the addition of the manganese has the effect of increasing the tensile strength of the aluminium. Beyond 10 per cent. the alloys become very hard and brittle.

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CHAPTER XIV.

SILVER AND GOLD ALLOYS.

Silver Alloys.

The alloys of silver with copper may alone be said to have any important industrial applications. From time to time many other silver alloys have been suggested; but none of them have taken the place of the well-known silver-copper alloys. The importance of these alloys may be realised when it is remembered that the average weight of standard silver articles, hall-marked at the Assay Offices of Birmingham, Sheffield, and Chester alone, during the last five years amounts to 6,037,214 oz., or nearly 225 tons; and it has been estimated that the amount of standard silver melted annually in the United Kingdom is close on 700 tons.

The constitution of the silver-copper alloys has been thoroughly investigated by Roberts-Austen and Heycock and Neville, and the results of their researches are plotted in the freezing-point curve shown in fig. 50.* It will be seen that the metals form a simple series of alloys with a eutectic containing 71·9 per cent. of silver and melting at 778°. This is the alloy which Levol in 1854 considered to be a definite compound on account of its remarkable homogeneity.

The alloys of industrial importance are few in number, and contain not less than 80 per cent. of silver. The following table shows the composition of the silver standards used for coin and for plate in different countries:—

* The extent of the line representing the eutectic has not been accurately determined, but it should be much longer than that shown in the diagram.

SILVER STANDARDS.

Country.	Coinage.		Plate.
	Denomination.	Fineness.	Fineness.
Austria-Hungary	5 crowns	900	950
,, ,, . . .	1 crown	835	900
,, ,, . . .	Thaler	833½	800
,, ,, . . .	...	...	750
Belgium	5 francs	900	900
,, ...	2 and 1 franc and 50 centimes	835	800
Bolivia	1 boliviano	900	
Brazil	2 milreis	916·6	...
Bulgaria	21 lew	835	...
Chili	1 peso	900	...
Denmark	Crown	800	826
Egypt	10 Piastres	900	...
France	5 francs	900	950
,, ...	Others	835	850
Germany	Marks	900	800
Greece	5 drachmas	900	...
,, ...	Others	835	...
Great Britain	All	925	925
,, ...	...	...	959
British Colonies—			
Canada and Newfoundland .	50 cents	925	...
Australasia	Shilling, etc.	925	...
Hong Kong & Straits Settlements	Cents	800	...
Holland	Florin	945	934
,, ...	...	...	833
India (Burma, Ceylon, and Mauritius)	Rupee	916·6	...
Italy	5 liras	900	950
,, ...	...	...	900
,, ...	...	...	800
Japan	Yen	900	...
Mexico	Peso	902·7	...
Norway	Kroner	800	828·1
,, ...	50 ore	600	...
Peru	Sol	900	...
Portugal	5 testoons	916·6	916·6
,, ...	...	...	833
,, ...	...	...	800
Roumania	5 leys	900	...
Russia	Rouble	900	910
,, ...	Kopecks	500	880
,, ...	...	...	840
Servia	5 dinars	900	...
Spain	5 pesetas	900	916·6
,, ...	2, 1, and 1½ peseta	835	750
Sweden	2 and 1 kroner	800	828·1
,, ...	50 ore	600	...
Switzerland	5 francs	900	875
,, ...	2, 1, and ½ franc	835	800
Turkey	20 piastres	900	900
United States	All	900	...

It will be seen that an alloy containing 90 per cent. or 900 parts of silver per thousand is most generally adopted, while the British standard contains 92·5 per cent. or 925 parts per thousand. It should be mentioned that the composition of silver and gold alloys is seldom expressed in percentages, but in parts per thousand. Thus an alloy of "925 fine" signifies an alloy containing 925 parts of fine or pure silver per thousand.

