

Dental metallurgy; a manual for students and dentists.

Contributors

Griffiths, A. B. 1859-

Publication/Creation

London : Scott, Greenwood, 1903.

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DENTAL METALLURGY

A.B. GRIFFITHS, PH.D.



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DENTAL METALLURGY

DENTAL METALLURGY

A MANUAL FOR STUDENTS AND DENTISTS

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ON MICRO-ORGANISMS" "A MANUAL
OF BACTERIOLOGY" ETC. ETC.

WITH THIRTY-SIX ILLUSTRATIONS

LONDON

SCOTT, GREENWOOD & SON
8 BROADWAY, LUDGATE HILL, E.C.

CANADA: THE COPP CLARK CO. LTD., TORONTO
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SIR RICHARD OWEN, K.C.B., F.R.S.

In Memoriam

PREFACE

THE aim of the present manual has been to produce, within moderate limits, a handbook of *dental* metallurgy for students and dentists. Dental metallurgy is a subject of great importance, as it treats of the metals, alloys, etc., used in dentistry; and it should be mastered in the *laboratory* rather than in the study or lecture-room.

The book is not intended to supersede the experience and practical knowledge that can be gained only in the dental laboratory; but I hope it will be found a useful adjunct to, and contribute to a clearer understanding of, these things.

As this work is not a text-book of metallurgy, full descriptions of the various ores and processes for extracting the metals have not been given in its pages.

A full account has been given of the various metals, alloys, and amalgams used in dentistry; and it may be stated that the work more than covers the Syllabus issued by the

Royal College of Surgeons of England; but the chief aim of the work is to educate rather than to inform.

In conclusion, I take this opportunity of thanking Mr. C. A. Clark, L.D.S.I., for much valuable work.

A. B. GRIFFITHS.

CHEMICAL AND ASSAY LABORATORIES,
171 BRIXTON ROAD, LONDON,
June 1903.

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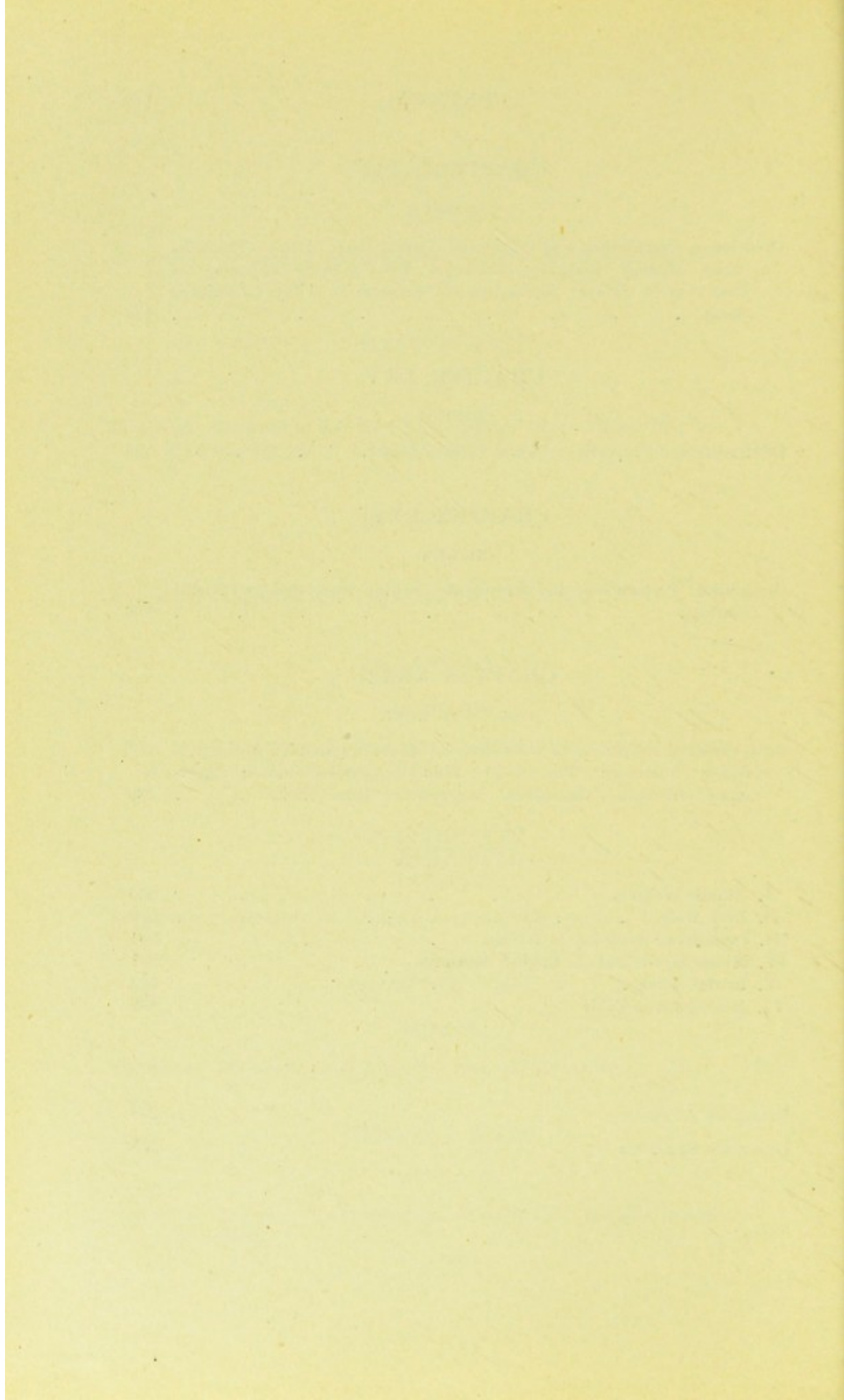
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DENTAL METALLURGY

CHAPTER I

INTRODUCTION

METALLURGY is the art of extracting metals from their ores, and has been known from ancient times. Anvils, forges, and tongs, as well as gold washing and melting, are represented on ancient Egyptian tombs and monuments. Seven metals were known to the ancients—gold, silver, mercury, copper, tin, lead, and iron. None is more commonplace now than iron, but in these early days it was thought very precious, owing to the difficulty of working it. Xenophon states that iron ores were first smelted by the Chalubes (*vide* Xenophon's *Anabasis*, lib. 4 and 5). Copper was then more extensively used than any other metal, and it was generally alloyed with tin to form bronze. In working and casting metals the ancients were very advanced. Gold, silver, and bronze were used by the ancient Egyptians,¹ Jews, Assyrians, Phœnicians, Greeks, and Romans, as their sacred vessels, arms, medals, statues, etc., bear testimony.

Copper-mining and the production of swords, armour, etc., in bronze, formed the staple trade of Cyprus from the heroic

¹ Concerning the metals and workers of Egypt, see *La Vie Privée des Anciens*, par Ménard, t. iii. pp. 197-267.

ages down to the times of the Romans. That the quality of the armour was highly prized in Homer's time, may be gathered from his description of the present made by Cinyras to Agamemnon. Alexander the Great had a Cyprus sword given him by the king of Citium, and praised it for its lightness and good quality.

The Japanese were acquainted with the most important metals in very early times. In the first half of the eighth century, at the time of Shômu-Tennô, the ability to work skilfully in metals, generally, had already reached a high state.

The inhabitants of China, Persia, India, and other parts of Asia also worked in metals from the earliest times;¹ and gold was used for *dental* purposes more than two thousand years ago. Cicero states that the Romans used gold for fixing artificial teeth.

Metals are found native (*e.g.* gold, copper, silver, etc.) or as ores (that is, in combination with the non-metallic elements, forming *minerals*). The methods of extracting metals from ores, and purifying them, are metallurgical processes; and *dry* or *wet* methods are used for the purpose. The former are conducted in furnaces, whereas by wet methods the metal is extracted by a suitable solvent.

¹ See Berthelot's *Collection des Alchimistes grècs; Les Origines de l'Alchimie; La chimie au moyen âge*; and Ray's *History of Hindu Chemistry* (1902).

CHAPTER II

PHYSICAL PROPERTIES OF THE METALS

LUSTRE is a characteristic property of the metals, by which they have the power of reflecting light. The bright appearance of a polished metallic surface is well known, but it disappears when the metals are reduced to a state of fine division (precipitated gold and powdered iron are examples). The metallic lustre varies in colour: copper is red; gold is yellow; tin, platinum, silver, etc., are white; zinc, lead, and antimony have a blue tint; bismuth, a reddish hue; while iron and some other metals are greyish.

SPECIFIC GRAVITY, or density of a metal, is the weight of a certain bulk of it as compared with the same bulk of water. The specific gravity often constitutes an important distinguishing property, and the weights of all metals have been compared with the weight of an equal bulk of water taken as the unit.

The following are the chief methods for obtaining specific gravities:—

(a) *By the Balance.*—Weigh a small piece of the metal on a balance (Fig. 1, A); next place a little bridge over the scale pan (without touching it), and on this set a small beaker of distilled water at 60° F. (or correct for that temperature). Tie a piece of silk around the metal, and suspend it in the water from the scale-beam hook so that the metal does not touch the sides or bottom of the beaker, shaking off all air bubbles, and weigh again.

Formula as follows:—

$$\begin{aligned}\text{Weight of metal in air} &= x \\ \text{,, ,, water} &= y \\ \frac{x}{x-y} &= \text{specific gravity.}\end{aligned}$$

(b) *By the Flask.*—Take a specific-gravity flask, and fill it with distilled water of 60° F. (15°·5 C.), so that when the

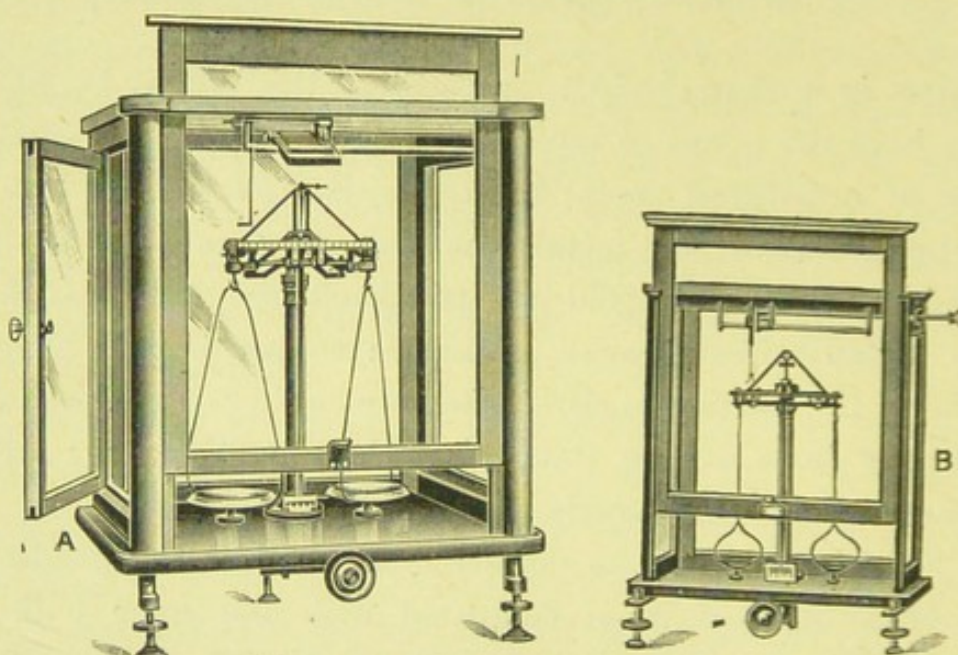


FIG. 1.—Balances (suitable for the Dental Laboratory).

A, Chemical. B, Assay.

stopper is squeezed in the water will overrun through the narrow opening at the top, and weigh carefully. Powder or file some of the metal, empty a little of the water from the flask, pour in the powdered metal, fill with water, as before, and again weigh. In both weighings the bottle is tared by an equal weight on the other scale pan.

Formula:—

$$\begin{aligned}\text{Weight of metal in air} &= x \\ \text{,, flask and water} &= y \\ \text{,, ,, metal, and water} &= w \\ \frac{x}{(x+y)-w} &= \text{specific gravity.}\end{aligned}$$

If the metal is attacked by water, the specific gravity is taken in some other liquid (of known density), and the specific gravity obtained is multiplied by the specific gravity of the liquid, which gives the specific gravity of the metal in reference to water as the unit.

(c) *By Jolly's Spring Balance.*—The Federwage (Fig. 2) is suitable for the dental laboratory, and is a useful instrument for taking specific gravities of metals, alloys, and amalgams. Immerse the lower pan (*b*) in distilled water, and read the position (*x*) of the index bead (*c*) on the graduated scale (*d*). Place the metal in the upper pan (*a*), and take a second reading (*y*); subtract *x* from *y*; this gives *w*, the weight of the metal in air. Remove the metal to the lower pan (*b*), taking care to dislodge air bubbles. Read off the new position *v*. Then $y - v$ gives loss of weight by immersion *z*.

Then $\frac{w}{z}$ = specific gravity.

Thus: *metal*—

$$\begin{array}{rcl} x = 15.8 & 25 - 15.8 = 9.2 = w \\ y = 25.0 & 25 - 21.2 = 3.8 = z \\ v = 21.2 & \end{array}$$

$$\frac{9.2}{3.8} = 2.421 \text{ sp. gr.}$$

The specific gravities of metals are increased by hammering, rolling, and wire-drawing. Increase of temperature means a reduction of the specific gravity. Metals are lighter in the molten than when in the solid state, the only exception being bismuth, which attains its maximum density just before its solidifying point.

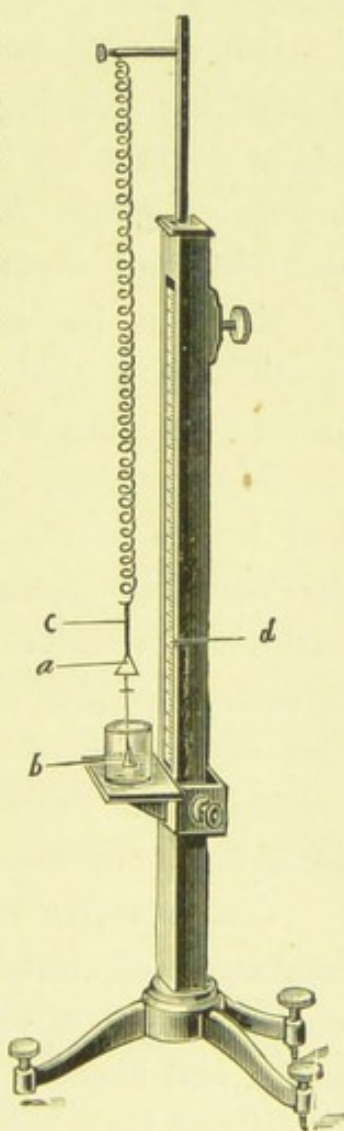


FIG. 2.—Jolly's Federwage or Spring Balance.

SPECIFIC HEAT of a metal is its capacity for heat in comparison to the unit (water). Specific heat is the quantity of heat required to raise a given weight of any metal through a certain range of temperature, as compared with the quantity required to raise the same weight of water through the same range of temperature. Thus, to raise 1 lb. of iron one degree requires $\frac{1}{10}$ of the quantity of the heat required to raise 1 lb. of water one degree; hence the specific heat of iron is 0.1 (water = 1).

The specific heats of the metals are very variable. Hammering, heating, etc., reduces the specific heats; and this property must be taken into consideration in the manufacture of plates for artificial dentures. The high specific heat and the low conductivity of palladium render it suitable for plates, as these properties prevent the chill felt in the mouth with a gold plate on drinking cold liquids, and also prevent scalding with hot fluids.

CONDUCTIVITY FOR HEAT.—The property of conducting heat is one of the chief characteristics of the metals, or, in the words of Berzelius: “la propriété d’être meilleurs conducteurs du calorique que les autres corps, est un des caractères les plus saillants des métaux.” The metals are the best conductors of heat among solids, but their power varies considerably. Silver and copper are the best conductors, while antimony and bismuth are the worst.

CONDUCTIVITY FOR ELECTRICITY.—The metals are also good conductors of electricity, but the power of conduction varies considerably. Silver and copper are the best, and lead, antimony, and bismuth the worst conductors. The conductivity is reduced by a rise of temperature, but this reduction varies with each metal.

Electrical *conductivity* is defined as *the reciprocal of resistance*, and the name “microhms” has been given by Lord Kelvin to the unit of conductivity. The specific conductivity

of annealed silver is $\frac{1}{\cdot 000001501}$ or 666500 *mhos.* The

worst conductors have greater resistance, and the "specific resistance" of a material is expressed in "microhms" or millionths of an ohm at 0° C. of a cubic centimetre or of a cubic inch.

	Resistance in Microhms at 0° C.	
	Cubic Centimetre.	Cubic Inch.
Silver annealed	1·48	0·583
Silver hard drawn	1·58	0·622
Copper annealed	1·55 to 1·61	0·610 to 0·633
Copper hard drawn	1·59 to 1·64	0·626 to 0·646
Gold annealed	2·05	0·807
Gold hard drawn	2·089	0·822
Aluminium annealed	2·90	1·14
Zinc	5·61	2·21
Platinum annealed	9·04	3·55
Gold (2)—Silver (1) alloy	10·8	4·27
Tin	13·2	5·19
Lead	19·6	7·71
Platinum (1)—Silver (2) alloy	24·3	9·58
Antimony	35·4	13·9
Bismuth	108	42·5

The numbers given in the previous table can be used to calculate the resistance of a wire or rod of any length and of any transverse section composed of any one of the metals at 0° C. For example, if a be the specific resistance per cc., l and d the length and diameter of the wire in centimetres, the resistance is

$$\frac{4}{\pi} \frac{la}{d^2} = \text{microhms.}$$

By adding certain metals to alloys their specific resistances are raised and temperature coefficients reduced.

Electrical Units.

Ampère, or unit of current. The strength of a current is directly proportional to the amount of chemical decomposi-

tion produced in a given time; and the current that deposits 0.00111815 gramme, or 0.017253 grain, of silver per second on one of the plates of a silver voltameter, the liquid employed being a solution of silver nitrate containing from 15 to 30 per cent. of the salt, is called an "Ampère." The current produced by 1 volt through a resistance of 1 ohm = 1 ampère; or $\frac{1 \text{ volt}}{1 \text{ ohm}} = 1 \text{ ampère}$. The milliampère is the one-thousandth part of an ampère.

Ohm.—An ohm is the unit of resistance, and is the resistance of a column of mercury 106.3 centimetres long, one square millimetre in sectional area, at a temperature of 0° C. A megohm is one million ohms. A microhm is the one-millionth of an ohm.

Volt.—A volt is the unit of the electro-motive force, and is the difference of potential generated at the ends of a wire of one ohm resistance, when a current of one ampère passes through it: $1 \text{ ampère} \times 1 \text{ ohm} = 1 \text{ volt}$.

Watt.—A watt is the unit of electrical power, and is the power developed in a circuit when one ampère flows through it, and when the P.D. at its terminals is one volt, or $1 \text{ volt} \times 1 \text{ ampère} = 1 \text{ watt}$. The kilowatt is one thousand watts.

Coulomb is the unit of electrical quantity, and is defined as the quantity of electricity that flows per second past a cross section of a conductor with a current of one ampère flowing through. $1 \text{ ampère} \times 1 \text{ second} = 1 \text{ coulomb}$.

EXPANSION BY HEAT.—Metals expand when heated, and, within certain limits, the coefficient of expansion is proportionate to the increase in temperature. In metals we distinguish between the linear, superficial, and cubical expansion. The fraction of its length, surface, or volume which a metal expands for 1° C. is termed respectively its linear, superficial, and cubical coefficient of expansion. For all practical purposes the superficial coefficient of expansion is

twice, and the cubical coefficient three times, that of the linear. If the side of a cube of metal at 0° C. be unity, and a its linear coefficient of expansion, then at 1° its side will measure $1+a$, its surface $(1+a)^2$, and its volume $(1+a)^3$. The linear coefficients of the metals are given under each metal ($\text{Cu} = 0.00167$; $\text{Ag} = 0.00193$; $\text{Pt} = 0.00089$).

FUSIBILITY.—All metals melt or fuse if heated sufficiently, but their fusing points vary considerably: tin melts at 227° , copper at 1050° , and iron at 1600° C.; and at still higher temperatures the metals may be converted into the gaseous state.

Most metals increase in volume on melting, but some decrease. In the case of the former the effect of pressure is to lower, in the latter, to raise, the melting point.

COHESION is the force of attraction exerted between the molecules of a metal, and this force varies considerably in different metals. The following *four* properties will suffice to illustrate this variation in the case of metals:—

1. *Malleability.*—A metal is said to be malleable when it can be hammered or rolled out into plates—gold, silver, copper, and lead are malleable metals. Malleability is affected by impurities—lead, bismuth, arsenic, and some other metals render gold brittle. Prolonged hammering and rolling impairs the malleability of most metals, but this property is, however, regained by annealing. Hence the reason that the plates for artificial dentures have to be often annealed during swaging. Cohesion is interfered with by hammering, the molecules being forced into unnatural positions, but they are brought back again into their proper positions by the process of annealing.

2. *Ductility.*—A metal is said to be ductile when it can be drawn out into wire. Gold, silver, and copper are ductile metals. Wires are produced by passing a rod of metal through the holes in a steel draw-plate (Fig. 3). In

most cases the wire is annealed from time to time in order to prevent undue hardness; in some cases, however, annealing is omitted (hard-drawn wire).

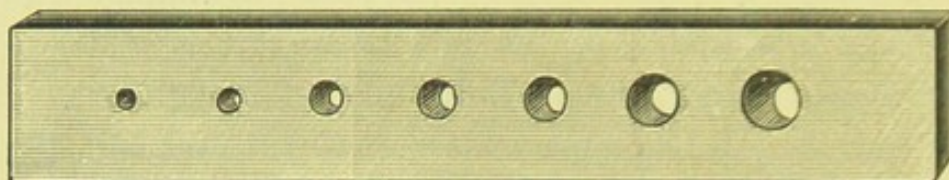


FIG. 3.—Draw-Plate.

3. *Brittleness*.—A metal is said to be brittle when it breaks readily under a blow (*e.g.* bismuth and antimony); but some brittle metals become malleable when heated (*e.g.* zinc), and some malleable metals become brittle when heated. This is an important point in the preparation of dies and counter-dies.

4. *Elasticity*.—A metal is said to be elastic when, after stretching or bending, it tends to return to its original form (*e.g.* steel). Elasticity varies in different metals, and is utilised in matrices, clasps, etc. Wire-drawing, rolling, and hammering increase the elasticity of metals, while annealing generally diminishes it. "Limit of elasticity" is the point at which metals are incapable of regaining their original form.

ADHESION is the force of attraction exerted between the particles of different metals. It is an important property, but requires further investigation. It may play an important part in alloys and amalgams. The union of metals by solders is due to adhesion.

TENACITY.—A metal is said to be tenacious when it possesses the property of resisting fracture when subjected to a tensile or pulling force. The tenacity is tested by taking wires of the same diameter, fixing them at one end and suspending weights at the other, and then noting the *greatest* weight each wire is capable of supporting without breaking. Steel is the most and lead the least tenacious of

the metals. Rolling, hammering, and wire-drawing increase, while annealing reduces, the tenacity.

HARDNESS.—A metal is said to be hard when it offers resistance to a penetrating force. Lead is a soft metal, and is easily scratched; steel, on the other hand, is a hard metal. A die must be *hard* in order to stand the force applied to it in making the plate. Hardness is reduced by an increase of temperature.

CRYSTALLINE CHARACTER.—Most metals and alloys can be obtained in the crystalline state, and in this state many of them are found in nature.

Metallic crystals are formed by—

1. Fusing and cooling (*e.g.* Zn Bi, Pb)
2. Condensation from vapours (*e.g.* Zn, Cd)
3. Electrolysis of metallic solutions (*e.g.* Pb, Au)

Crystals or geometrical forms are common objects, and their number and variety are considerable, but they may all be arranged under six systems. In these systems the planes of the crystals are assumed to be disposed round certain imaginary lines called axes. While the crystals of one and same system differ from each other in the manner in which the planes are arranged round the axes, the crystals of different systems are distinguished by the inclination and relative lengths of the axes.

I. *Cubic, Regular, or Quadratic System.*—Three axes all equal in length, and all at right angles to each other.

II. *Square Prismatic or Tetragonal System.*—Three axes, one shorter or longer than the other two, and all at right angles to each other.

III. *Right Prismatic or Rhombic System.*—Three axes, different lengths, but all at right angles to each other.

IV. *Oblique Prismatic or Monoclinic System.*—Three axes of equal length, and two at right angles, the third inclined at an angle other than 90 degrees.

V. *Doubly Oblique or Triclinic System*.—Three axes of unequal length and different angles.

VI. *Hexagonal System*.—Four axes, three in one plane cutting each other at angles of 60 degrees, the fourth at right angles to the plane formed by the other three, the three axes in one plane being equal in length, the fourth shorter or longer.

CHANGE OF VOLUME ON SOLIDIFICATION.—Metals change their volume on passing from the fluid to the solid state—the change as a rule being contraction (bismuth is an exception). In the preparation of dies for swaging plates, it is important that the die should not alter to any great extent by changes of temperature. The contraction of metals may be diminished by alloying them with other metals; hence the value of alloys in dentistry.

GALVANIC ACTION is produced when two dissimilar metals are immersed in a fluid. It is a weak electric current, and is sometimes experienced when different metals are in contact in the mouth. In acid saliva, if a silver fork touches the filling of a tooth, it may give rise to galvanic action, and an unpleasant taste is experienced.

METALLOGRAPHY is the study of alloys and metals under the microscope. An alloy may be compared to a rock which contains different constituents, all of which may be united in the liquid condition, but separate on cooling, forming two or more alloys of different densities and of different fusibilities; or many solid alloys when heated release certain of their constituents that have different freezing points from the remainder. In fact, a cooling mass of metals often behaves like water containing suspended matter does in freezing, when the ice first formed rejects the foreign matter; and so the portion of the alloy which first solidifies rejects certain other portions of the constituent metals.

Polishing the metal is a matter of great importance for

exact examination of the structure of metals under the microscope. Metallography may throw considerable light on the nature of some dental alloys and metals (*e.g.* zinc).¹

The composition of alloys is now receiving attention from another standpoint, namely, by studying their characters by means of Röntgen ray photography.²

¹ See Roberts-Austen's article in *Encyclopædia Britannica*, and Lewis' paper in *Chem. News*, vol. lxxxvi. p. 211.

² See Heycock and Neville's paper in *Journ. Chem. Soc.*, vol. lxxiii. p. 714.

CHAPTER III

ACTION OF CERTAIN AGENTS ON METALS

AIR.—As a rule, the metals are not acted upon by *dry* air; and, with the exception of iron, lead, zinc, and copper, they remain unchanged in *moist* air at the ordinary temperatures. In moist air containing carbon dioxide, zinc, lead, copper, and iron are attacked. The majority of the metals are oxidised when heated in contact with the air.

WATER has little or no action on the metals, with the exception of iron, copper, zinc, and lead. If, however, the water contains dissolved oxygen and carbon dioxide, the above-mentioned metals become coated with carbonate, which prevents further corrosion.

ACIDS act, more or less, upon all metals (except gold, platinum, and palladium, which are not soluble in any single acid).¹ Gold, platinum, and palladium are soluble in aqua regia ($3\text{HCl} + \text{HNO}_3$).

(a) *Acetic Acid* (vinegar) attacks lead, but has little or no action on the other metals.

(b) *Sulphuric Acid* does not attack gold, platinum, and palladium. Most of the metals are, however, soluble in this acid (strong or dilute). Boiling sulphuric acid (*Schwefelsäure*) attacks antimony and lead, forming sulphates. The strong, but not the dilute, acid dissolves silver, aluminium, mercury, zinc, and bismuth.

(c) *Hydrochloric Acid* has no action on gold, platinum,

¹ Gold is soluble in selenic acid.

palladium, and mercury, and hardly any action on lead, copper, silver, and bismuth. The other metals are, however, dissolved by it, forming chlorides.

(*d*) *Nitric Acid* has no action on gold, platinum, and palladium. Antimony and tin are converted into oxides by its action. All the other metals are soluble in nitric acid (either strong or dilute), forming nitrates.

(*e*) *Tartaric Acid*.—A solution of this acid acts upon some metals and their alloys.

(*f*) *Citric Acid*.—A solution of this acid attacks lead and some other metals. It is the acid of lemons and other fruits.

(*g*) *Malic Acid*, in solution, also dissolves certain metals. It is present in the juices of apples, pears, etc.

ALKALIS.—Aluminium is readily dissolved by soda and potash; and lead, tin, zinc, and cadmium are also acted upon by solutions of the alkalis. Ammonia slowly dissolves copper, and alkaline chlorides (*e.g.* common salt) attack silver by converting it into a chloride which is soluble in the alkaline chloride. The other metals are not attacked by alkaline solutions.

SULPHURETTED HYDROGEN readily blackens silver and copper, and tin and lead are tarnished, owing to the formation of sulphides. Cadmium is also attacked, becoming coated with a film of yellow cadmium sulphide. The other metals are not acted upon by sulphuretted hydrogen.

EFFECT OF EXPOSURE IN THE MOUTH.—The oral secretions act, more or less, upon all metals, except gold, platinum, and palladium. Silver, copper, and cadmium are attacked by the sulphuretted hydrogen of the mouth; but this action may be modified by adding platinum to silver. Carbon dioxide, which is always present in the oral secretions, acts upon lead and zinc. The acids of fruit and other foods slowly attack copper, silver, and some other metals, as well as their alloys.

Aluminium is unfortunately attacked by the alkaline fluids of the oral cavity; and many drugs (medicine) act detrimentally upon metals.

The bacteria present in the mouth cause decay of the teeth by an indirect action on alloys (fillings and plates). They produce compounds (soluble salts, and probably ptomaines) that act upon the metals. Gold alone is not attacked by exposure in the mouth, but when alloyed with copper it becomes more or less tarnished.

CHAPTER IV

ALLOYS

IN 1863, Otto Graham suggested that the solid, liquid, and gaseous conditions of matter probably always exist in every liquid or solid substance, one predominating over the others; and the results of researches conducted by Spring and by the late Sir William C. Roberts-Austen have confirmed that theory, demonstrating the continuity of the three states of matter, and explaining why that continuity exists. Gases are conceived as consisting of molecules continually moving in all directions, the velocity of this movement being increased by raising the temperature. Liquids are also composed of molecules which are capable of moving about freely, though less rapidly than in the case of gases (the "free path" is less in a liquid than in a gas). At the "critical point," where matter passes from the gaseous to the liquid state, or the reverse, it combines the properties of the gas with those of the liquid; and it has been proved, as Prince Kropotkin points out, that mechanical laws which hold good for gases are as fully applicable to liquid solutions as if they really contained gaseous molecules. Apparently there is no substantial difference between the inner structure of a gas and that of a liquid, what difference there is being one of degree only, in the relative freedom, mobility, and speed of molecules, and perhaps in the size of the particles. But even in seemingly inert masses of metal and other solid bodies the molecules are not devoid of motion, and metallurgical experiments prove conclusively that these minute particles of matter never cease

to move about, changing place indefinitely, and entering into new and varied combinations. The *study of alloys* has afforded the necessary evidence required to convert a supposition into certainty. Alloys are compound metals, and they combine the characteristics of merely physical mixtures and chemical compounds. They are totally different in their properties from the component metals, usually varying in colour, hardness, resistance to electric currents, and melting point. Thus, when tin, lead, and bismuth are mixed rapidly with mercury, after being as finely divided as possible, the temperature is reduced to 14° F., a freezing mixture being thus produced. A mixture of bismuth, lead, tin, and cadmium fuses in boiling water, though tin alone, the most readily fusible of the four metals, does not melt below 446° F. The addition of a minute trace of tellurium to bismuth so changes its aspect that it might be taken for a totally distinct elementary body. Similarly, gold is coloured purple by the addition of aluminium, and green by the addition of zirconium, whilst the presence of thallium causes it to lose half its strength, and a trace of silicon causes it to soften in the flame of a candle. Bismuth in copper destroys the latter's electric conductivity, and iron can be obtained in all sorts of conditions, from the pure metal, soft as copper, to chrome steel shells which will pierce 9-inch armour plates, backed by 8 feet of solid oak, without their points being deformed. "A block of an alloy is thus quite a world, almost as complicated as an organic cell." Moreover, a close resemblance has been shown to exist between molten alloys and solutions of salts in water and other media, the same complicated physical and chemical phenomena being produced by dissolving one metal in another, or by mixing two molten metals, as when a salt is dissolved in water, or the latter mixed with alcohol. The physical properties of the metal used as a solvent, observes Prince Kropotkin, are entirely altered as the molecules of the

dissolved metal travel, as if they were in a gaseous state, amidst its own molecules. "Some of them are dissociated at the same time, and new chemical compounds of an unstable nature are formed, only to be destroyed and reconstituted again. In a word, all laws based on the assumption of a nearly gaseous mobility of molecules and atoms, which have been found to be applicable to solutions of salts in water, can be fully applied to molten alloys as well."

But the question remained whether the mobility of the molecules disappears or not when an alloy is solidified; and to this the answer is supplied in Spring's experiments. He has been able to weld small cylinders of steel, aluminium, bismuth, cadmium, copper, tin, lead, gold, and platinum by simply pressing them together by means of a hand-vice, after their ends had been carefully planed true to $\frac{1}{2500}$ of an inch. Whether the cylinders consisted of the same or different metals, they were invariably found to be solidly welded to each other, after remaining under pressure for a few hours. If, at the same time, they were heated to a temperature very remote from their fusion temperature, all traces of the joint disappeared; and when the united cylinders were subsequently torn asunder by means of a powerful machine, quite new tearing surfaces were produced. Real alloys can thus be formed by simple contact, interpenetration of the molecules of the two component metals taking place, though both remain perfectly solid meanwhile, and "the great puzzle of plasticity in the most solid rocks and the most brittle metals thus ceases to be a puzzle." Alloys have also been prepared by pressing together fine filings of different metals; and, finally, Spring has proved that *metals in the solid state evaporate from their surfaces*, just as camphor evaporates.¹ It was previously known that rods of lead, steel, or glass

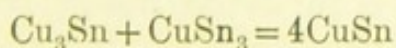
¹ See papers by Pellat (*Comptes Rendus*, t. cxxvi. p. 1338) and Russell (*Chemical News*, vol. lxxvii. p. 167).

will become permanently bent if left resting on their two ends only for a considerable time ; and that solid lead, copper, or steel under pressure will "flow" through an opening, exactly in the same way as clay, which reproduces the flow of a vein of water through the same opening. Adding to these facts the phenomena observed by Spring,—which show that the superficial molecules of a solid piece of metal enjoy the same mobility as if that surface were in the liquid state, and can as easily be freed from cohesion with their neighbours and projected into space, as if they were gaseous molecules,—Graham's broad generalisation of forty years ago is clearly verified, and enables the required explanation of these recently noted phenomena to be furnished. A decisive proof of the theory, which has been practically lost sight of for many years, was furnished by Roberts-Austen when he announced, in a lecture before the Royal Society seven years ago, that gold can diffuse through lead cylinders ; and it now appears that metals "probably are never quiescent, and fully deserve that the methods so fruitful for the study of living beings should be applied to them and their alloys."

Alloys may be divided into two classes—those which consisted of solutions of the constituent materials, and those which contained chemical compounds. Modern research has proved that some of the old ideas regarding solutions require modification. Paradoxical as it may seem, for example, solids can dissolve solids. One of the most important advances which has been made in this subject in recent times is the discovery that the best instruction one can get in the nature and character of alloys is to be obtained in observing carefully their behaviour in cooling.

An alloy may have two or more freezing points, according to the number of metals which entered into its composition ; and as each of these become squeezed out of the compound, the freezing point of the alloy changes.

Neville, Heycock, and Griffiths¹ have proved that at least three series of solid solutions are formed during the solidification of the alloys of copper and tin. The first series (α) consists of crystals, isomorphous with pure copper, and varying in composition from pure copper to an alloy containing about 9 per cent. by weight of tin. These alloys solidify to a uniform mass, and remain unchanged at all lower temperatures. The second series (β) contains percentages of tin varying from 22.5 to 32. Alloys between 9 and 22.5 per cent. of tin solidify as a complex of crystals of α and of β . But all the alloys from 9 to 32 per cent. of tin undergo important re-crystallisations after they have wholly solidified, and their final condition below 500° C. is that of a complex of α and a crystalline body which has the composition Cu_4Sn . Alloys from 32 to 57 per cent. of tin begin to solidify by the formation of a third type of crystalline solid solutions, which may be designated (γ). The γ crystals resolve themselves at lower temperatures into a complex of crystals of the compound Cu_3Sn and another substance. Cu_3Sn is a solid solution when first solidified, and is not converted into the compound until a lower temperature is reached. A reduction of temperature means a change in the nature of the solid solution, and fractional crystallisation takes place. γ -Crystals containing more than 41 per cent. of tin resolve themselves on cooling into solid Cu_3Sn and a liquid. Between 57 and 93 per cent. of tin the first body formed on solidification consists of crystals Cu_3Sn , but when the temperature falls to 400° C. these crystals become unstable, and a reaction takes place between them and the liquid, which results in their partial transformation into CuSn . The reaction *may be* the following:—



¹ *Proceedings Royal Society*, vol. lxix. p. 320.

Between 93 and 99 per cent. of tin the compound CuSn is the first substance formed during solidification; between 99 and 100 per cent. tin crystallises first.

Such is some of the most recent work on the nature of alloys.

Most metals unite to form alloys. Alloys possess the physical and chemical properties common to metals (lustre, ductility, etc.); while retaining these properties, the compounds produced are often so modified in some of their properties that they may be regarded as new metals. Alloys are of the utmost importance in dentistry, as one metal counteracts the detrimental properties of another,—thus, copper hardens gold.

Many alloys are definite compounds, while others are metallic solutions. Many metals are thoroughly mixed in the fused state, but on cooling they separate (lead and zinc liquefy or separate on cooling).

Some alloys may be formed by pressure (Wood's and Rose's alloys are examples);¹ that is, without fusion.

Colour.—The colours of the metals are greatly modified by alloying (5 per cent. of aluminium makes copper a yellow colour; 50 per cent. of silver added to gold renders the latter colourless; 22 per cent. of aluminium added to gold produces a ruby coloured alloy; and when antimony and copper are fused in equal proportions by weight, a purple alloy is the result—"the regulus of Venus").

Density.—An alloy has rarely the average of the densities of the constituent metals, being sometimes greater and sometimes less. Increase of density is due to contraction, and the formation of a chemical compound (or compounds); while decrease of density is due to expansion.

Fusibility.—As a rule, the fusing point of an alloy is lower than the average melting point of the constituent metals.

¹ See *Journ. Chem. Soc.*, 1882, p. 92.

Newton's fusible alloy (8Bi, 3Sn, 5Pb) melts at 95° C., although the fusing points of its constituent metals are 268° , 227° , and 325° C.

Specific Heat.—The capacity for heat of alloys is the average of the specific heats of the constituent metals.

Expansion by Heat.—The expansion of alloys is nearly in the proportion of the relative volumes of the metals which compose them.

Conductivity for Heat and for Electricity.—In some cases the conducting powers are the averages of the same properties of the constituent metals; while in other cases there is no such relationship.

Malleability and Ductility are usually diminished, and sometimes destroyed by alloying.

Hardness.—The addition of platinum to silver renders the latter metal harder; and, as a rule, alloys are harder than the average hardness of their constituent metals.

Action of Solvents on alloys is sometimes different from their action on the component metals alone. Acids dissolve alloys if their constituent metals are also soluble in the acids. Nitric acid has no action on platinum; but if alloyed with much silver, it dissolves.

Preparation of Alloys.—Plumbago crucibles are generally used in the preparation of alloys.

Sometimes the constituent metals are mixed and fused together; while at other times the metal of highest fusing point is first melted, and the others added in the order of fusibility. A small quantity of powdered charcoal is placed on the surface of the charge to prevent oxidation; the fused metal is stirred with a wooden, fireclay, or clean iron rod after each addition; and the molten alloy should be *poured* at the lowest possible temperature.

Alloys for Dies and Counter-Dies should possess certain properties: they should be hard enough to resist the action

of repeated blows. They should melt at a low temperature, and should not contract on cooling. Alloys for dies should not be brittle, and possess enough cohesion to prevent cracking. No metal or alloy possesses all these properties at the same time; and most dies deteriorate by constant use. The alloys used for dies or counter-dies are the following:—Type metal, Babbitt's metal, Spence's metal, brass,¹ Austen's metals,² alloys of antimony and tin, and alloys of zinc and tin. These alloys are described under the various metals.

Determination of Melting Points of Fusible Alloys.—These alloys are described in the chapter on bismuth; and they all melt at low temperatures. To determine the melting point of a fusible alloy, a small quantity of it is placed in a test-tube (*B*) to which a thermometer (*A*) is attached (Fig. 4). The tube and thermometer are placed in a beaker containing water, and the latter is gently heated until the alloy melts; the burner is then removed, and *the temperature at which the alloy solidifies* is noted. Several determinations are made, and the mean taken as the melting point of the alloy. Liquids of higher boiling points than that of water (*e.g.* analine, mercury, etc.) may be used if necessary. An iron vessel may be substituted for the test-tube, and is then partly filled with mercury; in this vessel is placed a metal tube containing the broken alloy, in which a thermometer is inserted. Heat is applied, and the temperature of solidification noted.

