small samples whether the alloy has the correct composition. For this purpose a small quantity of the melted metal is taken from the crucible by means of a ladle and poured upon a cold stone and then tested as to its behavior in the mortar; if it can be readily pulverized, it indicates an excess of zinc.

This excess of zinc can be removed by keeping the alloy in flux for some time with the crucible uncovered, whereby a considerable quantity of zinc volatilizes, and, after continuing the heating for some time, an alloy showing the required content of zinc is obtained. This method is, however, expensive, as it consumes time and a considerable quantity of fuel. It is, therefore, more suitable to throw small pieces of strongly heated German silver into the melted alloy and effect an intimate mixture of the metals by stirring with a wooden rod.

If a sample of the alloy cannot be pulverized or broken into pieces by vigorous blows with a hammer, it is a sure proof that zinc is wanting. This defect can be more readily corrected than the preceding one, it being only necessary to throw a small quantity of zinc into the crucible and distribute it as uniformly as possible in the melted mass. After repeating the addition of zinc and testing once, or at the utmost twice, a solder answering all requirements will be obtained.

Argentan-solder has a pure white color and strong lustre. It melts at quite a high temperature and for this reason is well adapted for soldering, for instance, lamps used for the production of high temperatures (so-called Berzelius lamps) which were formerly much used in chemical laboratories, but which at the present are generally replaced by gas.

## XLIII.

### SOLDERS CONTAINING PRECIOUS METALS.

Solders containing precious metals—gold and silver—are chiefly used in the manufacture of gold and silver wares, but are also employed for soldering articles of cast-iron, copper, bronze, etc., and by manufacturers of fine mechanical works. Generally these solders consist of an alloy of silver and copper, or silver and brass, for silver-solder; sometimes a small quantity of tin is added, which lowers the melting point and gives a soft silver-solder. The composition of silver-solders varies according to the purpose for which they are to be used. In the following the compounds employed in the preparation of the solders most frequently used are given.

*Ordinary hard silver-solder.*—Copper 1 part, silver 4. This alloy is quite tenacious and very ductile. It is preferably used for soldering articles to be worked under the hammer or stamped.

*Brass silver-solder.*—The alloy known under this name shows also considerable hardness and ductility, and has a somewhat whiter color than the preceding. It is prepared by melting together a fine quality of brass with silver and is consequently an alloy of silver, copper, and zinc. It is composed of sheet-brass 1 part and silver 1.

*Soft silver-solder.*—The solders given above have a comparatively high melting point. To facilitate the working of smaller articles, solders with a lower melting point are used, which is attained by the addition of a small quantity of tin, which must, however, be very pure. An excellent soft silver-solder is composed of sheet-brass 32 parts, silver 32, tin 2.

*Hard silver-solders: a. Very hard.*—Silver 40 parts, copper 10.

*b. Hard.*—Silver 40 parts, copper 2, brass 18.

*c. Middling hard.*—Silver 40 parts, copper 10, brass 40, tin 10.

*Soft silver-solders: a. For after-soldering, i. e.*, for soldering articles that have parts already soldered, silver 20 parts, brass 10.

*b. Quick running and brittle.*—Silver 25 parts, brass 30, zinc 10.

The last composition is frequently used for soldering silver-alloys with a very small content of silver. In consequence of the great brittleness of such solder the soldered places readily spring open.

*Silver-solder for cast-iron.*—Silver 20 parts, copper 30, zinc 10.

*Silver-solder for steel.*—Silver 30 parts, copper 10.

For soldering articles of silver the alloy itself of which they are manufactured is in many cases used. But the manipulation is somewhat troublesome on account of the difficulty of keeping the places to be soldered clean, and the pieces must be very nicely fitted together. The solder, in this case, is used in the form of fine shavings and is melted by means of a keen flame. For small articles the flame of a blow-pipe suffices as a rule, but for larger articles it is best to use a special small blowing apparatus, by means of which the solder can be applied very uniformly. It offers the further advantage of leaving both hands free, which is of importance for turning the vessel in front of the flame and for the application of the solder.

