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CHAPTER XVI.

MISCELLANEOUS ALLOYS.

Amalgams.

THE word *amalgam* is used to describe the alloys of mercury with other metals. Owing to their low melting-points they were the first alloys to be investigated, but recently they have attracted little attention.

Mercury alloys with a number of metals, the union being in many cases accompanied by the evolution of considerable heat, but very few of the amalgams have been put to any use, and the applications of those that are used industrially are strictly limited.

The principal amalgams are those of tin, copper, cadmium, bismuth, sodium, silver, gold, and palladium.

Tin-amalgams are made by adding mercury to molten tin. The amalgam of equal parts of mercury and tin is a brittle solid; but with more mercury a plastic mass is obtained which becomes hard in the course of a few days. This and similar alloys containing cadmium, silver, or gold, are used by dentists for stopping teeth. The amalgams are used in a plastic condition, and harden with little or no expansion.

Copper-amalgams.—Copper does not alloy readily with mercury under ordinary conditions. By mixing mercury with precipitated copper in presence of mercuric nitrate solution, however, the mercury unites with the copper to form an amalgam.

Copper-amalgam is plastic when newly made, but becomes hard in a day or two. It may be softened again by immersing it in boiling water or by simply pounding it; and it is capable of being hammered, rolled, and polished. It hardens without expanding or contracting, and on this account makes an excellent stopping for teeth, while at the same time it has the property of rendering the tooth in contact with it extremely hard. Unfortunately, however, it is rapidly blackened by sulphur compounds, and it is now seldom used. Copper-amalgam can be used as a cement for metals, and is also used for cementing china and porcelain.

Cadmium and **palladium-amalgams** are both employed as dental amalgams, the latter being considered the best amalgam for the purpose.

Bismuth-amalgam, either in the pure state or with additions of lead and tin, is occasionally used for silvering glass.

Silver- and **gold-amalgams** are of some interest on account of their formation in the extraction of gold and silver from their ores. Silver-amalgam is also used for silvering glass. Silver and mercury form a definite compound, corresponding to the formula Ag_2Hg_2. By squeezing the excess of mercury through chamois leather an amalgam of fairly uniform composition is obtained. It contains 43·7 parts of silver to 100 of mercury, or $Ag_2Hg_2 + 4{\cdot}6$ per cent. mercury.

Gold forms with mercury a compound $AuHg_4$, and the amalgam remaining after squeezing the excess of mercury through chamois leather contains 33 per cent. of gold.

Fusible Metals.

The expression "fusible metal" is usually applied to alloys whose melting-point is below that of tin; and the alloys possessing this property may be either binary, ternary, or quaternary alloys of the metals lead, tin, bismuth, and cadmium. The constitution of the alloys will be sufficiently clear from a consideration of Charpy's work on the ternary alloys of lead, tin, and bismuth. All the metals of the fusible metal group form simple alloys with one another, *i.e.* they form neither compounds nor solid solutions, but consist of practically pure metals and eutectics. Now, we know that a eutectic has a lower melting-point than either of the metals of which it is composed, and that a triple or ternary eutectic has a lower melting-point than a binary eutectic; so that, by combining three metals of low melting-point in the proportions

necessary to form the eutectic, we may obtain an alloy whose melting-point is much lower than that of any of the single metals. Similarly, by adding a fourth metal a quaternary eutectic of still lower melting-point may be obtained. Heine has collected formulæ, from all available sources, relating to fusible alloys, and those in the following table are taken from his list.

Fusible Alloys.

Composition.				Melting-point.
Lead.	Tin.	Bismuth.	Cadmium.	
25·0	12·5	50·0	12·5	65·5°
26·7	13·3	50·0	10·0	60 – 68
26·0	14·8	52·2	7·0	68·5
28·6	14·3	50·0	7·1	70·0
27·6	10·3	27·6	34·5	75·0
35·1	20·0	35·3	9·5	80·0

The eutectic alloy of lead, tin, and bismuth possesses the property of expanding on cooling, and it is, therefore, used for taking impressions, as the finest details are faithfully reproduced.