Comparative tests of fusibility may be made with the blowpipe on charcoal. Thus a piece of tin (melting at 227° C.) placed beside an alloy may melt before the alloy is fused, though a piece of lead (melting at 325° C.) remains solid at the melting point of the alloy; therefore the fusing point of the alloy lies between the melting points of tin and lead.

¹ H. Rose, *Brit. Journ. Dental Science*, vol. xxxviii. p. 530.

² *American Journ. Dental Science*, vol. vi. p. 367.

Solders are alloys used in joining metals together. Solders are more fusible than the metal or metals to be joined; and they must possess the property of *flowing* readily. Solders should not alter by age, or become discoloured, and they should contain metals that possess a strong affinity for the material to be soldered. They should resist the action of the oral secretions, and the action of foods, etc. When a solder melts at a temperature *above* a red heat, it is called a "hard solder," and if *below* it is "easy" or "soft." Each metal, as a rule, requires a particular kind of solder; these are described under each metal.

Solders are prepared in a similar manner to other alloys. Silver and gold solders are usually rolled into *sheets*, soft solders (tin and lead) are in *sticks*, while other solders are used in the form of *filings*.

Soldering is an important process in dentistry, and has for its object the union of two or more pieces of metal. A flux (usually borax) is used to facilitate the operation, to remove films of oxide, to prevent oxidation, and to keep a clean surface. In soldering it is necessary to use an alloy that melts at a lower temperature than the metals to be united. The solder should flow readily, and its colour should correspond, as nearly as possible, with the plate or article. For dental purposes, solders should be about $\frac{1}{32}$ of an inch in thickness. Sometimes solder filings are mixed with the flux (borax), and then applied to the metals to be united. Excess of either solder or flux proves want of skill, and an oxidising flame should be avoided.

The method of soldering with the blowpipe is known as *hard soldering*; whereas in the case of *soft soldering* a soldering

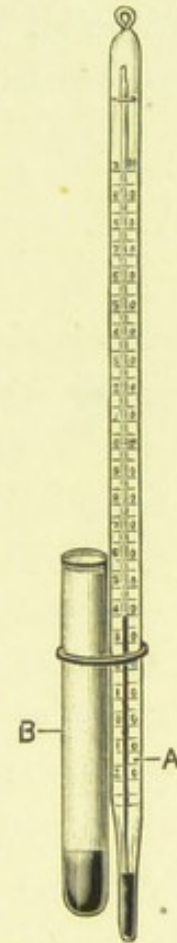


FIG. 4.—
Melting Points
of Fusible
Alloys.

iron is used instead of the blowpipe. Soft solders contain usually lead and tin, and the flux is a solution of zinc chloride. The soldering iron consists of a piece of copper ("the bit") attached to an iron stem, which is fixed into a wooden handle.

CHAPTER V

ACTION OF ORAL BACTERIA ON ALLOYS

SINCE there is a profusion of microbes in the atmosphere, it can easily be understood why they should be found in the mouth. They are for the most part harmless, and Miquel estimates the number of bacteria introduced into the human system by respiration at 300,000 a day. It is well known that bacteria produce chemical changes in albumen—ptomaines, toxines, and other compounds being formed; and these substances, although produced in extremely small quantities, appear to act seriously on dental and other alloys. Alloys become corroded when placed in culture tubes containing the living bacteria of saliva; and there is no corrosion in sterile tubes of gelatine and other media (Fig. 5).

According to Miller, there are no less than six different fungi which exist in carious teeth. Some of these fungi give rise to optically active lactic acid, and probably to ptomaines. When sound teeth are exposed to the action of these microbes, they are rapidly deprived of lime, and numbers of microbes are to be found in the dental channels (Fig. 6, B).

Acids and other compounds are produced in the mouth by bacteria, and no doubt they act upon many of the alloys used in dentistry.

The microbes found in caries and in the saliva are represented in Fig. 5; and the *Bacterium of Dental Caries* (the chief cause of the disease) grows in gelatine, agar, and bouillon (Fig. 6).

The action of oral bacteria and their products on dental alloys is a subject well worthy the attention of bacteriologists.

These organisms have great vitality, and Weil states that *leptothrix* bores its way through the enamel. In carious

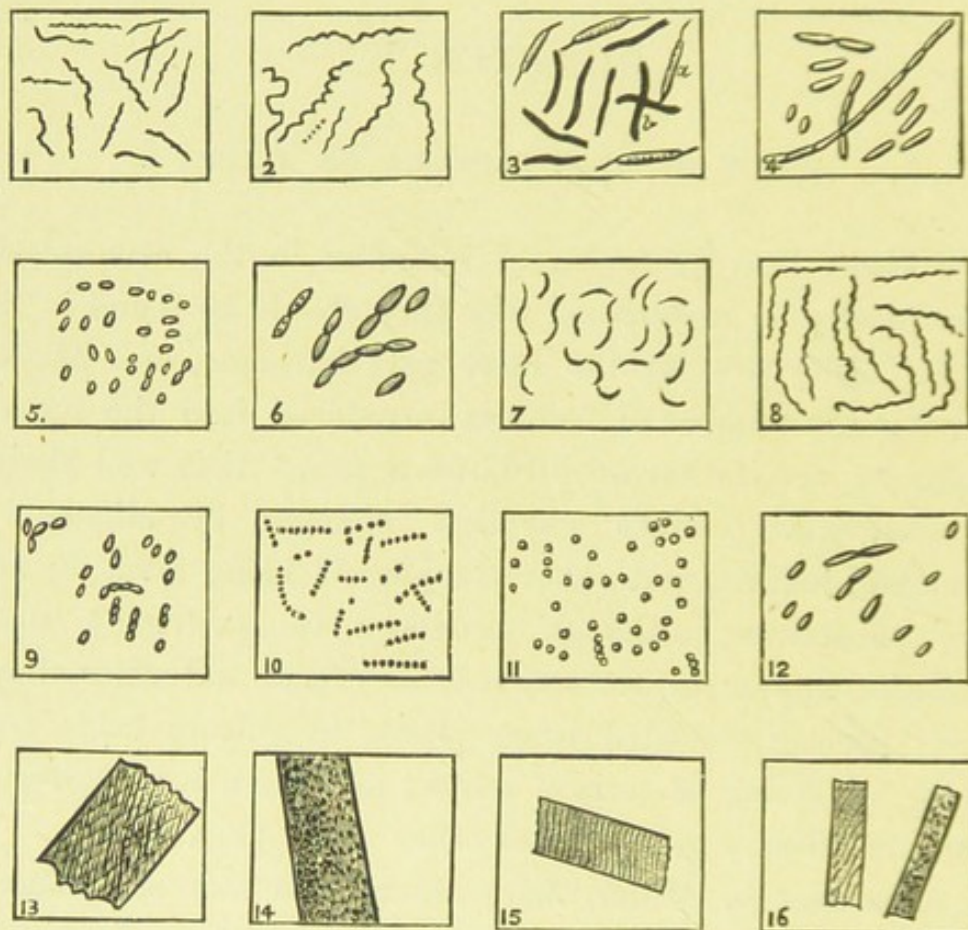


FIG. 5.—Oral Bacteria and their Action on certain Alloys.

1. *Leptothrix buccalis*. 2. *Leptothrix plicatilis*. 3. *Vibrio rugula*. 4. *Bacillus subtilis*. 5. Bacterium of Dental Caries. 6. *Bacillus dentalis viridans*. 7. *Spirillum sputigenum*. 8. *Leptothrix gigantea*. 9. *Bacillus gingivae pyrogenes* (suppurating pulp of tooth). 10. *Micrococcus salivarius septicus* (in the saliva of puerperal women). 11. *Micrococcus salivarius pyogenes*. 12. *Bacillus salivarius septicus*. 13-16. Dental and other alloys corroded by oral bacteria (from culture experiments).

teeth, organisms are found in dentine along the tubes, in cementum along Sharpy's fibres; it therefore seems, according to Goadby,¹ to be perfectly possible that, *pari passu* with the

¹ "Bacteriological Aspect of Dental Caries," a paper read before Guy's Hospital Dental Society. See Goadby's *Mycology of the Mouth* (1903).

extrinsic acid production, an intrinsic production is set up, due to the destruction of the sheaths of Newman and the uncalcified matrix, resulting in the formation of glycol (from elastin or chondrin); hence the destruction of the teeth. The mouth becomes a perfect incubator for microbes, as they find the temperature of 98° F. most suitable for their life-

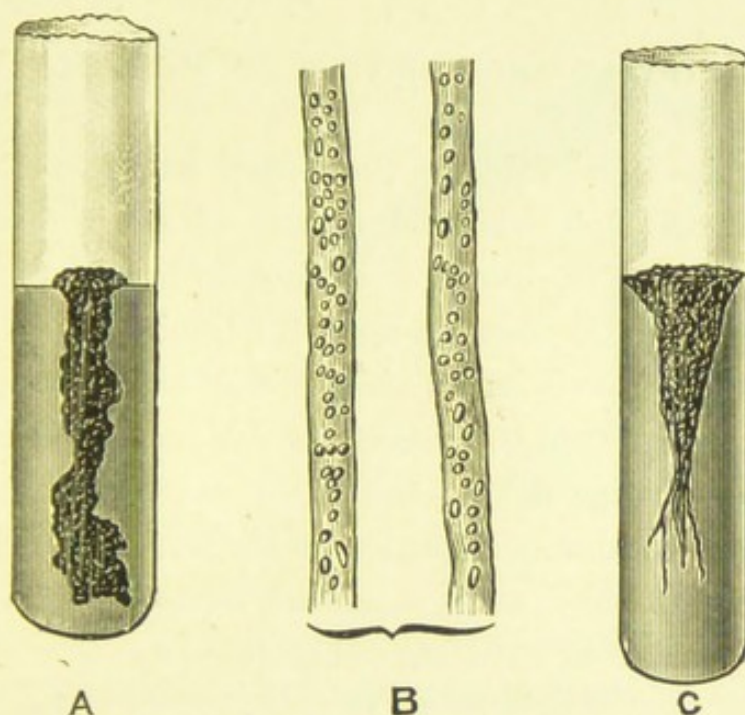


FIG. 6.—Bacterium of Dental Caries.

A. Culture in gelatine. B. Bacterium of dental caries in the dentine tubules. C. Culture in agar.

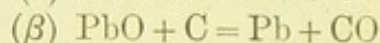
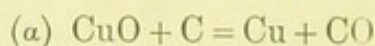
histories. An impure mouth in which decomposing matter is to be found is a regular microbe nest, in which whole generations of them are produced and flourish. Here they settle permanently in diseased gums, and in the diseased dental substance of decayed teeth, whence they pass into other parts of the body.¹ The products of decay act upon teeth, artificial dentures, alloys, etc.

¹ See a paper by A. B. Griffiths in *The Sphere*, January 3, 1903 (entitled, "What are Bacteria? What is an Antiseptic?").

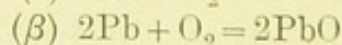
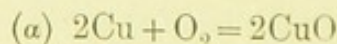
CHAPTER VI

THEORY AND VARIETIES OF BLOWPIPES

THE blowpipe is of value in the dental laboratory, and is an instrument through which a stream of air is forced into a flame in order to produce a more intense heat. If a coal gas, a candle, or an oil flame is used, its luminosity is destroyed when the blowpipe is used; this is due to the oxygen of the air burning nearly all the carbon in the flame. There are two parts of a blowpipe flame—the inner zone, which is blue and pointed, and an almost colourless outer zone. The inner zone is a *reducing flame*, as it contains *excess* of carbon, and is therefore capable of reducing oxides, etc., *e.g.*—



The outer zone is an *oxidising flame*, as it contains excess of oxygen, and readily converts metals into oxides, *e.g.*—



The reducing flame is produced by placing the nozzle of the blowpipe (Fig. 7) in the edge of the flame and blowing somewhat gently; the tip of the flame is luminous (Fig. 7, *a*). The oxidising flame is obtained by placing the nozzle into the flame, and blowing a strong blast of air into the flame. In soldering operations the *reducing* flame should be used, in order to prevent the formation of oxides.

Mouth Blowpipes.—On the Continent, chemists are more

particular about the form of blowpipe used in their investigations than we are in England.

Fig. 8, *a*, represents an ordinary mouth blowpipe, and it should be made of brass. It consists of a bent tube about 10 in. long, and a nozzle at the end, the aperture of which should be circular. To prevent moisture collecting near the nozzle, a ball or cylindrical chamber (Fig. 8, *b* and *c*) is sometimes attached to the mouth blowpipe. If a higher temperature is required than can be obtained by the ordinary blowpipe, a hot-blast mouth blowpipe (Fig. 8, *d*) is used for the purpose.

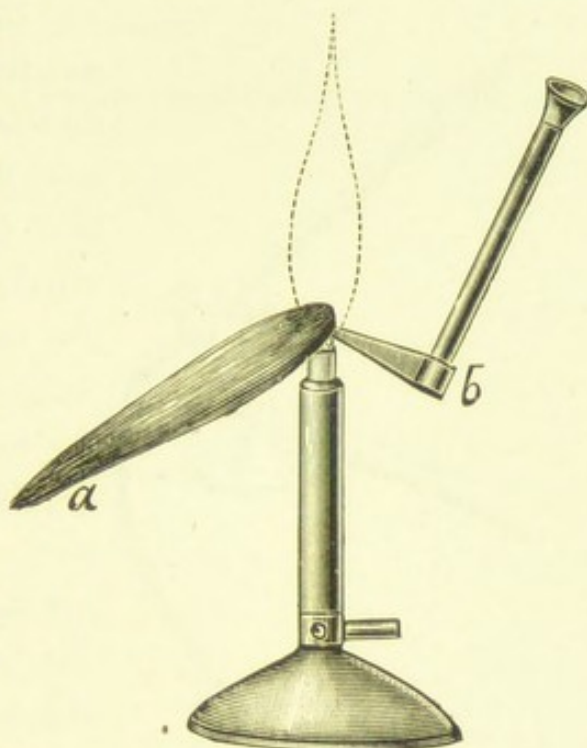


FIG. 7.—Blowpipe Flame.

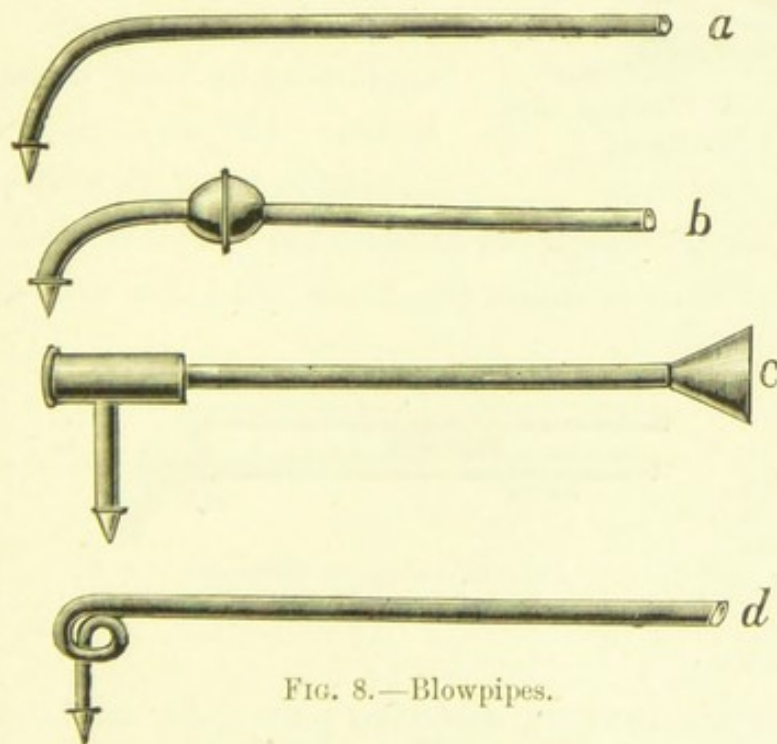


FIG. 8.—Blowpipes.

The nozzle end of the blowpipe is coiled so that the air

becomes heated before it is forced into the flame, hence the temperature of the latter is considerably raised.

In using the blowpipe, the mouth is filled with air, and the muscles of the expanded cheeks keep up a steady pressure; respiration being allowed to go on as usual through the nose. When the method has been mastered, no fatigue is experienced after using the blowpipe for a long period.

Many operations in the laboratory require a still higher temperature than that obtainable with the mouth blowpipe. For this object blowpipes with *foot-blowers* are used (Fig. 9). Automatic blowpipes are also effective instruments for producing high temperatures, and are necessary appliances in most dental laboratories. Air or oxygen (Fig. 10) is used in these blowpipes. These

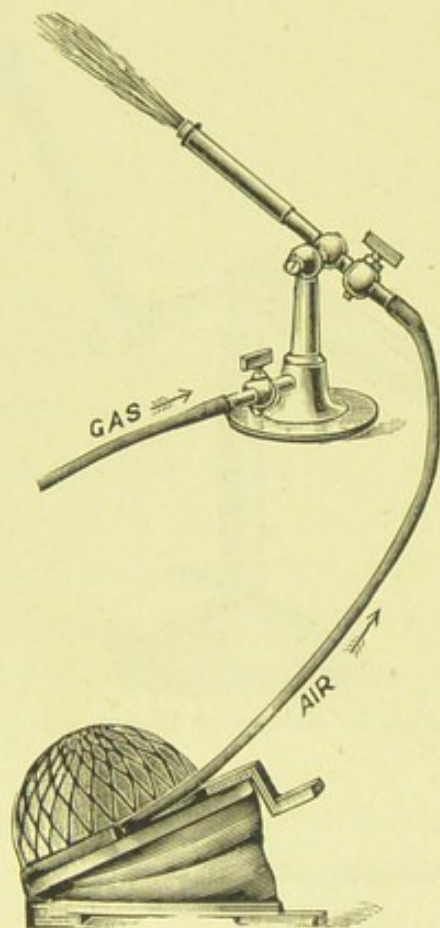


FIG. 9.—Gas Blowpipe with Foot-blower.

instruments are sometimes constructed so that the air or oxygen is heated before it enters the flame; in other words, hot-blast

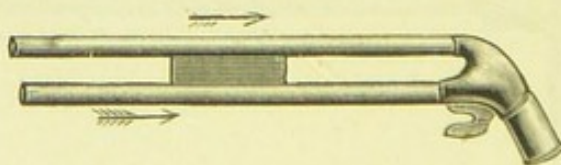


FIG. 10.—Oxygen Blowpipe (for high temperatures).

blowpipes are used for soldering pure gold, as in continuous gum work. These instruments furnish an intense heat.

Foot-Blowers (Fig. 9) are bellows, so constructed that a continuous supply of air is capable of being forced into the flame. They are invaluable in a laboratory.¹

¹ For further information on the blowpipe, see Plattner, *On the Blowpipe* (English edition).

CHAPTER VII

FLUXES

A FLUX (from the Latin *fluo*, I flow) is a substance which, added to ores, metals, or other bodies, combines with the impurities and forms a fusible *slag*. A flux is added to slag off impurities, to protect the surface of the metal, and to produce a fusible mass. Oxides may be removed from metallic surfaces by using a suitable flux; and sometimes an oxidising flux is used, in order to oxidise impurities, which then combine with the flux to form a slag. Impure and brittle gold is refined by melting it with a small quantity of nitre (KNO_3) and borax. The nitre oxidises the impurities, which combine with the borax, forming a liquid slag.

Borax is the chief flux used in the dental laboratory (for soldering purposes and for melting metals).

Nitre or potassium nitrate is used as an oxidising flux in the purification of gold.

Ammonium Chloride is used as a flux for purifying metals. When in the molten state they decompose it, forming metallic chlorides and liberating ammonia. It is used in the purification of gold and zinc. Charcoal and ammonium chloride is sometimes used for the same purpose.

Sodium Chloride (salt) is a flux, and prevents oxidation. It is also used to moderate the action of nitre, which causes violent ebullition (for this reason it enters into the composition of the mixture for purifying sweep or lemel).

Lime is used to slag off silica present in siliceous ores.

Silica is used to slag off lime and other bases in calcareous ores.

Charcoal Powder is used to prevent oxidation when melting metals.

Paraffin Wax is used to prevent oxidation when soldering aluminium (see Sellon's solder-alloy, Chapter XX.).

Glass is sometimes used as a flux (*e.g.* in the assay of iron ores).

CHAPTER VIII

FURNACES, MELTING APPLIANCES, TOOLS, ETC.

FURNACES.—There are blast, reverberatory, cupellation, crucible, ladle, injector, and electric furnaces.

Blast Furnace (see chapter on Iron) consists of a vertical cylindrical shaft, which tapers somewhat at the hearth. Air (cold or hot) is forced in at the lower portion of the furnace. The mixture of ore, fuel, and flux is charged at the top; while the metal obtained from the ore flows into moulds from the bottom of the furnace.

Reverberatory Furnace (see chapter on Lead) is a horizontal furnace consisting of three parts: fireplace, hearth, and chimney. The flames are reflected over the hearth or bed.

Cupellation or Muffle Furnace is one of the most important appliances in a laboratory. The muffle is a kind of oven, and is made of fireclay. It is fixed in the furnace so that the flames from gas or coke completely surround it. The muffle is perforated with holes or slits, through which air is drawn; by this means the lead or bismuth used in cupellation is oxidised, and sinks into the porous cupel, carrying with it certain impurities.

Fig. 11 represents permanent muffle and crucible furnaces. Fig. 12 is a useful form of portable furnace, and is suitable for the dental laboratory. Both furnaces are heated by means of coke (oven coke should be used). Fig. 13 represents Hersfeld's electric muffle furnace, the tem-

perature of which can be regulated to a nicety by simply registering the strength of the current; in fact, the voltmeter

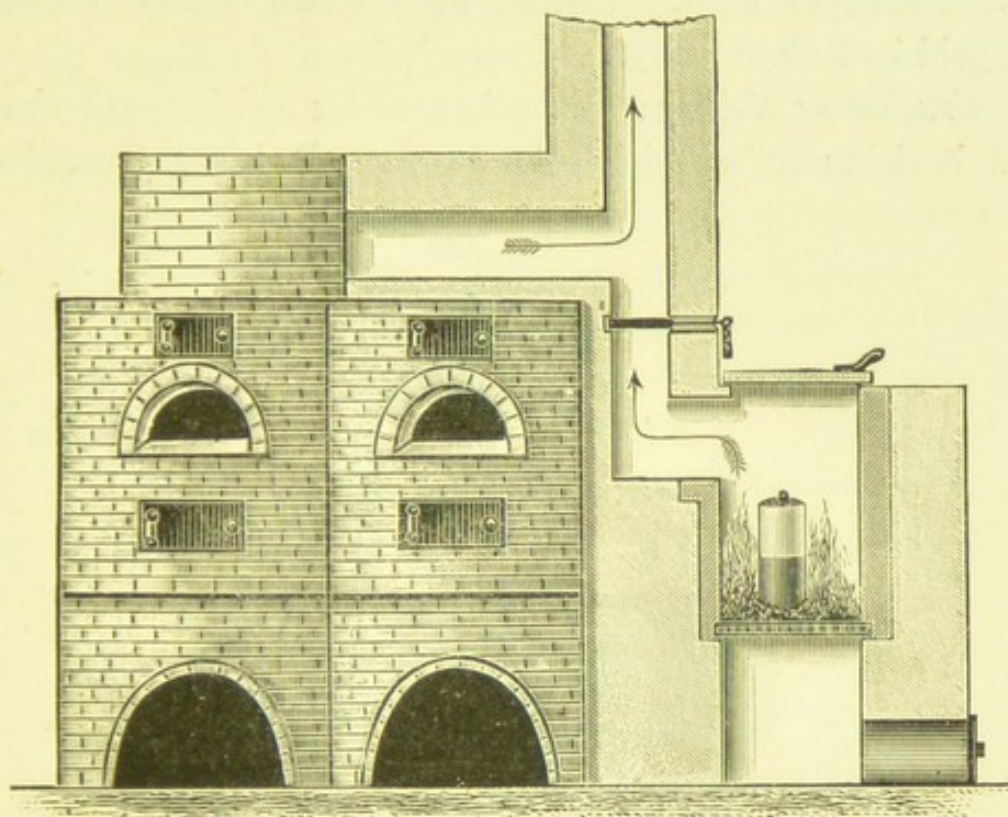


FIG. 11.—Muffle and Crucible Furnaces.

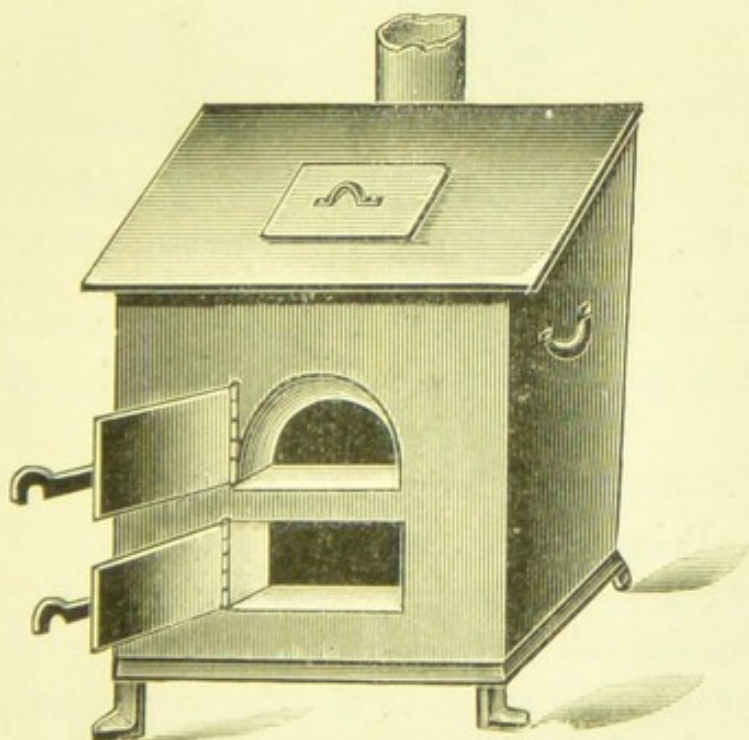


FIG. 12.—Muffle Furnace.

and ampèremeter act as a pyrometer, so that the same temperature can be obtained at any time. It is invaluable for continuous gum work. Fletcher's *gas* muffle furnace is useful for gold and silver assays.

Crucible or Melting Furnace is used for melting operations, and is either heated with coke or gas. It is constructed of

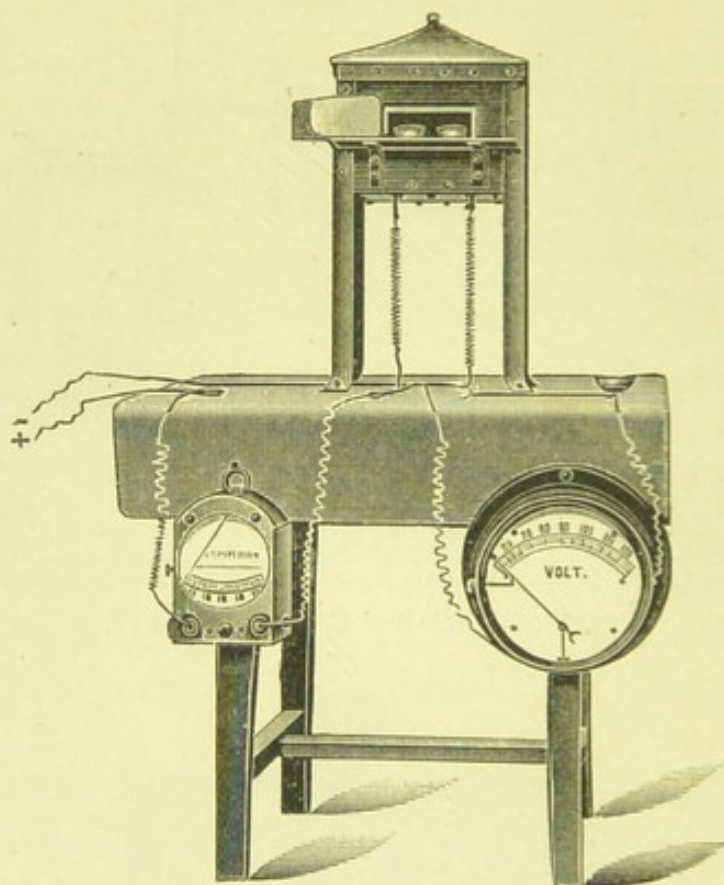


FIG. 13.—Dr. A. Hersfeld's Electric Muffle Furnace.

fireclay or fire-bricks (Fig. 11, right-hand portion), and is useful for preparing alloys, purifying metals, reducing ores, etc.

Ladle Furnace is a device well adapted for melting lead and zinc. It is an open vessel, heated by a Fletcher burner; and ladles (of cast or wrought iron) are used for extracting and pouring the metal.

Injector Furnaces are made of refractory material, and the heat is produced by means of a mixture of gas and air

forced into the furnace by means of a special burner, the blast being obtained by a foot-blower. High temperatures are readily obtained by these furnaces. The nozzle of the burner is placed in the aperture of the furnace, and the flame plays against the crucible. To prevent any "cold spot," Fletcher has introduced a concentric jet gas-burner.

Injector oil furnaces are used when gas is not obtainable. They are fitted with a lamp for burning petroleum oil.

Injector furnaces are blast furnaces, while cupellation and crucible furnaces may be termed "air" or "non-blast" furnaces.

Electric Furnaces are suitable for many operations requiring extremely high temperatures. Fig. 14 represents an

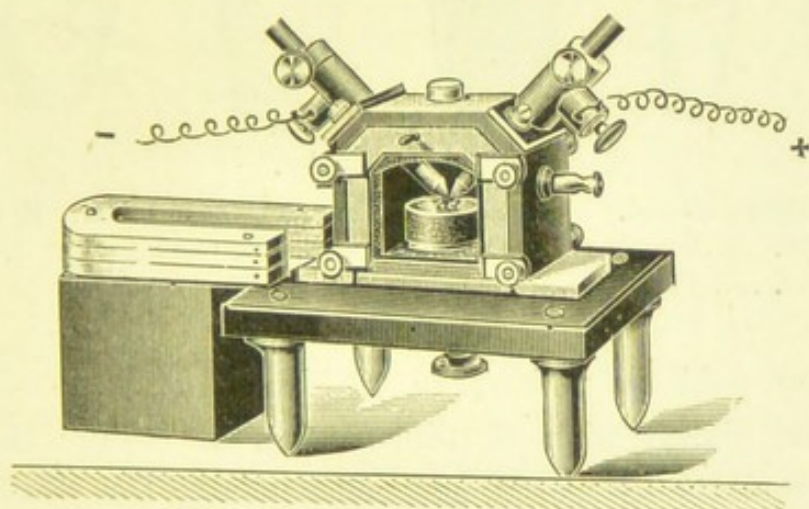


FIG. 14.—Electric Furnace suitable for the Dental Laboratory
(works with a current of 8 ampères),

electric furnace, and is invaluable for melting platinum and alloys of the metal.

CRUCIBLES (Fig. 15) are made of fireclay, plumbago, and platinum. The fireclay crucibles are made of raw and burnt clay—the latter being added to prevent shrinking. Plumbago crucibles are made of fireclay and powdered graphite and coke. They are useful for melting alloys of gold, silver, and other metals. Most of them should be annealed before

use, as they will split when suddenly heated. This is done by placing them in a warm place (say in the ashpit of a furnace) for some time.

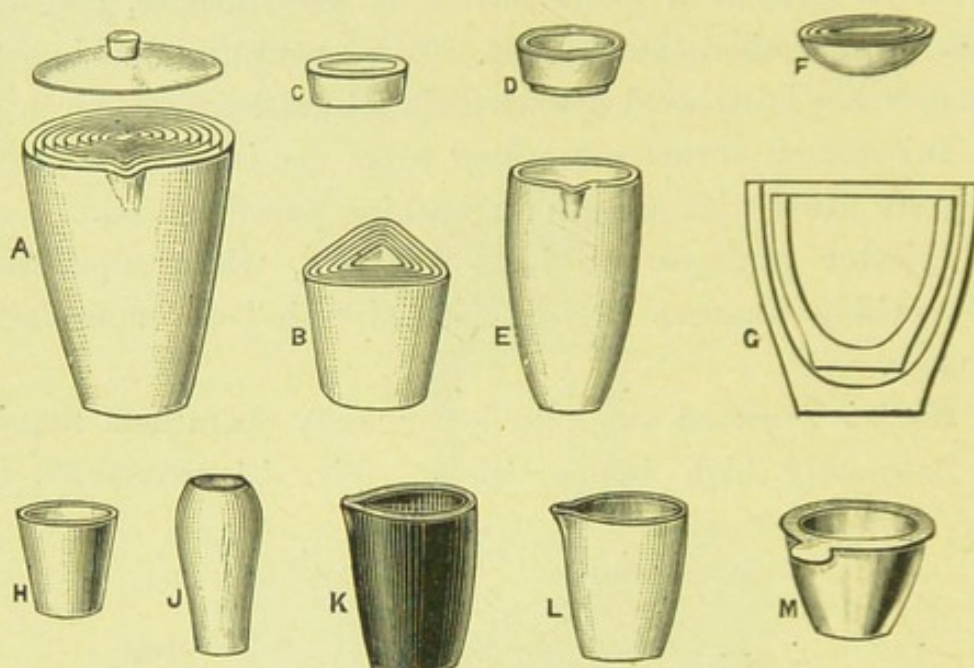


FIG. 15.—Crucibles.

A, Battersea Round. B, Triangular. C, Cupel. D, Scorifier. E, Fluxing Pot. F, Roasting Dish. G, Cornish. H, Gold Assay. J, Skittle Pot. K, Plumbago. L, London Round. M, Platinum.

When gold is melted in fireclay crucibles, the latter should be glazed with a thin coating of borax; the pores of the crucibles are closed, and consequently the fireclay does not retain any globules of gold.

CUPELS are made of bone-ash or magnesia (Fig. 15, C). They are porous, and readily absorb molten oxides, leaving the unoxidisable metals on their upper surfaces. The following table gives the absorptive power of different sizes of cupels:—

Diameter in Inches . .	$\frac{3}{4}$	$\frac{1}{2}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$2\frac{1}{4}$
Absorption in grammes .	3	5	8	10	16	20	28	40	56	106

Magnesia cupels have a greater absorption than bone-ash, and are not so fragile (*vide* Process of Cupellation).

MOULDS.—Ingot moulds are of various shapes and sizes. Fig. 16 represents three ingot moulds: *b* is a button mould,

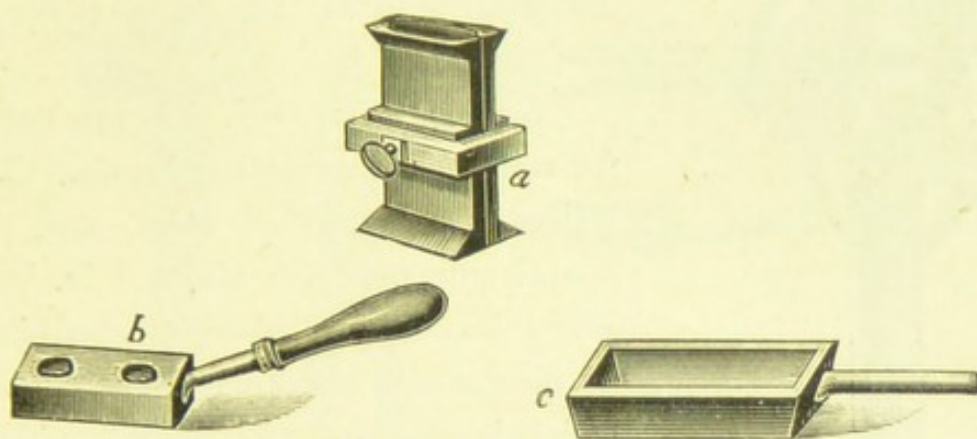


FIG. 16.—Ingot Moulds.

and *a* and *c* are ingot moulds. They are made of cast iron, and *a* is in two parts, for convenience in removing the ingot. Before casting, the moulds should be heated and rubbed over with an oiled rag (blacklead is frequently used for rubbing the inner surfaces of moulds).

A block of compressed charcoal is used as a "crucible" for melting small quantities of gold or silver. A cavity is cut in the block, and in this cavity the metal is melted by the blowpipe flame; an ingot mould is carved at the other end of the block for the reception of the molten metal, which is made to run into the mould by a channel connecting the two cavities. This appliance is used in dental laboratories, and by jewellers and assayers. A similar form of combined melting apparatus is made of asbestos; and a convenient form of apparatus, embodying the principles just described, is Fletcher's "melting arrangement," for melting gold or silver without the use of a furnace. The metal is melted in a shallow carbon crucible supported by an iron plate. When the metal is melted, the apparatus is tilted, so that the former runs into an ingot mould. A blowpipe is fitted

above the carbon crucible, and the gas flame is injected by a blower on to the metal. This appliance, which is mounted

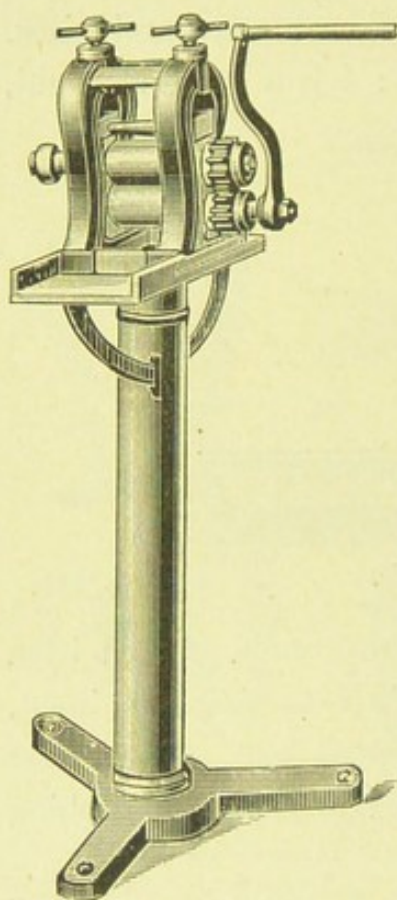


FIG. 17.—Flattening Mill.

on a swivel, is of use in melting scrap. It is capable of melting 20 oz. of 18-carat gold or 14 oz. of silver in five minutes.

Rolling Mills (Fig. 17) are useful for rolling or laminating ingots. The rollers are made of steel, and for dental purposes are about 4 in. long. The thickness of a plate is determined by means of a *gauge-plate*, the edge of which is provided with a series of slits gradually diminishing in size. The slits are numbered, the numbers corresponding with fixed standards.

WIRE-DRAWING.—Wire rods are pulled through the holes in a steel draw-plate (Fig. 3); the holes are of various sizes, according to the size of the wire required. The holes in the

draw-plate are filled with fat, in order to facilitate the operation. In rolling and wire-drawing the metal is frequently annealed, as both processes make the metal hard and liable to crack or break.

METALLURGICAL TOOLS (Fig. 18).—In the dental laboratory certain tools are necessary: hammers, shears, chisels, scoops, and anvils. Hammers for flattening buttons, etc.; shears and chisels for cutting metals; scoops for fluxes; and anvils for supporting metals when struck with the hammer. In addition to the above-mentioned tools, there are a variety of tongs for crucibles, cupels, and scorifiers (Fig. 19). An amalgamator (Fig. 20) is useful for grinding metals and ores in contact with mercury.

BALANCES (Fig. 1) are necessary for determining the accurate weights of metals, alloys, etc.; and those used in the metallurgical laboratory are of two kinds: analytical and

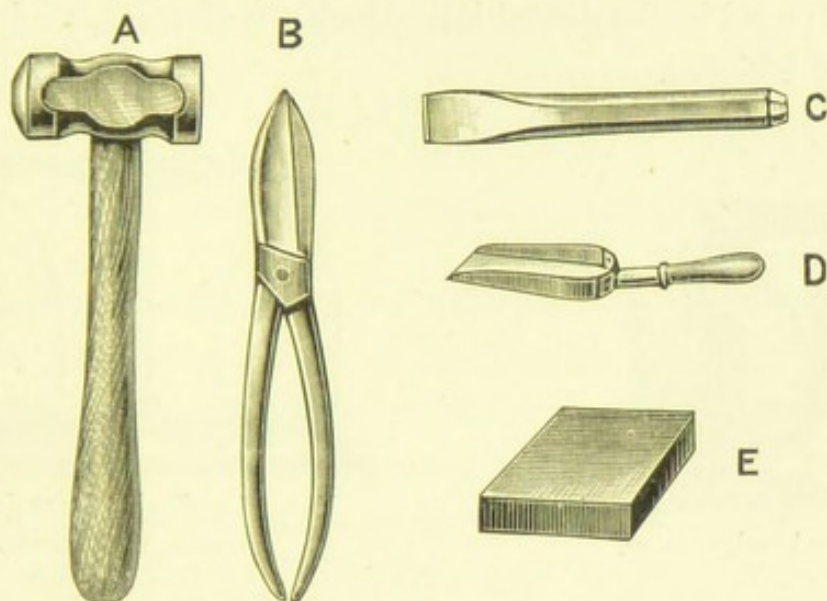


FIG. 18.—Metallurgical Tools.

A, Hammer for Buttons. B, Shears. C, Chisel.
D, Scoop. E, Anvil.

