

PROPERTIES OF METALS AND ALLOYS.

The properties of the common metals and alloys are well marked, and the different degrees in which these qualities are possessed by the different metals and alloys render each better adapted for certain purposes than the others. These properties are:

Metallic lustre, Tenacity, Ductility, Malleability, Conductivity, Fusibility, Specific gravity.

Each of these qualities is of special value in its place. The capacity for taking a polish in brightening, and planishing, and finishing copper and tinned goods. **Tenacity**, or the strength of a metal or alloy to resist stress, pressure, pulling, bending in vessels, bars, rods, wires. **Ductility**, or the capacity for drawing out, upon which properly the art of wire-drawing is based. Without **Malleability** it would be impossible to roll thin sheets, or to flatten or raise them into curved forms. The good **Conducting** power of metals for heat renders them suitable for warming and domestic purposes, while their power of conducting electricity is a property of equal value, as bearing on wires and plates. **Fusibility** lies at the basis of all casting, but though the sheet-metal worker is but slightly interested in this branch, a knowledge of the fusibility of alloys is essential to the practice of brazing and soldering. The **Specific gravities** or relative weights of the metals is an important property, even from the point of view of the

worker in sheet metals, since all sheets of tin, lead, copper, and zinc are sold by pounds weight to the foot. A few remarks by way of explanation of these several qualities, possessed in common by metals and alloys, therefore, preface the descriptions of the metals and alloys to follow.

Metallic lustre. This is, in fact, nothing more than the power of reflecting light rays. If a surface absorbs light rays largely, the reflection is broken, and the appearance of the surface will not be bright, but dull. A broken or rough surface absorbs and scatters the light rays, a smooth surface, in the sense of being polished, reflects them. A porous substance cannot be polished. For a surface to be capable of taking a polish and becoming lustrous it must be dense, close, or hard. Thus no amount of polishing would make the natural surface of wood lustrous like that of iron, and no amount of polishing would make the surface of iron as lustrous as that of the harder steel. Metals not hard enough in themselves to take a high polish can be rendered harder and more lustrous by the admixture of another metal. Tin and copper in various proportions form speculum metal and bell metal, each extremely hard and lustrous, and so of alloys and of other metals.

Tenacity is equivalent to strength, or the resistance offered by a body to forces tending to pull its particles asunder. It is measured in pounds or tons per square inch. That is, if the ultimate tensile strength of a bar of iron is 40,000 pounds per square inch, that means that a load of 40,000 pounds suspended at the end of a bar 1 inch square, in cross section, would just suffice to tear the bar asunder. Tenacity, in this sense of

breaking strength, is not of so much relative interest to the sheet-metal worker as it is to the engineer. Still, there are some matters cognate thereto which it is well to be aware of, such as the effect of the presence of impurities, the effect of temperature and the effect of drawing out. In brief, the presence of foreign matters varies, in some cases and in certain proportions tending to increase, in others to diminution of strength. The effect of increase of temperature is to lessen the tenacity of metals, the effect of excessive drawing out is to lessen the tenacity by overcoming the cohesive strength, and replacing the fibrous condition by the crystalline, on the other hand, the tenacity is raised by moderate drawing out. Steel and iron possess the highest tenacity, while zinc, tin and lead possess the least.

Ductility. In proportion to the ductility of metals and alloys they are adapted for the purpose of wire-drawing, hence, steel, wrought iron, and copper, being highly ductile, are used for this purpose. Gold, silver, and platinum stand highest in the range of ductility, but their cost precludes their use for any but some special purposes. Tenacity is closely related to ductility, inasmuch as a weak metal will break before it can be reduced to a fine wire. Zinc, tin, and lead, though soft, will not stand drawing down, because their tenacity is so low. Ductile metals become hardened and crystallized during the process of wire-drawing, until they reach the limit of the coherence of their particles. Then annealing becomes necessary. This is effected by heating the metal, and allowing it to cool slowly, the effect of heat being to produce a natural rearrangement of the molecular particles.