*Gold-solders.*—In color and fusibility the solder used for articles of gold should approach as nearly as possible the alloy of which they are made; the smaller the content of gold in the alloy to be soldered the more fusible the alloy used for soldering must be. Gold-solders consist in most cases of alloys containing, besides gold, copper and silver; by adding, as is sometimes done, small quantities of zinc, solders with a comparatively low melting point are obtained, the use of which has, however, the disadvantage of the soldered places frequently acquiring a black color during the subsequent coloring of the articles.

Manufacturers use for articles of gold of various fineness solders which must correspond in regard to color and fusibility with the alloy to be soldered. The following table gives the composition of some gold-solders in general use:—

| | Parts. | | | |
|---|---|---|---|---|
| | Gold. | Silver. | Copper | Zinc. |
| Hard solder for fineness 750 | 9.0 | 2.0 | 1.0 | — |
| Soft " " " 750 | 12.0 | 7.0 | 3.0 | — |
| Solder " " 583 | 3.0 | 2.0 | 1.0 | — |
| " " " 583 | 2.0 | 0.5 | 0.5 | — |
| for less fineness than 583 | 1.0 | 2.0 | 1.0 | — |
| " " " " 583 | 1.0 | 2.0 | — | — |
| " " " " 583 | 1.0 | — | 2.0 | — |
| " readily fusible . . | 11.94 | 54.74 | 28.17 | 5.01 |
| " " " for yellow gold . . . . | 10.0 | 5.0 | — | 1.0 |

*Solder for enamelled work.*—Articles which after being finished are to be decorated with enamel cannot be soldered with every kind of gold solder, since many enamels require so high a degree of heat for fusion as to endanger the durability of the soldered joints. Hence solders with a high melting point have to be used. The following compositions will be found to answer all requirements:—

*a. Refractory solder.*—Gold 74 parts, silver 18.

*b. More readily fusible solder.*—Gold (750 fineness) 32 parts, silver 9, copper 3.

*Fine gold-solder.*—For soldering platinum vessels to be used in laboratories chemically pure gold was formerly used, as alloys of gold and silver are attacked by sulphuric acid, etc., at a boiling heat and even below that temperature. Soldering with fine gold is, however, very difficult, as gold requires a very high temperature to become fluid, and even then runs so thick as to require special skill for the production of a perfect joint. In modern times soldering with gold has been almost entirely abandoned, the pieces of platinum being now directly united with the assistance of the flame of oxy-hydrogen gas.

*Aluminium-solder.*—This solder is frequently used by dentists for joining together the separate metallic portions of sets of artificial teeth. Besides aluminium it generally contains gold and silver, though in the place of the latter platinum and copper are now frequently used. In the following we give two receipts for preparing aluminium-solder:—

I. Gold 3 parts, platinum 0.1, silver 2, aluminium 10.

II. Gold 5 parts, silver 1, copper 1, aluminium 20.

Alloys containing precious metals must, on account of their costliness, be brought into such shape that as little as possible be wasted in using them. In most cases they are cast into thin rods and rolled between steel rolls into thin sheet, which is cut with the shears or pressed into thin strips, the so-called "pallions," or filed into dust, which is no doubt the best method of using them.

# XLIV.

## TREATMENT OF THE VARIOUS SOLDERS IN SOLDERING AND SOLDERING FLUIDS, ETC.

Solders adhere only to bright and clean metal, and the surfaces of the places to be soldered must consequently be subjected to a special treatment in order to remove any oxide, grease, etc.

Many substances are used for this purpose in the practice, the most important of which will be briefly discussed in the following: According to their behavior the chemical preparations used in soldering can be divided into several groups, namely, in those which produce a bright surface of the metals by dissolving the layer of oxide upon it.

Dilute mineral acids are generally used for pickling the places to be soldered, hydrochloric acid being chiefly employed for the purpose. By touching the place where the solder is to be applied with a brush dipped in dilute hydrochloric acid, the oxide is at once dissolved and the melted solder spreads rapidly over the surface. Hydrochloric acid is used upon zinc as well as upon tin. The combination formed by the solution of zinc in hydrochloric acid is, however, very volatile in the heat imparted to the metal by the soldering iron, and a considerable quantity of vapors injurious to health, and also to the metal of the soldering iron are evolved. It is, therefore, recommended to provide the workshop, where much of such soldering is done, with a thorough ventilation.