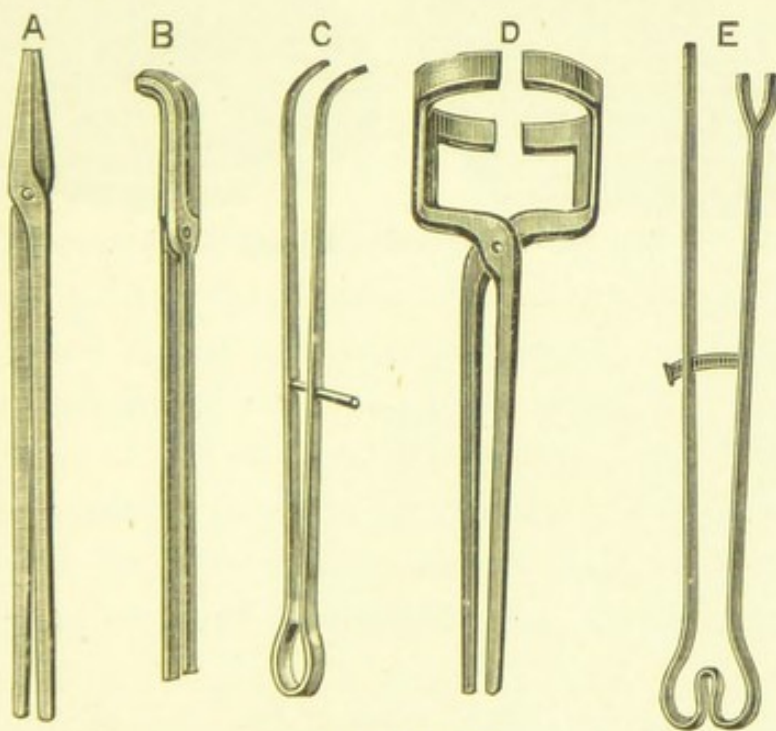


FIG. 19.—Tongs.

A and B, Crucible. C, Cupel. D, "Basket."
E, Scorifier.

assay. The latter is useful for weighing beads of gold and silver after cupellation.

Fluxes, etc., are weighed on scales (Fig. 21) The weights (Fig. 22) used in the dental laboratory are gramme, avoirdupois, and troy weights.

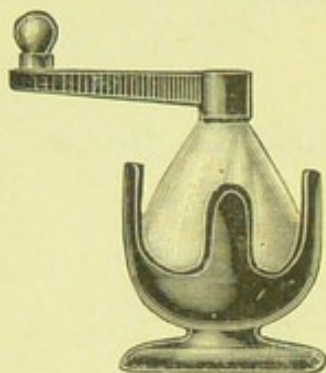


FIG. 20.—Amalgamator.

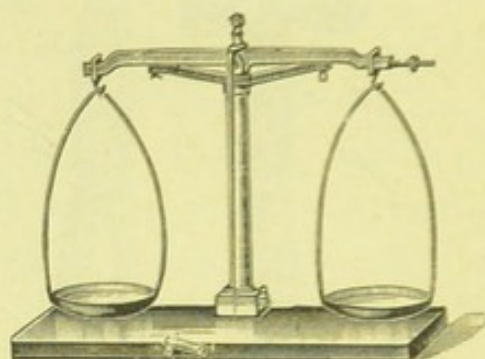


FIG. 21.—Scales for weighing Metals, Fluxes, etc.

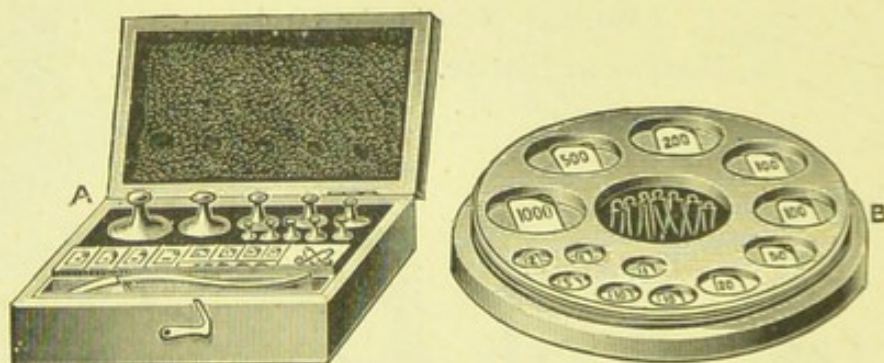


FIG. 22.—Analytical and Assay Weights.

CHAPTER IX

HEAT AND TEMPERATURE. PYROMETERS

HEAT has been defined as the *vis viva* of the molecules. To increase their temperature is to increase their *vis viva*; to lower their temperature is to decrease their *vis viva*. As heat is necessary for most operations in the dental laboratory, we intend to describe some of the appliances used in measuring the temperatures of furnaces, etc.: these instruments are called *pyrometers*.

1. *Callendar and Griffiths' Thermometers* consist of a fine platinum wire, the resistance of which varies with the temperature. This is attached to a galvanometer combined with a Wheatstone bridge, and so arranged that by turning two screws the temperature is read directly in centigrade or Fahrenheit degrees.

2. *Siemens' Electrical Pyrometer*.—The principle of this instrument is, that as the electrical conductivity of platinum, iron, and other metals decreases as they increase in temperature, their increase of *resistance* to the passage of the current is a measure of the heat to which the metal is subjected. Thus, the resistance having been ascertained at 0° C., it can be calculated for higher temperatures; and, *vice versa*, as the resistance can be found by measurement, the temperature can be calculated.

A platinum wire of a known resistance at 0° C. is coiled on a cylinder of fireclay so that the convolutions do not touch one another. This coil is protected by a platinum

tube. Leading wires are arranged to connect the coil with an instrument suitable for measuring its varying resistance, from which the temperature can be calculated. The instrument for measuring the resistance is essentially a differential voltameter. This voltameter consists of two separate glass tubes, in each of which water containing sulphuric acid is decomposed by an electrical current passing between two platinum electrodes immersed in the liquid. The gas which is generated is collected in the upper portion of the carefully calibrated tubes, and its quantity is read off by means of a graduated scale fixed behind the tubes. Movable reservoirs communicating with the tubes regulate the level of the liquid. The current from the battery is divided by a commutator into two circuits, one of which consists of a constant resistance in the instrument and the platinum electrodes in one tube; the other, of the resistance to be measured and the electrodes in the other tube. The quantities of gas developed in the two tubes are in inverse proportion to the resistances of their respective circuits, and the resistance in the instrument being known, the other can be calculated.

3. *Siemens' Water Pyrometer* consists of two cylindrical copper vessels having an air space between them. The inner vessel is constructed, with a view to prevent radiation, of a double casing of copper with an intermediate packing of felt, and is of sufficient size to hold rather more than a pint of water. A mercurial thermometer is fixed against one side of the inner vessel, and protected by a perforated tube. The upper half of the thermometer projects above the copper vessel, and is graduated in the ordinary degrees (F. or C.); while by the side of it is a small brass sliding scale, graduated and figured with degrees of the same denomination as the thermometer. Cylinders of copper, iron, or platinum are provided with each pyrometer, their size being accurately adjusted so that the capacity for absorbing heat between 0°

and 100°C . is equal to one-fiftieth of that of a pint of water. As, however, this capacity (specific heat) increases with the temperature, the divisions on the sliding scale expand with the rise in temperature, and in a different ratio for the three metals mentioned, thus necessitating a special sliding scale for each metal of which the cylinders are composed. The temperature of the furnace is ascertained in the following manner:—A pint (568 cc. or 34.66 cub. in.) of water is placed in the pyrometer vessel, and after this has stood for a few minutes, the zero point of the sliding scale is set at the temperature indicated by the thermometer. One of the metal cylinders is then exposed (from 2 to 10 minutes) to the heat to be measured, and allowed to remain in it until it has acquired its temperature; it is then quickly withdrawn and dropped into the water, the temperature of which rises gradually until a maximum is reached. This rise of temperature, as indicated by the sliding scale, added to the temperature of the water at the end of the experiment, gives that of the furnace. The range of the pyrometer, with copper and iron cylinders, extends to 1000°C . or 1800°F ., but with platinum cylinders to 1500°C . or 2700°F .

4. *Roberts - Austen's Electrical Pyrometer* measures and records high temperatures. It consists of two mahogany cases, the larger of which contains a Holden-D'Arsonval dead-beat galvanometer, with a suitable arrangement of lenses, mirrors, etc. The smaller one contains a drum, which is made to revolve by clockwork once in 24, 12, or 6 hours. The surface of the drum is covered with sensitised photographic paper. A ray of light is thrown by means of a mirror, at an angle of 45 degrees, on to the mirror of the galvanometer, and is projected thence to the surface of the drum, and acts photographically on the sensitised paper. The galvanometer is connected by copper wire to a thermojunction inserted in the place the temperature of which it

is desired to record. The temperatures may also be read from a scale from time to time.

TEMPERATURES

	Degrees Centigrade.	Degrees Fahrenheit.
Incipient red heat	525	977
Dull "	700	1292
Incipient cherry red	800	1472
Cherry red	900	1652
Orange	1100	2012
White	1300	2372
Dazzling white	1600	2912

Thermometers are instruments for measuring degrees of temperature. In the Fahrenheit scale the boiling point of water is 212° and the freezing point 32° ; in the centigrade scale the boiling point is 100° and the freezing point 0° ; and in the Reamur scale the boiling point is 80° and the freezing point 0° . The method of converting the degrees of one scale into those of another is thus stated—

$$\begin{aligned}
 &\text{To convert F. to C.} - 32 \times \frac{5}{9} \\
 &\text{" C. ,, F.} \times \frac{9}{5} + 32 \\
 &\text{" R. ,, F.} \times \frac{9}{4} + 32 \\
 &\text{" F. ,, R.} - 32 \times \frac{4}{9} \\
 &\text{" C. ,, R.} \times \frac{4}{5} \\
 &\text{" R. ,, C.} \times \frac{5}{4}
 \end{aligned}$$

TEMPERING TABLE

Colour.	Degrees Fahrenheit.	Instruments.
Yellow	430 to 450	Tools for metals, excavators, etc.
Straw	470 ,, 490	Tools for wood.
Brown	500 ,, 520	Chipping tools, saws.
Blue	550 ,, 590	Springs.

Calorimeters are instruments for measuring the *quantity* of heat, and are used in specific heat determinations (see Ganot's *Physics*).

CHAPTER X

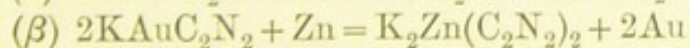
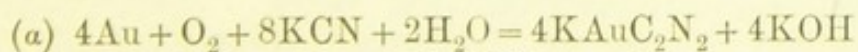
GOLD

Symbol, Au ; Atomic weight, 197.2

OCCURRENCE.—Gold is almost always found in the metallic state, usually associated with small quantities of silver, copper, and iron. Though one of the rarest of metals, it is widely distributed. The metal is extracted from quartz veins, or from deposits of alluvial gravel.

PREPARATION.—(1) The gold quartz is powdered by stamps. The stamps, working in a mortar-box, are raised by means of cams. As the stamps drop, the ore is reduced to powder, and the liberated gold amalgamates with mercury on copper plates. The amalgam, separated from the plates and powdered quartz, is then retorted ; the mercury being driven off by distillation, there remains spongy gold, which is then cut up and melted into bars.

The ore, after having been crushed and passed over the amalgamated copper plates, is called *tailings*. These tailings are then either concentrated, or run into vats and treated with a solution of potassium cyanide, and the solution so obtained is passed over zinc shavings, or is decomposed by the electric current—



In both cases gold is deposited ; it is then pressed, dried,

and melted into ingots. A million tons of tailings are annually treated by the cyanide process in the Transvaal.

The Siemens and Halske process is a modification of the old cyanide method, in which the gold tailings are first leached with a dilute solution of potassium cyanide, whereby the gold is dissolved, and then the gold is precipitated on to zinc by filtering the solution through zinc shavings. In the Siemens and Halske process, the filtration is done away with, and instead the gold is deposited by the electric current. The solution is electrolysed, the anodes (+) used being of iron, and the cathodes (−) of sheet-lead, on to which the gold is deposited. A current density of about one ampère per square foot is used; and when the required amount of gold has been deposited, the cathodes are then removed and the gold recovered by cupellation.

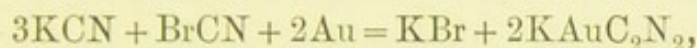
Mr. Cowper-Coles uses cathodes of aluminium (instead of lead); a film of oxide, which always forms on the surface of the plate, prevents the gold from adhering firmly. The gold is stripped off in thin sheets after the deposition, and melted.

There are numerous other modifications of the cyanide process, and new details of practical working are constantly coming into being. A great deal of technical skill is necessary for the proper working of the cyanide process, there being many reasons why the extractions may be poor; for instance, soluble sulphides may be formed, the gold may be too coarse, or in the form of telluride;¹ again, base metals may be present, and these enter into combination with the cyanide and consume it. Ores containing much silver will consume a good deal of cyanide (as much as 6 lb. of cyanide per ton of ore). It is essential to analyse the solution; and, having found the amount of metals in solution, if the copper

¹ Tellurium and selenium precipitate gold from its solutions; see paper of Hall and Lenher in *Chemical News*, vol. lxxxvi. p. 309.

be multiplied by 3, the silver by 1·2, the iron by 7, and the gold by 0·7, the consumption of cyanide due to each metal can be determined.

An important recent improvement in the cyanide process is the introduction of bromo-cyanide (BrCN) [1 of bromo-cyanide to 4 of potassium cyanide], as the latter accelerates the rate of solution of the gold. The reaction is the following:—



and the process is known as the Sulman-Teed. The presence of air is unnecessary in the bromo-cyanide process.¹

These remarks may be of value in the dental laboratory.

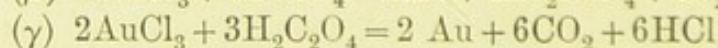
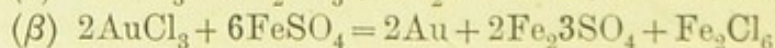
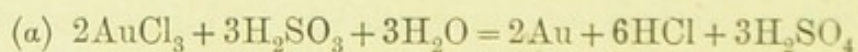
(2) In the *chlorination process* the auriferous pyrites is roasted, so that iron is converted into ferric oxide, and subjected to the action of chlorine. The gold is transformed into chloride, which is soluble in water. The solution is then treated with ferrous sulphate or oxalic acid, and the gold precipitated. The precipitate is washed, dried, melted, and cast into bars. *From first to last the extraction of gold is a matter of chemistry*; and, roughly speaking, mercury captures 50 per cent. of the gold, the cyanide 28, and chlorine 12 per cent. There is still left in the slimes 10 per cent., more or less, unrecovered. In the course of a year there must be at least £750,000 worth of gold thrown away on the Witwatersrand. Treatment of the slimes, now in progress, is saving a fraction of this amount. This waste of man is nothing to the waste of nature, as the reefs that remain are a mere patch probably of those that once existed; in fact, they are what is left after ages of denudation.

The gold extracted from its ores contains silver and traces of other metals. These are separated by the process of parting or refining.

¹ For further details, *vide* Eissler's book, *The Cyanide Process for the Extraction of Gold* (3rd ed.).

(a) *Miller's process* consists in melting the gold in a crucible and passing chlorine into the molten metal. The silver and other impurities are converted into chlorides, which rise to the surface. After allowing the gold to solidify, the still molten chlorides are poured off. The gold is cleaned from adhering chloride (which is soluble in ammonia), and then re-melted and cast into ingots. (b) The process of parting or quartation is a method for separating silver, copper, and iron from gold. The gold is melted with three or four times its weight of silver.¹ The alloy is granulated, and in this form it is boiled with strong sulphuric acid. The silver, copper, and iron are converted into sulphates, so that on lixiviation with water these compounds are dissolved, and the gold left as a residue. The residue is washed, dried, melted, and cast into ingots. The silver is recovered by placing sheet-copper in the solution, which precipitates the silver. Nitric acid is also used for parting.

The "refined gold" obtained by parting is not "chemically pure gold." The latter is prepared by dissolving parted or standard gold in aqua regia, and evaporating. The gold chloride is dissolved in water (any silver chloride present being separated), and the gold precipitated by sulphurous acid, iron sulphate, oxalic acid, or other precipitating agents. The reactions may be represented by the following equations:—



The precipitated gold is washed, dried, melted (with a little borax and acid potassium sulphate), and cast. If platinum is present, the chloride is treated with a solution of potassium chloride and alcohol; and the double chloride of platinum and

¹ The silver must not be in less proportion than 3 of silver to 1 of gold, or the acid would not dissolve out the silver.

potassium filtered off, before diluting with water and precipitating the gold.

PROPERTIES.—Gold is a yellow metal, and is the most malleable and ductile of the metals. It is not acted upon by air, hydrogen sulphide, alkaline solutions, or any single acid (except selenic); but it is dissolved by aqua regia (which liberates Cl) and chlorine. It amalgamates with mercury, and forms with other metals an important series of alloys. Copper heightens the colour of gold, and silver renders it paler. The alloys are harder and more durable than pure gold.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . .	19·4
Specific heat (water = 1)	. . .	0·0324
Hardness (diamond = 100)	. . .	32·5
Fusibility	. . .	1061° C. or 1942° F.
Malleability (most malleable)	. . .	1
Ductility (most ductile)	. . .	1
Tenacity (per square inch in tons)	. . .	9·1
Conductivity of heat (silver = 100)	. . .	53·2
Conductivity of electricity (silver = 100)	. . .	76·7
Expansion by heat	. . .	0·00145
Change of volume on solidification	. . .	decrease.

DENTAL USES.—Gold is a valuable metal in the dental laboratory. It is used, when alloyed, for the base plate of artificial dentures. Alloyed with small quantities of platinum, sheet-gold is struck into crowns. Pure gold is used in the form of foils, pellets, and cylinders for filling teeth; and as an alloy for amalgamating with mercury. These amalgam-alloys should be plastic, work smoothly, set hard, possess great edge-strength, and have little or no contraction.

Gold is used for clasps, wire, springs, swivels, washers, strengtheners (for vulcanite dentures); as a solder for crown, bar, and bridge work; and in a finely divided state it is used as a colouring matter for artificial teeth.

VARIETIES OF GOLD.—(1) *Brittle Gold* may be refined by melting it in a crucible with borax and nitre. The impurities are oxidised, and form a liquid slag. (2) *Cohesive and Non-Cohesive Gold* are two varieties of the metal used in dentistry. Cohesive gold foil is weldable in the cavity of the tooth by means of pluggers and mallets; whereas in the non-cohesive variety, union does not take place between the pieces of gold foil introduced into the cavity. The non-cohesive gold is retained in its position mechanically. Soft non-cohesive gold foil is rendered cohesive by annealing over a *spirit flame* before use. The cohesiveness of gold foil is destroyed by moisture, grease, and exposure to air; and during annealing, care should be taken not to overheat the gold,¹ as it becomes "harsh." Non-cohesive gold is produced by the action of some vapour,² or by the action of carbonised paper on leaves of gold. *Cohesive gold* makes a hard and compact filling, but takes longer to work than non-cohesive foil; and it remains smoother and the edges stand better than non-cohesive gold. It is claimed for *non-cohesive gold* that the fillings are much more rapidly made, that it tends to preserve the tooth better than the other variety, and that it can be more thoroughly burnished to the edges. Combinations of the two varieties are frequently used—the claim being that a "better joint is obtained at the cervical edge than with cohesive foil." (3) *Gold Foils* (for dental purposes) are generally beaten from pure gold, and not from alloys of the metal. Small ingots of the metal are passed through the rolls (Fig. 17), and reduced to strips having a thickness of about 0.003 ($\frac{1}{300}$) of an inch. During the rolling the gold is frequently annealed. The strips are then cut into small squares (1 in.), and a hundred or more are piled between sheets of parchment (goldbeater's skin), and the whole is beaten with

¹ A dull red heat is required for the purpose.

² Grayston in *Dental Record*, vol. xvi. p. 105.

a hammer until the strips measure about sixteen times the original area.¹ These sheets or foils are used for filling teeth. The foils vary in thickness, and are numbered according to the weight of the foil, the standard size being 4 in. square. No. 3 foil measures 4 in. square, and weighs 3 grains. No. 8 foil measures 4 in. square, and weighs 8 grains. No. 16 measures 4 in. square, and weighs 16 grains. "Foils ranging from No. 32 upwards are usually employed, and are prepared by folding a sheet of No. 4 foil, so that it becomes equivalent to No. 8 foil, and then folding it again to make it as thick as No. 16 foil, and then again to make it equal to No. 32 foil. When heavier foils are needed, several sheets can be folded together."

Gold fillings retain their shape and form water-tight plugs, and they withstand the attrition to which fillings are exposed. There is, however, one disadvantage—the high density of gold. The heavy metal has a tendency to force the walls of the cavity outwards during attrition. (4) *Precipitated and Spongy Gold*.—When a solution of gold chloride is treated with sulphurous acid, iron sulphate, oxalic acid, and other agents, gold is deposited in various forms according to the nature of the precipitant, the strength of the solution, and the mode of operating. Gold chloride is readily prepared by dissolving pure gold in aqua regia.

Ferrous sulphate precipitates gold as a brown powder. The powder is washed and dried. Sulphurous acid precipitates gold from hot solutions in the form of a scaly brown powder. Oxalic acid precipitates gold in several forms, from spongy masses to the various crystalline or powdery varieties, according to the temperature and strength of the solution of gold chloride (the solution of oxalic acid is added to a *hot* solution of gold chloride). Many metals and organic substances also

¹ In the arts the beating is continued until the leaves are about $\frac{1}{282000}$ inch thick.

precipitate gold from its solutions. Lamm's "shredded gold" (once used as a filling) was produced by the addition of sugar and gum-arabic to an acid solution of gold chloride. Precipitated gold is weldable, and several forms of this kind of gold are used by dentists. (5) *Crystal Gold* is produced by the electrolysis (weak current) of a solution of gold chloride. The anode (+) is a plate of gold, and the cathode (−) of platinum; and on the latter the gold is deposited in the form of crystals. "Watts' Crystal Gold" is produced in this way, and is a spongy cohesive form of gold. Another crystalline variety of gold is obtained by heating an amalgam in order to volatilise the mercury; or by dissolving out the greater portion of mercury by means of nitric acid, and then heating to expel the remainder.

THE EFFECT OF IMPURITIES ON THE PROPERTIES OF GOLD.—The malleability and ductility of gold are seriously impaired by tin, arsenic, zinc, antimony, bismuth, etc.; and even traces of lead impair its malleability and ductility, rendering it brittle. Lead also reduces the tenacity of gold. Arsenic, bismuth, and antimony render gold brittle. Copper, silver, and platinum harden gold, and do not practically impair its malleability. Iron does not affect the malleability in the proportion of 1 to 11; but zinc and tin render gold more or less brittle. It is absolutely necessary in the dental laboratory that gold, in any form, should be kept away from metallic contamination.

ASSAY OF GOLD.—Gold alloys are assayed by the processes of cupellation and parting. About 1 gm. (15 grains) of the alloy is carefully weighed (on balances, Fig. 1), and wrapped in lead foil with a piece of pure silver three times the weight of the alloy. The alloy is then cupelled (in a cupellation furnace; see Figs. 11, 12, and 13), the oxidised lead and copper being absorbed by the cupel (Fig. 15, C), while the bead of gold and silver remains on the cupel. The bead is

rolled into a strip, annealed, and coiled into a spiral or "cornet." The silver is parted from the gold by heating the cornet in a flask with dilute nitric acid for twenty minutes, and then with strong acid. The silver is dissolved, and metallic gold remains as a brown residue. The gold is washed, dried, and heated in a small crucible (Fig. 15, H) for a short time, when it acquires its characteristic yellow colour and metallic lustre. After cooling, the gold is weighed, and the percentage calculated. For example—

$$\begin{aligned} \text{Weight of alloy taken} &= 1.1040 \text{ gm.} \\ \text{Pure gold} &= 0.1612 \text{ ,,} \\ \frac{0.1612 \times 100}{1.1040} &= 14.6 \text{ per cent. of gold.} \end{aligned}$$

The gold always retains a small quantity of silver, so that when the greatest accuracy is required checks or proofs must be used. A known weight of pure gold is alloyed with the other metals so that the check corresponds in composition with the alloy to be assayed. The check and alloy are assayed under the same conditions. If the gold remaining from the check weighs less than the pure gold taken, the difference is added to the weight of gold from the alloy; and, conversely, if it weighs more, the excess is subtracted.¹

The fineness of a gold alloy can only be accurately determined by an assay; but the fineness may be approximately ascertained by the touchstone method. The *touchstone* is a basaltic stone, and the alloy is rubbed on a small block of the stone, leaving a streak behind. The effect of the action of a drop of nitric acid (sp. gr. about 1.2) on the streak gives rise to a green colour, the intensity of the colour being in proportion to the amount of copper in the alloy. The green colour is compared with the colour produced upon a number of touch-

¹ For full details of the assay, see Brown and Griffiths' *Manual of Assaying* (Heinemann).

needles (strips of alloys of known composition). Thus the fineness of the alloy is ascertained by comparison.

Instead of using touch-needles, a card (Fig. 23) can be

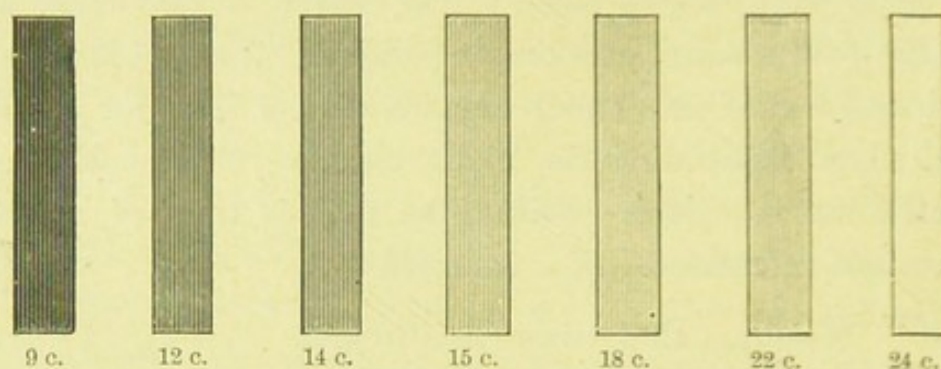


FIG. 23.—Gold and Gold Alloys (with Nitric Acid).

painted so as to represent the exact shades of green produced by nitric acid on gold alloys of various degrees of fineness (say 22, 18, 15, 14, 12, and 9 carats). The touchstone method is used by jewellers and assayers. It is of use to the latter in determining the approximate fineness of the gold, in order to regulate the amount of lead required in the process of cupellation.

DETECTION AND ESTIMATION OF GOLD IN ALLOYS.—Dental amalgam-alloys contain silver and tin, and small quantities of gold, platinum, and other metals. (1) The presence of gold may be *detected* by treating the alloy with nitric acid. The gold remains undissolved as the purple of Cassius (*i.e.* the tin in the alloy becomes oxidised, and then attacks the gold). If no tin is present, the gold remains pure; and if gold is absent, the residue may be white (metastannic acid). The presence of gold in an alloy may be detected by dissolving the alloy in aqua regia, and then adding to the solution—

(a) A solution of stannous and stannic chlorides, when the purple of Cassius is precipitated.

(b) Oxalic acid, which precipitates gold from hot solutions.

(c) Ferrous sulphate, which precipitates gold.

(d) Sulphurous acid, which also precipitates gold.

(e) Sulphuretted hydrogen, which precipitates gold as sulphide.

(2) The gold in alloys is *estimated* in the following way:—

(a) When tin is *present*, a weighed quantity of the alloy is treated with nitric acid, and the precipitate of purple of Cassius is filtered off and then fused with potassium hydroxide; soluble potassium stannate is formed, and the gold remains unchanged. The gold is filtered, washed, ignited, and weighed.

0.26 grm. of alloy yielded 0.009 grm. of gold, therefore the alloy contained 3.46 per cent. of gold.

(b) When tin is *absent*, the alloy is treated with nitric acid, and the gold residue is collected, washed, dried, ignited, and weighed.

(c) The gold in dental amalgam-alloys is estimated by submitting a weighed quantity of the alloy to scorification, cupellation, and parting. The alloy is mixed with about ten times its weight of granulated lead in a scorifier (Fig. 15, D), and heated in a muffle furnace. The base metals oxidise and form a slag with the litharge, while the gold and silver form a triple alloy with the excess of lead. The alloy so formed is then cupelled, and the resulting bead of gold and silver is parted with nitric acid, as already described. If platinum is present, the bead is treated with aqua regia. The gold and platinum dissolve, and the silver remains as an insoluble chloride. The silver chloride is separated, the solution evaporated, potassium chloride and alcohol added, when the platinum is precipitated as potassio-platinum chloride. The precipitate is filtered off, and the filtrate treated with ferrous sulphate, when gold is precipitated. The precipitated gold is collected, washed, dried, ignited, and weighed.

The gold in dental amalgam-alloys varies from one-tenth to about 6 per cent.

PURIFICATION OF LEMEL OR SWEEP.—Lemel, or the gold

dust of the dental laboratory, is treated in the following way :—(a) Burn off organic matter (wax, etc.); (b) extract iron by the magnet; (c) the residue heat with sodium carbonate, sodium chloride, acid potassium sulphate or nitre, in a skittle-pot (Fig. 15, J). About 80 parts of lemel are mixed with 18 parts of sodium carbonate (dry), and 2 parts of acid potassium sulphate or nitre (KNO_3), and placed in the crucible (pot) of such capacity that it is only half full. The mixture is then covered with about 5 parts of sodium chloride (salt), and gently heated at first. When the action has ceased, a higher temperature is necessary to completely liquefy the mass; and, after stirring with a clean iron rod, the contents of the crucible are poured into a mould. When cold, the mass is broken open, and the metallic button obtained is cleaned from the slag, weighed, and alloyed with about four times its weight of silver. The alloy is granulated by pouring into water, and the small particles are collected and parted in the usual way (*loc. cit.*).

If much platinum is present in the granulated alloy, it is treated with aqua regia. Silver chloride is first separated, and the solution is then evaporated and alcohol and potassium chloride added, when the platinum is precipitated. The filtrate is treated with ferrous sulphate in order to precipitate the gold, which is collected, washed, dried, fused with a small quantity of acid potassium sulphate, after which it is cast into an ingot mould.

RECOVERY OF GOLD FROM SCRAP.—Plate clippings, old plates, etc., may be re-melted and again converted into plate. If, however, the scrap is contaminated with filings, platinum, solder, etc., the gold is *recovered* by the following method :—

(a) The scrap is melted and granulated.

(b) The granulated alloy is treated with aqua regia (*l'eau régale*), whereby all the metals are converted into chlorides.

(c) The *insoluble* silver chloride is collected, washed, dried,

and reduced with four times its weight of dry sodium carbonate. By this means the silver is recovered.

(*d*) The solution of soluble chlorides is evaporated, alcohol and potassium chloride added to precipitate platinum. The precipitate is ignited, and the platinum recovered.

(*e*) The solution, after the separation of the platinum, is treated with ferrous sulphate, when the gold is precipitated. The precipitated gold is collected, washed, dried, and fused in a crucible with a small quantity of acid potassium sulphate, and then cast in an ingot mould.

Gold may also be recovered from scrap by melting the latter with nitre and borax, alloying it with four times its weight of silver, granulating the alloy, and subsequently parting it as previously described.

ALLOYS OF GOLD.—Gold is a soft metal; it is therefore alloyed with other metals to increase its hardness, although the other valuable properties of gold must not be impaired.

1. *Gold and Silver* unite in all proportions. These alloys are harder and more fusible than gold. The Australian gold sovereigns contain 22 parts of pure gold and 2 parts of silver in 24 parts of alloy; hence the difference in colour from the English sovereigns, which contain 2 parts of copper instead of silver. The Australian gold coins are of the same standard (fineness), weight, and value as the coins of this country. The sovereign weighs 123·27 grains, and contains 113 grains of pure gold (91·6 per cent.). An alloy containing 30 per cent. of silver is green, and one containing 50 per cent. is white. Silver hardens, toughens, and renders gold more elastic, without impairing its malleability. Alloys of the two metals do not oxidise on exposure to air, but they are more or less tarnished by sulphuretted hydrogen. "Electron" is gold containing about 20 per cent. of silver—the "Asem" of the ancient Egyptians.

2. *Gold and Copper* alloy together in all proportions.

The gold coins of England contain 916·6 parts of gold and 83·3 parts of copper—the alloy being called “standard gold” (or a “fineness” of 22 carats); and the investigations of Roberts-Austen, Peligot, and others have proved that these alloys are homogeneous; there is no separation of the baser metal on solidification of the alloy. Copper increases the yellow colour of the gold, and if it does not exceed 12 per cent. the malleability of the alloy is scarcely less than that of gold.

Traces of arsenic, antimony, tin or lead in the copper impair both the malleability and ductility of the alloy.

3. *Gold-Silver and Copper* form alloys used by dentists and jewellers; and they are tough, ductile, and malleable. Alloys containing the three metals are used as gold solders. Gee¹ gives the following proportions of gold, silver, and copper used in these triple alloys:—

Carat.	Gold.	Silver.	Copper.
23	23	$\frac{1}{2}$	$\frac{1}{2}$
22	22	1	1
20	20	2	2
18	18	3	3
15	15	3	6
13	13	3	8
12	12	$3\frac{1}{2}$	$8\frac{1}{2}$
10	10	4	10
9	9	$4\frac{1}{2}$	$10\frac{1}{2}$
8	8	$5\frac{1}{2}$	$10\frac{1}{2}$
7	7	8	9

4. *Gold and Tin* form brittle alloys. The colour is paler than that of gold. The union of the two metals produces contraction; *i.e.* their specific gravities are in excess of the mean of their constituents.

5. *Gold and Platinum* form ductile and elastic alloys of a paler colour than gold. In casting alloys of the two metals, Matthey² has shown that the platinum in cooling liquates

¹ *Goldsmiths' Handbook*, pp. 41, 52.

² *Proc. Royal Society*, 1890.

from the gold and becomes concentrated towards the centre of the alloy.

6. *Gold and Palladium* form grey or white alloys. They are ductile.

7. *Gold and Mercury* combine together, forming amalgams. When gold amalgams are heated, the mercury volatilises, leaving the gold behind.

STANDARD GOLD.—The alloys used in various countries for coinage purposes consist of gold and copper; the latter metal has the property of hardening gold. The alloy for coins is termed *standard gold*. The English sovereign weighs 123·27447 grains, and remains a *legal tender* until it is reduced below 122·5 grains, the difference between the two weights being the *remedy* allowed by law for loss by wear. Standard gold contains intrinsically its full value of gold. The half-sovereign weighs 61·63733 grains. Standard gold is 22-carats *fine*, or contains 916·6 parts of gold and 83·3

	Carat.	Decimal.
Pure gold	24	1000
English gold coin	22	916·6
Portuguese „		
Turkish „		
American „		
German „		
French „	21	900
Belgian „		
Italian „		
Swiss „		
Greek „		
Dutch ducats	23·57	982
Austrian „	23·66	986
Hungarian „	23·74	989
Dentists' gold	20	834
„	19·2	800
„	18	750
„	17	709
„	16	667
„	15	625
„	13	542
„	12	500

parts of copper per 1000, the remedy being 0.002, or $\frac{1}{500}$ of a grain. Pure gold is 24 carats, or 1000 fine. The relation of the carat to decimals is given in the table on preceding page. Pure gold is 24-carat fine—the pound, or 1000 parts, being divided into 24 parts. Thus, 18-carat gold means that in 24 parts there are 18 parts of gold and 6 parts of copper or other metals (*i.e.* $\frac{18}{24}$ gold and $\frac{6}{24}$ copper).

The terms “standard” and “fineness” mean the amount of gold in an alloy. Thus, the coin of the realm has a *fineness* of 22 carats, or *standard* of 916.6 parts in 1000. Gold plate and wire for dental purposes are 22, 20, 18, 17 and 16-carat fine, swivels and springs are 13-carat fine, and solders 20, 18, 16 and 12-carat fine.

TO ASCERTAIN THE CARAT OF A GIVEN ALLOY.—As the weight of the alloy (A) is to the weight of gold it contains (B), so is 24 to the carat sought (C); or

$$\frac{B \times 24}{A} = C.$$

For example, an alloy is composed of—

Gold	5 parts.
Silver	3 „
Copper	2 „
	<hr/>
	10

$$\frac{5 \times 24}{10} = 12$$

Hence the alloy is 12-carat fine.

“Standard gold” instead of pure gold is frequently used in the preparation of dental alloys, and the following example illustrates the mode of calculating the fineness of such alloys:—

Standard gold (22 c.) . . .	36 parts.
Silver	8 „
Copper	2 „
	<hr/>
	46

As the gold used is only 22-carat fine, $\frac{1}{12}$ of it is other metal; therefore, the 36 parts of standard gold contain only 33 parts of pure gold, and the fineness of the alloy equals—

$$\frac{33 \times 24}{46} = 15.04,$$

or a little above 15-carat.

TO RAISE GOLD TO A HIGHER CARAT.—Multiply the weight of alloy used by the difference between its carat and that of the metal added, and divide by the difference between the carat of the metal added and that of the alloy required. The quotient (which is the weight of the required alloy), *minus* the weight of the alloy used in the first instance, gives the weight of pure or alloyed gold to be added. The following are examples:—

A. Raise 11 dwt. of 16-carat to 18-carat gold, using pure gold (24 c.)—

$$24 - 16 = 8 \text{ c.}$$

$$24 - 18 = 6 \text{ c.}$$

$$\frac{11 \times 8}{6} = 14 \text{ dwt. 16 grs.}$$

$$14 \text{ dwt. 16 grs.} - 11 \text{ dwt.} = 3 \text{ dwt. 16 grs.}$$

Therefore, 3 dwt. 16 grs. of pure gold are required to be added to 11 dwt. of 16-carat gold to raise it to 18-carat, or the fineness required.

B. Instead of using pure gold, standard gold (22 c.) is only available, then—

$$22 - 16 = 6 \text{ c.}$$

$$22 - 18 = 4 \text{ c.}$$

$$16 - 11 = 5 \text{ dwt.}$$

$$\frac{11 \times 6}{4} = 16 \text{ dwt.}$$

Therefore, 5 dwt. of standard gold (22 c.) are required to be added to 11 dwt. of 16-carat gold to raise it to 18 carat.

Other alloys are readily calculated by following the above examples.

TO REDUCE GOLD TO A REQUIRED CARAT.—Multiply the weight of the alloy or gold used by its carat, and divide by the carat required. The quotient (which is the weight of the alloy), *minus* the weight of the alloy used in the first instance, gives the weight of baser metal to be added.

The following is an example:—

Reduce 3 dwt. of pure gold (24 c.) to 18-carat gold.

$$\frac{24 \times 3}{18} = 4 \text{ dwt.}$$

$$4 - 3 = 1 \text{ dwt.}$$

Therefore, 1 dwt. of baser metal is required to reduce 3 dwt. of pure gold to 18-carat gold.

DENTAL GOLD PLATE is an alloy, as pure gold is too soft to be used for artificial dentures. Silver, copper, and platinum increase the hardness, strength, and elasticity of the metal. Gold is alloyed with platinum for bands and clasps, as the latter metal gives strength and elasticity; for this reason platinum is a valuable metal for alloying with gold. A much thinner plate may be used with this alloy, as it is strong, elastic, and resists the action of the oral secretions much better than ordinary 18 or 20-carat gold. Plates of gold-platinum alloy may be swaged between zinc dies and counter-dies. The method of swaging between zinc and lead is not effective with alloys containing platinum.

Gold alloys, for different dental purposes, have the following degrees of fineness:—

Gold plate and wire should be 22, 21, 18, 17, and 16-carat fine. Gold plate for crown, bar, and bridge work should be 24, 22, and 20-carat; gold swivels and springs 16 and 13-carat (they should be elastic, and uniform in strength); gold washers 16-carat; and strengtheners for vulcanite dentures are sometimes made of 16-carat gold plate; while bands and clasps are made of 16 and 20-carat gold.

Gold base plate for artificial dentures may be made by

the following formulæ,¹ which are largely used for the purpose :—

18-Carat Gold Base Plate

Pure gold	. 18 dwt. = 75.0 per cent.	Standard gold	20 dwt. = 83.4 per cent.
Copper	. 4 „ = 16.7 „	Copper	. 2 „ = 8.3 „
Silver	. 2 „ = 8.3 „	Silver	. 2 „ = 8.3 „

20-Carat Gold Base Plate

Pure gold	. 20 dwt. = 83.4 per cent.	Standard gold	22 dwt. = 91.7 per cent.
Copper	. 2 „ = 8.3 „	Copper	. 0 „ = 0 „
Silver	. 2 „ = 8.3 „	Silver	. 2 „ = 8.3 „

22-Carat Gold Base Plate

Pure gold	. . . . . 22 dwt. 0 grs. = 91.70 per cent.
Copper	. . . . . 1 „ 0 „ = 4.16 „
Silver	. . . . . 0 „ 18 „ = 3.10 „
Platinum	. . . . . 0 „ 6 „ = 1.04 „

16-Carat Gold Base Plate

Pure gold	. . . . . 16 dwt. = 66.6 per cent.
Copper	. . . . . 4 „ = 16.7 „
Silver	. . . . . 4 „ = 16.7 „

Gold plate for clasps, wire, etc., may be made by the following formulæ :—

20-Carat Gold Alloy for Clasps and Wire

Pure gold	. 20 dwt. = 83.48 per cent.	Standard gold	22 dwt. = 91.70 per cent.
Copper	. 2 „ = 8.30 „	Copper	. 0 „ = 0 „
Silver	. 1 „ = 4.15 „	Silver	. 1 „ = 4.15 „
Platinum	. 1 „ = 4.15 „	Platinum	. 1 „ = 4.15 „

16-Carat Gold Alloy for Clasps, Wire, etc.