Sterling silver was first defined by a statute of Edward I., and must contain 11 oz. 2 dwt. of fine silver and 18 dwt. of copper to the pound. The word "sterling" was apparently derived from the Easterlings, or workmen who came from Germany, and who were the first to make and work the alloy in this country. Stow says in his *Survey of London*, published in 1603: "But the money of England was called of the workers thereof, and so the Easterling pence took their name of the Easterlings, which did first make this money in England in the reign of Henry II., and thus I set it down according to my reading in Antiquitie of money matters, omitting the imaginations of late writers, of whom some have said Easterling money to take that name of a starre stamped on the border or ring of the penie: other some, of a bird called a stare or starling stamped on the circumference, and others (more unlikely) of being coined at Stiruelin or Starling, a towne in Scotland."

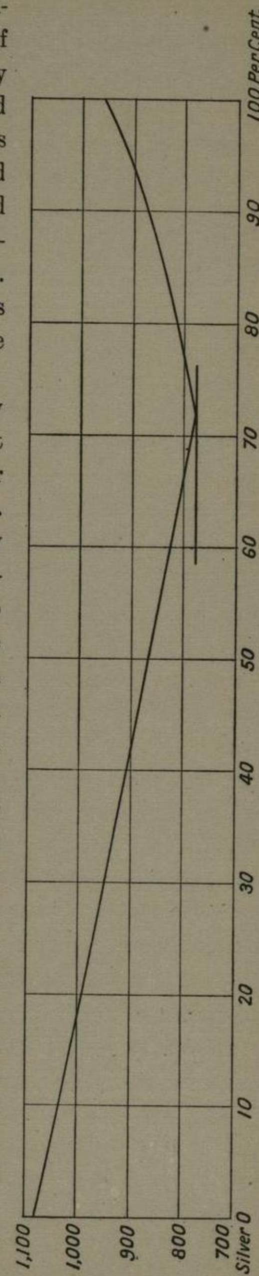

FIG. 50.—Freezing-point Curve of Silver-copper Alloys.

The history of the coinage standard has been well described by Roberts-Austen, and we cannot do better than quote his own words:—

"Anglo-Saxon and Anglo-Norman coins are believed to have been of the 'old standard' 925, and a coin of William the Conqueror which I assayed proved to be 922·8. In England this old standard appears to have remained unchanged until the thirty-fourth year of King Henry VIII., when a great fall took place. A still deeper fall in the standard fineness ensued in 1545, and again in 1546, and in the reign of Edward VI. It fell to its lowest point in the fourth year of the latter monarch, when the pound of silver contained only 3 oz. of fine silver and 9 oz. of base metal, that is, the standard, expressed decimally, was only 250. Strangely enough, this base coinage was projected with a view to secure by the transaction the sum of £160,000, to be devoted to the restoration of the standard generally. Half this sum appears to have been actually obtained. As a step to the withdrawal of the base money, it was almost universally decried, that is, the coin which had been current at rates far above its intrinsic value, was officially reduced to a value nearly corresponding with its standard of fineness. Dreadful distress was caused to the people, and the saddest pictures are drawn of the financial condition of England at the time. In 1552 the standard was restored to nearly its original richness, as coins containing 11 oz. 1 dwt. of pure metal and 19 dwt. of base metal, or standard 921, were issued, and this alloy was maintained by Queen Mary. Queen Elizabeth further contributed to the restoration and maintenance of the standard fineness of the coin. A proclamation, dated September 27, 1560, stated that 'her Majesty, who, since she came to the throne, never gained anything by the coinage, nor yet ever coined any manner of base monies, for this realm, had begun a coinage of fine money in the Tower of London.' Notwithstanding the Queen's efforts to restore the coinage in England, the coins circulated in Ireland were deplorably low, as the pound only contained 2 oz. 18 dwt. of fine silver, and 9 oz. 2 dwt. of copper (that is, the standard was only 241).

"The restoration of the standard of the silver begun in the reign of King Edward VI. was, however, completed by Queen Elizabeth, and it has not been since debased."