Instead of dilute hydrochloric acid the so-called soldering fluid is used in many places. It is prepared by dividing a certain quantity of hydrochloric acid into two equal parts, compounding one of these parts with pieces of zinc and leaving it in contact with an excess of it until the development of gas has ceased. The other portion of hydrochloric acid is compounded with carbonate of ammonia until no more effervescence due to the escape of carbonic acid takes place. The two liquids are then combined. In place of the saturated solution of carbonate of ammonia a solution of sal ammoniac in water can be used, equal volumes of the zinc solution and sal ammoniac being in this case taken for the preparation of the soldering fluid.

For brass articles ammonia alone is frequently used, which acts by reducing the layer of oxide upon the surface of the metals. As fluxes for coarser work turpentine, colophony, and a mixture of sal ammoniac and olive oil are also used. The composition known under the name of "soldering fat" may be prepared by introducing powdered colophony in melted and strongly heated tallow and adding sal ammoniac. The mass is stirred until homogeneous and then allowed to solidify.

For hard soldering, substances are used which dissolve the layer of oxide, and form with it a glass-like combination which is melted by the heat and forced out by pressing the soldered pieces together. The best-known agent of this kind is borax, which readily dissolves the oxides in consequence of the excess of boric acid it contains. For higher degrees of temperature readily fusible glass finely pulverized also does good service, the fused glass dissolving the oxides. A solution of water-glass also answers the purpose and is frequently used in hard soldering.

*Hard-soldering fluid.*—The composition known under this name consists of a solution of phosphoric acid in alcohol. It is prepared by dissolving phosphorus in nitric acid, evaporating the solution to expel any excess of nitric acid and mixing the syrupy mass with an equal quantity of strong alcohol. The phosphoric acid dissolves the layer of oxide, the combination formed melting under the soldering iron, and is displaced by the melted solder which now comes in contact with the bright metallic surface. The hard-soldering fluid can be advantageously used in soldering copper as well as brass, bronze and argentan. The phosphate of ammonia or of soda is also used in soldering copper.

Still more suitable as a flux in hard soldering is the use of quartz-sand and some decomposed soda. Quartz-sand consists of silicic acid and soda of sodium carbonate. Both these substances on coming together in a strong heat combine to sodium silicate, which, if silicic acid be present in excess, dissolves the oxides. For very high temperatures, as for instance in welding iron, the use of pure quartz-sand by itself suffices. By strewing the sand upon the red-hot iron, placing the other piece of iron also red hot upon it, and uniting both by vigorous blows of the hammer, the combination of the silicic acid with the ferric oxide formed upon the surfaces of the pieces of metals is pressed out in a fluid form, and the two surfaces of iron having become bright will unite.

# APPENDIX.

## COLORING OF ALLOYS.

In many cases alloys are provided with a coating, the object being either to increase their beauty or to protect them from oxidation and discoloration. Articles of ordinary alloys, which are not to be exposed to the fire, are frequently only provided with a coating of a lacquer consisting usually of a solution of shellac in alcohol, that made with "stick lac" being, as a rule, the best. The lacquer may be colored by any permanent transparent alcoholic solution giving the desired tint. Dragon's blood, red sanders, or annotto is generally used for red, and gamboge, sandarac, saffron, turmeric, or aloes for yellow; these coloring matters may be replaced by aniline colors. In applying the lacquer care should be had to keep the article to be lacquered warm and of uniform temperature, and to perform the work as quickly and smoothly as possible. Keep the lacquers in well-stoppered bottles, best of opaque material. For use pour them into dishes of convenient size, and apply them with a thin, wide flat brush. The following is Graham's* table of lacquers:—

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* Brass-Founder's Manual, London, 1887.