Pure gold	. . . . . 24 dwt. = 85.71 per cent.
Copper	. . . . . 2 „ = 7.15 „
Silver	. . . . . 1 „ = 3.57 „
Platinum	. . . . . 1 „ = 3.57 „

17-Carat Gold Alloy for Bands and Clasps

Pure gold	. . . . . 17 dwt. = 70.85 per cent.
Copper	. . . . . 4 „ = 16.70 „
Silver	. . . . . 2 „ = 8.30 „
Platinum	. . . . . 1 „ = 4.15 „

¹ Richardson's *Mechanical Dentistry* (with the addition of the percentage composition of each alloy). Some of the formulæ are original.

13-Carat Gold Alloy for Springs

Pure gold	13 dwt. = 54·17 per cent.
Copper	4 „ = 16·70 „
Silver	5 „ = 20·83 „
Platinum	2 „ = 8·30 „

GOLD SOLDERS are used for joining various parts of gold plate, etc.; and they have a lower melting point than the metal or alloy to be soldered. A solder for 18-carat gold plate can be made by adding a certain proportion of silver and copper to 18-carat gold.

Coloured gold solders contain 1 part of silver to 4, 5, or 6 parts of gold alloy, according to the degree of fusibility required; and borax is the flux to be used.

Gee ¹ gives the following tables for coloured gold solders:—

	Pure Gold.	Silver.	Copper.
Best solder	12½ parts	4½ parts	3 parts
Medium solder	10 „	6 „	4 „
Common „	8½ „	6½ „	5 „

The following table gives the composition of various solders for alloys of different standards:—

	Gold.	Silver.	Copper.	Zinc.
Hard solder for pure gold	10	5	...	1
Hard solder for 16-carat gold . . .	9	2	1	...
Soft „ „ „ „	12	7	3	...
Solder for 13-carat gold	1	2	1	...

Zinc, in the form of brass, is a valuable addition to gold solders, as it causes the solder to flow more freely; but it should be used only in small quantities. Gold solders for dental work vary from 20 to 12-carat; and their *hardness*

¹ *Goldsmiths' Handbook*, 1881, pp. 136, 217.

and *softness* depend upon their fusibilities; a high melting point is characteristic of a hard solder, whereas a lower melting point is indicative of a soft solder.

The following solders are largely used in dental laboratories:—

15-Carat Solder ("Best Quality")

Pure gold .	15 dwt. = 62.50 per cent.	Standard gold	16.5 dwt. = 68.74 p. c.
Copper .	5 „ = 20.83 „	Copper .	3.5 „ = 24.59 „
Silver .	4 „ = 16.67 „	Silver .	4.0 „ = 16.67 „

13-Carat Solder ("Medium Quality")

Pure gold .	13 dwt. = 54.17 per cent.	Standard gold	14 dwt. = 58.33 per cent.
Copper .	5 „ = 20.83 „	Copper .	4 „ = 16.67 „
Silver .	6 „ = 25.00 „	Silver .	6 „ = 25.00 „

12-Carat Solder ("Most Fusible")

Pure gold .	12 dwt. = 50 per cent.	Standard gold	13 dwt. = 54.16 per cent.
Copper .	6 „ = 25 „	Copper .	5 „ = 20.84 „
Silver .	6 „ = 25 „	Silver .	6 „ = 25.00 „

16-Carat Solder

Pure gold .	16 dwts. = 66.66 per cent.
Copper .	5 „ = 20.83 „
Silver .	3 „ = 12.51 „

This solder is suitable for 18 or 20-carat gold base plate.

15-Carat Solder

Pure gold .	15 dwt. = 62.50 per cent.	Standard gold	17 dwt. = 70.84 per cent.
Copper .	4 „ = 16.67 „	Copper .	4 „ = 16.67 „
Silver .	4 „ = 16.67 „	Silver .	2 „ = 8.33 „
Brass .	1 „ = 4.16 „	Brass .	1 „ = 4.16 „

18-Carat Solder

Pure gold	18 dwt. = 75.00 per cent.	Standard gold	19½ dwt. = 81.26 per cent.
Copper .	2½ „ = 10.42 „	Copper .	1 „ = 4.16 „
Silver .	2½ „ = 10.42 „	Silver .	2½ „ = 10.42 „
Brass .	1 „ = 4.16 „	Brass .	1 „ = 4.16 „

Gold and silver for alloying purposes should be free from lead and other impurities. The impurities produce brittle

alloys, and many samples of so-called "chemically pure gold and silver" are unsuitable for dental purposes. Standard gold (the coins), however, is always reliable, and produces excellent alloys for plates, solders, wires, swivels, etc.

The following table shows the amount of alloy to be added to *one ounce of standard gold* in making gold of various degrees of fineness:—

Fineness (carat).	Alloy added.			Fineness (carat).	Alloy added.		
	oz.	dwt.	grs.		oz.	dwt.	grs.
21	0	0	23	17	0	5	21
20	0	2	0	16	0	7	12
19	0	3	4	15	0	9	8
18	0	4	10				

The following table shows the amount of alloy to be added to *one ounce of pure gold* in making gold of various degrees of fineness:—

Fineness (carat).	Alloy added.			Fineness (carat).	Alloy added.		
	oz.	dwt.	grs.		oz.	dwt.	grs.
23	0	0	20	18	0	6	16
22	0	1	18	17	0	8	5
21	0	2	20	16	0	10	0
20	0	4	0	15	0	12	0
19	0	5	6				

PREPARATION OF GOLD PLATE AND SOLDER.—Alloys for *gold plate* are melted in previously annealed plumbago crucibles (Fig. 15, K), and a layer of the best charcoal powder is placed on the surface of the metal to prevent oxidation of the copper. The crucibles are covered with lids, and placed in a furnace (Fig. 11, right-hand portion) at a bright red heat. When the alloy is melted, it is stirred with a hot iron rod, and cast into a warm ingot mould (Fig. 16, a)

previously blackened. Finally, it is rolled into sheets of the required thickness.

In melting scrap, care must be taken to prevent admixture of alloys of inferior or different qualities, impure filings, dental alloy, etc.

Gold solders are prepared in a similar way, the various metals being carefully weighed. Brass or zinc is added after the other constituents are melted. The alloy is then stirred and cast. Great care is necessary in the preparation of solders and other gold alloys, as the inferior metals are liable to oxidise; and if oxidation does occur, the resulting alloy would not have the desired composition and qualities.

THE COLOURING OF GOLD is a process by which a film of pure gold is obtained on articles made of gold alloys in order to improve their appearance. The operation is extremely ancient, and is mentioned in the alchemistic papyri of Leyden, V. and X. In these oldest writings of the alchemists are recipes for making alloys, and for cleaning the surfaces of metals, as are used by metal workers of the present day. In the Leyden papyri it is distinctly stated that a gold-copper alloy was treated with "Royal Cement,"¹ so as to remove a superficial layer of copper, leaving pure gold in relief.²

There are two methods for colouring gold, namely, *wet* and *dry* colouring.

Many different mixtures are used for *wet* colouring, among them being the following:—

Nitre	.	.	.	.	.	.	12 parts.
Salt	.	.	.	.	.	.	6 „
Hydrochloric acid	.	.	.	.	.	.	3 „
Water	.	.	.	.	.	.	1 „

¹ The active ingredients were calcined green vitriol and salt.

² For further information on this interesting subject, see Berthelot's *Les Origines de l'Alchimie, Collection des Alchimistes grècs, La Chimie au Moyen âge, et Introduction à la Chimie des Anciens et du Moyen âge*.

The mixture is boiled, and the article to be coloured (which has been previously cleansed in a hot solution of soda) is suspended in the liquid by means of a platinum wire for about a minute, and then washed with water. This operation is repeated several times, until the desired colour is attained. It should be stated that, after each operation, the colouring liquid is diluted with water before each immersion. The article is then dried in sawdust.

Another method for *wet* colouring is the following:—The article to be coloured is first heated in a Bunsen flame, and then placed in weak nitric acid. By this means a film of pure gold remains upon the surface.

For *dry* colouring, 8 parts of nitre, 4 of salt, and 4 of alum are melted in a plumbago crucible, and the article to be coloured is first dipped into nitric acid and then into the colouring mixture (for about 90 seconds). It is then washed, and the operation repeated.

Both processes require some skill to prevent irregular colouring; and a good quality solder is a *sine qua non*, or the joints may become loose by the galvanic action set up in the colouring fluid.

ELECTRO-GILDING is a process for depositing gold on gold plates by means of the electric current. The article to be gilded is first cleansed by means of a hot solution of soda (NaOH), or by a scratch-brush, or in an acid bath. It is then washed and placed in the gilding solution, which contains gold and potassium cyanides. The article is suspended in the bath by a copper wire connected with the negative pole (cathode), while a plate of pure gold is suspended in the bath, and is attached to the positive pole (anode) of the battery. The solution is heated to 66° C. (150° F.), and requires from one-half to an ounce of gold to the gallon. The strength of the bath remains constant during gilding, owing to the gradual dissolving away of the gold plate. After the

operation is complete, the gilt article should be of a yellow-brown colour; and when scratch-brushed or burnished, produces a bright surface of fine gold.

If the battery is too strong, the deposit will be black; if the bath is too cold, or the battery too weak, the gold will be straw colour.

A Bunsen battery is usually employed for producing the electric current; although dynamos are sometimes used for the purpose.

Another process for gilding is the following:—The article to be gilded is first cleaned, and then suspended by means of a copper wire in a bath containing 1 litre of water, 80 grms. of sodium pyrophosphate, 8 grms. of hydrocyanic acid (12 per cent.), and 2 grms. of gold chloride. The solution is heated to the boiling point. The process is used in Germany.

Articles are also gilded by what is known as *fire gilding*. The article is cleansed, then dipped into a solution of mercuric nitrate, whereby it becomes coated with mercury. It is afterwards pressed upon a pasty gold amalgam, and finally heated to drive off the mercury. The film of gold, which remains, is then burnished.

THE PURPLE OF CASSIUS was discovered by Cassius (of Leyden) in 1683, and is used for giving porcelain teeth a pink tint. It is prepared by adding a solution of stannous and stannic chlorides to a neutral solution of gold chloride; and the precipitate obtained is supposed to be a stannate of gold and tin ($\text{SnAu}_2\text{Sn}_2\text{O}_6, 4\text{H}_2\text{O}?$). This compound may also be prepared by digesting metallic tin in a neutral solution of gold chloride; or by adding a solution of stannous chloride to ferric chloride until the mixture becomes pale green; the mixture is then added to a solution of gold chloride.

The purple of Cassius used in the preparation of *gum*

enamel is sometimes obtained by the following method :—An alloy containing 8·53 per cent. of gold, 6·16 of tin, and 85·31 of silver, is melted, granulated, and treated with nitric acid. The silver is dissolved, and the *purple* residue washed and dried.

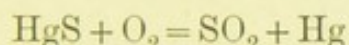
CHAPTER XI

MERCURY

Symbol, Hg; Atomic weight, 200.

OCCURRENCE.—Although mercury is occasionally found in small quantities in the free state, its chief ore is cinnabar, or mercury sulphide (HgS). It is also found in combination with chlorine and iodine, and amalgamated with gold and silver.

PREPARATION.—The process for extracting mercury from cinnabar consists in roasting the ore in a furnace to which a series of condensers is connected. The air that enters the furnace oxidises the sulphur of the ore to sulphur dioxide, and the mercury volatilises and finally condenses—



Sometimes lime or iron oxide is mixed with the ore, and the sulphur retained as calcium or iron sulphide. The metal thus obtained contains small quantities of lead, bismuth, zinc, etc., and it must be purified before it can be used for dental and other purposes.

PROPERTIES.—Mercury, or quicksilver (mercure, quecksilber, hydrargyrus, ὑδράργυρος), is the only liquid metal at the ordinary temperatures. With most of the metals it forms alloys called *amalgams*. It has a silvery lustre, and is not oxidised by exposure to moist or dry air; if, however, it contains other metals, oxidation takes place, and the surface of the metal becomes coated with a grey powder. The metal

is not attacked by carbon dioxide, and sulphuretted hydrogen acts very slowly on it. Hydrochloric acid, water, alcohol, and alkaline solutions have no action on mercury. Nitric and strong sulphuric acids dissolve it. At its solidifying point (-40° C.) mercury is a ductile, malleable metal. When mercury is shaken with oil, or mixed with lard, chalk, etc., it forms a grey powder. This operation is called *deadening*, and is employed in the preparation of *unguentum hydrargyri*, *pilula hydrargyri*, and *hydrargyrum cum creta* of *The British Pharmacopœia*.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . . . .	13.596
Specific heat (water = 1)	. . . . .	0.0333
Hardness (diamond = 100)	. . . . .	...
Fusibility	. . . . . -40° C. or -40° F.	
Boiling point	. . . . . 360° C. or 680° F.	
Malleability (gold = 1 most malleable)		13 (solid Hg)
Ductility (gold = 1 most ductile)	. . . . .	...
Tenacity (per square inch in tons)	. . . . .	...
Conductivity of heat (silver = 100)	. . . . .	13.5
Coductivity of electricity (silver = 100)	. . . . .	1.8
Expansion by heat	. . . . .	0.00018
Change of volume on solidification	. . . . .	decrease.

DENTAL USES.—Mercury is used in the preparation of amalgams for filling teeth; it is also used in small quantities in certain fusible alloys. Vermilion, or mercuric sulphide, is the colouring material in most dental rubbers.

PURIFICATION OF MERCURY.—There are certain methods for purifying mercury. (1) The metal, mixed with iron filings, is distilled in iron or fireclay retorts. The filings retain the impurities, and help to prevent bumping of the mercury. The mercury distils into water, and is freed from a film of oxide by treating it with hydrochloric acid. The mercury is then washed and dried. (2) By heating commercial mercury with dilute nitric acid, and finally washing and drying the

metal. This method answers every requirement for dental purposes. The acid dissolves the impurities.

TESTING THE PURITY OF MERCURY.—Mercury for dental purposes should be pure, as the impure metal greatly interferes with the preparation of amalgams. The purity of mercury can be ascertained by allowing a globule of it to run over a smooth wooden surface; if it is pure it will not leave a "tail" behind it. Pure mercury should leave *no* residue when dissolved in nitric acid, evaporated, and ignited. When agitated in a bottle with dry air, it should not yield any grey powder. Mercury which has been squeezed out in the preparation of dental amalgams should not be returned to the bottle containing pure mercury, as it always contains small quantities of other metals.

VERMILION, or mercuric sulphide (HgS), is used for colouring rubbers and celluloid; and its colour varies considerably. The tint of vermilion depends on the purity of the substances used, and on the manner in which it is prepared. The Chinese method is to heat one part of sulphur with four parts of mercury in a shallow iron pan. The mixture is continually stirred, which causes the mercury to chemically combine with the sulphur, forming a brown or black powder. This powder is heated in iron pans with earthenware domes, in which the vermilion sublimes. The sublimate is ground to a powder, put into water, allowed to settle, when the fine sediment is collected and dried.

Brunner's method consists in heating the following mixture to 122° F. (50° C.):—

Mercury	.	.	.	.	.	32	
Sulphur	.	.	.	.	.	12	
Potassium hydroxide	.	.	.	.	.	8	} = solution of 16.6 per cent.
Water.	.	.	.	.	.	48	

100

The mass becomes red after several hours, and when the right colour is attained it is poured into water, collected on a filter, washed, and dried.

Detection of Impurities.—Vermilion should sublime without leaving any residue. This operation is readily performed in any ordinary reduction tube. If a residue is left, the vermilion contains impurities—the usual adulterants being red lead, brick-dust, and ferric oxide.

Properties of Vermilion.—Water, alcohol, alkalies, nitric, sulphuric, and hydrochloric acids, have no action, on vermilion. Aqua regia attacks it vigorously with the production of mercuric chloride; hence the reason that aqua regia should on no account be used in removing *tin-foil* employed as a coating for plaster casts in rubber work. If the tin-foil adheres, it should be removed by means of hydrochloric acid.

When heated with charcoal, certain metals, caustic alkalies, alkaline carbonates, and lime, vermilion yields metallic mercury. Silver and copper reduce vermilion to the metallic state: this is a most important property, as it renders the combination of silver and vulcanisable rubbers impracticable.

If pure vermilion is used in the preparation of dental rubber, no deleterious effects are produced in the mouth. The saliva has no action on it, and no poisonous salt of mercury is produced. These remarks, however, do not apply to rubber prepared with impure vermilion; and serious mouth diseases, salivation,¹ etc., may occur by using impure material for such purposes.

AMALGAMS are formed by the union of mercury with other metals; and in most cases the union is easily effected; but with iron, nickel, cobalt, and platinum, union takes place with

¹ Mercurial stomatitis (ptyalism) is an inflammation of the mouth and salivary glands, and may be caused by mercury.

difficulty. Combination of metals and mercury may evolve heat, or may absorb heat, or there may be no thermal manifestation of heat. The combination of most metals with mercury causes little or no change of volume; although in some cases there is a decrease, while in others an increase of volume is readily noticed. Many metals unite with mercury at the ordinary temperatures, while others require heat. Amalgams are either solid, semi-solid, or fluid. The solid amalgams are regarded as definite chemical compounds, while the liquid amalgams consist of a compound dissolved in an excess of mercury; the excess being separated by pressure through chamois-leather. The chemical affinity existing between the constituents is but feeble; but many liquid amalgams ultimately become solid and crystalline. Many amalgams harden with time, hence their value for fillings: this is one of the most important properties of amalgams from a dental standpoint.

Amalgams are formed by the following methods:—

- (a) Direct union of the metals with mercury.
- (b) By adding mercury or sodium-amalgam to a solution of a salt of a metal.
- (c) By placing a metal into a solution of a mercury salt.
- (d) By placing the metal in contact with mercury and an acid.

Antimony Amalgam is prepared by adding antimony to heated mercury, or by triturating antimony in a mortar with dilute hydrochloric acid and mercury. The amalgam is soft, and is decomposed by air and water, with the separation of antimony. Chase's "alcohol tight" amalgam contains 5 per cent. of antimony. Amalgams containing antimony are plastic, fine-grained, and unshrinkable, but are dirty to work. In small quantities, antimony controls shrinkage.

Aluminium Amalgam is formed when powdered aluminium

is brought into contact with mercury, and heat applied. The amalgam is unstable, as aluminium becomes oxidised. The formation of this amalgam is accompanied by an increase of volume.

Bismuth Amalgam is readily formed in the cold. It is sticky and adhesive.

Cadmium Amalgam is formed at the ordinary temperatures. When complete saturation takes place, a compound of 78.3 per cent. of mercury and 21.7 per cent. of cadmium ($= \text{Hg}_2\text{Cd}$) is formed. It is a silver-white, crystalline, brittle mass, heavier than mercury, and crystallises in the octahedral form (Cubic System, *vide* Chapter II.). Cadmium amalgamates easily and sets quickly, but fillings of it gradually soften and disintegrate. Cadmium amalgams decalcify the dentine, which becomes stained yellow, owing to the formation of cadmium sulphide.

Copper Amalgam is used as a filling, but the copper has a tendency to blacken. Various methods are described under "copper" for the preparation of copper amalgam. This amalgam becomes hard and crystalline, while its soft and plastic character is restored by kneading or pounding, or by placing it in boiling water. Its density is the same in the hard as in the soft state, therefore it is stated that it does not expand in hardening. The less mercury the amalgam contains the quicker it sets, and the harder it becomes.

Gold Amalgam is readily formed in the cold, but for rapid amalgamation heat is used. Gold added to amalgams of silver and tin controls shrinkage, balling, and discoloration, adds to edge-strength, and facilitates setting; and amalgams containing gold are easily worked.

Iron Amalgam is prepared by adding sodium-amalgam to a solution of ferrous sulphate.

Lead Amalgam is readily prepared in the cold. It is denser than either lead or mercury, therefore contraction

takes place during combination. Lead and iron amalgams are of no use for dental purposes.

Nickel Amalgam is prepared by adding sodium amalgam to a solution of nickel sulphate or any other soluble salt of nickel. The amalgam decomposes, nickel oxide and mercury being formed.

Palladium Amalgam is obtained by rubbing finely divided palladium with mercury. Great care is necessary in the mixing of the metals, as great heat is evolved, and an explosion may occur. The amalgam sets very rapidly; therefore it is necessary to mix it quite soft in order to make a filling before it is too hard to use. It is worked quickly and with heated instruments. Gold, and a small quantity of silver, improves the dental properties of palladium amalgam in more ways than one. This fact is well known to those who have had experience with amalgam of palladium; as gold and silver render the amalgam more tractable, easier to work, and add to edge-strength. Palladium amalgam forms a water-tight filling. It turns black, although it does not stain the dentine, like cadmium and some other amalgams.

Platinum Amalgam is prepared by triturating spongy platinum with mercury in a warm mortar. It may also be obtained by adding sodium amalgam to a solution of platinic chloride. Platinum amalgams do not harden well; one containing 12 per cent. of platinum is soft and greasy; but they become more solid as the amount of platinum is increased. The solid amalgam containing the most mercury is PtHg_2 .

Platinum forms valuable amalgams when alloyed with gold, or with tin, silver, and gold; and with the proper amount of mercury valuable fillings may be produced. These amalgams set well, and become extremely hard. Fletcher has proved the value of gold in platinum amalgams, and his work has been confirmed by others.

Silver Amalgam may be prepared in the cold, but much more rapidly with the aid of heat. Precipitated silver, or silver-leaf, or silver in the form of powder, combines with hot mercury almost immediately. In most cases there is an increase of volume and a rise of temperature, although in certain proportions a decrease may be observed. Silver amalgam varies in character according to the composition, temperature, mode of formation, etc., and is soft, crystalline, or granular. Silver amalgam dissolves in excess of mercury, but the excess is readily separated by squeezing through chamois-leather. Fillings of the two metals change their shape, but silver alloyed with other metals (gold, zinc, tin, and copper) is the most important metal in a good amalgam for filling teeth. The oral secretions blacken silver fillings, and the teeth become stained.

Tin Amalgam is readily produced in the cold, but more rapidly at the melting point of tin. Amalgams of the two metals do not harden sufficiently for dental purposes, but, alloyed with other metals (*e.g.* silver, zinc, copper, and gold), tin is a valuable constituent, as it prevents staining, diminishes conductivity, and facilitates amalgamation.

An amalgam containing 10 per cent. of tin is liquid, but with 50 per cent. it is solid. Tin amalgam is white, more or less brittle and granular, according to the proportion of mercury present. The union of the two metals causes a decrease in volume.

Zinc Amalgam is generally prepared by adding mercury to molten zinc. The amalgam is white, granular, and brittle, but when mercury is in excess the amalgam is pasty. Zinc amalgams are not used alone: zinc added to silver and tin controls contraction or shrinkage, and improves the colour of the filling. It is a constituent of several well-known amalgam alloys. Chandler uses *zinc powder* at the time of amalgamating the alloy, and has obtained excellent results;

and other dentists who have tried this method speak in favourable terms of it.

AMALGAMS IN DETAIL.—In studying the subject of amalgams for filling teeth, it would be as well perhaps to first consider what constitutes an ideal filling. It will be generally conceded that an ideal filling should possess the following properties:—

1. Freedom from discoloration.
2. Durability, which includes—
 - (a) Insolubility.
 - (b) Edge-strength.
 - (c) Non-porosity.
 - (d) Non-expansion on setting.
 - (e) Non-contraction on setting.
 - (f) Unaltering shape.
 - (g) Uninfluenced by oral secretions and food débris.
 - (h) Hardness.
 - (i) Contour strength.
3. Adhesiveness.
4. Not-transmitting thermal changes.
5. Chemically non-irritant.
6. Antiseptic.
7. Plastic and quick setting.
8. Submarine.
9. Non-staining of the tooth-tissue.

1. *Permanent Colour.*—At present no filling has this property. The zinc cements possess it in some degree, but still leave much to be desired. Gutta-percha fillings possess freedom from discoloration more or less, but they frequently change their colour after being subject to the fluids of the mouth a few months. Inlays are the best and amalgams the worst in this respect. Copper amalgams turn quite black from the formation of a sulphide, and silver alloys darken from the same cause. Gregory's amalgam ("white metallic filling") contains a large percentage of the only metal which forms a *white* sulphide, namely, zinc; but it is far from being ideal, as it has a weak edge.

2. *Durability*.—(a) Insolubility is most desirable for a good filling; and solubility is the chief fault of copper amalgam, and it does not resist caries at the cervical edge. (b) Edge-strength. Owing to the weakness of the edge of an amalgam filling, it is usual to make the edge of the cavity square so as to obtain the greatest strength for the amalgam; but the question arises as to what should be the character of the edge-strength. Should it be tough, and bend under pressure like that of a gold filling, or glass-like (*i.e.* break without bending)? Most probably a tough edge is the better of the two. (c) Non-porosity. If porous fillings were used, they would permit of caries taking place, and would become septic; but this is not one of the faults of amalgams, except under conditions to be mentioned. (d and e) Non-expansion and non-contraction on setting. Of the two evils, expansion is the less, as no leakage, and consequently no caries, can take place as in a contracting amalgam; and the force of expansion, moreover, is very slight, the usual consequence being that the amalgam protrudes from the cavity. This does not, as a rule, happen until the filling has been in the tooth for a few years, and then all that is necessary is to grind it down and polish it. (f) Unaltering shape. It sometimes happens that an amalgam will not preserve its original shape. This is principally due to the age or freshness of the amalgam. Old amalgams have already undergone shrinkage, alteration of shape, etc., and form satisfactory fillings. (g) Uninfluenced by oral secretions, etc. The secretions of the mouth act upon a number of metals and alloys. Copper amalgams wash out, and are rapidly dissolved by acid saliva. (h and i) Hardness and contour strength. These are important properties of a filling, and all silver amalgams, when properly inserted, are hard enough for mastication and contour work.

3. *Adhesiveness*.—No amalgam possesses this property, although the addition of bismuth has been advocated. It is

possible, however, to overcome this difficulty by lining the cavity with phosphate cement, then placing the amalgam in it, and thoroughly burnishing it all over the cavity, thus leaving a film of cement between the walls of the cavity and the amalgam.

4. *Not-transmitting Thermal Changes.*—As a filling material, gold is the worst in this respect and gutta-percha the best, though even with gold it seldom happens that the tooth does not soon become accustomed to it, and this difficulty pass off, provided that the filling is not too near the pulp. But it is this proximity to the pulp which often causes difficulty, especially in very small teeth. A protecting layer has then to be placed over the pulp, and perhaps also a cap, the result being a weak filling.

5. *Chemically non-irritant.*—All amalgams possess this property, but not cements.

6. *Antiseptic.*—Although this property is most desirable in preventing decay taking place in other parts of the tooth, it is not a *sine quâ non*, as amalgams or gold fillings remain in cavities for many years.

7. *Plastic and quick setting.*—Good amalgams should be plastic, and set in about fifteen minutes. They should be easily and quickly inserted, and set hard, so as to prevent the possibility of injury.

8. *Submarine.*—The insertion of an amalgam under water is occasionally desirable, and the one that is the least affected in this particular is copper amalgam.

9. *Non-staining of the Tooth-Tissue* is a most essential property in fillings for front teeth.

It may be mentioned, *en passant*, that no amalgam in use possesses *all* the properties of our ideal filling.

*The composition of some alloys used for dental amalgams is given in the table on the following page.

In forming dental amalgams, the best results are said to be obtained when the metals are united in *atomic* proportions, *i.e.*

to form definite chemical compounds; and the solid amalgams appear to be definite compounds, capable of being dissolved in an excess of mercury. It has been proved in the laboratory that when filings of an alloy are thoroughly mixed and kneaded with sufficient and known quantities of mercury, new compounds are formed, which are soft and plastic. After a short time, however, the amalgam becomes crystalline and changes its volume; and the mass is said to be a molecular compound of mercury and other metals—the whole mass being dissolved in an excess of mercury.

	Tin.	Silver.	Gold.	Platinum.	Copper.	Zinc.
Fletcher's platinum - gold alloy	50·35	43·35	3·35	1·30	1·65	...
„ gold alloy	56·00	40·00	4·00	...	...	...
Lawrence's amalgam	47·00	47·00	1·00	...	5·00	...
Flagg's contour alloy	37·00	58·00	5·00	...	...	...
„ submarine	35·00	60·00	...	...	5·00	...
„ facing	35·00	57·00	5·00	...	...	3·00
Townsend's alloy	54·50	44·50	1·00	...	...	...
Alloy ¹ { A	51·50	45·00	2·00	...	...	1·50
B	52·00	43·00	2·50	...	1·50	1·00
C	49·20	44·80	5·00	...	1·00	...

When the amalgam is required for filling teeth, most of the excess of mercury is removed by squeezing through chamois - leather. Bonwill uses the amalgam plastic, and squeezes it dry in the cavity of the tooth—the excess of mercury being absorbed by pads of bibulous paper or gold-foil.

Tomes employs *old* amalgams, which are first heated, and then used alone or rubbed up with a small quantity of new amalgam. Old amalgams set rapidly, and produce water-tight plugs. They have also the advantage of having undergone the change of volume (shrinkage), alteration of shape, etc., characteristic of new or fresh amalgams.² Old amalgams are

¹ Assayed in the author's laboratories.

² C. S. Tomes, *British Journal of Dental Science*, vol. xxxviii. p. 242; vol. xxxix. p. 529

first heated in a spirit or Bunsen flame, and then placed on a hot plate to keep them soft (the state of *amorphism*). They harden again on cooling, passing into the crystalline condition.

The composition of the various amalgam-alloys used for filling purposes have already been given, and these alloys in the form of shavings or filings are mixed with from 30 to 50 per cent. of mercury. Amalgams that contain the most tin are soft, plastic, and slow in setting; while those with an excess of silver set quickly, and are harder. Amalgams with excess of mercury removed become hard within a few hours, and acquire their full degree of hardness in from twenty-four to forty-eight hours. They may then be dressed with a file and polished.

Gold, silver, zinc, and platinum are used to improve the qualities of silver-tin alloys. To a certain extent gold improves these alloys; but Bonwill has proved that when the quantity added to is carried beyond a certain limit, the advantage ceases. This remark also applies to an excess of other metals when added to silver-tin alloys.

Let us now consider amalgams in everyday use under four headings:—

1. Mixing amalgams.
2. Their manipulation, or the manner of inserting them into the cavity.
3. Finishing the fillings.
4. Changes observed in fillings after insertion.

1. *Mixing*.—It does not appear to be essential that the mercury should be in exact proportion to the filings, as claimed by some, or that filings and mercury should be mixed by shaking in a tube. It may be that this should be done on theoretical grounds; but in actual practice many dentists of great and varied experience find that it is best to have the mass of amalgam in three portions, soft, medium, and the third squeezed in chamois-leather by a pair of pliers

into a biscuit. These three portions necessarily contain varying proportions of mercury. In filling a cavity, the soft portion is first, which is thoroughly burnished over its entire surface, thus ensuring contact; next is added the medium portion; and, lastly, the biscuit—the reason for this being that mercury always rises to the surface worked on, and not to the sides.

Washing the amalgam with alcohol is without reason, and is one of the causes of porosity; but the greatest cause of porosity is the practice of “palm kneading.” Not only is this uncleanly, but the amalgam becomes disintegrated and rendered useless by the sweat of a “moist” hand.

2. *Manipulation*.—The usual method is that of burnishing the amalgam into the cavity of the tooth with ball-pointed instruments, while malleting has been suggested. Bonwill's method consists of burnishing in the amalgam, and then by pressing wool or bibulous paper on the surface by means of an instrument, squeezing out all mercury, next scraping off all the soft amalgam, again adding more amalgam, and again squeezing out the mercury, and so on until the cavity is filled; but it is stated to produce a filling that expands, and the failure of some layers for want of mercury occasionally occurs.

Squeezing mercury out by means of chamois-leather and pliers is considered bad by some dentists, on the ground that the mercury carries with it some metal, and in an amalgam containing gold it would be particularly this metal. But if it is wrong to squeeze the mass with pliers, why should it be right to squeeze mercury from the tooth-cavity as in the Bonwill method? If gold or other constituent of the alloy is removed in the one case, it must be so in the other. The mercury squeezed out from amalgams has been tested in the author's laboratories, and found to contain gold and other metals.

3. *Finishing the Fillings.*—When the cavity is filled, the surplus mercury on the surface must be absorbed by burnishing the filling with tin-foil or, better still, gold-foil. Here, again, is mercury absorbed from the amalgam, and an unknown quantity of a metal (or metals) abstracted with it.

The method of finishing adopted by some dentists is to heap up the amalgam considerably above the surface of the tooth, to absorb all mercury with tin-foil, and then with large spoon-excavators to cut the filling down to the level of the enamel, where it is found to be quite hard.

4. *Changes that take place.*—If fillings that have been in the mouth for a few years are carefully examined, a change in their form will be found to have taken place. Some will have expanded, and the force of expansion being slight, the fillings protrude from the cavity, thus forming a lodgment for food, etc.; so that occasionally caries takes place from this cause. Other fillings will be found to have contracted, producing of necessity leakage and caries; while others will be noticed to have the edges curled away from the margins, but this may be due to careless filling or finishing.

It is well known that the greatest durability is found in front teeth; and in this situation it is not unusual to see amalgam fillings quite good after twenty or thirty years. It is most important to bear in mind that it is impossible to obtain uniform results in all parts of the mouth; some cavities, for instance, may be very difficult of access, and the dentist would use the amalgam rather soft, in which case more or less contraction would result.

EFFECT OF DIFFERENT METALS IN AMALGAMS.—1. *Silver* in silver-tin amalgams controls the contraction of the tin, and increases the hardness; but it is seriously influenced by the sulphuretted hydrogen of the mouth, which blackens it, and thereby stains the tooth.

2. *Gold* reduces contraction and discoloration, produces

good edge-strength, and also reduces the property of setting.

3. *Tin* contracts, is slow in setting, causes loss of edge-strength, and prevents discoloration. To a certain extent it is a valuable constituent in amalgam alloys.

4. *Platinum* contracts, and is slow in setting; but when it is added to a silver-tin amalgam containing gold, it confers the property of setting quickly, and gives rise to a filling of great hardness (Fletcher).

5. *Copper* reduces contraction, facilitates setting, produces great edge-strength, and increases discoloration.

6. *Zinc* reduces contraction and discoloration, causes loss of edge-strength, and rapid setting.

7. *Palladium* increases discoloration, and sets rapidly.

8. *Cadmium* causes rapid setting and discoloration.

9. *Antimony* reduces contraction and facilitates amalgamation.

10. *Bismuth* reduces expansion, hardness, and edge-strength, but facilitates amalgamation.

11. *Aluminium* increases expansion, sets slowly, and has a tendency to alter in shape.

12. *Lead* causes slow setting and discoloration, and facilitates amalgamation.

CHANGE OF VOLUME.—Silver-tin amalgams form the most important fillings for teeth; and as to whether they contract or expand, there is much diversity of opinion. Hitchcock and Tomes¹ state that contraction takes place; while Kirby² claims that the amalgam first contracts, and then expands. It should be pointed out that probably the experiments were not conducted under the same conditions—quantity of mercury used, etc. Black³ has proved that amalgam alloys

¹ *Trans. New York Odont. Soc.*, 1874.

² *British Journal of Dental Science*, vol. ix.

³ *Dental Cosmos*, vol. xxxviii. p. 975.

containing less than 50 per cent. of silver first contract and finally expand. Alloys of 50 to 62 per cent. of silver contract only; those containing 65 to 75 per cent. of silver expand when fresh cut, but contract when "aged"; and those containing 75 per cent. or more of silver expand only.

One of the methods used for determining the contraction or expansion of an amalgam is to carefully pack it into a small glass tube¹ until full, and then to make the surface level. If contraction takes place the amalgam will slide out of the tube; while expansion will be readily seen, with the aid of a magnifying glass, by the projection of the amalgam above the mouth of the tube. Comparative results are easily measured with a micrometer.

Kirby's apparatus for ascertaining change of volume consists of a V-shaped metallic trough with a movable end, to which a micrometer is attached. By this means any contraction or expansion is accurately measured. The amalgam is placed in the trough, and allowed to remain there for some time. Any change in volume is readily ascertained by this useful instrument.

The change of volume is also determined by taking the specific gravity of the amalgam (*vide* Chapter II.); for it has been ascertained that when the density of an amalgam or alloy is greater than that of the mean of the constituents, it proves that contraction is the result of the union; while a decrease in the density means that expansion has taken place.

Delicate balances (see Figs. 1 and 22) are a *sine qua non* for this work, and with several precautions (see Ure's *Dictionary*, vol. i. p. 92).

PERMANENCE IN THE MOUTH of an amalgam filling depends upon the preparation of the cavity, the soundness of the

¹ Black's tubes are two-fifths of an inch in diameter and three-tenths of an inch deep, with a flat bottom.

remaining portion of the tooth, the proper manipulation of the amalgam, and its composition. Amalgams containing much silver and copper, being attacked by the oral secretions, tend to wear away, and are consequently less permanent than those containing smaller proportions of such metals. With silver and copper, sulphuretted hydrogen is the cause of the decay of the amalgam. Metals acted upon more or less by sulphuretted hydrogen, and by acid and alkaline fluids, are frequently protected from corrosive action when alloyed with other metals (*e.g.* copper and zinc). Some amalgams shrink from the edges of the tooth, and thus reduce the permanency of the stopping. The difference in densities of the filling and the remaining portion of the tooth is also against permanency. The heavy filling has a tendency to burst the shell surrounding it during the mastication of food.

Galvanic action causes the wasting or corrosion of amalgam fillings; and this is caused by *the action of other metals in the mouth*. If metals (silver forks, spoons, etc.) come into contact with amalgam fillings, galvanic action is the result.

AGEING is a term applied to the change that takes place after a time in the properties of amalgam-alloys of silver and tin. Ageing is said to be due to the formation of a film of oxide or oxides; and this film has a tendency to retard amalgamation. Black states that the ageing, or the change that occurs in a cut alloy, depends upon the temperature at which it is kept. He has proved that the ageing of alloys of definite composition can be produced artificially by means of heat; and that ageing is due to a *molecular change* and a hardening process. By further heating an "aged" alloy, it becomes annealed, and thereby returns to its normal state. The molecular change observed in ageing is comparable to the formation of allotropes of certain ele-

ments and isomers of certain compounds. Ageing and the return to the normal state of alloys may be looked upon as a kind of "reverse action."

QUANTITY OF MERCURY to form an amalgam is variable, and differs with every alloy. As a rule, the proportions vary from 30 to 50 per cent. of mercury; but mercury must be used in such quantities as will form a definite compound. If the quantity of mercury is deficient, the mass will consist of amalgam and unamalgamated alloy. The right quantity of mercury to use may be ascertained by adding filings or turnings of alloy to a globule of mercury until a mass of proper working consistency is obtained; or to add an excess of mercury, and then remove the excess of mercury by squeezing through chamois-leather with the aid of pliers. It has been stated that a small quantity of the alloy is removed in solution by squeezing through the leather, and that the process does not remove all the excess of mercury. If, however, a plastic amalgam is made, and then inserted in the cavity, the excess of mercury can be forced out, and finally removed by gold-foil or bibulous paper.

MERCURY BALANCES are used for obtaining the right quantity of mercury. The two chief forms are those of Kirby and Fletcher (Fig. 24, *a* and *b*). In Kirby's balance (*a*) mercury is placed in the cup, the proper quantity being ascertained by the pin-weight. The latter is placed in the different holes (1 to 4), according to the quantity of mercury required. In Fletcher's balance (*b*) filings are placed in cup 1 and mercury in cups 2 or 3, according to the quantity required.

MIXING AMALGAMS is an important process, and requires skill. The filings and mercury are rubbed together in the palm of the hand; but moisture and dirt may retard amalgamation. Union may be produced by rubbing the filings and mercury together in a Wedgwood mortar; but the attri-

tion burnishes the alloy, and consequently retards amalgamation. A heated mortar, however, aids amalgamation. Fletcher

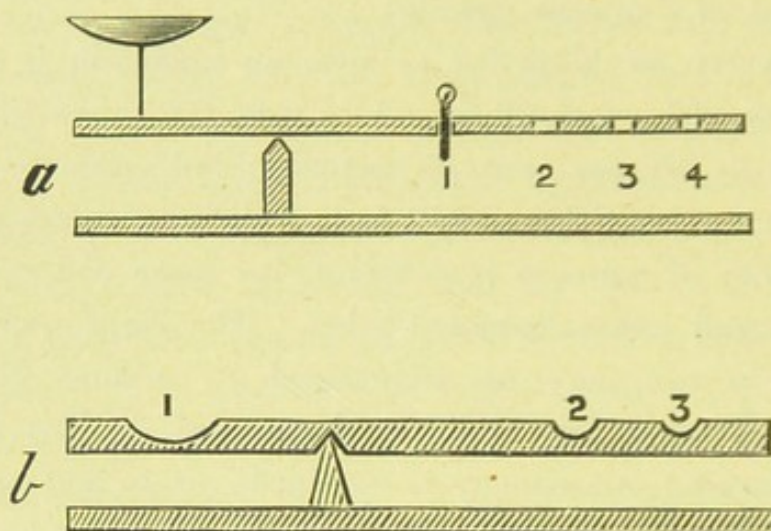


FIG. 24.—Mercury Balances.

recommends a glass mixing-tube; filings and mercury are put into the tube, and the latter is well shaken. By this means union takes place. The tube may be heated in order to facilitate amalgamation. Kirby also recommends tubes for mixing amalgams; and these are certainly cleaner than the "palm" method.