The standard for plate was raised in 1696 to 11 oz. 10 dwt., or 959 fine, in order to prevent the melting of coins for conversion into plate; but the alloy proved less durable and serviceable than the old standard, to which a return was made in 1697. Both these standards are in existence at the present time, but the purer alloy, which is known as Britannia standard from the hall-mark representing the "figure of a woman commonly called Britannia," is seldom used except for very fine work and complicated designs, where its greater softness is an advantage.

The assaying and hall-marking of standard silver is carried out at authorised "Assay Offices" in London, Birmingham, Sheffield, Chester, Edinburgh, Glasgow, and Dublin, and the marks usually found on silver are—a Lion Passant indicating the standard of 925, the initials of the maker, the year of assay represented by a letter, and the heraldic arms of the place of assay. The heraldic arms of the different Assay Offices are as follows:—

London—the head of a leopard.

Birmingham—an anchor.

Sheffield—a crown.

Chester—a sword between three garbs.

Edinburgh—a castle, and the standard represented by a thistle.

Glasgow—a tree growing out of a mount, with a bell pendant on the sinister branch, and a bird on the top branch, over the trunk of a tree a salmon in fesse, and in its mouth an annulet. The standard is also represented by a thistle.

Dublin—the standard 925, and place represented by a harp crowned.

Standard silver is harder than the pure metal, but is sufficiently malleable and ductile to be rolled into thin sheets and drawn into fine wire. At the same time it is perfectly white, and takes a fine polish. These properties make it admirably suited to the purposes of coinage. Unlike most of the malleable alloys, however, it is not a homogeneous solid solution, and this is perhaps its greatest drawback, as it is practically impossible to obtain an ingot of uniform composition owing to liquation. This has been a very serious difficulty in the production of the Standard Trial Plates against which the coinage of the country is ultimately tested. As far back as 1781 Jars suggested the use of hot moulds for this purpose, and in 1873 Roberts-Austen obtained a fairly uniform mass by extremely slow cooling. Matthey, in 1894, adopted the method of casting the alloy in the form of thin sheets, and attempts have also been made to cast the alloy at a temperature very slightly above its melting-point. Numberless experiments have been made from time to time, but none of them have proved entirely satisfactory; and the method finally adopted has been to cast an ingot considerably larger than required, which is rolled to the proper thickness and a number of assays made from different parts of the plate. A piece is then cut out of the plate where the assays are practically uniform and of the correct standard. A lack of uniformity is found in all standard silver, although it is, of course, not of so much importance as in a trial plate. For example, a five-shilling piece, whose diameter is almost the width of the fillet from which it is cut, is richer in the centre than at the edges; while with smaller coins, such as a shilling, where two coins are cut in the width of a fillet, the edge corresponding to the centre of the fillet is richer in silver than the other edge which corresponds to the outside of the fillet. In the case of the strips sold for silversmith's work it has been stated that the average difference between the outside and centre varies from ·8 to 1 part per thousand; and where the alloy is to be hall-marked the manufacturers usually add a small quantity of silver to compensate for any irregularity in composition. The result of this is that at the annual examination at the Royal Mint of duplicate samples submitted by the Assay Offices and known as the "Diets," the mean assays show results varying from 4 to 8 parts per thousand above standard.

Standard silver is melted in plumbago crucibles, which are nearly always heated in coke furnaces. The crucibles vary in size, but those used at the Mint hold about 4000 ounces of metal. They will stand a large number of meltings, and are finally broken up and sold to the smelters. Experiments conducted at the Mint have shown that the average temperature of pouring is about 980°, and the temperature the silver "blanks" are annealed at is about 640°. If insufficiently annealed, or annealed at too high a temperature, the metal is liable to crack with mechanical treatment.

In addition to standard silver, a small quantity of alloy 900 fine, which is not hall-marked, is used in Birmingham for

jewellery; and it is stated that alloys as low as 600 fine are employed, but the quantity used must be very small.