| Number. | Shellac. | Mastic. | Canada balsam. | Spirits of wine. | Pyro-acetic ether. | Spirits of turpentine. | Turpentine varnish. | Simple pale lacquer. | Dragon's blood. | Annotto. | Sanders. | Turmeric. | Gamboge. | Saffron. | Cape Aloes. | Sandarac. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | oz. | dr. | dr. | pt. | oz. | dr. | oz. | pt. | dr. | dr. | gr. | dr. | dr. | dr. | dr. | dr. | |
| 1 | 4 | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | Strong simple. |
| 2 | 1 | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | Simple pale. |
| 3 | 1 | — | — | 1 | — | — | — | — | — | — | — | — | 1 | — | 3 | — | Fine pale. |
| 4 | 1 | — | — | 1 | — | — | — | — | — | — | — | 1 | 1 | 2 | — | — | " |
| 5 | 1 | — | — | 2 | — | — | — | — | 1 | 1 | — | — | 16 | 4 | — | 8 | " |
| 6 | 2 | — | — | 2 | — | — | — | — | 1 | 8 | — | 32 | — | — | — | 8 | Plate gold. |
| 7 | 2 | — | — | 1 | — | — | — | — | — | — | — | — | 2 | — | 4 | — | Pale yellow. |
| 8 | 5 | — | — | 3 | 30 | — | — | — | — | — | — | — | — | — | — | — | " |
| 9 | — | — | — | — | — | — | — | 1 | — | 1 | — | 4 | — | — | — | — | Full yellow. |
| 10 | 3 | — | — | 1 | — | — | — | — | — | 2 | — | 16 | — | 2 | — | — | Gold. |
| 11 | 3 | — | — | 4 | — | — | 6 | — | — | — | — | 64 | 6 | — | — | 14 | " |
| 12 | 1 | — | — | 1 | — | — | — | — | — | — | — | 20 | — | — | 2 | 5 | " |
| 13 | 3 | — | — | 1 | — | — | — | — | 4 | — | — | 16 | — | — | — | — | Deep gold. |
| 14 | 3 | — | — | 1 | — | — | — | — | 4 | — | — | 1 | — | — | — | — | " |
| 15 | 3 | — | — | 1 | — | 30 | — | — | 40 | — | 12 | 10 | — | — | — | — | " |
| 16 | — | — | — | — | — | — | — | 1 | 8 | 32 | — | — | — | — | — | — | Red. |
| 17 | 1 | — | — | — | — | — | 1 | — | 8 | 24 | — | — | — | — | — | 27 | " |
| 18 | 15 | 30 | 30 | 6 | — | — | — | — | 20 | — | — | 60 | — | 10 | — | — | Tin lacquer. |
| 19 | — | — | — | — | — | — | — | 1 | — | — | — | 4 | 1 | — | — | — | Green, for bronze. |

By coating articles of copper or brass with good fat copal lacquer, and heating after drying until the lacquer commences to smoke, a coat is obtained which protects the articles as well as the tinning against the action of acid liquids.

Articles of copper and bronze exposed for a long time to the action of the air acquire a beautiful brown or green color, which considerably contributes to their handsome appearance. This color is known as *Aerugo nobilis* (noble rust) or *patina.*

Though there are many agents by means of which a layer of patina can be produced upon the bronze, the coating thus obtained cannot compare, as regards beauty and durability, with the genuine patina.

In order to obtain a coating similar to genuine patina, it is recommended to pursue as nearly as possible the same course by which the latter is naturally formed. By the action of the rain, which always contains salts, though in very minute quantity, in solution, the copper is attacked and basic salts of copper are formed upon the surface, which in the course of time are converted by the action of the carbonic acid of the air into basic copper carbonate. The latter has a beautiful green color and is found in nature as malachite. But besides this process others also take place upon the surface of the article, especially upon that of monuments erected in large cities. The air of the latter is constantly charged with certain quantities of sulphur combinations originating partially from the putrefaction of excrements, etc., in the sewers and partially from the combustion of coal containing sulphur. Now copper being very sensitive to the action of sulphuretted hydrogen, a coating of black cupric sulphide is consequently formed upon the surface of the object, which explains why bronze statues erected in large cities frequently turn black. Dust and fine particles of soot, which deposit themselves especially in the depressions of the objects, further contribute to their becoming black. Cupric sulphide has, however, the property of becoming rapidly converted in the air into copper sulphate, from which is again formed copper carbonate, or, so to say, a coating of malachite. Genuine patina, especially that observed on very antique statues, consists, therefore, of a very firmly adhering coating of malachite.

To produce upon a statue a patina like deposit, brush it over with a very dilute solution of cupric nitrate to which a small quantity of common salt solution may be added. When the statue is entirely dry, brush it with a fluid consisting of 100 parts of weak vinegar, 5 parts of sal ammoniac, and 1 part of oxalic acid, and repeat the application after drying. In consequence of this treatment the statue in the course of about one week acquires a green-brown color resembling that of genuine patina.