PREPARATION OF ALLOYS for amalgams. The various constituents are melted in a graphite crucible, but not altogether. The order would be as follows:—

- 1st. Platinum and silver;
- 2nd. Gold and copper;
- 3rd. Tin.

The alloy is then stirred and poured into an ingot mould (see Fig. 16, *a*). Charcoal or borax is placed on the molten alloy to prevent oxidation. The temperature of the furnace should be sufficiently high in order to obtain a uniform alloy; but oxidation must be prevented, or the alloy has not its true composition.

The ingot is filled from time to time, and the filings used as required.

TESTING ALLOYS.—A small quantity of the amalgam-alloy is treated with nitric acid, heated, and then diluted with water. A *residue* and a *solution* are the result of the operation.

- | | | | | |
|----|----------------------|---|---|----------------------------|
| 1. | The residue is white | . | . | Presence of tin. |
| 2. | „ „ „ purple | . | . | „ „ gold. |
| 3. | „ „ „ black | . | . | „ „ platinum. ¹ |

To the solution add hydrochloric acid; a white precipitate indicates the presence of silver: filter, evaporate the filtrate to dryness, add a solution of potassium chloride and alcohol; a yellow precipitate denotes the presence of platinum. Allow the precipitate to settle, pour off the clear liquid, expel the alcohol by boiling, and then dilute. Divide the solution into two portions (*a* and *b*). To *a* add an excess of ammonia; a deep blue coloration indicates the presence of copper: add to the same solution *a* a solution of potassium cyanide until it becomes colourless: and, finally, pass a current of sulphuretted hydrogen into the solution; a yellow precipitate indicates cadmium. Into *b* pass a current of sulphuretted hydrogen, filter off the precipitate, then add ammonia; if a white precipitate is produced, it indicates the presence of zinc.

Old amalgams can be tested in the same way, but the mercury should be first removed by heat.

ALTERATION OF SHAPE.—Some amalgams have a tendency to form a convex surface; this is known as spheroiding, and is due to a change of volume. The amalgam being held down on all sides but one, gives rise to a convex surface. Kirby states that this alteration of shape is due to an unequal distribution of mercury throughout the filling; that part of the filling containing the most mercury causing contraction, whereas in that containing the least mercury there is expansion. When the mercury is equally distributed, there is neither contraction nor expansion, and therefore no change in shape.

¹ If platinum is in *small* quantities, it is dissolved.

Alteration of shape can be seen by using a good lens. Cunningham¹ tests alteration of shape of a filling by using the surface as a mirror, and observing the reflection in it of parallel straight lines.

EDGE-STRENGTH is a most important property of an amalgam; and to test this property a dynamometer (instrument for measuring force) is required. "This usually consists of a carefully balanced and graduated metal beam, upon which a sliding weight is placed. A chisel-shaped steel rod is also fixed to the balanced beam, and so arranged that the pressure necessary for testing the strength of the amalgam filling can be applied to the chisel by moving the sliding weight along the graduated scale. The instrument is also provided with suitable screws for accurate adjustment. The amalgam to be tested is mixed as for ordinary fillings, and made into small blocks in order to obtain the greatest edge-strength of which the specimen is capable. After allowing the amalgam to harden, it is carefully secured in position upon the instrument, so that the point of the chisel rests upon the edge of the specimen. The sliding weight is then slowly pushed out along the graduated scale on the beam until the pressure produced is sufficient to break the edge of the specimen" (Smith). The position of the sliding weight denotes the point of fracture or edge-strength, and by the dynamometer the relative edge-strength of various amalgams may be ascertained.

LEAKAGE is an unfortunate property of some amalgams, which prevents the plugs from being watertight. Leakage is tested by packing amalgams into small holes bored through pieces of bone or ivory. These pieces are then placed into ink for some time; on being removed, the plugs are split, and the surfaces are examined for ingress of ink.

CHANGE OF COLOUR occurs in many dental amalgams.

¹ *British Journal of Dental Science*, vol. xxxix. p. 609.

Copper facilitates discoloration, while gold aids an amalgam in retaining its colour. Excess of mercury causes blackening ; but the chief cause for a change of colour is due to the formation of sulphides by the action of the secretions of the mouth. Silver and mercury unite readily with sulphur. Some copper and palladium amalgams readily blacken.

Change of colour is tested by covering the amalgam with sulphuretted hydrogen water.

CHAPTER XII

SILVER

Symbol, Ag; Atomic weight, 107.93

OCCURRENCE.—The chief natural forms are metallic silver, silver glance (Ag_2S), stephanite (5AgS , Sb_2S_3), stromeyerite (Ag_2S , Cu_2S), and horn silver (AgCl). Silver is also present in galena.

PREPARATIONS.—The principal methods employed for the extraction of silver from its ores are the following:—

1. By amalgamation.
2. By wet processes.
3. By desilverizing lead, and cupellation.

1. *Amalgamation Processes.*—Several methods have been described, depending on the action of mercury on compounds of silver, whereby the silver becomes amalgamated, the mercury being separated by distillation. The retorted silver is melted and cast into ingots. Some ores are previously roasted with common salt and crude copper sulphate before being treated with mercury (Mexican or Patio process).

2. *Wet Processes.*—(a) The ore is roasted with common salt, the silver being converted into a chloride. The silver chloride is dissolved in a solution of sodium chloride or sodium thiosulphate ("hyposulphite"). The silver is then precipitated by placing sheets of copper in the solution, or by the electric current. The spongy silver so formed is finally melted and cast into bars. The above method was

devised by Augustin, and has been modified by Von Patera in the following way:—The solution of silver chloride in sodium thiosulphate is treated with sodium sulphide, and the precipitated silver sulphide is finally decomposed in a muffle or retort. (b) In the Ziervogel process, the ore containing the sulphides of silver, copper, and iron is roasted in a reverberatory furnace, in order that the three metals are converted into sulphates. The sulphates are then exposed to a high temperature, with the result that the sulphates of copper and iron are converted into *insoluble* oxides, but *soluble* silver sulphate remains undecomposed. The latter is extracted by water, and metallic silver precipitated therefrom by means of scrap copper.

3. *Desilverising Lead*.—Lead (from galena) contains silver, and is extracted by either Pattinson's or Parke's process.

The Pattinson process depends on the fact that pure lead solidifies at a higher temperature than an alloy of silver and lead. By melting the lead in iron pots (Fig. 25), and then

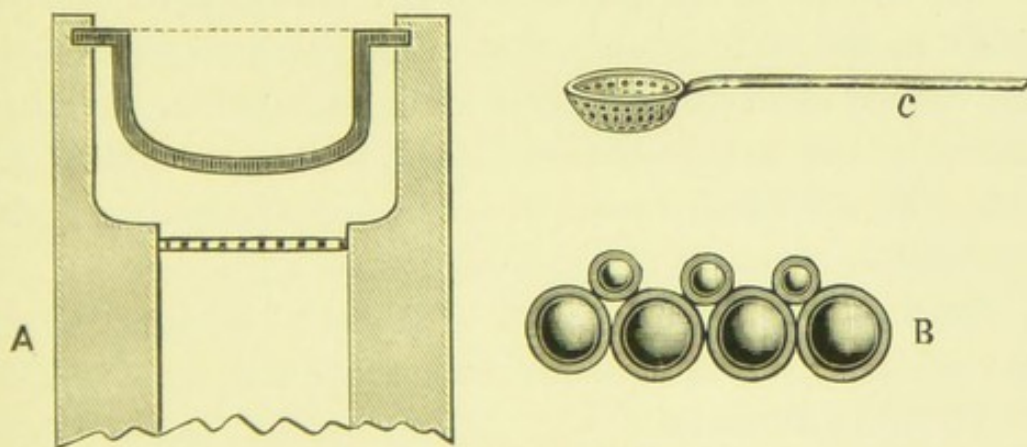


FIG. 25. Pattinson's Process.

A, Section of a Pot. B, Plan of the arrangement of the Pots. C, Ladle.

by sprinkling water upon it, the lead crystallises out first; and if this be removed by a perforated ladle, the molten metal remaining is richer in silver. This operation is repeated several times, and finally the rich silver-lead alloy is cupelled.

In Parke's process, zinc is added to the metal, whereby an alloy of silver, lead, and zinc solidifies, and the molten lead remaining in the pots is free from silver.

Cupellation.—The alloys are melted in a furnace on a porous bed of bone-ash (the *cupel*). A blast of air blows over the surface, the lead oxidises, and the melted oxide is absorbed by the cupel, carrying with it the impurities, and leaving the silver on the surface of the cupel.

PROPERTIES.—Silver is a white metal, and capable of taking a high polish. Silver does not oxidise in air, but traces of sulphuretted hydrogen cause it to become coated with a film of sulphide. Dilute hydrochloric and sulphuric acids have little action upon the metal. Hot strong sulphuric acid acts upon it, forming silver sulphate. Nitric acid readily dissolves silver. Water has no action upon it, but alkaline solutions slowly attack it. Silver is the most malleable and ductile of the metals (except gold). Wire-drawing and hammering render the metal more or less brittle, consequently it requires frequent annealing. Molten silver occludes gases; in fact, it is capable of absorbing twenty-two times its own volume of oxygen, which is again liberated on the solidification of the metal—the evolution of the gas causing the surface of the silver to acquire a frosted appearance. This phenomenon is known as “spitting.”

Small quantities of arsenic, antimony, bismuth, tin, and zinc render silver brittle and difficult to roll.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . . . .	10.5
Specific heat (water = 1)	. . . . .	0.0570
Hardness (diamond = 100)	. . . . .	32.9
Fusibility	. . . . .	945° C. ¹ or 1733° F.
Malleability (gold = 1, most malleable)	. . . . .	2

¹ The melting point of silver was formerly stated to be 1050° C. Violle (*Comptes rendus*, vol. lxxxv. p. 543) states that it is 954° C.

Ductility (gold = 1, most ductile)	2
Tenacity (per square inch in tons)	18.2
Conductivity of heat (silver = 100)	100
Conductivity of electricity (silver = 100)	100
Expansion by heat	0.00193
Change of volume on solidification	decrease.

SPECIFIC GRAVITIES OF SILVER-GOLD ALLOYS.—Prof. J. W. Richards¹ has recently determined the specific gravities of an important series of silver-gold alloys. The results are given in the table on the following page.

DENTAL USES.—Silver is used in amalgam-alloys for filling teeth, and is the principal constituent in most “submarine,” “usual,” and “contour” alloys. It is also a constituent of dental alloy (Ag and Pt), which is largely employed as a base for artificial dentures.

ALLOYS.—(1) *Silver and Copper* combine together in any proportions, and the alloys produced are fairly uniform in composition, although the practical worker knows that ingots frequently undergo “liquation” on cooling—the ingot being no longer homogeneous; sometimes the interior, and at other times the exterior of the ingot, is richer in silver. These alloys are white, until the copper amounts to 50 per cent., when the copper becomes yellow and red as the copper increases. Copper increases their hardness and elasticity; the hardest alloy containing 31.25 per cent. of silver and 68.75 per cent. of copper. Silver-copper alloys are ductile, although the ductility is less than that of pure silver, and their specific gravity is less than the average of the constituent metals. When heated in air, these alloys oxidise on the surface.

Roberts-Austen² has ascertained the melting points of a number of silver-copper alloys, and finds that an alloy containing 63.029 per cent. of silver and 36.971 per cent.

¹ *Journal American Chemical Society*, vol. xxiii.

² *Proc. Roy. Soc.*, vol. xxiii. pp. 349, 481.

Silver per Cent.	Specific Gravity.	Silver per Cent.	Specific Gravity.
0	19.258	51	13.488
1	19.099	52	13.409
2	18.940	53	13.331
3	18.785	54	13.254
4	18.632	55	13.178
5	18.483	56	13.103
6	18.335	57	13.029
7	18.190	58	12.955
8	18.047	59	12.882
9	17.906	60	12.811
10	17.767	61	12.739
11	17.631	62	12.669
12	17.497	63	12.600
13	17.364	64	12.531
14	17.234	65	12.463
15	17.106	66	12.395
16	16.979	67	12.329
17	16.855	68	12.253
18	16.731	69	12.198
19	16.610	70	12.133
20	16.491	71	12.069
21	16.374	72	12.007
22	16.258	73	11.944
23	16.144	74	11.882
24	16.031	75	11.821
25	15.920	76	11.761
26	15.810	77	11.700
27	15.702	78	11.641
28	15.595	79	11.582
29	15.490	80	11.525
30	15.386	81	11.467
31	15.283	82	11.410
32	15.183	83	11.353
33	15.083	84	11.297
34	14.984	85	11.242
35	14.887	86	11.187
36	14.791	87	11.133
37	14.697	88	11.079
38	14.603	89	11.026
39	14.511	90	10.973
40	14.420	91	10.921
41	14.330	92	10.871
42	14.241	93	10.819
43	14.153	94	10.768
44	14.066	95	10.718
45	13.980	96	10.668
46	13.896	97	10.619
47	13.813	98	10.570
48	13.730	99	10.521
49	13.648	100	10.473
50	13.568		

of copper (represented by the formula AgCu) has a lower melting point than silver or any other silver-copper alloy. The original melting point of this remarkable alloy was given as 846.8°C .; but this is too high, as the fusibility of silver was taken as 1040°C ., whereas more recent determinations make it 945°C . The corrected melting point of AgCu is probably 769°C . Another remarkable combination of silver and copper is Levöl's homogeneous alloy (Ag_3Cu_2), which undergoes no liquation or separation on cooling. It contains 71.893 per cent. of silver and 28.107 per cent. of copper, and melts at 870.5°C .

The British silver coin and plate contain fixed proportions of silver and copper regulated by law. The coin contains 925 parts of silver per 1000, or 11 oz. 2 dwt. of silver per lb. troy, the remaining 18 dwt. being copper. This alloy is *standard* or *sterling* silver, and has a specific gravity of 10.3. Plate stamped with the "Hall Mark" is always made of sterling silver. Standard silver has been used in America for temporary dentures, but it is not a suitable alloy for the purpose, being readily acted upon by the oral secretions. Filings of silver-copper alloys are used as stoppings for teeth. They have been largely used in France and Belgium as amalgam-alloys. These amalgams slightly expand on setting, and preserve the teeth. Alloys of silver and copper are readily prepared by melting the two metals together, under a layer of charcoal, in an annealed plumbago crucible. (2) *Silver and Aluminium* combine together to form white alloys; they admit of a high polish, and are harder than silver. Tiers-argent contains 33.3 per cent. of silver and 66.7 of aluminium, and is used in France for a variety of purposes. Another alloy contains 4.8 per cent. of silver and 95.2 per cent. of aluminium. (3) *Silver and Gold* combine in all proportions (*vide* Gold Alloys, and Richards' Table of Specific Gravities, *loc. cit.*). (4) *Silver*

and *Platinum* form an important series of alloys for dental purposes. The metals are melted together, although higher temperatures are required as the percentage of platinum increases. When small pieces of platinum-foil are added gradually to a crucible containing molten silver, they readily combine with the silver. There is a tendency of the two metals to separate or liquefy on cooling, the platinum sinking to the bottom. Silver-platinum alloys are less ductile and malleable than silver, and are also less readily tarnished than the latter metal. An alloy containing 98 per cent. of silver and 2 per cent. of platinum dissolves in nitric acid; but with sulphuric acid the platinum remains undissolved. If, however, an alloy contains more than 2 per cent. of platinum, part of the platinum is insoluble in nitric acid.

"Dental alloy" is the best known combination of silver and platinum for dental purposes, and contains from 20 to 30 per cent. of platinum (*vide* Platinum Alloys). It makes an excellent artificial denture, which is stronger, more rigid, and more durable than one made of sterling or standard silver. Von Eckart's alloy contains 19·8 per cent. of silver, 13·8 per cent. of platinum, and 66·4 per cent. of copper, and is used in France as a base for artificial dentures. It is malleable, hard, and elastic, and is blackened by sulphuretted

No.	Metals.	Percentages.	Specific Gravities.
I. . . {	Silver . . . Tin . . .	50 50	} 8·8671
II. . . {	Silver . . . Tin . . . Gold . . .	49 50 1	} 8·8792
III. . . {	Silver . . . Tin . . . Gold . . . Copper . . . Platinum . . .	42 50 4 3 1	} 9·2164

hydrogen. (5) *Silver and Tin* unite together to form an important series of amalgam-alloys for stopping teeth. The addition of tin in the alloy has a tendency to retain the whiteness of the plug. The amalgam-alloys given in the table on preceding page are useful for filling teeth.

These alloys are the outcome of some years of experimental research, and have been put to a series of practical tests as to their durability and efficiency, and have been proved to be invaluable for the dentist. Townsend's silver-tin alloy contains 44.5 per cent. of silver and 55.5 per cent. of tin. It is a valuable amalgam-alloy, but its permanence in the mouth is less than silver and some other alloys.

Although the combinations of silver and tin make good amalgam-alloys for dental purposes, they are hard and more or less brittle. The tin in these alloys is readily removed by fusing the latter with mercuric chloride; the tin volatilises as chloride, and the silver remains behind in a pure state. (6) *Silver and Mercury* combine to form amalgams. Filings of silver unite readily with mercury, and when precipitated silver is used, combination takes place almost immediately with the evolution of much heat, and considerable expansion of the mass. Silver amalgams are white, soft, crystalline or granular substances; they expand during union, and harden slowly. They are largely used for filling teeth, but become discoloured owing to the action of sulphuretted hydrogen. The silver sulphide formed preserves the tooth from decay, as it possesses antiseptic properties.

SILVER SOLDERS are more fusible than the articles to be soldered. They should run well when fused, and produce a good junction between the two surfaces. The best solders contain a small percentage of zinc, and tin increases their fluidity. Hard solders contain silver and copper only, medium solders contain zinc, and soft solders tin, in addition to silver and copper. It is necessary for good work that the two

surfaces to be joined should be clean, but during heating oxidation takes place, so that *borax* must be added (as a flux), in order to prevent oxidation as much as possible, and also to dissolve any oxide formed during soldering.

Richardson's solders¹ contain—

Fine silver	62.26 per cent.	Fine silver	66.66 per cent.
Copper	28.31 „	Copper	23.23 „
Zinc	9.43 „	Brass	11.11 „

The following are also suitable solders for dental purposes:—

	I.	II.	III.	IV.	V.
Fine silver	74	80	75	73	75
Copper	26	20	24	25	22
Zinc (free from arsenic and lead) . . . . .	...	...	1	2	2
Tin . . . . .	...	...	...	...	1

Silver solders are used for soldering articles of silver, and also for soldering gold alloys, brass, steel, cast iron, and German silver. They are usually employed in the form of thin plate, and sometimes as filings.

For the preparation of silver solders, plumbago crucibles (see Fig. 15, K) are used; and the silver and copper are heated together under a layer of charcoal. When melted, the mixture is stirred with an iron rod, and the alloy is then poured into a flat mould. When zinc enters into the composition of the solder, it is previously heated, and cautiously added to the molten silver and copper, and the mixture stirred. After casting in a flat mould, the ingot is suitable for rolling. When tin is a constituent of the solder, it is added after the silver and copper are melted; and when brass is used, it is added after melting the silver.

¹ *Mechanical Dentistry*, 1894, p. 111.

Silver coins alloyed with zinc are sometimes used for soldering purposes. These solders contain—

	I.	II.
Silver coin	90	83
Zinc	10	17

Solders are useful for joining plates of dental alloy, and of other combinations of silver and platinum.

PREPARATION OF PURE SILVER.—Silver scrap is dissolved in dilute nitric acid, and hot water added.¹ Hydrochloric acid, or a solution of sodium chloride, is added to precipitate the silver as chloride; and after standing for some time the liquor is poured off, the precipitated silver chloride is thoroughly washed with hot water, and finally dried. It is then mixed with four times its weight of anhydrous sodium carbonate, and the mixture placed in a crucible and heated until the chloride is reduced. The contents of the crucible are poured into a mould and allowed to cool, after which the sodium chloride is removed by hammering the button of silver, and finally washing it in hot water.

Silver may also be obtained from the chloride by covering it with acidulated water, and then adding sheet zinc. The silver, which is deposited in a spongy form, is washed with hot hydrochloric acid to dissolve zinc, and finally washed with water. It is then dried, melted, and cast. Plates of copper and malleable iron are sometimes used instead of zinc to precipitate the silver.

If dental alloy (Ag + Pt) is treated with nitric acid, the whole of the silver and part of the platinum is dissolved, the remainder being left as a black powder, which is filtered off. After precipitating the silver and filtering, the filtrate

¹ If any platinum or gold is present, it remains as a black powder, and should be separated from the solution of silver nitrate.

is treated with zinc, which precipitates the platinum in a spongy form.

PRECIPITATED SILVER is used as a filling; and is prepared for dissolving silver in dilute nitric acid, diluting with water, and then placing strips of zinc or copper in the solution. The spongy mass is washed and dried.

ASSAY OF SILVER BY CUPELLATION.—This operation consists in oxidising lead, and the litharge formed by the heat of the furnace is gradually absorbed by the cupel (Fig. 15, C). The litharge also removes the base metals (copper, etc.) in the form of oxides, leaving the silver as a bead on the surface of the cupel. The cupels used for the purpose are made of bone-ash, and are highly porous. They readily absorb the oxides, but not the noble metals. The assay of an alloy of silver is conducted in the following manner:—1 gramme of alloy is wrapped in a weighed quantity of lead-foil (free from silver) about six times the weight of the alloy, and then placed into the cupel, previously heated in a muffle or cupellation furnace (see Figs. 11 and 12). The lead and impurities in the alloy oxidise, and are absorbed by the cupel. After all the base metals have been absorbed, the globule of silver brightens. The cupel is then gradually brought to the door of the muffle, in order to allow occluded oxygen to disperse, and thereby prevent splitting of the silver.

The globule of silver is detached, brushed, and weighed. The weight of the globule does not give the true proportion of silver in the alloy, as small quantities of silver are lost by volatilisation and absorption. The losses are determined by placing in the muffle with each batch of assays one or more "check" or "proof" assays of the same weight of similar alloy but of *known* composition. The calculated loss sustained by the check is added as a correction to the weight of the silver globule from the alloy. For example—

1 gram. of alloy yielded 0.21 gram. of silver; and check loss = 0.01 gram.

$0.21 + 0.01 = 0.22$. Therefore—

$$\frac{100 \times 0.22}{1} = 22 \text{ per cent. of silver in the alloy.}$$

When gold or platinum is present in the alloy, it remains in the silver, and is subsequently separated (*vide* Gold Assays).¹

If the silver alloys contain zinc or tin, they are first submitted to *scorification*, as the oxides of these metals are not absorbed by the cupel. About 5 grms. of the alloy are mixed with 50 grms. of granulated lead, and heated in a scorifier (Fig. 15, D) in the muffle. The base metals become oxidised and form a fusible slag with the litharge which is formed by the partial oxidation of the lead; the remaining portion of the lead forms an alloy with the silver. The contents of the scorifier are poured into a mould, and when cold the slag is detached and the lead cupelled.

ASSAY OF SILVER IN THE WET WAY.—A weighed quantity of the alloy is dissolved in dilute nitric acid, and any gold, platinum, or tin present remains as an insoluble residue, which is filtered off. The filtrate is then treated with an excess of hydrochloric acid, which precipitates the silver as chloride. The precipitate is collected on a filter paper, washed, dried, and weighed, and the percentage of silver calculated. For example—

Weight of alloy = 0.956 gram.

Weight of silver chloride = 0.6985 gram.

$\therefore \frac{0.6985 \times 107.93}{143.38} = 0.5328$ gram. of silver in 0.956 gram. of alloy.

$\frac{0.5328 \times 100}{0.956} = 55.7$ per cent. of silver.

¹ For further information, see Brown and Griffiths' *Manual of Assaying* (Heinemann).

Volhard's method¹ for the assay of silver bullion is by means of a standard solution of ammonium thiocyanate.²

Silver is recovered from pieces of dental alloy by dissolving the alloy in nitric acid, filtering off platinum, and then placing strips of copper or zinc in the filtrate. The silver is precipitated in a spongy form. The precipitated silver is washed, dried, and finally melted.

ELECTROPLATING is the deposition of metallic silver on the surface of baser metals and alloys (*e.g.* copper, German silver, brass, etc.). The article to be plated is cleaned by immersing it in a hot solution of potassium hydroxide (sometimes in an acid solution), then brushing it with a wire brush ("scratch-brush"), and finally washing it in water. The article is next treated with a solution of mercuric nitrate, becoming coated with a thin film of mercury. It is then suspended by means of a copper wire in a *cold* solution of silver cyanide in potassium cyanide. The article is connected with the negative pole of the battery or dynamo,³ and a plate of pure silver is fastened to the positive pole and suspended in the cyanide solution. The electric current decomposes the silver salt, and deposits the silver on the article, while the silver plate dissolves gradually, and thereby maintains the strength of the plating liquid. A few drops of carbon disulphide added to the solution (electrolyte) causes the silver to form a *bright* surface on the article.

¹ *Chemical News*, vol. xxxvii. p. 77.

² See Dr. T. K. Rose's paper in the *Journal Chemical Society*, 1900, p. 232.

³ A dynamo giving 6 volts 30 ampères forms a first-rate plating machine.

CHAPTER XIII

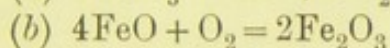
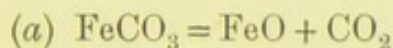
IRON

Symbol, Fe; Atomic weight, 55.9

OCCURRENCE.—Iron occurs in the metallic state (meteoric iron), and as *oxides*—magnetite (Fe_3O_4), hæmatite (Fe_2O_3); *carbonates*—spathic ore, clay-ironstone, black-band (all FeCO_3); and *sulphides*—iron pyrites, marcasite (FeS_2), etc.

PREPARATION.—Iron of commerce exists as cast iron, wrought iron, and steel—each variety possessing its own characteristic properties.

(a) *Cast Iron*.—The carbonated ores are first calcined in heaps or kilns—



During calcination, moisture, carbon dioxide, arsenic, and sulphur are expelled; and the ferrous oxide is oxidised in order to avoid the production of ferrous silicate in the blast furnace.

The hæmatites are not previously calcined. The smelting is performed in a blast furnace (Fig. 26);¹ the charge, consisting of calcined or raw ore, limestone, and coke, is introduced at the summit of the furnace, and air is forced in at the bottom. The reduction of the ore takes place, and the cast iron is run out of the furnace periodically into sand

¹ Figs. 26 and 27 are from a paper by A. B. Griffiths in *Mechanics and Science*, 1879, p. 148.

moulds, forming cast or pig iron. The reactions are partly represented by the following equations:—

1. $C + O_2 = CO_2$
2. $CO_2 + C = 2CO$
3. $3CO + Fe_2O_3 = 3CO_2 + 2Fe$

In Italy cast iron is also produced in the electric furnace;

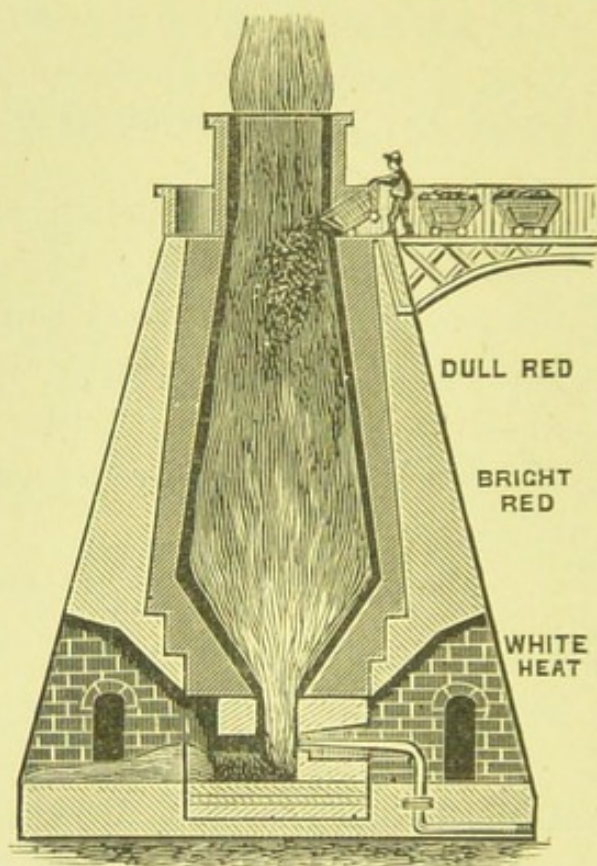


FIG. 26.—Blast Furnace.

and, in the Stassano process, hæmatite (containing 1 to 2 per cent. of manganese), lime, coke, and tar are moulded into briquettes, and smelted in the electric furnace; the product being a manganiferous iron. The furnace consumes 1000 ampères at 50 volts, and yields one ton of iron per 3000 H.P. hours. The consumption of coke by this process is about 10 cwt. per ton less than in the blast furnace.

Vast deposits of iron ores in Norway contain only about 40 per cent. of iron, and are therefore too poor to be

profitably shipped in a crude state. Mr. T. A. Edison has invented a milling and magnetic process for separating, on the spot, the iron contents from the earthy and other impurities in the crude ore, so that a high grade ore is the result. The crude ore is powdered and the iron oxides separated magnetically from the gangue, the phosphorus is practically eliminated, and the concentrated ore is briquetted for shipment. Edison's process extracts both magnetite and hæmatite. It may be stated that as the finally divided ore is not suitable for use in the blast furnace, it is made into briquettes, which contain more than 65 per cent. of metallic iron and less than 0.03 per cent. of phosphorus.

This is the latest development in the iron industry, and it will undoubtedly prove of the greatest value in the treatment of certain iron ores.

(b) *Wrought Iron*.—Cast iron is converted into wrought or malleable iron by the process of puddling. This operation is conducted in a reverberatory furnace (Fig. 27). The cast iron is placed on the bed of the furnace, and becomes covered with a crust of ferric oxide. The melted mass is stirred in order to mix the oxide with the metal; it is then hammered and rolled whilst hot, the mechanical pressure serving to develop a fibrous texture, and to squeeze out slag and other matter retained by the iron. During the process of puddling the percentage of carbon is greatly reduced; and a malleable variety of iron is the result of the operation. In the process, the melted

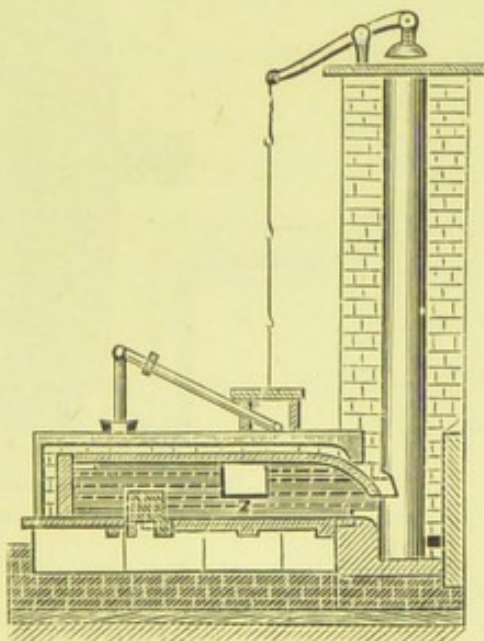


FIG. 27.—Puddling Furnace.

mass of iron is stirred by workmen, but the mechanical rabblers, invented by Griffiths and others, are appliances for superseding manual labour.

(c) *Steel*.—This variety of iron is chiefly produced by the following processes:—cementation, Bessemer, and Siemens-Martin.

Cementation consists in heating wrought iron bars for some days (seven to fourteen) in contact with charcoal or carbonaceous matter; the bars gradually absorb carbon, the outer parts being more fully carbonised than the inner. To secure uniformity of composition and texture, the product is melted, rolled, and hammered.

The Bessemer process is conducted in a vessel called a *converter* (Fig. 28), which is lined with bricks made of ganister

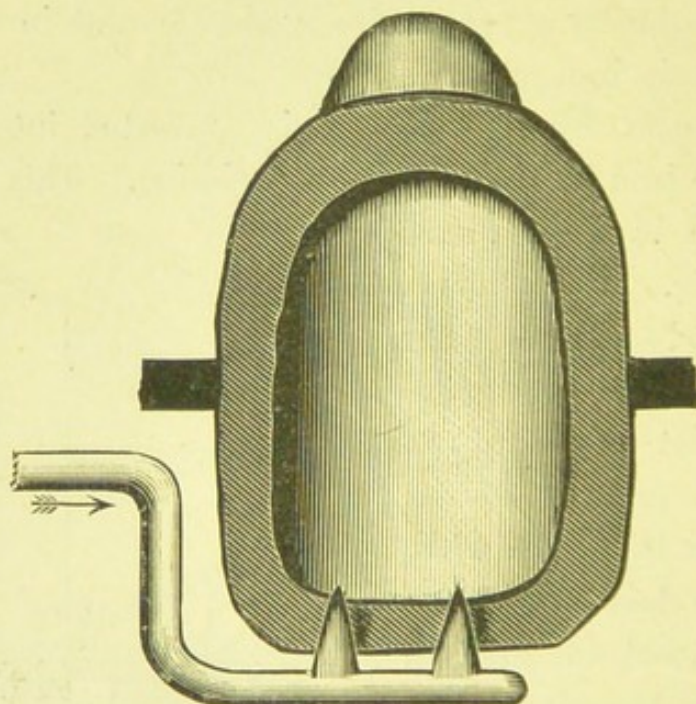


FIG. 28.—Bessemer Converter.

(a siliceous limestone). It is large enough to hold a charge of 10 tons of molten cast iron. Air is blown into the molten metal, and the silicon and carbon are oxidised. What remains is practically wrought iron; to convert this into steel, the necessary amount of carbon must be added. This is done

by adding a quantity of molten spiegeleisen, a substance containing from 5 to 15 per cent. of manganese and about 6 per cent. of carbon, or ferro-manganese, a similar body, which contains about 20 per cent. of manganese. The carbon converts the iron into steel, the temper of which varies according to the amount so introduced, whilst the manganese increases the malleability. The converter is capable of rotation in a vertical plane, for which purpose it is supported upon a pair of trunnion arms resting on standards.

Phosphorus and sulphur greatly interfere with the properties of steel. The former makes it brittle when cold ("cold-short"), and the latter makes it brittle when hot ("red-short"); the addition of manganese counteracts the effect of the sulphur; but if the original ore (used in the preparation of the cast iron) contained more than a minute quantity of phosphorus, a modification of the Bessemer process must be made in order to eliminate phosphorus. In the Thomas-Gilchrist process the converter is lined with a basic material (*burnt* dolomite— CaOMgO), and lime is added at the last "blow"; by this means the phosphorus (oxidised) is retained in the lining and slag.

In the Siemens-Martin process the cast iron is melted in an open-hearth furnace, and wrought iron or scrap steel is added in such quantities as to yield a product containing the requisite amount of carbon.

The percentages of carbon in the three varieties of iron are as follows:—

Cast iron	.	.	.	.	.	1.5 to 5
Steel	.	.	.	.	.	0.3 to 1.5
Wrought iron	.	.	.	.	.	0.1 to 0.3

PROPERTIES.—(1) *Cast Iron* is the product of the blast or electric furnace, and contains the largest amount of carbon; it also contains silicon and small quantities of phosphorus and

sulphur. It is hard, brittle, unweldable, and almost void of ductility. It contracts slightly on solidification. Cast iron melts at a lower temperature than wrought iron or steel. It produces fine castings, and is suitable for dies. (2) *Wrought Iron* is malleable and ductile; but the malleability and ductility are impaired by the presence of small quantities of impurities. These properties are increased with the temperature to which the metal is heated. Wrought iron is weldable, and is the most tenacious of metals; when heated to redness and plunged into cold water, it is *not* hardened (like steel), but retains its softness. (3) *Steel* is the strongest, and one of the hardest and most elastic of the metals used for dental purposes. When it contains only a small amount of carbon, it is called mild or soft steel. Its melting point is higher than that of cast iron, and lower than that of wrought iron.

The *general* properties of iron are the following:—It is a white metal with a greyish tint; and it oxidises rapidly in moist air, and when heated to redness, forming “iron rust.” It is soluble in hydrochloric, nitric, and dilute sulphuric acids, but alkalis have no action on the metal.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . . . .	7.8
Specific heat (water = 1)	. . . . .	0.1138
Hardness (diamond = 100)	. . . . .	45.6
Fusibility	. . . . .	1600° C. or 2912° F.
Malleability (gold = 1, most malleable)	11 <i>wrought iron</i> .	
Ductility (gold = 1, most ductile)	4 <i>wrought iron</i> .	
Tenacity (per square inch in tons)	{ 10 <i>cast iron</i> .	
	{ 29 <i>wrought iron</i> .	
	{ 45 <i>steel</i> .	
Conductivity of heat (silver = 100)	. . . . .	11.9
Conductivity of electricity (silver = 100)	. . . . .	14.6
Expansion by heat	{ 0.00122 <i>wrought iron</i> .	
	{ 0.00107 <i>cast iron</i> .	
Change of volume on solidification	decrease 1.02 per cent.	

DENTAL USES of iron are chiefly in the manufacture of tools and instruments. When cold, iron is the least malleable of the metals in common use, but when heated its malleability is such that it can be rolled into thin sheets and drawn into the finest wire. Steel is used in the manufacture of extracting, excising, and splitting forceps, tweezers, nippers, elevators, excavators, scalpels, lancets, scissors, pliers, drills, enamel cutters, probes, pluggers, and many other instruments and appliances used in dentistry and in the dental laboratory.

EFFECT OF IMPURITIES.—The properties of iron are greatly affected by small quantities of impurities. Phosphorus makes wrought iron and steel brittle when cold, and sulphur renders them brittle when hot. One per cent. of phosphorus renders wrought iron extremely brittle. Carbon converts wrought iron into steel, and the latter into cast iron; in other words, carbon is capable of converting malleable iron into non-malleable or brittle iron (cast iron). Small quantities of copper render wrought iron and steel red-short or unworkable at a red heat; and silicon imparts hardness and brittleness, but with a loss of tenacity. Arsenic, antimony, and bismuth render malleable iron cold-short. Aluminium, in small quantities, makes steel extremely hard (Indian steel or Wootz); and tin renders it cold- and hot-short.

HARDENING AND TEMPERING.—When steel is heated to redness, and suddenly cooled by dipping into water or oil, it is rendered very *hard*, brittle, and elastic; its volume being slightly increased. By a process of *tempering* (that is, reheating and cooling), the steel is prepared for the various purposes for which it may be required, the temper of the metal depending on the temperature at which it is dipped, and the rapidity with which it is cooled. By this means different *degrees of hardness* are obtained, and the temperature necessary for each degree of hardness is determined by the colour of the thin film of oxide (Fe_3O_4) which appears on

the surface of the steel. The shades of colour vary from yellow to blue, and with an increase of temperature. Heated to 221°C . (420.8°F .), and cooled slowly (called tempering to the yellow), steel becomes hard, such as is required for scalpels; but if heated to 289°C . (552.2°F .) and then cooled (called tempering to the blue), it becomes highly elastic, a condition required for watch-springs, swords, etc.

The following table gives the temperatures required to temper various articles used in dentistry, etc. :—

Temperature.		Colour.	Temper of
C°.	F°.		
213	415	Pale yellow.	Lancets.
221	430	Pale straw.	Scalpels, enamel chisels, drills, etc.
228	442	Straw.	Razors.
240	464	Yellow.	Chisels, excavators.
257	494	Brown.	Probes, pluggers.
275	527	Purplish.	Saws, scissors.
289	552	Blue.	Watch-springs.

The temperatures mentioned in the table may be obtained with the greatest degree of nicety by using the Parkes-Martin alloys of lead and tin.¹

Instruments, after hardening, are also tempered by rotating them in a spirit-flame, or upon a block of iron heated to dull redness, until the desired colour appears, then they are plunged into cold water. Over-heating destroys steel, and deprives it of its characteristic qualities; it is therefore essential in heating to "*extract the temper*" of an instrument that is to be re-shaped, only a dull red (700°C . or 1292°F .) should be given to the metal. It is allowed to cool in air,

¹ These alloys contain 14, 15, 16, 17, 28, 60, and 100 parts of lead with 8 parts of tin in each case; for instance, an alloy of 14 parts of lead and 8 of tin melts at 213°C ., and the one containing 100 parts of lead and 8 of tin melts at 289°C .

and is then ready for re-shaping; finally, it is filed, smoothed, and tempered to the right degree of hardness.

CASE HARDENING, that is, the conversion of the surface of soft iron articles into steel, is effected by first heating them in contact with bone-dust, potassium ferrocyanide, or other substance containing carbon, and afterwards cooling the metal by dipping it into water.