In America sterling silver is manufactured on a large scale by mills making a speciality of rolling this alloy. The method of manufacture differs in some respects from that operating in this country. The alloy is melted in furnaces fired by oil, which has the advantage of being free from sulphur and producing no ash from which, in the event of accidents, the silver requires to be separated. The furnaces consist of a cast-iron shell lined with firebrick, with a hole at the bottom through which the jet enters at a tangent, so that the flame does not impinge directly upon the crucible. The crucibles used are of graphite and hold about 1200 ounces, half of this being made up of fine silver and shot copper in the calculated proportions, and the other half consisting of scrap. Under ordinary conditions the time required to melt this quantity is about forty minutes. Before pouring, the metal is deoxidised by adding metallic cadmium equal to 5 per cent. of the weight of the alloy, which is pushed down under the metal with tongs to prevent it rising to the surface and burning.

The ingot moulds are of the ordinary pattern, consisting of two parts held together by a ring and wedge, and take an ingot 12 ins. long by 10 ins. wide and $1\frac{1}{4}$ in. thick. After casting, the ingot is cooled in water and the top end is sheared off. It is now trimmed and planed to remove surface defects before rolling.

The rolling takes place in three stages. First, the plate is passed through the breaking-down rolls, in which it receives as heavy a pinch as possible and its thickness is reduced to $\frac{3}{8}$ in. The plate is then annealed in a muffle furnace (also oil-fired) and plunged, while still hot, into a pickling bath containing 1 part of sulphuric acid to 16 parts of water, after which it is dried and examined for surface defects, which are removed with a hammer and chisel. After straightening, the plate is then passed through the running-down rolls until its thickness is reduced to No. 10 B. and S. gauge, when it requires a second annealing and pickling. The sheet, which is now 10 or 12 ft. in length, is again examined for surface defects, and is then passed to the finishing rolls; on leaving the rolls it is again annealed, pickled, and dried in sawdust.

Standard silver can be readily soldered, and the alloys used for the purpose are of some importance. They consist of silver and copper with an addition of zinc, usually introduced in the form of brass; and where a very fusible solder is required, tin is sometimes added. The composition of a few characteristic solders is given in the following table:—

SILVER SOLDERS.

Composition.				Remarks.
Silver.	Copper.	Zinc.	Tin.	
80·0	13·2	6·8	...	Hard solder used for strong joints.
75·0	20·0	5·0	...	Medium solder.
70·0	22·5	7·5	...	,, ,,
69·4	22·1	8·5	...	,, ,,
66·7	33·3	...	...	,, ,, for enamelled work.
64·5	22·5	13·0	...	Ordinary solder for plate work.
62·5	30·0	7·5	...	Common solder.
62·5	31·2	6·2	...	Easy solder for chains.
62·5	20·9	16·6	...	,, ,,
62·5	20·9	10·4	6·2	Quick-running solder.
56·9	27·7	11·5	3·8	Common quick solder.

These solders possess the same characteristics as the lead-tin solders already referred to. There is a considerable range of temperature between the freezing-points of the constituents, with the result that the solder passes through a semi-solid or pasty stage during cooling.

Apart from the silver-copper alloys the only silver alloys of any importance are those with cadmium, platinum, and tin.

Silver-cadmium Alloys.—The alloys of silver and cadmium have long been known, and many years ago a company was formed with the object of electrodepositing an alloy of silver and cadmium in place of pure silver on account of its superiority as regards tarnishing. The attempt was unsuccessful for various reasons, but chiefly on account of the difficulty of obtaining a uniform deposit.

In 1904 Rose drew attention to the fact that silver is capable of dissolving cadmium to the extent of 20 per cent. to form a homogeneous solid solution, and he suggested that the standard trial plates might with advantage be replaced by a silver-cadmium alloy on account of its uniformity in composition. Trial plates were therefore made, and it was found that they were perfectly uniform in composition, and that the cadmium in no way interfered with the ordinary methods of assay. Some difficulty was experienced in melting the alloy on account of the volatility of the cadmium, but the method finally adopted was as follows:—Molten silver at as low a temperature as possible was poured on to the melted cadmium covered with charcoal and contained in a large crucible. By this means the loss of cadmium was reduced to about 0·15 per cent. of the weight of the alloy, and was fairly regular. The loss on remelting the alloy only amounted to 0·08 per cent.