A finer coating, which more closely resembles genuine patina, is, however, obtained by dipping the article into the solution of cupric nitrate, and placing it in a room where a large quantity of carbonic acid is developed, the fermenting room of a distillery being especially adapted for this purpose, since the high temperature prevailing therein promotes the formation of the green coating. The progress can in this case be watched from day to day, and if in about a week the statue has not acquired the desired coloration, the application of the above-mentioned solution is repeated, this being continued until the desired tint is obtained. The formation of the patina under these conditions taking place in a similar manner as in the open air, a very beautiful and durable coating is obtained.

For coating articles of brass with a green patina apply a solution prepared by dissolving 10 parts of copper in 20 parts of nitric acid, diluting the solution with 150 parts of vinegar and adding 5 parts of sal ammoniac. Allow the articles to stand a few days in the air, and when a green coloration has made its appearance, brush them with old linseed oil and after a few days rub them with a soft woollen rag. If after the application of the linseed oil the article readily bronzes, a very beautiful patina will soon appear.

There are several methods of giving an agreeable brown patina to medals. It is, however, most readily accomplished by heating the medal in a spirit flame and then brushing with graphite. To color a number of medals at the same time dissolve 30 parts of verdigris and 30 parts of sal ammoniac in 100 parts of vinegar, and add water to the solution until a precipitate is no longer formed. Place the medals without touching each other upon the bottom of a shallow dish, pour the boiling hot solution over them, and allow them to remain until they have acquired the desired tint, which should be a fine brown.

*Copper articles* before being brought into commerce receive generally a brown coloration, which is produced by polishing the articles with pumice stone and then coating them with a paste prepared from 5 parts of verdigris, 5 parts of colcothar, and some weak vinegar. The articles are then heated over a coal fire until the coating is entirely dry and has acquired a black color. It is then removed by washing with water, and the dry articles are rubbed bright with a rag greased with a very small quantity of tallow. A beautiful brown color is also obtained by applying a paste of colcothar and water, heating over a coal fire, and removing the coat by rubbing.

Another method of browning copper consists in rubbing it bright with glass paper, heating strongly over a coal fire, and brushing with the following solution: Crystallized acetate of copper 5 parts, sal ammoniac 7, dilute acetic acid 3, distilled water 85. Finally rub the article with a solution of 1 part of wax in 4 parts of oil of turpentine.

*To brown gun-barrels* prepare the following solutions: (*a*) Solution of ferric chloride (liq. ferri sesquichlor.) 1.40 parts, corrosive sublimate 3 parts, blue copperas 3 parts, fuming nitric acid 3 parts, and distilled water 80 parts. (*b*) Potassium sulphide 10 parts, distilled water 900. Apply solution *a* twice or three times to the polished barrel by means of a sponge or soft brush, placing it after each application in a cool room in order to retard drying, and brushing it thoroughly before each new application with a steel wire brush (scratch brush). When the barrel appears dark enough place it for 20 to 30 minutes in the bath *b*, and after taking it out wash with warm water and next with soap water. The dry barrel is finally rubbed with linseed-oil varnish.

For another method the following baths are prepared: (*a*) Fuming nitric acid 2 parts, distilled water 98. (*b*) Nitrate of silver 1 part, distilled water 99. The polished barrel is brushed over with *a*, and treated with the scratch brush in the same manner as described in the preceding process until a beautiful layer of oxide is formed. It is then thoroughly cleansed with the scratch brush and the bath *b* applied until it is sufficiently dark, and finally rubbed with linseed-oil varnish.