ANNEALING is a process for softening steel and iron which have become hard or brittle by rolling, hammering, etc. They are heated to a cherry-red (900°C. or 1652°F.), and allowed to cool slowly in ashes, sand, lime, and other bad conducting substances.

BURNING STEEL AND IRON.—When steel or iron is heated to redness and exposed to the air, a scale of oxide is produced upon the surface, and the steel or iron becomes “burnt.” In this state the metal is friable, unweldable, and cannot be restored *completely* to its original state.

ALLOYS.—(1) *Iron and Zinc* unite together to form alloys which are hard, crystalline, and brittle. (2) *Iron and Tin* unite to form slightly malleable alloys. One containing 70 per cent. of tin is ductile, but with 30 per cent. of tin the alloy is crystalline and brittle. (3) *Iron and Tungsten* unite to form valuable alloys; and steel containing tungsten forms excellent cutting tools. Mushet’s steel (containing 3 per cent. of tungsten) is softened by heating and quenching in water. (4) *Iron and Chromium* form alloys; and those containing 0.1 and 0.15 per cent. of chromium forge well and make excellent razors—especially for microtome work. The presence of chromium in steel increases its tenacity, but renders it unweldable.

Iron also alloys with nickel, cobalt, manganese, and other metals.

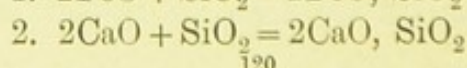
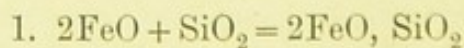
CHAPTER XIV

COPPER

Symbol, Cu ; Atomic weight, 63.6

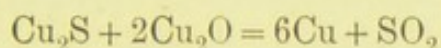
OCCURRENCE.—Copper is found as metal in considerable quantity in the vicinity of Lake Superior, as well as in other parts of the world. In combination with other elements, it occurs chiefly as cuprite (Cu_2O), copper glance (Cu_2S), malachite ($\text{CuCO}_3, \text{Cu}_2\text{OH}$), azurite ($2\text{CuCO}_3, \text{Cu}_2\text{OH}$), and associated with iron sulphide in copper pyrites.

PREPARATION.—1. *The Welsh Process* of extracting copper from sulphides consists of six operations, all of which are performed on the hearths of *reverberatory* furnaces (*vide* chapter on Lead). (a) Calcination is the first operation, the ore being heated to a low temperature on the bed of the furnace. The chief objects of this process are the removal of part of the sulphur and the volatilisation of as much arsenic and antimony as possible. As the atmosphere of the furnace is reducing (due to sulphur dioxide), ferric iron is reduced to the ferrous state. (b) Fusion is the second operation, and the calcined ore (from a) is heated to a higher temperature on the hearth of a furnace with a larger grate area in proportion to the hearth. At this stage ferrous oxide forms, and this combines with silica (added as a flux), forming the slag (ferrous and lime silicate)—



whilst the cuprous and ferrous sulphides still remaining form the regulus or "coarse metal." The contents of the bed or hearth are run off in two portions—the coarse metal into water to finely divide it, and the slag is thrown away.

The coarse metal is again calcined and fused for the same objects as already explained. The product obtained after the second fusion is termed "white metal," and is principally cuprous sulphide. (c) Reduction is the fifth operation, and its object is to partially oxidise the cuprous sulphide, and to induce the remainder of the iron and other impurities to form a slag. When the oxidation has proceeded far enough, the temperature is raised, and metallic copper is the result of the action of the oxide on the sulphide of copper—



The metal obtained in this operation is termed "blister copper." (d) Refining blister copper is performed in an oxidising atmosphere on the bed of a furnace, and impurities, such as iron, arsenic, sulphur, antimony, etc., still remaining, are oxidised and skimmed off as dross. Powdered anthracite is sprinkled on the surface of the molten metal, and a pole of green wood is thrust beneath the surface of the metal, when the gases and steam evolved from its decomposition reduce any copper oxide. By this means the metal is rendered malleable.

2. *The Continental Process* for extracting copper from its ores is to calcine them to the oxide, the latter being reduced to the metallic state with coke in a special form of blast furnace.

3. *The Electrolytic Process* is principally adopted for the removal of the impurities from crude copper, although it has been used for the purpose of obtaining copper from ores and "white metal."

For the removal of impurities, ingots of copper are suspended in tanks containing a solution of copper sulphate to

which sulphuric acid is added. The ingots constitute the anodes (+), while the cathodes (-) consist of thin sheets of copper; and during the passage of the electric current the pure copper is deposited on the cathodes. The impurities pass into solution with the exception of gold and silver, which collect at the bottom of the tanks. By the electrolytic process pure copper is obtained, as well as gold and silver. This process is by far the most important industrial application of electro-metallurgy, the value of the annual output of this variety of copper being over 12 million pounds sterling.

The copper produced by the electrolytic process is extremely pure, but unfortunately it has generally a crystalline and somewhat porous structure, and requires fusing before it is submitted to the rolling and drawing mills. This drawback has, however, been overcome by the process of Elmore and Secrétan. The copper is deposited from a solution of copper sulphate on to a slowly rotating steel mandrel,¹ and during the process of deposition the freshly deposited copper is continuously burnished by an agate burnisher which travels forwards and backwards along the length of the mandrel. By this means the metal is compressed and consolidated, and the crystalline-porous structure of electrolytic copper is obviated.

The current density used is about 16 ampères per square foot of cathode surface. It is stated that the copper produced by the Elmore-Secrétan process will stand a stress of 26.5 tons per square inch, with an extension of 16.5 per cent.; the limit of elasticity being reached with a load of 23.3 tons per square inch.

Mr. S. Cowper-Coles² has greatly improved the process for obtaining copper by electrolysis. His process consists in depositing the copper from an acid sulphate solution on a

¹ Previously black-leaded.

² *Journal Institution of Electrical Engineers*, 1900, vol. xxix. p. 258.

rapidly revolving cathode, the peripheral speed being about 500 feet per minute. Hard drawn wire made by this process has a tensile strength of 29 tons per square inch, and an electrical conductivity of 99 per cent. The solidity, hardness, etc., are partly produced by the burnishing action caused by the friction between the revolving cathode and the solution; and also partly to the throwing off, by centrifugal force, of any solid particles from the surface of the cathode. A high current density is used, namely, 200 ampères per square foot, and the copper deposited is in a coherent state, and does not require re-melting.

PROPERTIES.—Copper is a red metal. It is hard, elastic, sonorous, malleable, ductile, and tenacious. Dry air is without action upon it at ordinary temperatures, but in the presence of moisture and carbon dioxide the metal becomes corroded, and coated with a deposit of basic carbonate. Hydrochloric and sulphuric acids have no action upon it; the latter, however, undergoes decomposition when heated in contact with copper, sulphur dioxide being evolved. Copper is readily soluble in nitric acid. It is not acted upon by pure water, nor, indeed, has a current of steam any action on the red-hot metal. A solution of salt (NaCl) acts upon the metal, forming the green oxychloride; but alkalies (except ammonia) have very little action upon it. Sulphuretted hydrogen attacks it, forming a film of sulphide.

Copper is readily granulated by pouring the molten metal into water. It may be stated that most metals are granulated in the same way, the exception being lead.¹

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	.	.	8.95
Specific heat (water = 1)	.	.	0.0952
Hardness (diamond = 100)	.	.	45.2

¹ Lead is granulated by pouring the molten metal into a wooden box and shaking the latter, so as to finally divide the lead.

Fusibility.	1050° C. or 1922° F.
Malleability (gold = 1, most malleable)	4
Ductility (gold = 1, most ductile)	6
Tenacity (per square inch in tons)	13 to 15
Conductivity of heat (silver = 100)	85
Conductivity of electricity (silver = 100)	97·8
Expansion by heat	0·00167
Change of volume on solidification	decrease 7·1 per cent.

EFFECT OF IMPURITIES ON COPPER.—Small quantities of other metals greatly impair the properties of copper. Iron, arsenic, copper oxide, bismuth, antimony, silver, tin, lead, and sulphur are the principal impurities found in commercial copper.

Iron, sulphur, and antimony render copper hard, and thereby impair its malleability and tenacity. Copper containing copper oxide (Cu_2O) is brittle, and requires poling to render it malleable. Arsenic, in small quantities, hardens copper, but does not impair its malleability to the same extent as antimony; bismuth, however, deteriorates the toughness of the metal.

DENTAL USES.—Copper is used as a constituent of some dental amalgam-alloys; and in the form of frames for soldering flat teeth. Copper frames¹ prevent warping, by binding the plate and preventing its expansion.

Vulcanisers are also made of copper.

ALLOYS.—(1) Copper and gold unite in all proportions, and form an important series of alloys (see Gold). (2) *Copper and Silver* also combine in all proportions. These alloys are of great value in the arts (see Silver). (3) *Copper and Tin*² unite to form a series of alloys known as “bronzes”; and many of these alloys are described under the metal tin (*q.v.*).

¹ Pieces of sheet-copper bent into oblongs or semicircles; they are filled with the investing material, and the denture is then embedded.

² Babbitt's metal contains 9·12 per cent. Cu, 18·19 per cent. Sb, and 72·69 per cent. Sn. The alloy is non-shrinking, hard, and lower fusing point than zinc.

They melt at moderate temperatures, and form excellent castings. Miller and Jung's copper-tin amalgam-alloy contains 97·5 parts of copper and 2·5 of tin. It is hard, and sets well; and the tin lessens the action of the oral fluids on the copper, which is a valuable property. The colour of the fillings is grey, while the ordinary copper amalgams turn quite black from the formation of sulphide. This alloy has little or no shrinkage, and forms a watertight filling. As iron is the chief enemy in copper amalgams for dental purposes, it is of the utmost importance that the amalgam should be free from traces of iron; consequently electrolytic copper should be used in preparation of amalgam-alloys. (4) *Copper and Zinc* unite, forming a series of important alloys of which the following are only a few examples:—

	Copper.	Zinc.
Brass	70	30
Muntz metal	60	40
Pinchbeck	93	7
Mannheim gold	75	25
Dutch metal	76	24
Hard solder for copper or iron	57	43
Hard solder for brass	50	50

Brass is the typical alloy of copper and zinc, and its composition varies considerably. It has been prepared from ancient days, and a coin of Titus Claudius was found to contain 81·4 per cent. of copper and 18·6 per cent. of zinc. Brass is harder than copper, melts at a lower temperature, and forms fine castings. It is malleable and ductile; but both of these properties vary with the composition and temperature. (5) *Copper and Aluminium* produce alloys of a golden colour, which are malleable and ductile. If, however, the aluminium is in excess, the alloys become brittle and crystalline. The alloy containing 10 per cent. of aluminium

is known as aluminium bronze¹ (see Aluminium). (6) *Copper and Nickel* unite in all proportions, and an alloy containing 71.4 per cent. of copper and 28.6 of nickel is as white as silver. It is an excellent alloy for plating. (7) *Copper and Mercury* amalgamate when the former metal is in a finely-divided state. The amalgam becomes hard and crystalline after a short time. It is rendered soft and plastic by pounding and kneading, but again becomes hard after standing. Its density is the same in both the soft and hard states, so there is no contraction or expansion.² It is malleable, admits of a good polish, but is blackened by sulphuretted hydrogen, and thereby stains the teeth. This defect can be prevented by lining the cavity with a phosphate cement. Copper amalgam dissolves rapidly in acid saliva; therefore it has been suggested that a copper amalgam filling should be finished with a facing of ordinary amalgam. Copper amalgam is pleasant to work, fine-grained and plastic, sets either slowly or rapidly—the rapidity of setting being inversely proportional to the amount of mercury present in the amalgam. Although there are many advantages to be gained in using copper amalgams, there are also many disadvantages; for instance, copper sulphate, according to Tomes, is always formed on the exposed surface of the filling, and as the salt is soluble, it permeates the dentine. There are also other disadvantages well known to the manipulator of copper amalgams. (8) *Copper and Manganese* unite in all proportions. An alloy containing 99 per cent. of copper and 1 per cent. of manganese resists the action of corrosive fluids. The hardness of copper-manganese alloys is directly proportional to the amount of manganese present in the alloy. The 1 per cent. alloy is the softest, a 5 per cent. alloy is harder, and a 50 per cent. alloy is so hard that it is

¹ See Guillet's paper on copper-aluminium alloys (Cu_3Al , CuAl , CuAl_2) in *Comptes Rendus*, vol. cxxxiii. (1901).

² Dr. G. Cunningham says that it does contract.

impossible to file it with the best steel files. According to Lewis, alloys containing 70 and 80 per cent. of manganese spontaneously fall to powder, which is not the case with the alloy containing 90 per cent.

MODES OF PREPARATION, AND PROPERTIES OF COPPER AMALGAMS.—(1) *Rollins' Method* is the following:—A solution of copper sulphate, containing 50 lb. (5 gallons) of distilled water, 17 lb. of copper sulphate, and 1 lb. of sulphuric acid, is poured into a wooden barrel (Fig. 29); 10 lb.

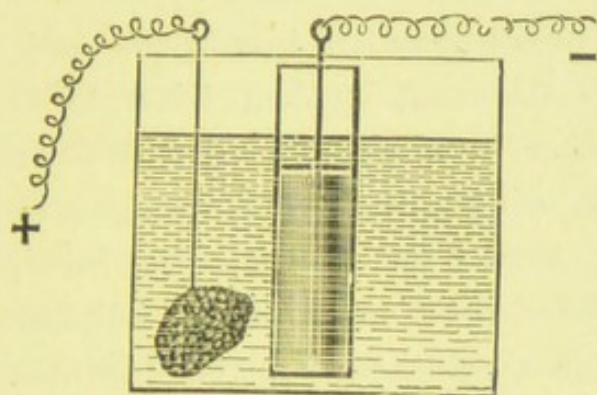


FIG. 29.—Preparation of Copper Amalgams.

of mercury are placed in a glass jar, which is then immersed in the solution of copper sulphate. The wire from the cathode (−) is immersed below the level of the surface of the mercury, and a bag containing granulated copper is suspended in the solution of copper sulphate by the wire from the anode (+) of the battery or dynamo. The current passes until the mercury has combined with enough copper to form a thick paste. The amalgam is washed, squeezed, and allowed to harden. (2) *Weagant's Method* is as follows:—A glass vessel is nearly filled with a 15 per cent. solution of copper sulphate, mercury is poured into the same vessel to cover the bottom, and a clean plate of iron (previously immersed in dilute sulphuric acid) is made to stand in the mercury. Copper is deposited on the iron, and the mercury amalgamates with the precipitated copper. The deposition is

allowed to continue until all the copper is precipitated. The liquor is then syphoned off, and more copper sulphate solution is added, until the mercury absorbs no more copper. The amalgam is placed in a mortar, thoroughly washed, and squeezed in chamois-leather to remove the surplus mercury. It is again washed, rubbed, and squeezed; these operations being repeated several times. When all the surplus mercury has been removed, the amalgam is gently heated in an iron crucible. The amalgam should set instantly, and become hard. Weagant's amalgam is used in the following way:—Place a small quantity in an iron spoon and “heat it until mercury begins to sweat”; then triturate it in a mortar, and work together in the hand. If it is too soft, squeeze in chamois-leather, using pliers. This amalgam improves by age. (3) *Chandler's Method* is as follows:—Precipitated copper (from an acidulated solution of copper sulphate by means of zinc) is placed in a solution of mercury nitrate. The copper becomes coated with mercury, and an amalgam formed. The amalgam is washed, triturated in a mortar, and finished by heating in a crucible.

Sullivan's Amalgam is prepared by placing plates or rods of iron or zinc (preferably iron) into a hot dilute solution of copper sulphate, and thereby precipitating the copper. The latter is washed, and triturated in a mortar with mercury, the amalgamation being facilitated by the addition of acidulated water. The amalgam is washed with dilute ammonia, and finally made into small sticks or pellets. The amalgam is composed of pure copper and mercury in variable proportions:—

	I.	II.	III.	IV.	V.
Copper . . .	3	3	$2\frac{1}{2}$	3	3
Mercury . . .	6	7	$5\frac{1}{2}$	$6\frac{1}{2}$	8

Copper amalgams soften on heating (amorphous state) and harden on cooling (non-amorphous or crystalline state). If they are heated too strongly, the mercury volatilises and the copper burns (CuO). Great diversity of opinion exists in regard to the advantages and disadvantages of Sullivan's amalgam as a filling material. Mr. Humby has proved beyond dispute that it does not resist caries at the cervical edge—a fact that every observer must admit. In any other situation where it does not touch the gum it will wash out; and Mr. C. A. Clark has seen roots, the crowns of which have been excised, that have had the canals filled with it washed out and globules of mercury remaining. Dr. G. Cunningham advises that Sullivan's amalgam should be finished with a facing of ordinary amalgam; and this is an excellent *modus operandi* which the dentist should note.

Another disadvantage is, that if alloy filings are added (with the object of increasing the durability) to Sullivan's amalgam while it is being prepared in the mortar, the resulting mass will never set hard. Sullivan's and other copper amalgams were supposed to possess antiseptic properties, but experience has shown that this is not the case, and Goadby has proved it experimentally. As submarine stoppings, copper amalgams are the least affected, as it is essential that a *soft* mass be used when filling. If a hard mass is used, it disintegrates and becomes unworkable.

It has already been stated that Sullivan's amalgam is attacked by the oral secretions, and washes out; but the following fact, first noted by Mr. C. A. Clark, may not be generally known. If a large cavity in an extracted molar is excavated and then filled with the copper amalgam, it will be found almost invariably that, if it is placed in ink, after a lapse of a few hours not only the tooth, but the filling will be split. If such a simple fluid as ink will cause a copper amalgam to expand with so much energy, will the oral secre-

tions, or the products of food and bacteria¹ in the mouth, influence amalgams in the course of months or years to expand or contract? It is an important problem of research, as the mouth becomes a veritable laboratory, with its various chemical, bacteriological, and electrical changes; and this remark applies to a greater extent when the mouth is in an abnormal condition—due to the action of specific diseases of the gums,² palate, etc.

¹ We know very little about the traces of alkaloidal and other substances produced in the mouth by bacteria.

² Concerning affections of the gums, see Klingelhöfer's paper in *Verhandlungen der deutschen odontologischen Gesellschaft*, Bd. vii. Hefte 1 und 2.

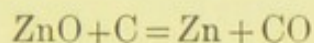
CHAPTER XV

ZINC

Symbol, Zn ; Atomic weight, 65.4

OCCURRENCE.—The chief ores of zinc are blende (ZnS), calamine (ZnCO_3), a silicate and an oxide.

PREPARATION.—Blende and calamine are roasted or calcined to expel sulphur (as SO_2) and carbon dioxide, and in each case to convert the zinc into oxide. The zinc oxide, mixed with coal, is distilled in cylindrical retorts ; the metal, being volatile, condenses in clay or iron receivers—



Zinc ores always contain cadmium ; and this, having a lower boiling point, volatilises first, producing brown fumes of cadmium oxide (CdO). When the brown fumes disappear, zinc begins to distil, and in the Belgian process iron nozzles are then placed on the open ends of the receivers. The metal obtained always contains zinc oxide, from which it is freed by re-melting. The oxide rises to the surface, forming a scum, which is removed, and the metal is finally cast into ingots. It is sent into the market as “spelter.”

The electrolytic extraction of zinc cannot yet be considered a commercial success ; although Casaretti and Bertani have invented a process for reducing zinc oxide in the electric furnace. A mixture of the oxide, 20–30 per cent. of coke, and chalk if silicates be present, is moulded into briquettes

and heated in a furnace with oscillating electrodes. A furnace of 200 H.P. yields over 220 lb. of zinc per hour.

The extraction of zinc from aqueous solutions by electricity cannot be said to have been an unqualified success. The great trouble is that the free acid formed on electrolysis re-dissolves the deposited zinc, and so lowers the efficiency of the process.

PROPERTIES.—Zinc is a bluish white metal with a crystalline fracture. It is soluble in dilute mineral acids and strong solutions of caustic alkalies. Dry air at the ordinary temperatures has no action upon zinc, but it becomes coated with a film of oxide when exposed to moist air. Zinc is attacked by hot water and by water impregnated with carbon dioxide, but pure cold water has no action upon it. It is a brittle metal at the ordinary temperatures; but when heated to between 100° and 150° C., it becomes malleable and ductile. Above 200° C. it loses its cohesion, and may readily be powdered. Zinc requires annealing in order to restore its malleability, as it is hardened by hammering and rolling. The metal burns at a red heat, forming zinc oxide. Commercial zinc contains traces of iron, cadmium, arsenic, and sulphur. It has the valuable property of precipitating most of the metals from their solutions.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . .	6.9
Specific heat (water = 1)	. . .	0.0955
Hardness (diamond = 100)	. . .	35.8
Fusibility	. . .	415° C. or 779° F.
Malleability (gold = 1, most malleable)	. . .	10
Ductility (gold = 1, most ductile)	. . .	10
Tenacity (per square inch in tons)	. . .	3.3 to 8.3
Conductivity of heat (silver = 100)	. . .	28.1
Conductivity of electricity (silver = 100)	. . .	29.6
Expansion by heat	. . .	0.00167
Change of volume on solidification	decrease 11.1 per cent.	

DENTAL USES.—Zinc is used in making dies for swaging plates, and occasionally it is used for counter-dies. The metal is hard, tough, malleable, and melts at a comparatively low temperature—properties of great value in making dies; but, unfortunately, zinc contracts considerably on solidification. Austin proved that a zinc die measuring 2 inches, transversely contracts 0.027 inch from outside to outside of the alveolar ridge. In an arch about half an inch in depth, the contraction between the level of the ridge and the floor of the palate would be 0.007 inch. As well may be imagined, this contraction is a most serious matter in deep arches.

When melting zinc for making dies, the metal should be heated to a temperature a little above its melting point, as over-heating completely spoils it; and in preparing counters, the metal (just fluid) is poured directly upon the zinc die—a film of oxide on the latter preventing the counter adhering to the die. Another method for preventing adhesion is to coat the die with blacklead. When cold, the die and counter readily separate. A zinc counter is necessary for swaging iridio-platinum (*q.v.*).

Metal plates are not as firm as rubber, because they do not represent so perfect a reverse of the mouth. This is owing to the contraction of the zinc: in reality, the plate has been struck to a model slightly smaller than the plaster one, so that when it is placed upon the latter it must ride or grasp upon the outer edges. According to Rollins, a perfect die can be made by preparing the surface of the impression for electrotyping and then depositing copper on it, which, if the die is to be used for striking, can be backed with a harder metal to the right firmness and form. Such a die is perfect, and harder than any now in use.

Dies of fusible metals have been used by some dentists. They are not so hard as those made of zinc, but they expand

on solidification—a property of the utmost value in preventing a plate from being a misfit.

Although zinc contracts 11.1 per cent. on solidification, it controls shrinkage in silver-tin amalgam-alloys. One part of zinc in 100 parts of alloy (40 silver, 60 tin) prevents contraction, imparts a pasty plasticity to the amalgam, adds to whiteness of the filling, and assists in maintaining its colour.

PURIFICATION OF ZINC.—By repeated melting, zinc becomes useless for dental purposes. This is due to small quantities of zinc oxide and iron (the latter from the ladle) dissolving in it.

Zinc may be purified by the following processes:—

(a) Melt the zinc, add a few lumps of sal-ammoniac (NH_4Cl), stir well, and cast.

(b) Melt the zinc, and pour on it a small quantity of hydrochloric acid, and stir with a stick. The impurities separate and collect on the surface as dross, which can be removed.

(c) To remove iron, sulphur mixed with grease is stirred about at the top of the molten metal. The iron, as sulphide, ultimately floats on the surface of the zinc.

(d) Lead is removed by allowing the zinc to cool slowly, when the two metals separate. The soft lead is then cut out with a chisel.

ALLOYS.—In suitable proportions, zinc imparts hardness to certain alloys, but in larger proportions it frequently induces brittleness. Zinc lowers the melting point of alloys, and renders them less liable to be attacked by exposure to the atmosphere. (1) *Zinc and Tin.*—Richardson's alloy, containing 80 per cent. of zinc and 20 of tin, is used for dies for swaging plates. This alloy is superior to zinc, as the impression from the sand is much finer, and the contraction on cooling is practically *nil*. (2) *Zinc and Copper* unite together to form a series of alloys (see Copper). (3) *Zinc and Bismuth* separate on solidification. (4) *Zinc and Lead*

also separate on solidification. (5) *Zinc and Iron*.—Galvanised iron is prepared by dipping iron plates into a bath of molten zinc. The iron becomes coated with zinc, which protects it from the action of air and moisture. Zinc can now be deposited on iron by means of the electric current; and in the Cowper-Coles process there is no reduction in the tensile strength of iron and steel galvanised. This is an important step forward in electro-metallurgy. (6) *Zinc and Mercury*.—As zinc readily amalgamates with mercury, it enters into the composition of many gold amalgam-alloys; but the amalgams of zinc and mercury alone are useless.

ZINC COMPOUNDS AND CEMENTS.—(1) *Zinc oxide* (ZnO) is prepared by burning zinc in air, and collecting the oxide in chambers; but for dental purposes it is prepared by adding a solution of zinc sulphate to one of sodium carbonate; the precipitated zinc carbonate is washed, dried, and ignited to expel carbon dioxide and water. Zinc oxide is a white, soft powder of a specific gravity, 5.6. It is yellow when hot, but becomes white on cooling. Zinc oxide is insoluble in water and dilute alkaline solutions, but is soluble in acids and strong alkaline solutions. It does not blacken by sulphuretted hydrogen. Zinc oxide is the chief ingredient in the filling materials known as cements. (2) *Zinc chloride* (ZnCl_2) is prepared by dissolving zinc or zinc carbonate in hydrochloric acid, and evaporating the solution to dryness. It is a white substance, which is soluble in water, alcohol, and ether, and is very deliquescent. Zinc chloride is used in dentistry as an antiseptic, disinfectant (germicide), and deodoriser; and its solution is employed in connection with zinc oxide, to make an osteoplastic filling for teeth. (3) *Zinc sulphate* (ZnSO_4) is made by dissolving zinc in sulphuric acid, and on a large scale by roasting blende in contact with air, whereby the sulphide is converted into sulphate. Zinc sulphate is soluble in water, insoluble in alcohol.

Zinc oxide, chloride, and sulphate form the basis of dental cements—a most important class of materials. Four principal varieties of cements are in use, under the names of—

1. Zinc oxyphosphates.
2. Zinc and aluminium oxyphosphates.
3. Zinc oxychlorides.
4. Zinc oxysulphates.

The materials used for the preparation of the cements consist of a powder and a liquid, and when mixed on a slab by the dentist they produce an osteoplastic filling.

Oxyphosphate Cement.—By the combination of zinc oxide and one of the varieties of phosphoric acid (H_3PO_4 , HPO_3 , or $\text{H}_4\text{P}_2\text{O}_7$) a plastic material is obtained, known as oxyphosphate cement. Zinc oxide should be worked into the acid *gradually* until the mass is stiff; the chief point to bear in mind is not to add too much oxide at a time.

Alumina is sometimes used as an ingredient in the powder of oxyphosphate cements. Fletcher's "dental porcelain" is a double phosphate of zinc and aluminium, and is a valuable filling. The oxyphosphate cements, when carefully prepared, are only slightly affected by the oral fluids, and can be contoured when submerged. They are, however, somewhat soluble in *alkaline* solutions, and their period of duration varies from two to nine years. Oxyphosphates are also used for setting crowns and bridges, and as linings for amalgam fillings.

Oxychloride Cement.—The powder is zinc oxide, or zinc oxide mixed with glass, borax, and silica; and the liquid is a solution of zinc chloride. According to Feichtinger, an excellent oxychloride cement is prepared by adding 3 parts of zinc oxide and 1 part of glass powder to 50 parts of a solution of zinc chloride (specific gravity = 1.5)¹ to which is further added 1 part of borax dissolved in the smallest

¹ Ruble's cement consists of zinc oxide and a solution of zinc chloride (sp. gr. = 1.9 to 2).

quantity of water. Another oxychloride cement is prepared by grinding together 30 parts of zinc oxide, 1 part of silica, and 2 parts of anhydrous borax. The mixture is heated in a crucible to bright redness. The mass or "frit" produced is ground to a fine powder, and then mixed with thrice its weight of zinc oxide. This powder is made into a stiff paste with a solution of zinc chloride (1 ounce of zinc chloride in 5 drachms of water).

Zinc oxychloride is plastic when mixed, but rapidly hardens with age. It is used for filling, lining, and restoring the colour of discoloured teeth. As osteoplastic fillings, the oxychloride cements are easily worked, harden in a few minutes, and may be polished with an agate burnisher. They are not permanent fillings, owing to the destructive action of the oral fluids. The addition of silica to these cements greatly increases the hardness after setting.

Oxysulphate Cement.—The powder contains—

	I.	II.
Calcined zinc sulphate .	25 per cent.	33 per cent.
Zinc oxide . . .	75 „	67 „

The liquid contains 15 grains of gum-arabic and 1 grain of calcium sulphite dissolved in $\frac{1}{2}$ ounce of water—and the solution filtered through cotton-wool.

Unlike the oxyphosphates and oxychlorides, the oxysulphate cements are non-irritating. They set rapidly, and are more or less acted upon by the oral fluids (acid and alkaline).

Fletcher's "Dentine" is a valuable variety of oxysulphate cement, and has been used by Miller¹ for the following purposes:—Capping exposed pulps; supporting pericementitic teeth while perforating or removing hard fillings from them; fixing loosened teeth while filling them with gold; pressing

¹ *Dominion Dental Journal*, 1892.

the gum away from cervical margins of cavities; enclosing applications of all kinds in pulp and tooth treatment; and fixing metallic caps over teeth in regulations.

In addition to the above-mentioned cements, there are certain varieties of the *oxychloride* cement; among them being the following:—(1) *Rostaing's Cement* contains calcium phosphate, zinc oxide, ammonium phosphate, phosphoric acid, cadmium oxide, magnesia, boric acid, and manganese dioxide or ochre (to tint). This mixture ultimately forms a "frit," and is ground to a powder. The powder is mixed with a syrupy solution of zinc chloride. It forms a hard cement. (2) *Huebner's Cement* contains zinc oxide, manganese dioxide, borax, glass-powder, and ochre (to colour) as the powder, which is mixed with a solution of zinc chloride. In the preparation of Ruble's, Rostaing's, and Huebner's cements, the zinc oxide is treated with nitric acid and then calcined, the object being to obtain a denser oxide.

Cements for filling teeth should possess the following qualities:—

1. They should be easily manipulated.
2. They should not set too rapidly, but the length of time of setting depends more upon the fluidity of the paste than upon anything else.
3. They should be dense, hard, and insoluble.
4. They should form watertight plugs.
5. They should be unaffected by contact with the fluids of the mouth.
6. They should be non-irritating.
7. They should be free from contraction or expansion.
8. They should adhere firmly to the walls of the cavity.

The oxy-cements in general use are all more or less acted upon by the acid and alkaline fluids of the mouth; consequently they do not form permanent stoppings. This is a misfortune, as they have practically the same specific gravity

as the tooth,¹ which is an important point to bear in mind when one considers the grinding action of molars, and the pressure exerted on the surrounding shell. A filling with a high specific gravity tends to force the walls of the tooth apart, *i.e.* during mastication.

¹ Non-metallic cements are used for temporary fillings; among them are—

<i>Mastic Cement.</i>					<i>Sandarac Cement.</i>				
Mastic	.	.	.	2 parts.	Sandarac	.	.	.	3 parts.
Ether.	.	.	.	1 part.	Ether	.	.	.	2 „
					Absolute alcohol	.	.	.	6 „

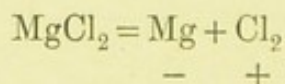
CHAPTER XVI

MAGNESIUM

Symbol, Mg; Atomic weight, 24.36

OCCURRENCE.—Magnesium occurs as dolomite, brucite, mica, asbestos, talc, and is present in other minerals.

PREPARATION.—The metal is prepared at the Hemelingen Works (Germany) in the following way:—A crucible of cast steel (Fig. 30) serves the place of both crucible and cathode (–). This crucible (A) is placed on the hearth of a furnace, by means of which magnesium chloride is brought to a state of fluidity. A cylindrical vessel (B) is let into the steel lid of the crucible which encloses the carbon anode (+). The bottom of the cylinder is perforated so that the contents of the crucible and the carbon are in direct contact with each other. The cylinder is closed at the top, and is connected with a pipe (C) through which the liberated chlorine escapes. The reaction is the following:—



A current of 6 to 8 volts is used, and it is generally calculated that from 40 to 45 grms. of the pure metal can be obtained per H.P. per hour.¹

Magnesium is also produced by heating the chloride with sodium or potassium.

¹ For further information, see Gerdes' *Einführung in die Elektrochemie*. This book gives a full account of ionic dissociation.

PROPERTIES.—Magnesium is a white, hard, *light*, malleable, ductile metal. It is not attacked by dry air, but

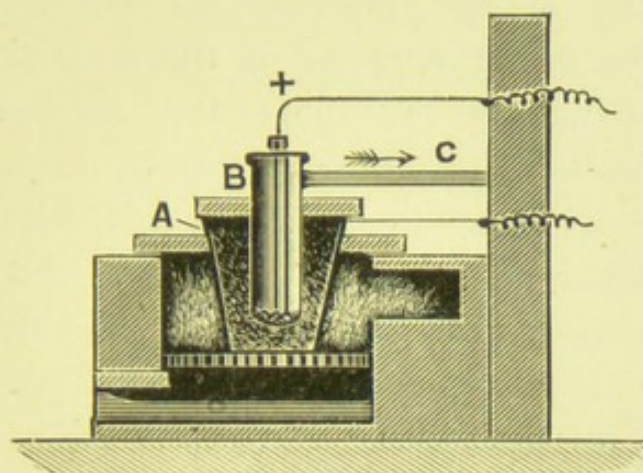


FIG. 30.—Magnesium Furnace.

oxidises in the presence of moisture. It burns in air, with the production of the brilliant magnesium light. Magnesium combines at a high temperature with nitrogen, forming a nitride (Mg_2N_3). Dilute acids dissolve it, but alkalies have no action on the metal.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . .	1.743
Specific heat (water = 1)	. . .	0.2499
Hardness (diamond = 100)	. . .	20
Fusibility	. . .	454.4° C. or 850° F.
Malleability (gold = 1, most malleable)	. . .	9
Ductility (gold = 1, most ductile)	. . .	9
Tenacity (per square inch in tons)	. . .	28
Conductivity of heat (silver = 100)	. . .	32
Conductivity of electricity (silver = 100)	. . .	41
Expansion by heat	. . .	0.00228
Change of volume on solidification	. . .	decrease.

DENTAL USES.—Magnesium has been used in the form of wire or ribbon to produce a white light for matching artificial teeth, and for operations in the mouth; but the latter use is now largely superseded by the electric light. As magnesium is lighter than aluminium, and as its salts are

non-poisonous, it is possible that its introduction into amalgam and other alloys would be of great advantage in dentistry. Although many of its properties are antagonistic to its general use for dental purposes, at the same time it should be borne in mind that its alloys have *not* necessarily the same properties as the metal (solubility in dilute acids, etc.). Magnesium would make the alloys of gold, silver, etc., much lighter, and this is an important property. An ideal filling should have, among other properties, the same specific gravity as the tooth. During mastication of food there is always a tendency to force the "shell" apart when the ordinary heavy fillings are used; and no doubt teeth are often destroyed by this means.

ALLOYS of magnesium have not been investigated to any great extent. (1) *Magnalium* is the name given by Mach to a series of alloys of magnesium and aluminium. These alloys contain from 5 to 30 per cent. of magnesium; and magnalium, containing 10 per cent. of magnesium and 90 of aluminium, has the colour of silver, and is unalterable in air and water. (2) *Magnesium and Mercury* amalgamate at ordinary temperatures, and the amalgam decomposes water like the amalgams of sodium and potassium. It should be mentioned, however, that the amalgams of magnesium alloys do not decompose water unless the magnesium is in excess. (3) *Griffiths' Alloy* contains magnesium (see Aluminium).

CHAPTER XVII

CADMIUM

Symbol, Cd; Atomic weight, 112.4

OCCURRENCE.—Cadmium accompanies zinc in its ores; and is also found as a sulphide in the mineral Greenockite (CdS).

PREPARATION.—Cadmium is more volatile than zinc, and distils over with the first portions of zinc in the smelting of that metal. The mixture of cadmium and zinc is dissolved in hydrochloric acid, and metallic zinc placed in the solution, which precipitates the cadmium in a spongy form. It is melted, and cast into rods about a quarter of an inch in diameter. The metal is also obtained from its oxide by reduction with charcoal.

PROPERTIES.—Cadmium is a white metal (with a bluish tint), resembling zinc in appearance. The metal is slowly oxidised on the surface by exposure to air. It is soluble in hydrochloric, nitric, sulphuric, and acetic (vinegar) acids. Water has no action upon cadmium, but alkaline solutions slowly attack it. Amalgam-alloys containing cadmium have been used as filling materials, but they do not withstand the action of the oral secretions, and frequently the plugs were stained yellow, owing to the formation of cadmium sulphide. The sulphide so formed protects the stopping from further action, as it is not attacked by alkaline fluids.

Cadmium is malleable and ductile, but at 80°C . is very brittle.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	8.7
Specific heat (water = 1)	0.0567
Hardness (diamond = 100)	25.2
Fusibility	320° C. or 608° F.
Malleability (gold = 1, most malleable)	9
Ductility (gold = 1, most ductile)	8
Tenacity (per square inch in tons)	3
Conductivity of heat (silver = 100)	20.1
Conductivity of electricity (silver = 100)	24.4
Expansion by heat	0.00306
Change of volume on solidification	decrease.

DENTAL USES.—Cadmium is a constituent of certain fusible alloys (see Bismuth); and it has been used in dental amalgam-alloys. The metal was first introduced as a filling material by the late Dr. Evans¹ in 1848. He used an alloy of tin and cadmium.

The *advantages* and *disadvantages* of cadmium in alloys and amalgams are—(a) Its presence in amalgams gives whiteness to the fillings. It readily amalgamates with mercury, and causes quickness in setting. (b) As cadmium lowers the fusibility of many alloys, it is a valuable constituent in fusible alloys. (c) Unfortunately, the metal is readily attacked by sulphuretted hydrogen, and the alkaline and acid fluids of the mouth; with the formation of cadmium sulphide and soluble salts. (d) When in the melted state, cadmium readily oxidises, consequently it is difficult to obtain an alloy of definite composition. (e) Alloys containing large quantities of cadmium are brittle.

ALLOYS.—(1) *Fusible Metals* (see Bismuth). (2) *Lipowitz's Alloy* contains 10 per cent. of cadmium, 26.6 of lead, 13.4 of tin, and 50 of bismuth. It melts at 158° F. (70° C.). (3) *An amalgam-alloy* contains 4 per cent. of cadmium and

¹ The celebrated dentist to the Emperor Napoleon III.

96 of tin. (4) *Cadmium and Magnesium*.—Boudouard¹ has prepared alloys of cadmium and magnesium, and found that they are of a more or less brilliant white appearance, and break when they are submitted to continuous hammering. It is almost impossible to prepare polished surfaces of these alloys so as to study their microscopic metallography. Three definite compounds have, however, been obtained— CdMg , CdMg_4 , and CdMg_{30} .

AMALGAMS.—Cadmium readily amalgamates with mercury, and the following examples are typical of cadmium amalgams:—

	I.	II.
Cadmium . . .	25·99	21·74
Mercury . . .	74·01	77·26

These amalgams have been used for filling teeth.

¹ *Bulletin de la Société Chimique de Paris*, S. 3, vol. xxvii.

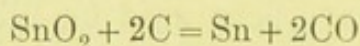
CHAPTER XVIII

TIN

Symbol, Sn ; Atomic weight, 119

OCCURRENCE.—Tin occurs chiefly as cassiterite or tinstone (SnO_2), and is occasionally found in the metallic state.

PREPARATION.—The ore is crushed, and the lighter gangue washed away ; it is then roasted, to drive off arsenic and sulphur. The purified tinstone is reduced to the metallic state by heating it with about one-fifth its weight of anthracite and a little lime or fluorspar—



The reaction takes place on the hearth of a reverberatory furnace. The tin so obtained is purified by liquation or melting, and running it off in the molten condition from a dross containing arsenic and iron, and finally stirring the molten metal with green wood, by which any remaining impurities are oxidised and carried to the surface as dross. The dross is removed, and the tin cast into ingots.

PROPERTIES. — Tin is a white crystalline metal. Its crystalline character is well shown in the *moirée métallique*, prepared by washing tin plate with dilute aqua regia. Tin undergoes little change in air at the ordinary temperatures. It may be melted at low temperatures, and cast with only a superficial oxidation ; but at high temperatures stannic oxide (SnO_2) is formed. Water has no action upon tin at the ordinary temperatures. Strong nitric acid has no action upon

the metal, but the dilute acid attacks it with the formation of metastannic acid ($\text{H}_{10}\text{Sn}_5\text{O}_{15}$). Dilute sulphuric acid has no action upon tin, but the strong acid dissolves it, forming stannous sulphate. Hot hydrochloric acid readily dissolves tin, forming stannous chloride. It is also soluble in aqua regia and alkaline solutions. Sulphuretted hydrogen slowly attacks the metal.