The melting-points of fusible alloys may be still further lowered by the addition of mercury.

Rare Metal Alloys.

Platinum.—The high price of platinum is a serious drawback to its use in the form of alloys, but a few of these are manufactured industrially. The alloys of platinum and silver have already been referred to as dental alloys, and an alloy of 66 per cent. silver and 34 per cent. platinum is prepared by Messrs Johnson & Matthey as a standard of electrical resistance. A number of alloys of platinum and copper have been suggested from time to time. Cooper's gold, containing 19 per cent. of platinum and 81 per cent. of copper, is said to be malleable, ductile and non-corrodible; it resembles 18-carat gold in appearance.

Platinum containing 10 per cent. of iridium is, perhaps, the most important alloy of platinum. It is now largely used as one of the wires in thermo-couples intended for the measurement of high temperatures, the other wire being of pure platinum. The standard metre made for the Parisian Commission of the International Metrical System in 1870 by Messrs Johnson & Matthey consists of platinum containing 10 per cent. of iridium, and was adopted as the material for the manufacture of the standard weights and measures after a thorough trial lasting over two years.

Platinum containing 10 per cent. of rhodium is also used in thermo-couples for high-temperature measurements.

Alloys used for Electrical Resistances.

The alloys employed in the manufacture of electrical resistances constitute an important class, and although their composition is very variable, it will be convenient to consider them together in the light of the property which renders them of value, rather than separately under the metals of which they are composed. The following table gives the composition of a number of these alloys in the order of their resistances :—

Alloy.	Copper.	Zinc.	Nickel.	Iron.	Manganese.	Aluminium.	Tungsten.
Aluminium-bronze	95	...	...	...	...	5	...
German silver .	60	25	14	0·3	...	...	...
German silver .	55·5	20	24	0·3	0·2	...	...
Nickelin . .	74·5	...	25	0·5	...	...	...
Platinoid . .	60	24	14	...	...	...	1 to 2
Nickel-manganese-copper	73	...	3	...	24	...	...
Manganin . .	84	...	12	...	4	...	...
Rheotan . .	84	4	...	...	12	...	...
Manganese-copper .	70	...	...	...	30	...	...
Manganese - steel (1 per cent. C.)	...	...	...	84·5	14	...	...
Aluminium - steel (0·2 per cent. C.)	...	...	...	94	...	5·5	...
Nickel - manganese steel (1 per cent. C.)	...	...	25	69	5	...	...

The electrical conductivity of alloys has already been referred to, and it will be remembered that Matthiessen divided the metals into three groups :—(1) Those whose conductivity could be represented by a straight line uniting the two pure metals when alloyed together; (2) those in which the addition of either metal to the other causes a rapid decrease in the conductivity, thus giving rise to a U-shaped curve; and (3) those in which the decrease in the conductivity of one of the metals is much greater than in the other, thus giving rise to an L-shaped curve. Now, on looking at the examples given by Matthiessen in the light of our present knowledge of the constitution of alloys, it will be seen that the metals in Matthiessen's first group are the same as those which with regard to their freezing-point curves Le Chatelier has placed in the first group of his scheme—that is to say, they form a simple series of alloys with a eutectic. Further, the metals of Matthiessen's second group correspond very closely to Le Chatelier's third group—that is to say, the isomorphous or solid solution group. And those in Matthiessen's third group correspond to Le Chatelier's second group. We have, therefore, a definite relation between the constitution of alloys and their electrical conductivity. In alloys consisting of pure metals and a eutectic the conductivity passes gradually from that of the one metal to that of the other; in alloys consisting of solid solutions the conductivity decreases rapidly, and rises again rapidly on the other side; while in those alloys forming solid solutions and their compounds, such as the copper-tin and copper-zinc alloys, the conductivity decreases rapidly until the point of saturation is reached and then takes a sudden bend and forms an L-shaped curve. Solid solutions therefore possess a maximum electrical resistance, and all the alloys in the foregoing table consist of single homogeneous solid solutions.