*The new bronze* upon French bronze figures shows all shades of pale or clay yellow to red brown and of red to dark and black brown. It has a bronze-like appearance and adheres tightly to the metal; *i. e.*, is chemically combined with it. To produce such colorations, solutions of sulphur combinations of arsenic and antimony have been successfully used. After chasing and pickling the article must be subjected to a thorough washing with water, as otherwise every trace of acid left behind will later on in drying or bronzing penetrate through the seams and produce indelible stripes and stains. The drying of the article must also be done with the greatest care. For applying the solutions a tuft of cotton or a soft, close brush is used. The work is best commenced by first applying a dilute solution of ammonium bisulphide as sparingly as possible, brushing over a certain limited portion of the figure at one time. The quicker and more uniformly this is done the better and more beautiful the bronzing will be. After drying the sulphur separated out is brushed off and a solution of sulphide of arsenic in ammonia applied, the result being a coloration similar to massive gold. The oftener this solution of sulphide of arsenic is applied the browner the color becomes, and a very dark brown can be finally obtained by a solution of sulphide of arsenic in ammonium bisulphide. By solutions of sulphide of antimony in ammonia or ammonium sulphide the coloration becomes reddish, it being possible to produce the most delicate rose-color as well as the deepest dark red. By rubbing certain portions somewhat more strongly a very fine metallic lustre is produced. Ammonia or ammonium sulphide redissolves the bronzing, so that places not thoroughly colored can be improved, though in such case it is better to rub off the entire figure with ammonium sulphide. In the same manner as the solutions in ammonia or ammonium sulphide, those in hydrate or sulphide of potassium or sodium can also be used, the latter being in some cases even more advantageous. By pickling the figure the color of the bronze is changed. If a casting of bronze or brass is left too long in the pickle, the metal becomes coated with a greenish-gray film, which on rubbing with a cloth rag becomes lustrous and adheres firmly. On treatment with the above metallic sulphides this coating acquires a dull-yellow coloration.

*Graham's bronzing liquids*[*] have a great range of composition and of application as follows:—

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[*] Brass-Founder's Manual, London, 1887.

### I. *For brass (by simple immersion).*

| Number. | Water. | Nitrate of iron. | Perchloride of iron. | Permuriate of iron. | Nitrate of copper. | Tersulphide of arsenic. | Muriate of arsenic. | Potash solution of sulphur. | Pearlash solution. | Cyanide of potassium. | Ferrocyanide of potassium solution. | Sulphocyanide of potassium. | Hyposulphite of soda. | Nitric acid. | Oxalic acid. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pt. | dr. | dr. | pt. | oz. | gr. | oz. | dr. | dr. | oz. | pt. | dr. | dr. | dr. | oz. | |
| 1 | 1 | 5 | — | — | — | — | — | — | — | — | — | — | — | — | — | Brown, and every shade to black. |
| 2 | 1 | — | 5 | — | — | — | — | — | — | — | — | — | — | — | — | " " |
| 3 | 1 | 16 | — | — | — | — | — | — | — | — | — | — | 16 | — | — | Brown, and every shade to red. |
| 4 | 1 | — | — | — | — | — | — | — | — | — | — | — | 16 | 1 | — | " " |
| 5 | 1 | — | — | — | 1 | — | — | — | — | — | — | — | — | — | 1 | Brownish-red. |
| 6 | — | — | — | — | — | — | — | — | — | — | 1 | — | — | 3 | — | " " |
| 7 | 1 | — | — | — | — | — | — | — | — | 1 | — | — | — | 4 | — | Dark brown. |
| 8 | 1 | — | — | — | — | 30 | — | — | 6 | — | — | — | — | — | — | Yellow to red. |
| 9 | 1 | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | Orange. |
| 10 | 2 | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | Olive-green. |
| 11 | 1 | — | 5 | — | — | — | — | — | — | — | — | 2 | — | — | — | Slate. |
| 12 | 1 | — | — | — | — | — | — | — | — | — | — | — | 20 | — | — | Blue. |
| 13 | 1 | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | Steel-gray. |
| 14 | 1 | — | — | 2 | — | — | 10 | — | — | — | — | — | — | — | — | Black. |

In the preparation of No. 5 the liquid must be brought to boil and cooled. In using No. 13 the heat of the liquid must not be under 180° F. No. 6 is slow in action, sometimes taking an hour to give good results. The action of the others is usually immediate.