Tin crackles when bent from the friction of the crystals. It is soft and malleable, but at 200°C . it becomes brittle. It possesses little ductility, and is wanting both in elasticity and tenacity. Tin emits a peculiar odour, which is characteristic of the metal.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . . . .	7.3
Specific heat (water = 1)	. . . . .	0.0562
Hardness (diamond = 100)	. . . . .	21.6
Fusibility	. . . . .	227°C . or 441°F .
Malleability (gold = 1, most malleable)	. . . . .	5
Ductility (gold = 1, most ductile)	. . . . .	11
Tenacity (per square inch in tons)	. . . . .	2 to 3.5
Conductivity of heat (silver = 100)	. . . . .	15.2
Conductivity of electricity (silver = 100)	. . . . .	14.4
Expansion of heat	. . . . .	0.00223
Change of volume on solidification	. . . . .	decrease 6.76 p. c.

DENTAL USES.—Tin is a constituent of amalgam-alloys, alloys for dies and counter-dies, and solders. As it has little affinity for sulphur, the metal, in the form of sheets ("soft metal"), is used for making models required in the construction of vulcanite dentures. Pure tin-foil is used as a filling for teeth, either alone or in combination with gold; and the late Dr. Evans of Paris used an alloy of tin and cadmium for the same purpose.

ALLOYS.—(1) *Tin-Zinc Alloys* have been investigated by Guettier,¹ and he finds that the specific gravity of these alloys

¹ *Guide Pratique des Alliages*.

is in proportion to the mean specific gravity of the two metals. The alloys in which tin predominates are more dense. The alloys are softer than zinc, and harder than tin; and less malleable than the latter metal. They are used in casting dies for swaging plates and other purposes:—

	Tin.	Zinc.
Richardson's alloy	20	80
Fletcher's alloy	33·5	66·5

Tin-zinc alloys are readily prepared by fusing the metals together. (2) *Tin-Copper Alloys*.—These metals form an important series of alloys, as they cast well, and melt at moderate temperatures. The following alloys are white or grey metals:—

	Tin.	Copper.
Sn_5Cu	90·27	9·73
SnCu_5	27·09	72·91
SnCu_4	31·72	68·28

As a rule, tin whitens copper more than zinc, although with a large excess of tin the alloy becomes grey. In the previous table the first alloy is grey, while the others are white metals.

There are many other alloys of the two metals, among which are the following:—

	Tin.	Copper.
Gun metal	11·00	89·00
White bell metal	40·00	60·00
Metal for jewellers' punches	16·70	83·30
Speculum metal	33·40	66·60

The bronze coin of the realm also contains the two metals, with the addition of zinc. It is a triple alloy of 4 per cent.

of tin, 95 of copper, and 1 of zinc. (3) *Tin-Antimony Alloys*.—There are many alloys of the two metals, which readily combine when melted together. Antimony reduces the malleability of tin, and its alloys are harder than the latter metal. Richardson's alloy for dies contains 83·4 per cent. of tin and 16·6 of antimony; while Babbitt's metal, for the same purpose, contains 66·7 per cent. of tin, 22·2 of antimony, and 11·1 of copper. An alloy of 80 per cent. of tin and 20 of antimony is sufficiently malleable to be hammered and rolled in the cold. Other alloys contain—

	Tin.	Antimony.
Britannia metal	94	6
Algier's metal	90	10
Claudet's metal	91	9

The composition of Britannia metal varies considerably. It is hard, malleable, and ductile, and can be rolled out and stamped into various shapes. It is a white metal with a bluish tint, and is used for the production of impression trays and other dental articles. Claudet's metal is a perfectly ductile alloy, and possesses many advantages. It is a valuable alloy for dental work. Meter metal is an alloy of tin, antimony, and lead, and is used for making matrix and polishing plates. Owing to its low melting point and other properties, it can be worked up in a steam swager, a thin piece of the metal being made to give accurate copies of the model. (4) *Tin and Mercury* unite readily at ordinary temperatures. Tin amalgam was used as a filling for teeth, but it does not retain its shape, and hardens slowly. Townsend's amalgam-alloy contains 55·6 per cent. of tin and 44·4 of silver, and is in general use for plugs. There are other amalgam-alloys of tin, containing silver, gold, and other metals, but they are described under the "noble metals."

(5) *Other Alloys.*—Solders containing tin are described under lead; and fusible alloys and alloys for dies containing the metal, are described under bismuth.

TIN-FOIL is made by rolling the metal into sheets, then heating and again rolling until it is thin enough for the purpose.

TIN-PLATE is prepared by dipping thin plates of iron into molten tin; by this means the iron becomes coated with tin, which protects it from rusting.

DETECTION OF TIN IN ALLOYS.—A small piece of the alloy is heated with dilute nitric acid until all action ceases. The solution is then diluted with water. If a white residue (metastannic acid) forms, tin is present in the alloy. If gold is also present, the residue will be purple, owing to the formation of the "purple of Cassius," a stannate of gold and tin.

CHAPTER XIX

LEAD

Symbol, Pb ; Atomic weight, 206.9

OCCURRENCE.—Lead occurs in nature as galena (PbS), cerussite (PbCO_3), anglesite (PbSO_4), and other ores. It also occurs in small quantities in the metallic state.

PREPARATION.—Three methods are used for extracting lead from its ores:—(a) Air reduction process ; (b) carbon reduction process ; and (c) the iron or precipitation process.

In the *Air Reduction Process* the pure galena is roasted

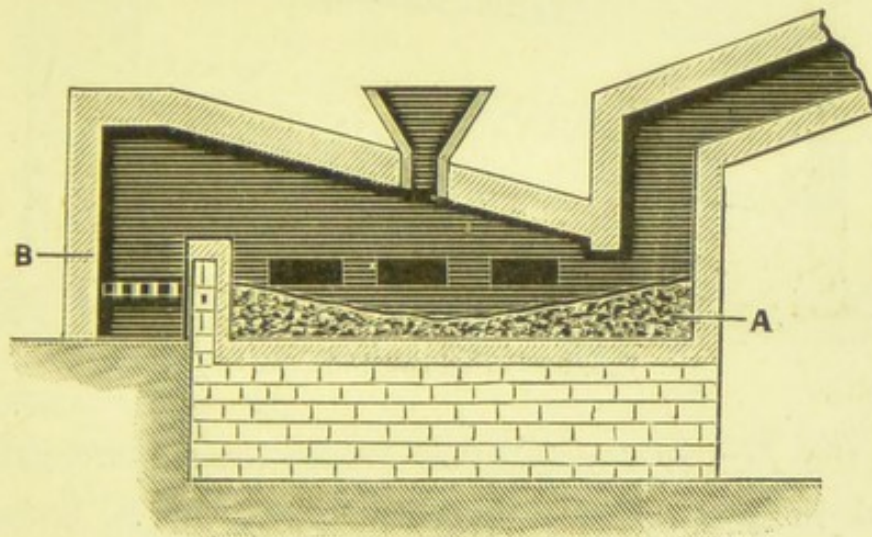
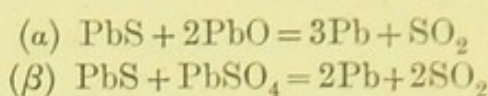


FIG. 31.—Reverberatory Furnace for Lead Smelting.

A, Hearth. B, Fireplace.

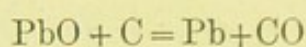
on the hearth or bed of a reverberatory furnace (Fig. 31), during which process two products, lead oxide and lead sulphate, are formed. The temperature of the fur-

nace is raised, and metal obtained according to the following equations :—



The lead obtained from galena always contains small quantities of silver, which is subsequently extracted by Pattinson's process followed by cupellation (*vide* Silver).

In the *Carbon Reduction Process* the ores are roasted, and finally reduced to the metallic state by carbonaceous matter—



The reduction is conducted in a Bleiberg furnace (Fig. 32), which is a kind of liquation furnace.

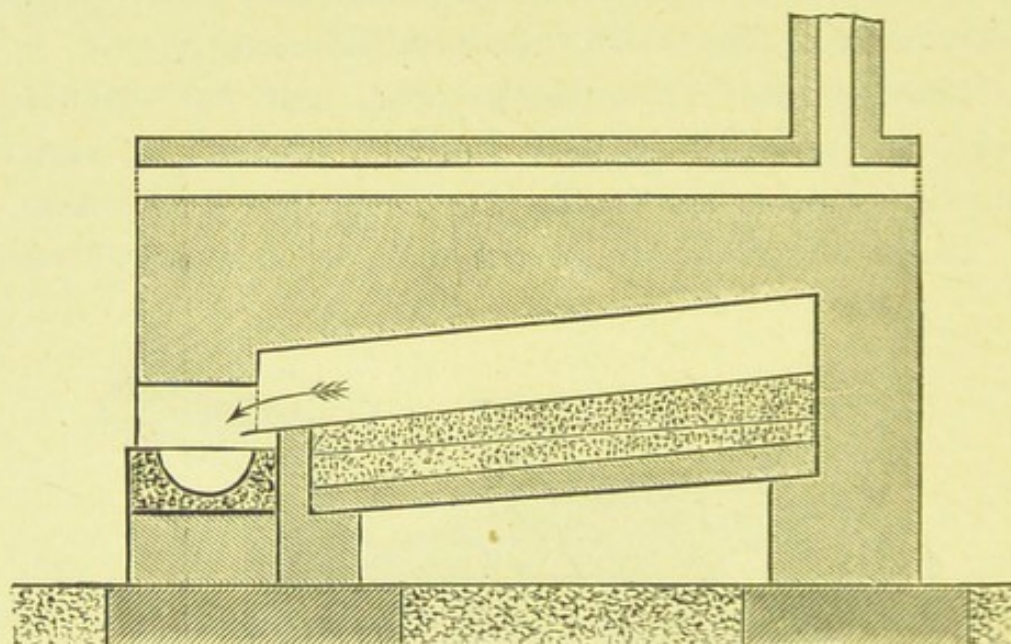
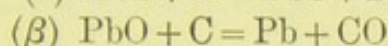
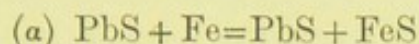


FIG. 32.—Bleiberg Furnace.

In the *Iron or Precipitation Process* the impure galena is smelted in two distinct reverberatory furnaces, technically known as the "calciner" and the "flowing furnace" respectively. The reactions within the furnaces are most complex, as oxygenated compounds of lead are formed, and these react upon a portion of the unaltered galena, yielding the metal, while the remaining portion of the galena is decomposed

in the flowing furnace by means of scrap iron and small anthracite—



PROPERTIES.—Lead is a bluish white metal. A freshly-cut surface possesses a bright metallic lustre, but its brilliancy disappears quickly when exposed to air, owing to the formation of a film of oxide upon its surface. Lead is both malleable and ductile; but when melted repeatedly it becomes hard and brittle, owing to the formation of oxide, which dissolves in the metal. The oxide is removed by poling or stirring the molten metal with a stick of green wood, or by the addition of charcoal. Lead crystallises in octahedra (cubic system). Nitric and sulphuric acids dissolve lead; hydrochloric acid has little or no action upon the metal; but acetic acid, in the presence of air, rapidly attacks it.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . . . .	11.4
Specific heat (water = 1)	. . . . .	0.0314
Hardness (diamond = 100)	. . . . .	18.9
Fusibility	. . . . .	325° C. or 617° F.
Malleability (gold = 1, most malleable)	. . . . .	8
Ductility (gold = 1, most ductile)	. . . . .	12
Tenacity (per square inch in tons)	. . . . .	0.8
Conductivity of heat (silver = 100)	. . . . .	8.5
Conductivity of electricity (silver = 100)	. . . . .	8.4
Expansion by heat	. . . . .	0.00292
Change of volume on solidification	decrease of	9.93 p. c.

DENTAL USES.—Lead is used in dentistry chiefly in making counter-dies. The counter is taken in either of two ways: (a) The zinc model is “let down” into the melted lead, or (b) the melted lead is poured over the zinc model. Lead is also used in the form of thin sheets for cutting patterns by which gold or silver plates are cut.

ALLOYS.—Lead alloys with most metals. The general effect of alloying on its properties is to reduce the malleability and increase the hardness of the metal. (1) *Type Metal* (see Antimony) is sometimes used for dies and counter-dies, and contains 80 per cent. of lead and 20 of antimony. (2) *Lead and Tin* unite in all proportions, forming an important series of alloys. Pewter is an alloy of these metals in the proportion of 20 per cent. of lead and 80 of tin; and it contains small quantities of other metals. Pewter containing 18 per cent. of lead and 82 of tin is not attacked by vinegar or wine, and is used in France for measuring vessels.

Alloys of lead and tin are used for tempering various articles of steel:—

Alloy.		Melting Point.	Articles.
Pb.	Sn.		
		C.	
14	8	213°·4	Lancets.
15	8	211°	Other surgical instruments.
16	8	228°	Razors.
7	8	240°	Cold chisels.
36	8	262°	Small scissors.
60	8	275°	Large scissors.

Soft solders are also alloys of lead and tin in various proportions (per cent.):—

	Lead.	Tin.
Fine solder	34	66
Common solder	50	50
Plumbers' solder	66	34

(3) *Lead and Zinc* may be melted in all proportions; but on cooling the alloy does not remain homogeneous—the

lead settles at the bottom, while the zinc rises to the surface. Small quantities of zinc harden lead without impairing its malleability. (4) *Fusible Alloys* also contain lead (see Bismuth). (5) *Lead and Mercury* unite to form amalgams, which remain fluid with as much as 33 per cent. of lead. Amalgams are prepared by mixing grain lead or filings with mercury; or by adding mercury to molten lead.

Lead also alloys with iron,¹ arsenic, manganese, and copper, in various proportions.

¹ Guettier, *Guide Pratique des Alliages*.

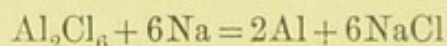
CHAPTER XX

ALUMINIUM

Symbol, Al; Atomic weight, 27.1

OCCURRENCE.—The larger portion of the earth's crust is composed of aluminium in union with silicic acid—such as granite, felspar, basalt, clays, etc. Corundum, bauxite, topaz, amethyst, cryolite, ruby, garnet, and many other minerals contain the metal.

PREPARATION.—Aluminium was discovered by Wöhler in 1827. He decomposed the chloride by means of sodium—



Deville passed the vapour of aluminium chloride over sodium heated to redness in copper and iron tubes. By this process larger supplies of the metal were obtained. On a larger scale, cryolite ($6\text{NaF}, \text{Al}_2\text{F}_6$) and sodium were thrown upon the bed or hearth of a reverberatory furnace previously heated to redness. A violent action took place, and the mass fused. The metal and slag were drawn off into moulds, where they separated into two layers—the upper being the slag and the lower one the metal.

Aluminium is now produced in the *electric furnace* (Fig. 33); and there are two principal processes for the production of the metal in use at the present day, which differ from one another only very slightly. In Hall's process, the bath

consists of alumina (from bauxite) fused in potassium fluoride. The fused mass is placed in the furnace along with carbon; but some furnaces consist of an iron box lined with carbon,

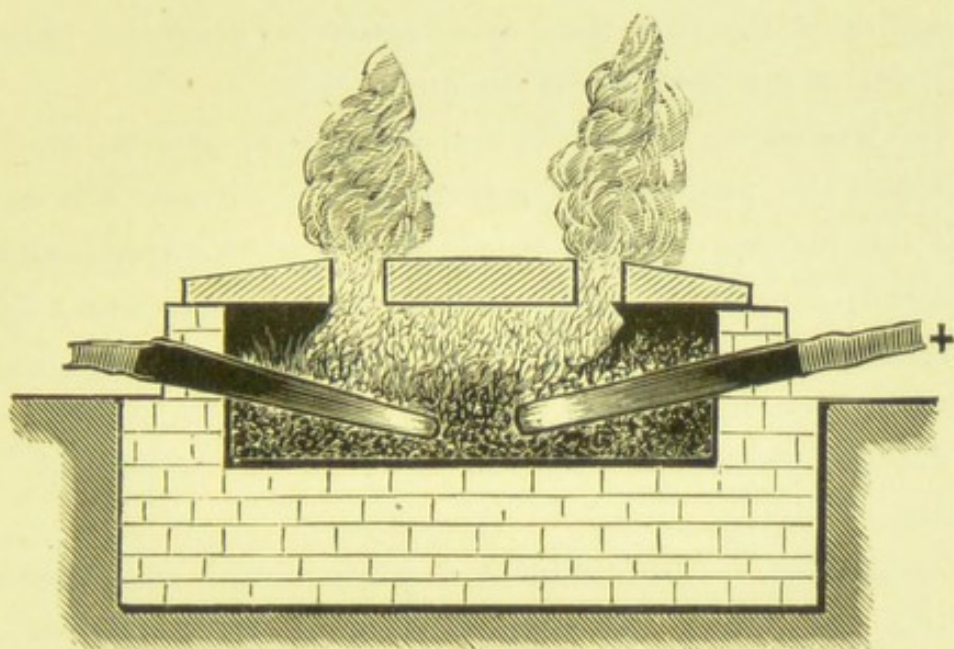


FIG. 33.—Electric Furnace for the production of Aluminium.

which is the negative electrode (cathode), while in the centre the positive electrode (anode) is a massive piece of carbon, or a number of carbon rods. In Herault's process, alumina is fused in cryolite, and this is the only point of difference between the two processes. In both processes a potential difference¹ of about 5 volts is required, and a high current density of about 700 ampères per square foot is used. It takes about 14 E.H.P. to deposit one pound of aluminium. The aluminium settles in a fused mass at the bottom of the furnace.

In both the Hall and Herault processes, the alumina is dissolved in the fluoride, which is kept fused by the heat generated by the current. Aluminium is separated out at the cathode, which is formed of the molten metal lying at the bottom of the furnace, the anode being formed of a group

¹ Or pressure difference.

of carbon rods, which are eaten away in course of time. It is found that the purity of these carbons largely affects the purity of the metal; and the improvement in the purity of aluminium during the last few years has been due to the recognition of the fact that great attention must be paid to the purity of all the ingredients employed.

An interesting point in the aluminium process is that, whereas at the proper temperature of the furnace the metal lies at the bottom of the furnace where it is wanted, and is periodically tapped off; if the temperature falls to any extent, the relative specific gravities of the aluminium and the electrolyte¹ change places, and the metal floats up through the molten electrolyte to the obvious detriment of the working.

PROPERTIES.—Aluminium is a white metal, sonorous and light (sp. gr. 2·67). It oxidises very slowly in air, is not affected by sulphuretted hydrogen, but is readily soluble in hydrochloric acid and alkalies. Aluminium resists cold inorganic and organic acids (except HCl). It enters into the composition of artificial teeth which are composed of the *body* and the *enamel*. The former consists of kaolin, felspar, and silica; while the latter is composed of felspar and colouring matter (metals and metallic oxides).

Recent analyses of artificial teeth gave the following figures:—

Silica	62·8
Alumina	21·6
Potash	10·0
Iron oxide	0·2
Magnesia	1·0
Titanium oxide	0·4
Water and loss	4·0
	<hr/> 100·0 <hr/>

¹ See Danneel's *Handbuch der Elektrochemie*.

<i>Body.</i>				<i>Enamel.</i>			
Alumina	.	.	14·20	Alumina	.	.	18·57
Potash	.	.	8·60	Potash	.	.	14·02
Lime	.	.	0·13	Lime	.	.	0·34
Magnesia	.	.	0·02	Magnesia	.	.	0·10
Soda	.	.	0·35	Soda	.	.	1·25
Silica	.	.	76·70	Titanium oxide	.	.	0·36
			<u>100·00</u>	Silica	.	.	<u>65·36</u>
							<u>100·00</u>

Artificial teeth stand the action of oral secretions better than natural teeth.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1) . . .	2·67
Specific heat (water = 1) . . .	0·2143
Hardness (diamond = 100) . . .	27·5
Fusibility . . .	625° C. or 1157° F.
Malleability (gold = 1, most malleable) . . .	3
Ductility (gold = 1, most ductile) . . .	9
Tenacity (per square inch in tons) . . .	12
Conductivity of heat (silver = 100) . . .	31·3
Conductivity of electricity (silver = 100) . . .	65·5
Expansion by heat . . .	0·00231
Change of volume on solidification . . .	decrease of 14·2 p. c.

DENTAL USES.—Aluminium is a somewhat disappointing metal for the preparation of plates, as it is gradually attacked by articles used in diet (salt, alkalies, etc.). Another disadvantage to the use of the metal is the large amount of contraction on cooling, and the difficulty in preparing suitable solders for the metal. In prosthetic dentistry, attempts have been made to utilise aluminium as a base for artificial dentures; but the plates have not been satisfactory. The metal is sometimes used as a base in connection with vulcanite—the teeth being attached to the vulcanite; but there is a great difference in the expansion of the two substances, and the heat of the mouth, hot drinks, oral fluids, etc., cause a separation.

On account of its low specific gravity, requiring no alloy, and the non-poisonous nature of its compounds, aluminium has been considered by some to be an ideal metal for dental work.

The method usually adopted to prepare a plate is to swage the metal with great care. It becomes hard and rigid during swaging, but is readily softened by heating to redness and plunging into cold water. The teeth are fastened to the plate with celluloid or rubber.

In casting aluminium for plates, great care is necessary, as the metal contracts considerably on solidification. The metal is melted in a Carroll's crucible, and when molten it is forced by air-pressure into the mould. It is stated that by this means fine castings have been obtained. Small quantities of copper, and an alloy of copper and magnesium, reduce the contraction of the alloy.

Although aluminium plates are made, they last only a few years, being attacked by the oral secretions; and they cannot compare with those made of gold, dental alloy, and other materials.

Concerning the dental uses of aluminium, it may be stated, *en passant*, that Hewitt's gags are made of the metal, and are light, strong, and clean. Strengtheners are also made of aluminium.

ALLOYS.—The most important alloy is probably (1) *Aluminium Bronze*, which is manufactured in different qualities by varying the amount of aluminium. The most useful quality contains 10 per cent. of aluminium and 90 per cent. of copper (pure). The copper is melted first, and the aluminium is then added. The alloy is at first brittle, but the brittleness is readily removed by re-melting a few times. Aluminium bronze possesses a gold colour, and has a tensile strength of 40 tons per square inch. It melts at 950° C. (1742° F.), and contracts on solidification. It is ductile and

malleable; becomes hard and stiff when worked, and requires frequent annealing. The alloy is annealed and tempered by heating to bright redness, cooling to a dull redness, and finally plunging it into cold water. Aluminium bronze has been used on the Continent as a plate for artificial dentures, and it is said to be free from oxidation. It is more easily manipulated than silver and gold alloys. An aluminium bronze plate requires frequent annealing during swaging. Sauer solders it with 14 to 16-carat red gold.

Brunck¹ has obtained a crystallised alloy of aluminium and copper. Equal weights of the two metals are melted together, and very fragile crystalline white ingots are obtained. By decanting before complete solidification, lance-like crystals are obtained (sp. gr. = 4.118). These crystals (Cu_4Al_9) are slightly attacked by nitric acid, partially by hydrochloric acid, and completely by aqua regia.

Many aluminium alloys have been produced by Cowles in the electric furnace, direct from minerals containing aluminium—a current strength of 5000 ampères flowing through the fused mass. (2) *Aluminium Brass* is prepared by adding zinc to molten aluminium bronze, or by melting together brass and aluminium bronze. Aluminium brass varies much in composition—

Copper	.	.	.	.	67 to 71 parts.
Zinc	.	.	.	.	32 „ 25 „
Aluminium	.	.	.	.	1 „ 4 „

It is a close-grained, tough alloy. (3) *Carroll's Alloy* contains—

Aluminium	.	.	.	.	90 to 93 parts.
Silver	.	.	.	.	5 „ 9 „
Copper	.	.	.	.	0 „ 1 „

¹ *Berichte der Deutschen Chemischen Gesellschaft zu Berlin*, Bd. xxxiv. p. 2733.

It is white, and is easily worked. It has been used for plates for artificial dentures. (4) *Griffiths' Aluminium-Magnesium Alloy* contains—

Aluminium	.	.	.	.	90 per cent.
Magnesium	.	.	.	.	7 "
Zinc	.	.	.	.	2 "
Copper	.	.	.	.	1 "

It is a white, tough alloy, that resists the action of the air, but is attacked by hydrochloric acid. It has a specific gravity of 2.7087, and a melting point between 650° and 700° C. (5) *Tiers-Argent* is an alloy containing 66 per cent. of aluminium and 34 per cent. of silver. It is a white, fine-grained alloy, harder than silver, and has been used in France for plates. It resists the action of air and sulphuretted hydrogen better than the alloys of silver and copper. (6) *Aluminium-Tin Alloys*.—Riche¹ first pointed out that an alloy of these metals, in the proportions of 25 per cent. of aluminium and 75 per cent. of tin, evolves hydrogen freely when placed in water; but this property is not confined to Riche's alloy, as Anderson and Lean² have proved that it belongs to a series of these alloys, whether cast or annealed. From the determinations of the cooling curves, it has been shown that tin dissolves in aluminium, but that in the case of alloys containing more than 10 per cent. of tin, a second break in the cooling curve takes place at 232° C., indicating an excess of tin (Gautier³). (7) *Aluminium-Gold Alloys*.—An alloy containing 21.52 per cent. of aluminium and 78.48 per cent. of gold was prepared by the late Sir William C. Roberts-Austen⁴ by melting the two metals together. This alloy

¹ *Journ. Pharm. Chem.*, 1895.

² *Report of British Association*, 1901.

³ *Comptes Rendus*, 1896, t. cxxiii. p. 109.

⁴ *Journal Chemical Society*, 1894, p. 75.

(Al_2Au) has great stability. Other alloys of the two metals have been prepared by Heycock and Neville.¹ Among these are the following:—

Aluminium	.	.	.	95	70	89
Gold	.	.	.	5	30	11

(8) *Aluminium-Iron Alloy*.—Brunck (*loc. cit.*) has obtained a crystallised alloy by melting 75 parts of aluminium and 25 parts of iron together, and then treating the fused mass with hydrochloric acid (2 per cent.). Pointed crystals Al_3Fe (sp. gr. = 3.734) of a grey colour are obtained, which are soluble in strong acids. (9) *Aluminium-Nickel Alloy*.—

Brunck has also obtained a crystalline alloy, represented by the formula Al_3Ni . It has a specific gravity of 3.681.

(10) *Aluminium-Platinum Alloy*.—An alloy having the composition $\text{Al}_{10}\text{Pt}_3$ has been obtained by Brunck. It requires prolonged fusion. The crystals (sp. gr. = 6.688), of a bronze colour, are attacked by strong hydrochloric acid. Alloys of aluminium and cobalt ($\text{Al}_{13}\text{Co}_3$), and aluminium and manganese (Al_7Mn_2), have been obtained in the crystalline state.

(11) *Aluminium Amalgam*.—Aluminium unites with mercury when it is moistened with sodium hydroxide (solution of caustic soda). The amalgam is brittle, and oxidises in the air.

(12) *Solders of Aluminium*.—Aluminium is a difficult metal to solder, as it readily oxidises, and the film of oxide cannot be removed by the ordinary fluxes used in soldering, as these attack the aluminium. *Schlosser's Solders* for dental purposes contain—

I.				II.			
Gold	.	.	55.5 per cent.	Gold	.	.	19.9 per cent.
Copper	.	.	11.1 „	Platinum	.	.	0.7 „
Silver	.	.	11.1 „	Silver	.	.	13.2 „
Aluminium	.	.	22.3 „	Aluminium	.	.	66.2 „

¹ *Journal Chemical Society*, 1898, p. 719.

Richards' Solder contains—

Aluminium	2.4 per cent.
Tin	71.2 „
Zinc	26.2 „
Phosphorus	0.2 „

The metal is to be filed clean, heated and soldered. No flux is used. *Sellon's Solder Alloy* contains: zinc 62.5, tin 25, and lead 12.5 per cent. The surfaces of the metal are cleaned by scraping or filing, and covered with a layer of paraffin wax, which acts as a flux. They are then coated with the fused solder-alloy, and finally soldered in the usual manner with any good solder. Paraffin wax may be used with advantage in soldering with other solders of aluminium. *Thowless' Solder* contains: aluminium 2.35, silver 5.88, tin 64.72, and zinc 27.05 per cent. The surfaces are cleaned by using a dilute solution of sodium hydroxide or potassium cyanide. They are washed, dried, heated over a spirit flame, then coated with the solder, and clamped together. No flux is used. The excess of solder is removed by heating the whole to the fusing point of the solder. A new *patent solder* for aluminium (No. 19,836, 1901) contains: aluminium 6, zinc 25, and tin 69 per cent. *Aluminium Bronze Solders.*—Richards recommends the following solders for aluminium bronze:—

	Hard.	Medium.	Soft.
Gold	88.88	54.40	14.30
Silver	4.68	27.00	57.10
Copper	6.44	18.60	14.30
Bronze [Cu 70 per cent., Sn 30 per cent.]	...	...	14.30
	100.00	100.00	100.00

The soldering of aluminium bronze is effected without the least difficulty.

CHAPTER XXI

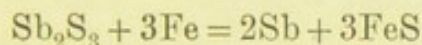
ANTIMONY

Symbol, Sb ; Atomic weight, 120.2

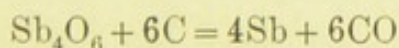
“Put this antimony, thus calcined, into a goldsmith's crucible, set in a fornace, and urge the fire with bellows, or put it into a wind-fornace, administering such fire as the antimony may flow like clear and pure water.”—Basil Valentine's *Triumphant Chariot of Antimony*, 1490, p. 63.

OCCURRENCE.—Antimony¹ is found both native and combined. In the combined state, it occurs as stibnite (Sb_2S_3), valentinite (Sb_4O_6), and several other ores.

PREPARATION.—Stibnite is purified from the gangue by liquation. The sulphide liquefies, and the earthy admixture, quartz, etc., remain behind in the solid state. The purified stibnite is decomposed by fusion with iron in covered crucibles—



To obtain the metal, a mixture of 2 parts of purified stibnite and 1 part of iron filings is heated to bright redness; on cooling, the antimony separates and settles on the bottom of the crucible, while the regulus of iron sulphide remains on the surface of the metal (Fig. 34). Another method for preparing antimony is to roast the purified stibnite to oxide; the latter is then reduced with charcoal or argol—



¹ Antimony was discovered by Basil Valentine.

Nine parts of antimony oxide require about $1\frac{1}{2}$ parts of charcoal for reduction to the metallic state.

PROPERTIES.—Antimony is a hard, bluish white metal, possessing a crystalline fracture. It is so brittle that it is easily powdered; it does not undergo any alteration on exposure to the air at ordinary temperatures. When heated in air, the metal burns with a white flame, producing dense fumes of antimonious oxide. Antimony is only slightly tarnished by sulphuretted hydrogen. Water and dilute sulphuric acid have no action upon the metal at ordinary temperatures; but strong sulphuric acid converts it into antimony sulphate. It is easily dissolved by cold aqua regia, as well as by hot hydro-

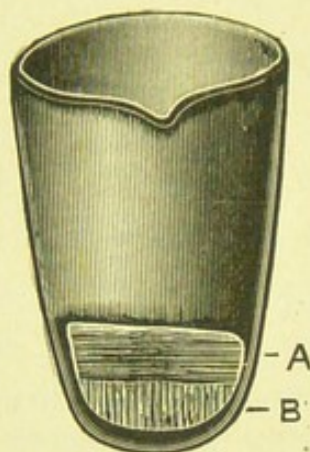


FIG. 34.—Preparation of Antimony.

A, Regulus of iron.

B, Antimony.

chloric acid. Nitric oxide converts antimony into a white insoluble oxide. Alkaline solutions have no action upon the metal.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	6.86
Specific heat (water = 1)	0.0508
Hardness (diamond = 100)	33.8
Fusibility	440° C. or 824° F.
Malleability (gold = 1, most malleable)	15
Ductility (gold = 1, most ductile)	<i>nil.</i>
Tenacity (per square inch in tons)	0.5
Conductivity of heat (silver = 100)	4
Conductivity of electricity (silver = 100)	3.6
Expansion by heat	0.00105
Change of volume on solidification	increase.

DENTAL USES.—Antimony is a valuable constituent of alloys. It gives hardness to the other metals, and causes them to *expand on cooling*—a most important property, as the mould is completely filled. The chief use of antimony

in dentistry is as a constituent of alloys for dies and counter-dies.

ALLOYS for dies and counter-dies: (1) *Type Metal* varies in the proportions of antimony and lead. Lead-antimony alloys, not exceeding 15 per cent. of antimony, have the property of expanding on cooling. The most suitable qualities of these alloys contain—

Antimony	.	.	.	20	15	10
Lead	.	.	.	80	85	80
Tin	.	.	.	...	...	10

Sometimes small quantities of arsenic, copper, and other metals are added to type metal.

Type metal is sometimes used for dies and counter-dies; it is a little softer than zinc, harder than lead, and gives sharp castings. In this respect it is superior to zinc, as the latter contracts considerably on cooling. Type metal is more fusible than zinc; but it is somewhat brittle, and therefore requires skilful manipulation when used as a die.

Type metal is prepared by first melting the lead, and then adding the tin and antimony. A layer of charcoal in the crucible is used to prevent oxidation. (2) *Fletcher's Metal* contains: antimony 17.64, copper 11.76, and tin 70.60 per cent. It makes a harder die than zinc, and contracts far less. The copper is melted first, the tin added, and finally the antimony. (3) *Haskell's Metal* is nearly as hard as zinc, and contracts far less. It is used for finishing the swaging of a plate, and contains: antimony 18.18, copper 9.09, and tin 72.73 per cent. As it fuses at a lower temperature than lead, Rose uses a counter-die, containing: lead 83.4, and tin 16.6 per cent. (4) *Babbitt's Metal* varies considerably in composition. One of the best qualities contains: antimony 22.3, copper 11.1, and tin 66.6 per cent. It is nearly as hard as zinc, and the shrinkage or contraction on cooling is practically *nil*. It is, however, somewhat brittle, and

requires careful manipulation. The melting point of the "metal" is higher than that of lead, and lower than that of zinc; therefore counter-dies of lead can be made to Babbitt's metal. It is prepared by first melting the copper, adding the tin, and, finally, the antimony. The fusion takes place under a layer of charcoal, to prevent oxidation. The alloy should be well stirred, and cast into moulds. (5) *Spence's Metal* is not an alloy, and varies in composition. It is prepared by dissolving metallic sulphides in melted sulphur; and antimony sulphide, dissolved in an excess of melted sulphur, forms one variety of Spence's metal. It expands on cooling, and has been employed for dies. It should be melted in clay crucibles (Fig. 15, A, B, or G), and *not* in an iron ladle. (6) *Regulus of Venus* is a violet alloy of antimony and copper in equal proportions.

There are other alloys of antimony, but they are described under the chief metal of each alloy.

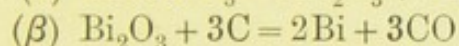
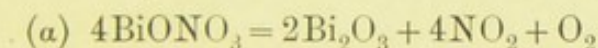
CHAPTER XXII

BISMUTH

Symbol, Bi; Atomic weight, 208.5

OCCURRENCE.—This metal occurs native (*i.e.* in the metallic state), and also combined with sulphur, oxygen, and other elements.

PREPARATION.—The native bismuth is purified from the gangue by liquation. The broken ore is placed in cylindrical iron retorts, which are arranged in an inclined position in a furnace. The heat causes the melted bismuth to flow into iron receivers, from which it is ladled and cast into ingots. By this means it is separated from the gangue, as the earthy matters do not melt at the same temperature as bismuth (liquation or the “fractional distillation” of the ore). The metal is purified by dissolving it in nitric acid, pouring the solution into water, and finally reducing the precipitated bismuth oxynitrate by means of charcoal in a crucible—



PROPERTIES.—Bismuth is a reddish, brittle metal, which shows no tendency to oxidise on exposure to the air at ordinary temperatures; but when it is heated in air it burns with a bluish flame, producing fumes of bismuth trioxide. Nitric acid and hot concentrated sulphuric acids readily dissolve bismuth; but hydrochloric acid has little action upon the metal. Water and alkaline solutions are without effect on

bismuth. The metal has the valuable property of *expanding on solidification*, consequently it is an important addition to many alloys; and as bismuth fuses at a low temperature, it lowers their melting points and imparts hardness.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . . . .	9.8
Specific heat (water = 1)	. . . . .	0.0308
Hardness (diamond = 100)	. . . . .	30.2
Fusibility	. . . . .	268° C. or 514° F.
Malleability (gold = 1, most malleable)	. . . . .	14
Ductility (gold = 1, most ductile)	. . . . .	<i>nil.</i>
Tenacity (per square inch in tons)	. . . . .	1.5
Conductivity of heat (silver = 100)	. . . . .	1.8
Conductivity of electricity (silver = 100)	. . . . .	1.4
Expansion by heat	. . . . .	0.00162
Change of volume on solidification	increase of 2.3 per cent.	

DENTAL USES. — The value of bismuth in dentistry depends on its low melting point, and its power of expanding on passing from the liquid to the solid state (2.3 per cent.).¹ It is used in the dental laboratory for making fusible alloys for dies and counter-dies; and an alloy of bismuth, tin, and lead is employed for testing the finish of a die.

ALLOYS.—(1) *Bismuth and Tin* combine to form alloys which are more fusible than either of the metals taken separately. The following table gives the composition of these alloys:—

	Bismuth.	Tin.	Melting Point.
			C.
Bi ₂ Sn ₃	54.27	45.73	143°
BiSn ₄	30.79	69.21	190°
BiSn ₂	47.09	52.91	160°
Bi ₃ Sn ₃	72.75	27.25	170°
Bi ₂ Sn	78.07	21.93	190°

¹ Roberts and Wrightson, *Proc. Phy. Soc.* 1884, p. 97.

(2) *Bismuth alloys for dies* contain—

Bismuth.	Lead.	Tin.	Antimony.	Melting Point.	Contraction.	Hardness.	Brittleness.
				C.			
3	2	1	...	93°	·00133	2·7	7
8	5	2	...	93°	·00200	2·5	8
1	1	1	...	121°	·00066	2·3	7
3	5	6	1	139°	·00266	1·7	9

These alloys were investigated by Austen, and in the above table the hardness of zinc is taken as 1 and the brittleness as 5; those alloys having a hardness above 5 being more brittle than zinc, and those below 5 being malleable.

(3) *Fusible Metals* are alloys that melt at low temperatures (as a rule lower than 100° C.), and far below the melting points of the constituent metals. The following are the principal fusible alloys used in dentistry:—

Name.	Bismuth.	Tin.	Lead.	Cadmium.	Melting Point.
					C.
Newton's alloy.	8	3	5	...	95°
Wood's	5	2	4	2	71°
"	7	...	6	1	82°
Rose's	8	3	8	...	79°
Dalton's	21	6	10	...	92°
Griffiths'	8	2	7	1	75° ¹
"	9	2	6	1	70° ²
Darcet's	2	1	1	...	93°
Onion's	5	2	1	...	92°
Mellotte's	8	5	3	...	100°

Any of the fusible alloys may be rendered more fusible by the addition of mercury. These alloys are hard and brittle, and expand on cooling. It is extremely difficult to obtain fusible metals in a perfectly homogeneous state, as the lead has a tendency to separate on cooling. Fusible alloys are prepared by melting the constituent metals together under a layer of charcoal. They are used in crown, bridge, and

¹ Specific gravity = 9·9350.

² Specific gravity = 9·8749.

vulcanite work. Mellotte's fusible alloy (used for crown and bridge work) is not as hard as zinc, but is harder than tin, and expands on solidification. Accurate models with it are obtained by using a plastic material called "moldine" (composed of kaolin and glycerine).

In connection with bridge work, Lennox¹ states that fusible alloys may be used (α) "to make a mandril for shaping the ferrule; (β) as a setting for a natural tooth to be used as a die for striking up crowns; (γ) as a means of obtaining a well-defined and not readily damaged cast of the mouth when a tooth is to be pivoted; (δ) to replace the old plaster slab bite in making an articulator; (ϵ) to form a base plate on which to mount composition for obtaining the articulation or bite." (4) *Bismuth Amalgam*.—Mercury dissolves a considerable quantity of bismuth without losing its fluidity; but the amalgams of bismuth are of little use. Bismuth renders amalgams sticky and adhesive.

¹ *British Dental Association*, 1891.

CHAPTER XXIII

PALLADIUM

Symbol, Pd; Atomic weight, 106.5

OCCURRENCE.—The metal is found associated with platinum in the metallic state. Platinum ores contain from 0.5 to 1 per cent. of palladium.

PREPARATION.—The “ore” is dissolved in aqua regia; and after the platinum has been precipitated from its solution by ammonium chloride, the filtrate is neutralised by the addition of sodium carbonate, and the palladium precipitated as palladium cyanide $\text{Pd}(\text{CN})_2$ with mercuric cyanide. The precipitate is collected, washed, and heated to redness; the spongy palladium thus obtained being afterwards heated, hammered, and welded.

Another method of effecting its separation from native platinum is to dissolve the “ore” in aqua regia, and precipitate the palladium as iodide (PdI_2) by the addition of a solution of potassium iodide (avoiding excess). The iodide is collected, washed, and heated.