Cadmium, however, is not only of use in the preparation of standard trial plates, but in other countries is extensively used in the manufacture of sterling silver, owing to its valuable properties as a deoxidiser. It increases the malleability and ductility, prevents blistering, and is said to improve the whiteness of the alloy. Moreover, an excess of cadmium is not very material, as it alloys perfectly with the metal without injuring its mechanical properties. An American authority states that cadmium is used by practically every manufacturer in the United States, and he gives 5 per cent. as the usual addition.

Silver-platinum Alloys.—These alloys are used to a limited extent, but are of sufficient importance to demand a brief description.

The preparation of the alloys is somewhat difficult, owing to the high melting-point of the platinum; but the alloying is effected by gradually adding the platinum in the form of sponge to the molten silver, the whole being thoroughly mixed by stirring. The resulting alloy is granulated and remelted to ensure uniformity of composition.

The most important of the silver-platinum alloys are those used by dentists and sold in the form of wire, sheet, and perforated sheet, under the name of *dental alloy*. They are much more durable, and do not blacken so readily as a silver-copper alloy. There are in the market two qualities, the first containing 67 per cent. of silver and 33 per cent. of platinum; and the second containing 75 per cent. of silver and 25 per cent. of platinum. The alloys occasionally contain a small quantity of copper.

Silver-platinum alloys are also said to be used by Birmingham jewellers, but it is probable that the advance in the price of platinum has been the means of checking their use. These alloys contain from 2·5 to 35 per cent. of platinum.

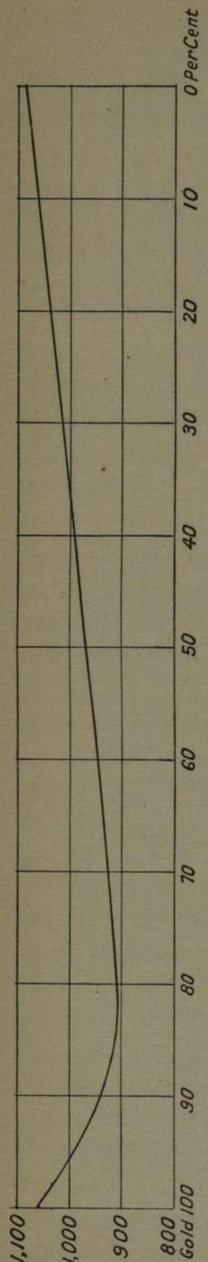

FIG. 51.—Freezing-point Curve of Gold-copper Alloys.

An alloy used for soldering platinum consists of 73 per cent. of silver and 27 per cent. of platinum; and an alloy containing 67 per cent. of silver and 33 per cent. of platinum is employed as the standard of electrical resistance.

Alloys of Silver and Tin.—Alloys of these metals are largely used by dentists as the basis of amalgams for stopping teeth. They come into the market in the form of filings or shavings containing from 40 to 60 per cent. of silver, and are mixed with mercury immediately before use. The amalgam thus formed becomes a hard mass within a few hours. Small quantities of other metals, usually gold, platinum or copper, not exceeding 5 per cent., are occasionally added to the alloy in order to improve its quality.

As regards other alloys of silver, those with zinc and aluminium have had some attention devoted to them, but so far they have not attained any degree of industrial importance.

Gold Alloys.

The important alloys of gold are those with copper and silver, and of these the gold-copper alloys are by far the more important, on account of their employment as alloys for coinage.