Malleability is not identical with ductility, though in some respects akin to it. The effect of hammering or rolling is to destroy the cohesion of the particles of metal, to restore which annealing is necessary. The softest metals are not the most malleable, neither are the most tenacious metals the most readily rolled and hammered. Lead and tin are soft, iron and steel are strong, or tenacious, but neither are malleable, as are gold, silver, and copper. Copper is the only really malleable substance used by sheet-metal workers, and that can be hammered into almost any form. Sheet-iron and steel can be bent and rolled, but cannot be raised under the hammer or in dies to anything like the same extent as copper. The malleability of thick metals is generally increased by heat, that of thin metals is not practically affected by it. The malleability of metal lies at the basis of the formation of work in sheet metal. There is an essential difference between the operations of the boilermaker and those of the sheet-metal worker. The materials are largely the same—steel, wrought iron, and copper—but the difference in thickness render the methods of working different. The first-named class of artisans do much of their work by the aid of heat, the second, in the cold. The difference is due to the relative thicknesses of the plates used by the first, and of the sheets used by the second. A thick plate cannot be bent to a quick curvature unless it is heated, a thin sheet can be bent, or hammered, or stamped, in the cold to almost any outline. The reason of this is readily apparent on a little consideration.

Take a plate of thick metal, a sheet of thin metal, and a sheet of rubber, and note the effect of bending

in each case. The thick plate can only be bent by the application of much force, assisted, if the curvature be quick, by heat, the thin steel can be bent most readily to the same curvature, the rubber also with extreme ease. In each case the effect of bending is to extend the outer layers, and compress the inner layers. The layers in the center of the plate, or sheet, are neither extended nor compressed, and this central plane of bending is called the neutral axis. The difference in bending thick and thin metal plates is due to the fact that in the first the layers which are in compression and extension are at a considerable distance from the neutral axis, while in thin plates these layers are practically coincident therewith, so that in a thin plate there is no appreciable amount of compression or extension, hence the ease with which they can be bent.

But if the metal in the plates were highly elastic and mobile, like rubber, then, even though thick, extension and compression would take place in thick plates as in thin. The effect of heating thick plates is to cause the molecules to move over one another, and to become rearranged permanently, and this not necessarily in a state of high extension or compression, such as would result if the plates had been bent cold, but in a safe and natural way, provided the amount of bending does not exceed the limit which the nature of the material will permit it to sustain. The same kind of thing occurs in thin sheet-metals which are subjected to severe rolling, hammering, or stamping. Some movement and rearrangement of the particles of metal take place, and the greater the amount of curvature or distortion of form produced, the more severe will be the stresses produced in the substance of the material. If

a flat plate is raised by hammering, or if it is deeply beaded or dished, or set out, it will be brought into so high a state of tension that it will probably crack, unless heating is resorted to for the purpose of re-arranging the particles of metal. It is therefore obvious that the result of hammering, rolling, and stamping is to cause the particles of metal to glide over one another, extending some parts and compressing others, with the frequent coincidence also of thinning down some of the portions which have been subjected to the most severe treatment. If, therefore, the metals did not possess this property of malleability and of ductility, but were such that their particles could not be made to glide one over the other, no irregular metallic forms could be produced by hammering or stamping, but casting would be the only method available for obtaining these forms.

Conductivity of heat is a property which renders the metals so valuable for heating purposes. The conducting power of metals varies, but it so happens that copper, which is the best conductor among the metals in common use, is also the most malleable. Wrought iron is also an excellent conductor. The thinner the sheets, the more rapidly is heat transmitted through them. And, moreover, heat is transmitted so quickly through thin malleable sheets that there is no risk of fracture occurring, due to unequal contraction, as there is in many metallic substances.

Fusibility. The melting of steel, copper, and brass does not concern the worker in sheet metal, but the relative fusibilities of the numerous brass, lead, and tin solders are matters of much practical importance to him. These all melt at comparatively low tempera-

tures, and it is essential to know at what temperatures certain solders melt, in order to employ on any given job a solder, the melting point of which is well below that of the material which has to be united. Coke or charcoal fires, jets of gas, and copper bits are used to fuse the various solders employed.