PROPERTIES.—Palladium is a hard, white metal. It does not undergo any alteration on exposure to the air at ordinary temperatures; when heated to dull redness it absorbs oxygen, but at a higher temperature the film of oxide is decomposed, and the metal regains its lustre. It occludes hydrogen, resists the action of sulphuretted hydrogen, and is soluble in nitric acid, hot sulphuric acid, and hydrochloric acid. Palladium

combines with iodine, forming palladium iodide PdI_2 . Hence, if an alcoholic solution of iodine be evaporated on the metal, it produces a black stain, which serves to distinguish palladium from platinum.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . .	11.5
Specific heat (water = 1)	. . .	0.0593
Hardness (diamond = 100)	. . .	41.6
Fusibility	. . .	1500° C. or 2732° F.
Malleability (gold = 1, most malleable)	. . .	7
Ductility (gold = 1, most ductile)	. . .	7
Tenacity (per square inch in tons)	. . .	13
Conductivity of heat (silver = 100)	. . .	10.6
Conductivity of electricity (silver = 100)	. . .	12.1
Expansion by heat	. . .	0.00117
Change of volume on solidification	. . .	decrease.

DENTAL USES.—Palladium is used in the form of an amalgam for filling teeth; and its alloys have been used for plates. The high price of palladium (more than £9 per ounce troy) prohibits any great use of it in the dental laboratory. Owing to its lightness (sp. gr. 11.5; platinum has a sp. gr. 21.5), hardness, and high specific heat, pure palladium is probably the best metal for plates and artificial teeth.

ALLOYS.—(1) *Palladium-Silver Alloys* contain—

	a.	b.
Palladium . . .	40 per cent.	34 per cent.
Silver . . .	60 „	66 „

These alloys are white, and are not blackened by sulphuretted hydrogen. They are extremely malleable and ductile. A palladium alloy for plates was assayed in the author's laboratories, and found to contain—21.1 per cent. of palladium and 78.9 per cent. of silver. It is white and malleable. (2) *Palladium-Gold Alloy*.—The two metals combine to form an alloy containing 20 per cent. of palladium and 80 per cent.

of gold. It is perfectly white and brittle; but other alloys of the two metals are ductile and malleable. (3) *Palladium-Tin Alloy*, containing 11·2 per cent. of palladium and 88·8 per cent. of tin, is remarkable for its great brilliancy. This alloy may be represented by the formula Pd_3Sn_2 . (4) *Palladium Amalgam*. — This amalgam is obtained by rubbing finely-divided palladium with mercury. Heat is evolved during the union. This amalgam expands on solidification, and forms a good watertight filling for teeth. Unfortunately, it turns black, but does not stain the teeth.

PRECIPITATED PALLADIUM is prepared by placing strips of zinc or iron in a solution of palladium chloride. The metal is precipitated as a black powder, which is washed and dried. Precipitated palladium is used for preparing palladium amalgam, as spongy palladium is too dense for the purpose. Fletcher states that "unless precipitated palladium sets very rapidly when mixed with mercury, it is totally useless for dental purposes; the plugs fail, unless fully hard, in so short a time, that the amalgam is difficult to insert whilst it remains plastic." Alloys of palladium and gold are ductile, but the colour of gold is greatly reduced by palladium: an alloy containing 5 per cent. of palladium and 95 of gold is a silver colour.

CHAPTER XXIV

PLATINUM

Symbol, Pt; Atomic weight, 194.8

OCCURRENCE.—Platinum occurs native in small grains alloyed with palladium, rhodium, iridium, osmium, and ruthenium (the platinum group of metals). It also contains iron, silver, and copper.

PREPARATION.—The platinum is separated from the other metals by digesting the "ore" with nitric acid to remove copper and silver, washing it with water, and treating with hydrochloric acid to dissolve iron, and finally digesting the residue with aqua regia; osmium and iridium remain undissolved, whilst the other metals pass into solution. Palladium is precipitated as palladium cyanide by adding a solution of mercuric cyanide to the solution containing the metals. The platinum is separated, in the form of ammonio-platinum chloride $(\text{NH}_4\text{Cl})_2\text{PtCl}_6$, on the addition of ammonium chloride to the filtrate. The ammonio-platinum chloride is washed, dried, and ignited in a plumbago crucible, when the metal remains in a spongy condition. The spongy platinum, after being powdered, is extensively heated, and hammered until it is welded into a solid mass; or it is melted in a lime crucible by means of the oxy-hydrogen blowpipe (Fig. 35).

Deville and Debray's process is as follows:—When the native platinum is strongly heated with lead sulphide and

oxide, the reduced lead dissolves the platinum (together with some iridium and rhodium), an easily fusible alloy of platinum

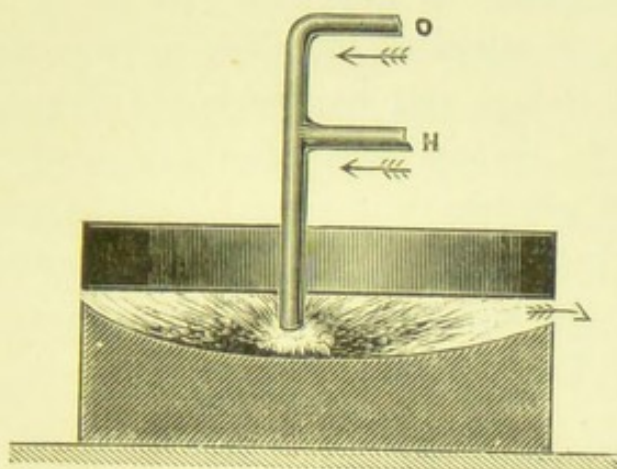
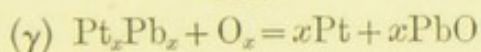
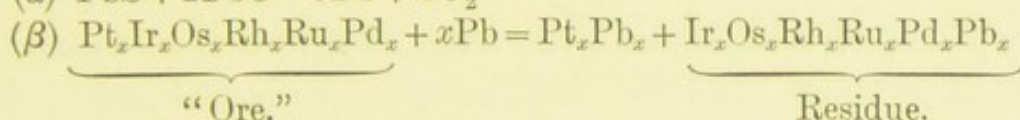
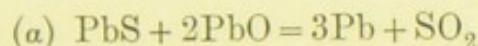


FIG. 35.—Lime Crucible for melting Platinum.

and lead being formed, at the same time that an alloy of iridium, osmium, etc., insoluble in the melted lead, sinks to the bottom of the platinum-lead alloy. The platinum-lead alloy is then ladled away from the insoluble residue, and finally cupelled. The platinum is subsequently refined by fusion in the oxy-hydrogen flame. The reactions are represented by the following equations:—



Platinum obtained by this method still retains iridium and rhodium.

PROPERTIES. — Platinum is a white metal, and is not attacked by water, air, sulphuretted hydrogen, or oral secretions. Nitric, sulphuric, and hydrochloric acids have no action on the pure metal; but when platinum is alloyed with a large quantity of silver, it is soluble in nitric acid. It dissolves in aqua regia ($3\text{HCl} + \text{HNO}_3$). Platinum combines with carbon at comparatively low temperatures, forming

carbides of the metal.¹ It is never advisable to melt the metal in plumbago crucibles, but in those made of fireclay lined with magnesia or lime.

Platinum is attacked by alkalies and cyanides. It is hardened by rolling and hammering, but may be softened by heating to redness and slowly cooling. Platinum is melted in the electric furnace, or by the oxy-hydrogen blow-pipe. It occludes oxygen when molten, but expels the gas on cooling. At high temperatures the metal is weldable.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	21.5
Specific heat (water = 1)	0.0324
Hardness (diamond = 100)	36.8
Fusibility	1775° C. or 3227° F.
Malleability (gold = 1, most malleable)	6
Ductility (gold = 1, most ductile)	3
Tenacity (per square inch in tons)	20
Conductivity of heat (silver = 100)	8.4
Conductivity of electricity (silver = 100)	14.5
Expansion by heat	0.00089
Change of volume on solidification	decrease (<i>slight</i>).

DENTAL USES.—Platinum is used in amalgam-alloys for plates of continuous gum teeth, for pins for fastening porcelain teeth to the celluloid or vulcanite plate, for colouring² the enamel of artificial teeth; and when alloyed with silver, platinum is used as a base for artificial dentures. The metal is frequently used for the nozzles of root-dressing syringes, and also for “caps” (crown work).

ALLOYS.—(1) *Platinum-Gold Alloys* are ductile, elastic, and more fusible than platinum. An alloy containing 50 per cent. of each metal is very malleable, and has nearly the

¹ A. B. Griffiths, *Chemical News*, vol. li. p. 97; *Moniteur Scientifique*, vol. xv. ; *Journal Chemical Society*, 1885, p. 487.

² “Platinum colour” contains 94.7 per cent. of felspar, and 5.3 per cent. of finely precipitated platinum.

same colour as gold ; but an alloy containing 66·5 per cent. of platinum and 33·5 per cent. of gold is brittle. Platinum and gold combined in the proportion of 9·4 per cent. of the former and 90·64 per cent. of the latter forms an alloy having the density of platinum and the colour of gold. Platinum has a tendency to harden gold, and alloys of the two metals are frequently used for plates in America and on the Continent. (2) *Platinum and Silver* unite in all proportions, and *dental alloy* (platine-au-titre) contains the two metals. Some recent assays of this alloy, from various sources, gave the following results per cent. :—

Platinum	. . .	20	22	25	30	28
Silver	. . .	80	78	75	70	72

It is extremely difficult to make this alloy uniform ; and experience teaches us that it is best to use an injector furnace, and when the metals are melted, to stir vigorously, and to pour quickly into an ingot mould previously oiled.

Dental alloy makes a stronger plate for artificial dentures than standard silver, and is more durable and more rigid. It has less tendency to blacken than standard silver when exposed to the oral secretions. Nitric acid attacks dental alloy, dissolving a portion of the platinum as well as the silver. Hot sulphuric acid dissolves the silver, but leaves the platinum as a black powder. The best material for joining pieces of dental alloy is gold solder. The alloy requires annealing during swaging. (3) *Le Chatelier's Alloy* contains 60 per cent. of platinum and 10 per cent. of rhodium, and is one of the thermo-elements in the Le Chatelier electric pyrometer which is used for ascertaining the temperatures of furnaces. (4) *Platinum and Iridium* unite in different proportions, but the oxy-hydrogen blowpipe is necessary to melt them. The alloys are harder, more elastic, more difficultly fusible than platinum, and the

platinum vessels used in chemical laboratories contain iridium, which makes them harder and stronger. An alloy containing 90 per cent. of platinum and 10 per cent. of iridium is used as a standard metal bar for the metric system. This alloy is unalterable on exposure to the atmosphere, and is *not* attacked by aqua regia. Small quantities of iridium add to the strength of platinum, and greatly increase its value in continuous gum-work. Iridio-platinum is also of value in combination with vulcanite for either entire or partial cases. These alloys are malleable, ductile, and capable of being worked. They require an electric furnace (see Fig. 14) or the oxy-hydrogen blowpipe to melt them; and pieces of them are soldered by using *pure* gold—the ordinary gold solders being unsuitable for the purpose. They are swaged by the use of a zinc counter-die. (5) *Platinum* alloys with tin, cadmium, lead, zinc, and other metals, but they are of no use in the dental laboratory. (6) *Platinum and Nickel*.—An alloy containing 50 per cent. of each metal is malleable, slightly yellow, and melts at a red heat. (7) *Platinum-Copper Alloys* are malleable and ductile, and are used by dentists for plates. (8) *Platinum Amalgam*.—Platinum does not amalgamate with mercury, but spongy platinum unites with the latter when worked with it in a warm mortar, or in contact with acetic acid. Fletcher states that platinum increases the rapidity of hardening of amalgams, and also the power of retaining their form after hardening.

PLATINUM BLACK is platinum in a finely divided state; and is prepared by precipitating the metal from an acidulated solution of platinic chloride by means of zinc; or by adding sodium carbonate and sugar to a boiling solution of platinic chloride. It is also prepared by alloying platinum with zinc, and dissolving out the zinc with sulphuric acid. Platinum black occludes gases, and when exposed to a red heat it assumes the appearance of spongy platinum.

SPONGY PLATINUM is produced by heating ammonio-platinum chloride to bright redness. It is weldable at a red heat, and also occludes gases.

PLATINUM FOIL.—Platinum is a malleable metal, and may be rolled or beaten out into foil. The foil used for filling teeth is gilded and annealed; but plugs of it are difficult to insert, so as to be water-tight; this being due to the “harshness” of the metal. The plugs are almost *white*, and in this respect there is an advantage over gold.

SOLDER FOR PLATINUM.—For dental purposes, pure gold is the most suitable solder for platinum, and the less used the better work.

DETECTION OF PLATINUM IN ALLOYS.—(1) Alloys used for *amalgams* are heated with strong sulphuric acid. The platinum and gold (if present) remain as an insoluble residue. The residue is washed with water, dissolved in aqua regia, and ammonium chloride and alcohol added, when the platinum is precipitated as $\text{PtCl}_4(\text{NH}_4\text{Cl})_2$. (2) In dental alloy and other silver alloys of platinum, the presence of the latter metal is detected by heating the alloy with nitric acid, when the platinum is partly dissolved, the remainder being left as an insoluble residue. The solution is treated with hydrochloric acid to precipitate the silver, and filtered; to the filtrate is added a solution of ammonium chloride and alcohol, when the platinum is precipitated as $\text{PtCl}_4(\text{NH}_4\text{Cl})_2$. (3) The presence of platinum in gold plate may be readily detected by dissolving a small piece of the plate in aqua regia; filtering off any silver chloride, concentrating by evaporation, and finally precipitating the platinum by means of a solution of ammonium chloride and alcohol (*loc. cit.*).

ESTIMATION OF PLATINUM IN ALLOYS.—(1) A weighed quantity of the alloy¹ is treated with concentrated sulphuric acid, and the residue dissolved in aqua regia. To the solution

¹ Weighed on delicate balances, *vide* Figs. 1 and 22.

is added ammonium chloride and alcohol; and the precipitate produced is washed, dried, ignited, and the spongy platinum weighed. If 3 grms. of the alloy yielded on assay 0.15 gm. of spongy platinum, the percentage of platinum present is—

$$\frac{.15 \times 100}{3} = 5 \text{ per cent.}$$

(2) Another method is to melt the weighed alloy, and gradually add mercuric chloride. By this means the tin volatilises as chloride along with the mercury, and the platinum remains behind in combination with silver. It is treated with nitric acid, and the silver precipitated with hydrochloric acid. The silver chloride is separated by filtration; the filtrate concentrated by evaporation, and the platinum precipitated by the addition of ammonium chloride and alcohol. The precipitate is washed, dried, and ignited, and the spongy platinum weighed. The small quantity of platinum usually present in ordinary amalgam-alloys passes into solution with the silver; but when large quantities are present a portion of it dissolves in the nitric acid, and a portion remains with the gold undissolved. This residue is dissolved in aqua regia, and the platinum precipitated as already described. (3) The platinum in *dental alloy* is estimated by weighing a piece of the alloy and treating it with nitric acid, which dissolves part of the platinum and all the silver. A stick of zinc added to the solution precipitates the platinum and silver; and by treating the precipitated metals with nitric acid, the silver only is dissolved. The two quantities of platinum are washed, dried, and weighed. The silver is readily recovered from the solution by precipitating it as silver chloride. The chloride is washed, dried, and decomposed by means of sodium carbonate (fusion), when silver remains behind.

PLATINUM SCRAP.—The recovery of platinum from scrap may be performed by the methods already described, or by fusing the scrap into a mass with antimony. When the alloy is heated in air, it leaves the platinum in a suitable state for working.

CHAPTER XXV

IRIDIUM

Symbol, Ir ; Atomic weight, 193

OCCURRENCE.—Iridium is found native in most platinum ores. It also occurs as an alloy with osmium (osmiridium).

PROPERTIES.—Iridium is a white lustrous metal. Air, water, and acids have no action on the pure metal—not even aqua regia. When alloyed with platinum, iridium is attacked by aqua regia. At ordinary temperatures it is hard and brittle, but at a red heat it becomes somewhat malleable.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	. . . . .	22.38
Specific heat (water = 1)	. . . . .	0.040
Hardness (diamond = 100)	. . . . .	42
Fusibility	. . . . .	1700° C. or 3092° F.
Malleability (gold = 1, most malleable)	. . . . .	10
Ductility (gold = 1, most ductile)	. . . . .	5
Tenacity (per square inch in tons)	. . . . .	21
Conductivity of heat (silver = 100)	. . . . .	9
Conductivity of electricity (silver = 100)	. . . . .	13
Expansion by heat	. . . . .	0.00102
Change of volume on solidification	. . . . .	decrease (<i>slight</i>).

DENTAL USES.—Alloyed with platinum, iridium is used in the manufacture of plates and wire.

ALLOYS.—Iridium increases the hardness of most metals, and forms valuable alloys with platinum for dental and chemical purposes (*vide* Platinum). Iridium cannot be alloyed with gold, although *pure* gold is the best solder for alloys of the metal.

CHAPTER XXVI

NICKEL

Symbol, Ni; Atomic weight, 58.7

OCCURRENCE.—Nickel is always associated with cobalt; and the ores are chiefly compounds of these metals with arsenic and sulphur.

PREPARATION.—(1) The ores are roasted, extracted with hydrochloric acid, and treated with sulphuretted hydrogen for the removal of antimony, lead, and copper, and any remaining arsenic. Chloride of lime (bleaching powder) is then added to oxidise the iron, so that it is precipitated on the addition of chalk. The solution now contains cobalt and nickel, and a further quantity of chloride of lime precipitates the cobalt as trioxide Co_2O_3 ; the nickel being subsequently precipitated as Ni_2O_3 by the addition of lime. The nickel oxide is reduced to the metallic state with carbon at a high temperature. If an *excess* of nickel oxide is heated with carbon, malleable nickel is formed; if, however, the carbon is in excess, the metal is hard and brittle. (2) Nickel is also extracted from its ores by first concentrating it in combination with arsenic and sulphur, and slagging off impurities. The rich nickel sulpho-arsenide is ultimately roasted to expel arsenic and sulphur, and the nickel oxide formed is reduced with carbon in a blast furnace.

PROPERTIES.—Nickel is a white metal with a yellow tinge. It is permanent in air at ordinary temperatures; and

is not attacked by sulphuretted hydrogen, water, or alkaline solutions. It is soluble in nitric acid, aqua regia, hydrochloric acid, and dilute sulphuric acid. Nickel is a magnetic metal.

PHYSICAL PROPERTIES.—

Specific gravity (water = 1)	8.5
Specific heat (water = 1)	0.1086
Hardness (diamond = 100)	46.8
Fusibility	1600° C. or 2912° F.
Malleability (gold = 1, most malleable)	12
Ductility (gold = 1, most ductile)	5
Tenacity (per square inch in tons)	29
Conductivity of heat (silver = 100)	11.4
Conductivity of electricity (silver = 100)	12.9
Expansion by heat	0.00127
Change of volume on solidification	decrease about 1 p. c.

DENTAL USES.—Nickel has been introduced into certain alloys used in dentistry—impression trays, matrices, etc. Owing to the poisonous nature and intense colour of its salts, nickel alloys are not used for fillings.

ALLOYS.—(1) *Nickel, Copper, and Zinc* combine together to form a series of alloys. German silver is one of these alloys, and varies much in its composition—

Nickel	20 per cent.	20 per cent.	20 per cent.
Copper	50 „	60 „	55 „
Zinc	30 „	20 „	25 „

The nickel may vary from 6 to 34 per cent. Owing to the high temperature required for the fusion of nickel, and the low melting point and ready oxidability of zinc, the preparation of German silver is attended with a considerable loss of zinc, and special care is therefore required in its preparation. The copper and nickel may be melted together in a separate crucible, and the heated zinc added to the bath

in small pieces; or the metals are arranged in the form of strata in the crucible, with copper at the bottom and top, the surface being covered with charcoal. The melted metals are stirred continuously to ensure their thorough incorporation.

German silver sometimes contains iron, tin, manganese, antimony, and lead in addition to nickel, copper, and zinc. German silver has a grey colour; it is hard, tenacious, ductile, and malleable. After casting, the alloy requires annealing; it can then be hammered or rolled. German silver becomes tarnished on exposure to air, due to the formation of sulphide. It is soluble in nitric acid, and is attacked by vinegar. (2) *Nickel* also combines with manganese, iron, aluminium, chromium, and other metals, forming hard and tenacious alloys.

NICKEL PLATING is a process for depositing nickel on other metals by means of an electric current. A *cold* solution of nickel ammonium sulphate $[\text{NiSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}]$ is used for the purpose; the articles to be nickeled are cleaned¹ and polished before being placed in the bath. The articles are then connected with the cathode or negative pole of the battery or dynamo—a plate of nickel being connected with the anode or positive pole. As the deposited nickel is extremely hard, it is necessary to polish the articles before placing them in the bath. Articles coated with nickel show a highly polished surface. The coating is, moreover, very hard and durable, and is not affected by the atmosphere or sulphuretted hydrogen.

The time required for electro-nickeling is from 30 minutes to 3 or 4 hours; and an electro-motive force of 6 volts and a current strength of 30 ampères are necessary for the purpose.

Root-nippers, forceps, cheek-distenders, scissors, clamps, and other dental instruments are frequently nickel-plated.

¹ Oxides are removed by acids, and grease by soda.

CHAPTER XXVII

PRACTICAL WORK

“Ce n'est pas assez de savoir les principes, il faut savoir manipuler.”

THE following *experiments* form a suitable course of practical work for students of dental metallurgy :—

Gold

1. *Malleability*.—Test its malleability either by hammering or rolling.

2. *Precipitation*.—Dissolve an alloy in aqua regia, evaporate, add water and a solution of ferrous sulphate, and heat. Precipitated gold is formed. It is a brown powder when dry, but when fused on charcoal it melts and assumes its metallic lustre. Also observe that it does not oxidise.

3. *Specific Gravity*.—Determine the sp. gr. of gold by the methods already described.

4. *Annealing*.—After rolling gold, note that it is hard, but heating and cooling it becomes soft (annealing).

5. *Welding*.—Place two pieces of gold under the rolls, or hammer them, and note that they weld.

6. *Chemical Action*.—Place a piece of gold in H_2S water, hydrochloric, nitric, and sulphuric acid, and a solution of sodium hydroxide, and note that there is no action.

7. *Impurities*.—Melt pieces of gold with small quantities of lead and antimony, and observe that the gold is made brittle. Test under the hammer.

8. *Refining*.—Refine the impure gold (7) by fusing it with potassium nitrate. After the fusion the gold will be found to be malleable.

9. *Cupellation*.—Cupel a gold alloy (Au+Cu) by the process already described.

10. *Parting*.—Fuse gold and silver together, then treat the alloy with nitric acid, and note that the silver dissolves, leaving the gold behind as a brown residue.

11. *Precipitations*.—(a) To a hot solution of gold chloride add a solution of oxalic acid, and note that *spongy* gold is precipitated. (b) To a solution of gold chloride add a solution of stannous chloride containing a little stannic chloride, and notice the precipitation of the purple of Cassius.

12. *Colour*.—(a) Melt gold and copper together, and note that the colour is deepened. (b) Melt gold and silver together, and note that the colour of the gold is reduced. Note also the malleability and hardness of the alloys.

13. *Amalgamation*.—Add finely divided gold to mercury, and observe that an amalgam is formed. Squeeze the amalgam in chamois-leather with the pliers, and note the nature of the amalgam. Then note its hardness after standing for some days. Heat the amalgam in a crucible until all the mercury has volatilised.

14. *Touchstone*.—Test alloys of gold by means of the touchstone.

15. *Alloys*.—Prepare alloys and amalgams of gold.

Mercury

1. *Purity*.—Pour a few globules of mercury on a glass plate, and notice that it leaves no "tail," and the glass is not "wetted" as with ordinary liquids.

2. *Volatilisation*.—Heat mercury in a crucible, and note that it completely volatilises.

3. *Oxidation*.—Note that mercury does not oxidise at

ordinary temperatures, but at its boiling point (350°C.) the metal begins to oxidise.

4. *Impurities.*—Add small quantities of lead and zinc to mercury, and note that it leaves a “tail” when poured upon glass. The impure metal is liable to oxidise.

5. *Distillation.*—Heat some mercury in a long glass tube, and note that it condenses after volatilisation—proving that mercury is capable of being distilled.

6. *Vermilion.*—Rub mercury and sulphur together in a mortar, and note the formation of black mercuric sulphide. Heat the black sulphide in a covered crucible, allow to cool, and observe the formation of vermilion or red mercuric sulphide. . . . Note that at a higher temperature the sulphide is completely volatilised. If the sulphide were adulterated with red lead (Pb_3O_4) or iron oxide (Fe_2O_3), a residue would remain.

7. *Specific Gravity.*—Ascertain the sp. gr. of mercury.

8. *Chemical Action.*—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , and NaOH on mercury.

9. *Conduction for Electricity.*—Put a wire from a battery into a vessel of mercury, and also another wire into the same vessel, and note that the current still passes (Fig. 36).

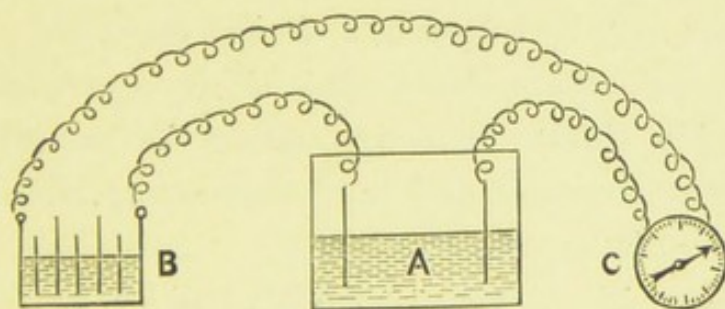


FIG. 36.—Conduction for Electricity.

A, Mercury. B, Battery. C, Galvanometer.

10. *Amalgamation.*—Add metals to mercury, and note that they amalgamate with it.

Silver

1. *Cupellation*.—Cupel an alloy of silver.
2. *Specific Gravity*.—Ascertain the sp. gr. of silver.
3. *Fusion*.—Melt silver before the blowpipe. Note that it is fusible, and does not oxidise. Allow it to cool quickly, and observe the "spitting," due to occluded oxygen. Melt an alloy of silver and copper, and note there is no "spitting."
4. *Purification*.—Dissolve an alloy of silver in nitric acid, add a solution of sodium chloride, filter off the precipitated silver chloride, wash and dry it, and finally reduce it with sodium carbonate in a crucible. The metal is "chemically pure silver."
5. *Malleability*.—Test the malleability by hammering or rolling. After rolling, note its *elasticity*.
6. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 and NaOH on silver.
7. *Conductivity for Heat and Electricity*.—(a) Place one end of a silver wire in a Bunsen flame, and note that the other end becomes hot. (b) Attach silver wires to the terminal of a battery, and note the oscillation of a needle on touching the binding screws of a galvanometer. These experiments prove that silver is a good conductor for heat and electricity (other metals may be tested in a similar way).
8. *Amalgamation*.—Note that silver amalgamates with mercury (*vide* Gold). Dissolve silver in nitric acid, add mercury, allow to stand, and note that a crystalline amalgam ("silver tree") is formed.
9. *Action of Metals*.—(a) Melt silver and platinum together. Note the hardness and toughness of the alloy. Treat alloy with HNO_3 , silver dissolves and platinum remains as a black residue.
10. *Galvanic Action*.—Dissolve silver in HNO_3 , add a strip of copper, and note the precipitation of silver (crystalline).

11. *Change of Volume*.—Pack a small quantity of silver amalgam into a glass tube until quite full, level the surface, and allow to stand until hard. Note whether expansion or contraction has taken place (using a lens).

12. *Alloys*.—Prepare alloys of silver, and note their properties.

Platinum

1. *Oxidation*.—Heat platinum before the blowpipe, and note that it does not oxidise.

2. *Specific Gravity*.—Ascertain the sp. gr. of platinum.

3. *Coefficient of Expansion*.—Fuse a piece of platinum into a glass tube, and note that the glass is not fractured on cooling. This proves that platinum and glass contract and expand equally (*i.e.* their coefficients of expansion are practically the same).

4. *Malleability*.—Roll a piece of platinum, or hammer it, and note that it is malleable.

5. *Annealing*.—Heat a piece of platinum, allow it to cool, and note that annealing has made it soft.

6. *Chemical Action*.—Note that platinum is not acted upon by H_2S water, HCl , HNO_3 , and H_2SO_4 .

7. *Welding*.—Heat two pieces of platinum to a white temperature, and hammer them together. Note that they have welded.

8. *Alloying*.—(a) Heat a piece of platinum to a white temperature, and place a piece of gold upon it. Note that union has taken place. (b) Note that lead does the same, but the alloy of Pt and Pb is brittle.

9. *Spongy Platinum*.—Dissolve platinum in aqua regia, evaporate nearly to dryness, add water and a solution of ammonium chloride, then alcohol; filter off the precipitate, wash, and finally dry and ignite the precipitate. The residue is spongy platinum. Heat to a white temperature, and

hammer. Note that the platinum assumes its ordinary metallic lustre.

10. *Precipitation*.—To a solution of platinum chloride add a few drops of HCl, and place a strip of zinc in the solution. Note the precipitation of *platinum black*.

11. *Amalgamation*.—Place the “platinum black” in a heated mortar, add mercury, and rub for some time. After squeezing the amalgam in the ordinary way, allow it to stand for some days, and note that it hardens very imperfectly.

12. *Conduction for Heat and Electricity*.—(*Vide* Silver.)

Tin

1. *Fusion*.—Note its low melting point.

2. *Crystalline Nature*.—Bend a piece of tin, and note the crackling sound.

3. *Specific Gravity*.—Ascertain the sp. gr. of tin.

4. *Softness*.—Test its softness by cutting the metal.

5. *Malleability*.—Test its malleability by rolling and hammering.

6. *Oxidation*.—Note that the metal readily oxidises in air.

7. *Welding*.—Take two pieces of tin, and pass them through the rolling mill. Note that they are welded.

8. *Chemical Action*.—Note the action of H_2S water, HCl, HNO_3 , H_2SO_4 , and NaOH on the metal.

9. *Fusible Alloys*.—Melt tin with lead and bismuth. Note that the alloy melts in boiling water. Determine the melting point of the alloy as already directed (*vide* Fig. 4).

10. *Alloys*.—Prepare alloys of tin, and note their characters.

11. *Amalgamation*.—Note the plastic nature of fresh amalgams of tin, and the brittleness of those that have been allowed to stand for some days. Note that excess of silver retards amalgamation.

12. *Change of Volume*.—Place an amalgam of tin in a glass tube, allow it to stand, and then note the contraction or expansion.

Lead

1. *Specific Gravity*.—Determine the sp. gr. of lead.
2. *Oxidation*.—Heat before the blowpipe, and note that the metal is oxidised ($2\text{Pb} + \text{O}_2 = 2\text{PbO}$).
3. *Malleability*.—Roll or hammer a piece of the metal.
4. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , acetic acid, and NaOH on the metal.
5. *Alloys*.—Prepare alloys of lead.
6. *Granulation*.—Melt lead in a crucible, and pour the molten metal into a wooden box, agitate the box, and note the granulation of the lead.
7. *Welding*.—Hammer two clean pieces of the metal, and note that they have welded.
8. *Brittleness*.—Heat an ingot of lead, and when about to melt, strike the metal with a hammer, and note that it is brittle.

Alloy lead with antimony, and note that the alloy is brittle.

Zinc

1. *Specific Gravity*.—Determine the sp. gr. of zinc.
2. *Brittleness*.—Fracture an ingot of zinc, and note its crystalline character and brittleness.
3. *Hardness*.—Cut the metal with a knife. Do the same with lead.
4. *Malleability*.—Heat zinc to about 150°C ., and hammer it. Note its malleability at the temperature. Heat to about 250°C ., and note the brittleness of the metal.
5. *Oxidation*.—Note that the metal oxidises before the blowpipe.
6. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , and NaOH on zinc.

7. *Zinc and Lead*.—Melt equal parts of zinc and lead, and cast in an ingot mould. Fracture the ingot, and note the upper half consists of zinc (which is crystalline and brittle), while the lower half is lead, being malleable and soft.

8. *Amalgamation*.—Rub zinc filings or powder with mercury. Note the character of the amalgam, and that union is facilitated by the addition of a few drops of acid.

9. *Change of Volume*.—Note the expansion or contraction of amalgams of zinc.

10. *Alloys*.—Prepare alloys of zinc, and note their characteristic properties.

Copper

1. *Specific Gravity*.—Determine the sp. gr. of the metal.

2. *Malleability*.—Roll and hammer an ingot. Note its malleability, and that rolling, etc., hardens it.

3. *Hardness*.—Cut a piece of copper, and note its hardness.

4. *Oxidation*.—Note that the metal is oxidisable, and that spongy copper oxidises readily in contact with air.

5. *Chemical Action*.—Test the action of H_2S water, HCl , HNO_3 , H_2SO_4 , acetic acid (vinegar), and $NaOH$ on the metal.

6. *Conduction for Heat and Electricity*.—Test as in the case of silver.

7. *Fusion*.—Melt on charcoal by means of the blowpipe. Note that the metal on cooling is somewhat brittle, owing to the presence of dissolved copper oxide.

8. *Brittleness*.—Melt copper and small quantities of arsenic and antimony. Note the brittleness of the metal.

9. *Deposition of Metals*.—(a) Place a strip of copper in a solution of mercuric chloride. Note the deposit of mercury. (b) Place a steel blade in a solution of copper sulphate, and note the deposition of copper.

10. *Amalgamation*.—Rub precipitated or spongy copper with mercury in a mortar. Note that amalgamation is facilitated by the addition of a little hot water and a few drops of sulphuric acid, or by adding a solution of mercuric nitrate to the spongy copper before the introduction of the mercury. After removing excess of mercury, note the hardness of the amalgam on standing, and that hammering renders it malleable.

11. *Change of Volume*.—Note the expansion or contraction of amalgams of copper.

12. *Alloys*.—Prepare alloys of copper, and note their properties.

Cadmium

1. *Specific Gravity*.—Determine the sp. gr. of cadmium.
2. *Fusion*.—Note its low melting point.
3. *Oxidation*.—Note that the metal burns, forming a brown oxide.

4. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , and NaOH on the metal.

5. *Amalgamation*.—Note that mercury produces a soft amalgam, that hardens and becomes brittle on standing, but softens when moderately heated.

6. *Change of Volume*.—Note the expansion or contraction of cadmium amalgams.

7. *Malleability, etc.*—Note that its malleability, softness, toughness, and welding properties are similar to those of lead.

Antimony

1. *Specific Gravity*.—Determine the sp. gr. of antimony.
2. *Brittleness*.—Note that it is a brittle metal.
3. *Fusion*.—Note its melting point.
4. *Oxidation*.—Note that it is readily oxidised.
5. *Amalgamation*.—Note that union does not readily take place.

6. *Alloys*.—Prepare alloys of antimony, and note their properties.

7. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , and NaOH on the metal.

Bismuth

1. *Specific Gravity*.—Determine the sp. gr. of bismuth.

2. *Brittleness*.—Note that it is a brittle metal.

3. *Fusion*.—Note its low melting point.

4. *Expansion on Cooling*.—Cast an ingot, and note that it expands on cooling. A valuable property of the metal.

5. *Amalgamation*.—Shake powdered bismuth and mercury in a bottle, and note the *liquid* character of the amalgam.

6. *Alloys*.—Prepare alloys of bismuth.

7. *Oxidation*.—Note that the metal oxidises before the blowpipe.

8. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , and NaOH (solution) on the metal.

Aluminium

1. *Specific Gravity*.—Determine the sp. gr. of aluminium, and note its low density.

2. *Malleability*.—Roll the metal to prove its malleability.

3. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , NaOH , and Na_2CO_3 on the metal.

4. *Alloys*.—Prepare alloys of aluminium.

Magnesium

1. *Specific Gravity*.—Determine the sp. gr. of the metal.

2. *Oxidation*.—Note that the metal oxidises, and produces a bright light when it burns.

3. *Alloys*.—Prepare alloys of the metal.

Iron and Steel

1. *Specific Gravity*.—Determine the sp. gr. of iron.
2. *Hardness*.—Note that iron wire is “soft,” and that steel wire is “hard.” Both can be bent.
3. *Burnt Iron*.—Heat a piece of soft iron at a high temperature with the blowpipe, until it is oxidised and “burnt.” Note that the metal is brittle.
4. *Fusion*.—Note that iron does not melt before the blowpipe (therefore high melting point).
5. *Chemical Action*.—Note the action of H_2S water, HCl , HNO_3 , H_2SO_4 , and NaOH on the metal.
6. *Tenacity*.—Note that a steel wire is capable of supporting a great weight without fracture.

Nickel

1. *Specific Gravity*.—Determine the sp. gr. of nickel.
2. *Malleability*.—Note that the metal can be rolled.
3. *Fusion*.—Note that it does not melt before the blowpipe.
4. *Chemical Action*.—Test the action of H_2S water, HCl , HNO_3 , H_2SO_4 , and NaOH on nickel.

APPENDIX.

I. ATOMIC WEIGHTS

THE atomic weights used in this book are those recommended by the Deutschen Chemischen Gesellschaft (Berlin).

O = 16.

Aluminium, Al	27.1	Magnesium, Mg	24.36
Antimony, Sb	120.2	Mercury, Hg	200
Bismuth, Bi	208.5	Nickel, Ni	58.7
Cadmium, Cd	112.4	Oxygen, O	16
Copper, Cu	63.6	Palladium, Pd	106.5
Gold, Au	197.2	Platinum, Pt	194.8
Hydrogen, H	1.008	Silver, Ag	107.93
Iridium, Ir	193	Tin, Sn	119
Iron, Fe	55.9	Zinc, Zn	65.4
Lead, Pb	206.9		

The above figures are all on the oxygen basis, and require dividing by 1.008 to bring them to the hydrogen standard.

II. TROY WEIGHT

4 Grains	1 Carat (c.).
6 Carats, or 24 Grains	1 Pennyweight (dwt.).
20 Pennyweights	1 Ounce (oz.).
12 Ounces	1 Pound (lb.).
25 Pounds	1 Quarter (qr.).
100 Pounds	1 Hundredweight (cwt.).
20 Hundredweights	1 Ton of gold or silver.

The ratio of a pound troy to a pound avoirdupois is as

14 to 17; the former containing 5760 grains and the latter 7000.

III. IMPERIAL OR AVOIRDUPOIS WEIGHT

16 Drams	1 Ounce (oz.).
16 Ounces	1 Pound (lb.).
14 Pounds	1 Stone (st.).
28 Pounds	1 Quarter (qr.).
4 Quarters or 112 lbs.	1 Hundredweight (cwt.).
20 Hundredweights	1 Ton.

IV. METRIC EQUIVALENTS IN ENGLISH MEASURES

1 Millimetre	= 0·03937 inch.
1 Centimetre	= 0·39371 inch.
1 Decimetre	= 3·93718 inches.
1 Metre	= 39·37 inches, or 1·093 yards.
1 Inch	= 2·539 centimetres.
1 Foot	= 3·0479 decimetres.
1 Cubic centimetre	= 0·061 cubic inch, or 0·00176 pint.
1 Litre or 1000 cc.	= 61·027 cubic inches, or 1·76 pints.
1 Cubic inch	= 16·38 cubic centimetres.
1 Gallon	= 4·543 litres.
1 Milligramme	= 0·0154 grain.
1 Centigramme	= 0·1543 grain.
1 Decigramme	= 1·5432 grains.
1 Gramme	= 15·4323 grains.
1 Kilogramme	= 15432·34 grains.
1 Grain	= 0·0647 gramme.
1 Gramme	= 1 cubic centimetre.
1 Cubic centimetre	= 17 minims.
1 Ounce troy (480 grains)	= 31·1034 grammes.
1 Ounce avoirdupois (437·5 grains)	= 28·30625 grammes.
1 Kilogramme	= 2·2046 pounds.
1 Pound	= 0·453 kilogramme.
1 Litre	= 0·220 gallon.

V. BRITISH COINS

Coins.	Standard Weight.		Least Current Weight.	
	Imperial Weight (grains).	Metric Weight (grammes).	Imperial Weight (grains).	Metric Weight (grammes).
Sovereign . . .	123·27447	7·98805	122·500	7·93787
Half-sovereign . . .	61·63723	3·99402	61·125	3·96083
Crown . . .	436·30363	28·27590	...	...
Double florin . . .	349·09090	22·62072	...	...
Half-crown . . .	218·18181	14·13795	...	...
Florin . . .	174·54545	11·31036	...	...
Shilling . . .	87·27272	5·65518	...	...
Sixpence . . .	43·63636	2·82759	...	...
Threepence . . .	21·81818	1·41379	...	...
Penny . . .	145·83333	9·44984	...	...
Halfpenny . . .	87·50000	5·66990	...	...
Farthing . . .	43·75000	2·83495	...	...

VI. MISCELLANEOUS TABLE

1 Horse-power . . .	= 33000 foot-pounds of work per minute.
1 Gallon of water . . .	= 70000 grains.
1 Atmosphere . . .	= 14·71 lb. per square inch ; 29·22 inches of mercury.
1 Bag of vermilion . . .	= 50 lb.
1 Bottle of mercury . . .	= 84 lb.

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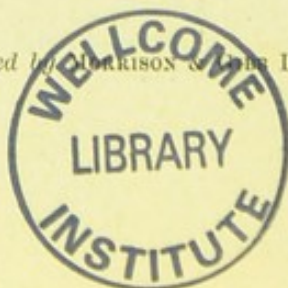
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[January, 1909.]