The constitution of the gold-copper alloys has been studied by Roberts-Austen and Rose, and the freezing-point curve of the series as determined by them is shown in fig. 51. It consists of two branches meeting at a point representing the eutectic, which contains 82 per cent. of gold and melts at 905°. The roundness of the curve suggests that the metals are to a considerable extent soluble in one

another, and the microscopical examination confirms this view; but the degree of solubility has not yet been ascertained. Standard gold, however, is a homogeneous solid solution of copper in gold, and possesses the crystalline structure of a pure metal. An old-fashioned system of expressing the fineness of gold alloys in "carats" and grains, or "carat grains," is still in use in this country, and requires some explanation. The Arabic word *Kyrat* and the Greek *Keration* appear to be the same, and were applied to beans or seeds which were used as weights. The word seems to have been retained after the introduction of standard weights, for we find a small Greek weight known as a *ceratium*, from which our carat, or "karrett," as it was formerly spelt, is derived. The carat contains 4 grains, and pure gold is taken as 24 carat, so that to take an example, 18-carat gold contains $\frac{18}{24}$ of pure gold, or 750 fine. This system was retained in the Mint until 1882, when it was replaced by the decimal or "parts per thousand" system; but it is still commonly employed by jewellers and goldsmiths.

In following the history of the gold coinage in this country we must again quote the words of that eminent authority the late Sir William C. Roberts-Austen. He begins with the year 1257, "the 41st year of King Henry III., who made a penny of the finest gold, which weighed two sterlings. This, as Ruding points out, is remarkable as the first coinage of gold in the kingdom, and it is extraordinary that it took place at the height of the king's distress for want of money. The next step of importance was taken in 1343, when King Edward III. coined, or projected a coinage of the standard 994·8 (23 carats, $3\frac{1}{2}$ grains, and $\frac{1}{2}$ grain of alloy), which was referred to by later writers as the 'old sterling' or 'right standard' of England; and Lowndes, quoting the Red Book of the Exchequer, says that the $\frac{1}{2}$ grain of alloy might be either of 'silver or copper.' Although these were not, as Stow considered, 'the first coining of gold in England,' the coins of Edward III. were of remarkable beauty; and it was asserted that they were struck from gold prepared by occult aid, by the well-known alchemist Raymond Lully, who had a laboratory in the Tower of London. There are, however, chronological difficulties in the way of this explanation of the origin of the precious metal. No further change was made in the standard fineness of the gold coin until the year 1526, when King Henry VIII. introduced a second standard, 916·66 (22 carats), the professed object being to prevent the exportation of the coin to Flanders. The further modification of the standard, which was effected in 1543, was preceded by a kind of scientific research, as the King ordered the officers of the Mint to prepare, whenever they should be so directed by the Privy Council, alloys to the value of one pound in weight, of such fineness as should be devised by the said Council, in order that the general nature of alloys, similar to those used in foreign realms, might the sooner come to his Majesty's knowledge. The standard 916·66 (which is the standard of the alloy used at the present day for the gold coinage of this country) was again issued in 1544. By a subsequent indenture, dated 1545, the gold was brought down to 833·3 (20 carats). King Edward VI. improved the fineness of the gold currency in 1549, and in 1552 an indenture was made authorising the coinage of gold both of the old standard 994·8 and of the standard 916·66. Queen Mary issued coins of fineness 994·8. Queen Elizabeth struck coins of both standards. The coinage of gold of the 'gold standard' 994·8 was abandoned in the 12th year of King Charles I., and since that time the standard 916·66 has alone been issued. Coins made of the old standard previously to that period continued to be current until the year 1732, when they were withdrawn from circulation by proclamation."

GOLD STANDARDS.

Country.	Denomination.	Fineness.
Austria-Hungary	Ducat	986
,, ,,	20 and 10 crowns	900
Belgium	20 and 10 francs	900
Denmark	20 and 10 kroner	900
France	All	900
Germany	All	900
Great Britain	Sovereign	916·6
Holland	Double ducat	983
,,	Ducat and 10 florin	900
Italy	All	900
Japan	...	...
Norway	20, 10, and 5 kroner	900
Portugal	All	916·6
Russia	All	900
Sweden	All	900
United States	All	900

From the above table, giving the composition of the gold

coinage alloys used in different countries, it will be seen that the standard most generally adopted, viz. 900 fine, is somewhat lower than in this country.