## II. *For copper (by simple immersion).*

| Number. | Water. | Nitrate of iron. | Sulphate of copper. | Sulphide of antimony. | Sulphur. | Muriate of arsenic. | Pearlash. | Sulphocyanide of potassium. | Hyposulphite of soda. | Hydrochloric acid. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | pt. | dr. | oz. | dr. | dr. | dr. | oz. | dr. | oz. | dr. | |
| 15 | 1 | 5 | — | — | — | — | — | — | — | — | Brown, and every shade to black. |
| 16 | 1 | 5 | — | — | — | — | — | 2 | — | — | Dark brown-drab. |
| 17 | 1 | — | 1 | — | — | — | — | — | 1 | 2 | " " |
| 18 | 1 | — | — | 2 | — | — | 1 | — | — | — | Bright red. |
| 19 | 1 | — | — | — | 1 | — | 1 | — | — | — | Red, and every shade to black. |
| 20 | 1 | — | — | — | — | 1 | — | — | — | — | Steel-gray, at 180° F. |

## III. *For zinc (by simple immersion).*

| Number. | Water. | Nitrate of iron. | Protochloride of tin. | Sulphate of copper. | Muriate of iron. | Muriate of lead. | Pearlash. | Sulphocyanide of potassium. | Hyposulphite of soda. | Garancine infusion. | Logwood infusion. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pt. | dr. | dr. | dr. | dr. | oz. | oz. | dr | dr. | | | |
| 21 | 1 | 5 | — | — | — | — | — | — | — | — | — | Black. |
| 22 | 1 | — | 1 | — | — | — | — | — | — | — | — | " |
| 23 | 1 | — | 1 | — | — | — | — | 1 | — | — | — | Dark gray. |
| 24 | 2 | — | — | 1 | 1 | — | — | — | — | — | — | " |
| 25 | — | — | — | — | — | * | — | — | — | — | — | " |
| 26 | 2 | — | — | — | 1 | — | — | — | — | — | — | Green-gray. |
| 27 | — | — | — | — | — | — | — | — | — | * | — | Red (boil). |
| 28 | 1 | — | — | 4 | — | — | 4 | — | — | — | — | Copper color. |
| 29 | 1 | — | — | 8 | — | — | — | — | 8 | — | — | " " (with agitation.) |
| 30 | — | — | — | — | — | — | — | — | — | — | * | Purple (boil). |

* Made to the consistency of cream.

To provide articles of brass or bronze with a very lustrous gray or black coating, the tendency of certain metallic salts of forming gray or black combinations with sulphur is utilized. For *gray* dip the article first into a very dilute solution of acetate of lead, or for *black* into a solution of sulphate of copper, and after drying into a hot dilute solution of hyposulphite of soda.

By using the solutions in a very dilute state the articles acquire a peculiar, iridescent appearance similar to soap-bubbles, and it is also due to the same cause. It is well known from the teachings of physics that many bodies show, when in very thin layers, the peculiar-color phenomenon termed iridescence, and this is also produced by a very thin layer of sulphide of lead or sulphide of copper. By repeating the treatment of the article in very dilute solutions, the iridescence passes into a red, brownish, or violet coloration. It is impossible to give exact proportions for the production of these colors, the success of the coloration depending largely on the skill of the operator.

Very beautiful, but not very permanent, iridescent coatings can be produced by placing the bright metal in a bath of a heavy metal decomposable by the galvanic current, touching it for a moment with the negative pole of the battery, taking it out, rinsing off and drying. The metal will show all the colors of the rainbow, but the coating is so delicate that it must be protected by immediately dipping the article after drying into a quick-drying varnish.

There are many means of providing small articles of brass with a coating of one color, various liquids being, for instance, used to produce determined shades of color upon brass buttons. For a pure *golden yellow*, the buttons are dipped for a few seconds in a perfectly neutral (absolutely free from acid) solution of acetate of copper. A *gray-green* shade is produced by repeatedly dipping them in a dilute solution of chloride of copper and drying after each dipping. A violet tint is obtained by heating the buttons to a temperature at which oxidation does not take place, and rubbing them with a tuft of cotton dipped in a solution of antimony in hydrochloric acid.

For the production of the *beautiful gold color* possessed by many French articles of brass the following process may be used: Dissolve 1.76 ounces of caustic soda and 1.41 ounces of milk sugar in 2.11 pints of water. Boil the solution for fifteen minutes, and after taking it from the fire compound it with 1.41 ounces of cold concentrated solution of sulphate of copper. The red precipitate of cuprous oxide, which is immediately formed, deposits on cooling upon the bottom of the vessel. The polished articles resting upon a wooden sieve are then placed in the vessel containing the solution. After about a minute the sieve is taken out in order to ascertain how far the operation has progressed; it is then replaced, and at the end of the second minute the golden color is generally dark enough. The sieve is then taken out, and the articles after washing dried in saw-dust. By allowing the articles to remain for a longer time in the solution they acquire in a short time a greenish tint, which soon becomes yellow and then bluish-green, until finally the iridescent colors are formed. In order to obtain a uniform coloration it is necessary to produce the color slowly, which is best attained at a temperature of from 132° to 136° F. The bath can be repeatedly used and kept for a long time in well-stoppered bottles. If partially exhausted, it can be restored by an addition of 5.64 drachms of caustic soda, sufficient water to replace that lost by evaporation, heating to the boiling point, and finally adding 14.11 drachms of cold solution of sulphate of copper.