Specific Gravity. The specific gravity of a metal is estimated relatively to that of a given equal bulk of pure water at a temperature of 62 degrees Fahrenheit. Beyond the commercial classification of sheets by weight, the relative weights of metals do not concern the sheet-metal worker much.

The manner in which the physical properties of the alloys is affected by small variations in the proportions of their constituents is often remarkable. Malleability, ductility, fusing points, even appearances are often radically modified. Some metals are more readily influenced in this way than others. Among familiar examples may be noted the effect which very minute percentages of carbon, phosphorous, and silicon exercise on steel.

Taking very common examples, it is remarkable that the union of two soft and malleable metals, as copper and tin, results in alloys ranging from the tough yellow gun metal to the brittle bell and speculum metals of silvery whiteness. So, too, copper alloyed with the very brittle and crystalline zinc forms the soft, yellow brass, which is bent and cut with so much ease. Or, copper with lead forms an alloy so soft as to be hardly workable. Again, tin and lead alloyed together fuse at a temperature lower than that of either of the constituents—a fact which renders them valuable as solders. And by adopting different proportions, various fusing

points higher and lower are obtained, suitable for soldering different qualities of metal or alloy.

Copper Alloys. Copper is not only highly valuable in the pure state, but its value is even perhaps greater when alloyed in various proportions with tin, lead, zinc, or other metals. It is only necessary to instance gun metal, brass, bell metal, and the solders. The subject of alloys is one of so great interest and value that volumes might be devoted to them. But, in strictness, the subject is of greater interest to the founder than to the sheet-metal worker. Still, there is very much of interest in it to the latter, since all brass sheets and wires are alloys. All tinning of copper vessels is effected by a union of the surfaces of dissimilar metals, the difference in qualities of sheets and wires depend mainly on the proportions in which certain elements occur. All solders, whether hard or soft, are alloys. So that for these and for other reasons a knowledge of the principles which underlie the union of dissimilar metals to form alloys is desirable.

Whether alloys are true chemical compounds has been doubted. At least, they are not recognized as such in science. The reason is, that there is no fixed and definite proportion in which, and in which alone, combination of the metallic elements occurs. In a true chemical compound such is the case. They invariably combine in definite proportions known as their combining weights, or in multiples of those combining weights. But true alloys are formed apart from any such definite combinations, so that one or other of the elements in one alloy shall be in excess by comparison with another alloy of the same metals. It seems, however, as though true chemical combination

must take place, but that the compound is mechanically associated with an excess of one or more of the elements. The reason for assuming the existence of a true compound is, that an alloy usually possesses physical characteristics very different from those possessed by its separate elements—a feature in which it closely resembles most true chemical compounds. The strength, tenacity, hardness, and fusing points of alloys are generally higher than those of their constituent elements, in some cases very much higher—effects which do not seem possible by a mere mechanical mixture of elements.

Copper is alloyed with tin, lead, and zinc in various proportions. When alloyed with tin alone it forms the gun metals, bronzes, bell metals, and speculum metal. When alloyed with zinc only it forms various brasses and spelter solders. Alloyed with lead only, it forms the very common pot metals. Alloyed with tin, zinc, and lead, it forms various gun metals and bronzes.

Alloys of copper with zinc alone are used chiefly to form spelter solder and brass. Copper and zinc mix in all proportions, but exact proportions are difficult to determine, because zinc volatilizes readily. The fusibility of copper-zinc alloys increases with the proportion of zinc. The color ranges, with the successive additions of zinc, from the red of copper to silvery white, and the malleability decreases until a crystalline character prevails.

An alloy of about 1 part of zinc to 16 parts of copper is used for jewelry, one of 3 to 4 parts of zinc to 16 parts of copper for sundry alloys once known as pinch-beck, about 6 to 8 parts of zinc to 16 parts of copper

form common brass, the latter being slightly more fusible than the former. Equal parts of zinc and copper form soft spelter solder, or 12 or 14 parts of zinc to 16 parts of copper would probably be the ultimate proportions after volatilization.