Standard gold is harder than the pure metal, but is extremely malleable and ductile, and admirably suited to the purposes of coinage. Moreover, the alloy being a homogeneous solid solution there is not the difficulty of preparing standard trial plates of uniform composition as in the case of standard silver.

The melting of standard gold is carried out in plumbago crucibles heated in coke-fired furnaces similar to those used in the melting of standard silver.

Alloys of gold and copper are largely used for jewellery; those most commonly used and hall-marked are 22 carat or 916·6 fine, 18 carat or 750 fine, 15 carat or 624·5 fine, and 9 carat or 375 fine. The first of these, namely, 22 carat, is too soft for hard wear, and is almost exclusively employed for wedding rings and those parts of rings which hold the precious stones and which have to be exceptionally ductile. The alloys of 18 and 15 carat are used in high-class jewellery, and the 9-carat alloy is used for cheap work. In addition to these a number of alloys containing silver in addition to the copper are used for jewellery, and in some cases iron is added. An alloy containing 750 of gold and 250 of iron is mentioned by several writers as "blue gold."

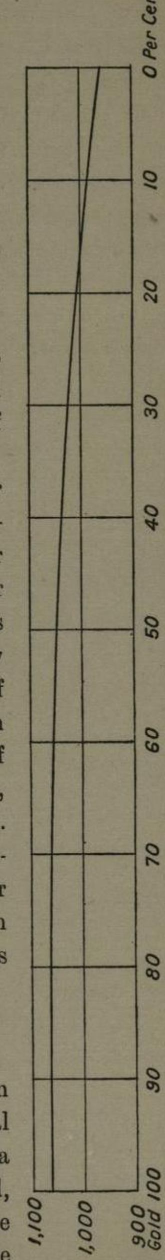

FIG. 52.—Freezing-point Curve of Gold-silver Alloys.

Gold-Silver Alloys.

Although the alloys of gold and silver can hardly be said to have any great industrial value they are of considerable interest from a theoretical point of view. It may be mentioned, however, that these alloys are used to some extent in the manufacture of jewellery, the colour being paler than in the case of the corresponding copper alloys. Until comparatively recently the sovereigns struck in Australia at the Sydney Mint were alloyed with silver instead of copper.

The constitution of the gold-silver alloys has received the attention of many metallurgists, and more particularly Gautier, Roberts-Austen, Rose, Erhards and Schertel, who all agree that the metals are isomorphous and form homogeneous solid solutions throughout the whole series of alloys. The freezing-point curve determined by Roberts-Austen and Rose is shown in fig. 52, and it will be noticed that the lowering of the freezing-point of gold by the addition of silver is very slight until 35 per cent. is reached.

It follows from the constitution of these alloys that they will be uniform in composition, and since 1902 a gold-silver alloy has been used at the Mint for the purpose of assay checks in place of fine gold.

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CHAPTER XV.

IRON ALLOYS.

In attempting to deal with the alloys of iron our attention is naturally directed to steel, and the question arises, Is steel an alloy? Many years ago Matthiessen declared his belief that steel should be considered as an alloy of iron and carbon, and his opinion has been amply confirmed by modern research. But here we are face to face with another difficulty, for the study of steel has received so much attention, and is in itself so vast a subject, that it would be obviously impossible to compress it into a part of a book on alloys. On the other hand, no book professing to deal with the subject of alloys can possibly ignore the alloys of iron. A compromise must therefore be made, and in the following chapter an attempt has been made to deal briefly with the essential facts and to supplement these with a bibliography sufficiently complete to form a reference to the important work dealing with the subject of steel and cast iron.

Iron and Carbon.

The constitution of the alloys of iron and carbon is somewhat complicated by the fact that iron is capable of existing in at least three allotropic modifications; and it is necessary, before dealing with the alloys, to consider the changes which may take place in the iron itself. Roberts-Austen showed that if a cooling curve is taken of the purest iron obtained by electrodeposition, two remarkable irregularities in the curve, due to an evolution of heat in each case, occur at temperatures of 895° and 766°. He considered that these evolutions of heat were due to allotropic changes in the metal, and this view has been supported by the