To produce *a beautiful silver color* upon brass proceed as follows: Dissolve in a well-glazed vessel 1½ ounces of pulverized cream of tartar and 2.25 drachms of tartar emetic in 2.11 pints of hot water, and add to the solution 1¾ ounces of hydrochloric acid, 4⅓ ounces of granulated, or, still better, pulverized tin, and 1 ounce of pulverized antimony. Dip the articles to be coated into the solution heated to the boiling point. After boiling one-quarter to one-half hour, they will be provided with a beautiful lustrous coating which is hard and durable.

*Browning liquid for copper.*—Add acetic acid to 11 drachms of spirit of sal ammoniac until blue litmus paper dipped into the liquid turns red. Then add 5½ drachms of sal ammoniac and sufficient water to make 2.11 pints. With the solution thus obtained repeatedly moisten the copper surfaces, rubbing after each application until the desired brown tint is produced.

*For coloring brass* Ebermayer, of Nürnberg, gives the following directions: (1) 8 parts of sulphate of copper, 2 of sal ammoniac, and 100 of water give by boiling a greenish color. (2) 10 parts of potassium chlorate, 10 of sulphate of copper, and 1000 of water give by boiling a brown-orange to cinnamon-brown color. (3) By dissolving 8 parts of sulphate of copper in 100 of water, and adding about 100 parts of caustic soda until a precipitate is formed, and boiling the articles in the solution, they acquire a greenish-brown color, which can be made darker by the addition of colcothar. (4) With 50 parts of caustic soda, 50 of sulphide of antimony, and 500 of water, and boiling, a light fig-brown color is obtained. (5) Boil 29 parts of sulphate of copper, 20 of hyposulphite of soda, and 10 of cream of tartar in 400 of water. The brass first acquires a rose color and then a blue color. By adding 20 parts of ammonio-ferric sulphate and 20 of hyposulphite of soda, the colors change from yellow to rose color and blue; after the latter yellow makes again its appearance, and finally a beautiful gray is formed. (6) 400 parts of water, 20 of potassium chlorate, and 10 of nickel salt give, after boiling for some time, a brown color, which is, however, not formed if the sheet has been pickled. (7) 250 parts of water, 5 of potassium chlorate, 2 of carbonate of nickel, and 5 of nickel salt give, after boiling for some time, a brown-yellow color playing into a magnificent red. (8) 250 parts of water, 5 of potassium chlorate, and 10 of nickel salt give a beautiful dark brown. (9) 250 parts of water, 5 of orpiment, and 10 of crystallized soda give at first a beautiful red which passes into blue, then into pale blue, and finally becomes white. (10) 250 parts of water, 5 of nickel salt, 5 of sulphate of copper, and 5 of potassium chlorate give a well-covering yellow-brown color. (11) 100 parts of water, 1 of liver of sulphur, and 5 of ammonia. The articles being allowed to lie in a closed vessel finally acquire a very beautiful blue color.

*Coloring of soft solders.*—For giving the solder used in soldering copper the same color as the latter, prepare first a saturated solution of pure sulphate of copper and apply it to the solder. By then touching the solder with an iron or steel wire the latter becomes covered with a film of copper, which can be augmented as much as desired by repeated moistening with the solution of sulphate of copper and touching with the wire. If the soldering is to show a yellow color, mix 1 part of saturated solution of sulphate of zinc with 2 parts of solution of sulphate of copper, apply the mixture to the coppered place and rub the latter with a zinc rod. If the soldered place is to be gilded, copper it as above described, then coat it with a solution of gum or isinglass, and strew bronze powder upon it. This forms a surface which, when the gum is dry, can be polished.

# INDEX.

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