Copper and tin also mix in all proportions, successive additions of tin increase the fusibility of the alloy, the malleability diminishes, and the color gradually changes from red to white.

Copper-tin or gun metal alloys range from about 1 part of tin to 16 parts of copper in the softest, to 2 or $2\frac{1}{2}$ parts of tin to 16 parts of copper in the hardest. Beyond the last proportion, up to 5 parts of tin to 16 parts of copper, range the bell metal alloys, from $7\frac{1}{4}$ to $8\frac{1}{4}$ parts of tin to 16 parts of copper form speculum metal.

The alloys of copper with lead alone are used in the cheap pot metals. The fusibility is increased with successive additions of lead, the malleability is soon lost, and the red color of copper gives place to a leaden hue. About 6 parts of lead to 16 parts of copper is the limit at which a true alloy can be formed, with an increase in the proportion of lead the latter separates in cooling.

Alloys of copper with zinc, tin, and lead are largely used under the names of brasses, bronzes, gun metals, and pot metal. There is practically no limit to the range of these alloys.

Generally, those alloys are not proportioned separately, but the copper is added to a brass alloy. In many mixtures lead is not used at all, but copper, tin, and zinc only. Antimony is also sometimes used. A little iron added to yellow brass hardens it. Lead, on

the contrary, makes it more malleable. Zinc added to a pure mixture of copper and tin makes it mix better, and increases the malleability. Pot metal is improved by the addition of a little tin, and also of antimony.

Aluminum. This metal when of 98.5 per cent purity is bright white in color, somewhat resembling silver, though its appearance depends much on the temperature at which it has been worked. It is capable of taking a high polish. Its fusing point is about 1,050° Fahrenheit, but this may be increased to 1,832° Fahrenheit if impurities are present or if it is alloyed with another metal. Aluminium is only slightly elastic, it is, however, fairly malleable and ductile, but these latter properties are impaired by the presence of its chief two impurities, silicate and iron. If of more than 99 per cent purity, it can be rolled into leaves 1-40,000th part of an inch in thickness, in this respect being inferior only to gold. Aluminium has a tensile strength of 12,000 pounds to the square inch. When pure, it is non-corrosive and resists the oxidizing action of the atmosphere, but this advantage has to be partly sacrificed to obtain increased hardness and elasticity by adding small quantities of copper, nickel, or zinc. It dissolves in hydrochloric acid and in most solutions of the alkalis, but is only slightly affected by dilute sulphuric acid, and not at all by nitric acid. The rolled or forged metal breaks with a fine silky fracture. Aluminium is not found in a metallic state, but when in combination with oxygen, various alkalis, fluorine, silicon, and acids, it is the base of many clays and soils. Frequent compounds of aluminium are felspar, mica, gneiss, and trachyte, whilst other aluminium

compounds, classed as precious stones, are the ruby, sapphire, garnet, turquoise, lazulite, topaz, etc. The ores from which aluminium is commercially reduced are bauxite, cryolite, and corundum. The chemical method of producing aluminium has been superseded by the cheaper and more satisfactory electrical process. There are three electrical methods, the first depending on the heating effect of the electric current and producing aluminium alloys only, whereas by the two latter methods aluminium salts are submitted to electrolytic action at a high temperature, pure metal being produced. The sheet-metal worker would do well to thoroughly acquaint himself with the many peculiarities of aluminium, which is replacing other metals for ornamental sheet metal work and in the formation of culinary and other utensils, for which purpose its indifference to the action of most acids and to atmospheric conditions renders it especially suitable. The great disadvantage of aluminium is the difficulty encountered in forming reliable soldered joints. This is caused by the formation of an oxide on the surface of the heated metal, the oxide preventing the soft solder from alloying with the aluminium and producing a good joint. With care the difficulty can be surmounted by employing soldering alloys of an easily fusible nature and by melting them with a special copper bit. Good solders for the purpose are given by authorities as follows: Tin 95 parts, and bismuth 5 parts. Tin 97, bismuth 3. Aluminum 2.5, zinc 25.25, phosphorus 25, tin 72. Aluminum 10, tin 90. Cadmium 50, zinc 20, tin 30. The copper bit should be wedge-shape and bent roundly to a quarter circle, its edge is then at right angles to the aluminium, and by lightly moving the

bit backward and forward over the metal and the flowing solder the film of oxide can be removed. The coated surface can then be soldered with an ordinary copper bit.

Antimony. This is a bluish white metal, very crystalline and brittle, and so can easily be powdered. Its chief use is in the formation of serviceable alloys, such as white metal and pewter, to which it imparts brittleness. The melted metal rapidly oxidizes if exposed to the air, and if highly heated burns with a white flame, giving off fumes of antimony trioxide. Antimony is dissolved by hot hydrochloric acid, hot concentrated sulphuric acid, and aqua regis, and if treated with nitric acid forms a straw-colored powder known as antimonie acid. Commercial antimony contains impurities in the form of potassium, copper, iron, and lead. Antimony occurs native, but generally the metal is found in combination with others, the chief antimony ore is stibnite. The antimony is recovered from this ore by two distinct processes, by the first of these is separated the antimony sulphide, which is in its turn refined by the second process. In Germany, where much of the commercial antimony comes from, the ore is placed in covered pots having perforated bottoms, below which are receivers. Between the pots is the fire the heat of which fuses the sulphide, which runs through the holes into the receivers. Crucibles heated in circular wind-furnaces are employed to refine the sulphide. The charge is 40 pounds of sulphide and 20 pounds of scrap-iron, and the product is antimony and iron sulphide, which is again melted, this time with sulphate of soda and some slag, a product of the next process. The resultant metal is melted with pearlash

and slag, and cast into ingots. Antimony can also be produced by electro-deposition.

Bismuth. This metal is reddish white in color, and has a bright lustre. It is very brittle and crystalline, volatilizes at a high temperature, and, burning, forms a crystalline scale—flowers of bismuth. The most important use of bismuth is in forming alloys, as its addition to any metal has the effect of considerably lowering the melting-point of that metal. Bismuth may be alloyed with antimony, lead, or tin. Bismuth solders may be formed of: Tin 4 parts, lead 4 parts, bismuth 1 part. Tin 3, lead 3, bismuth 1. Tin 2, lead 2, bismuth 1. Equal parts of tin, lead, and bismuth. Tin 2, lead 1, bismuth 2. Tin 3, lead 5, bismuth 3. Bismuth is found in the metallic state in the form of bismuth-glance (bismuth and sulphur), in combination with oxygen as an ochre, and in the ores of silver, lead, tin, copper, and cobalt. Furnaces for reducing bismuth each contain a number of inclined iron tubes, in which the ore is placed. A wood-fire is lighted, and the fused bismuth, together with some impurities, flows through apertures at the lower ends of the tubes into clay or iron pots heated by a fire underneath. The sulphur and arsenic contained in it are removed by again fusing the metal, this time accompanied by one tenth its weight of nitre.

Gold. This metal has a very limited application in the art of the sheet metal worker, but merely on account of its comparative scarcity to other metals, and hence its expensiveness. Were it not for this, its high malleability and ductility would cause it to be very extensively used in many of the industrial arts. So malleable is gold that it may be reduced to leaves only

the 290,000th part of an inch in thickness. It is but very slightly affected by the atmosphere, and resists the action of all solvents with the exception of selenic, aqua regia, and aqueous chlorine. Gold is found in a metallic state in the form of grains in sand and it is then often in combination with silver, copper, platinum, or iron. Veins of gold quartz occur, and occasionally the metal is found native in lumps, termed nuggets. The ores of galena, copper pyrites, and iron, sometimes contain traces of gold.

Tin. This metal has nearly the lustrous whiteness of silver, is highly malleable, harder than lead, but is not very tenacious. It oxidizes only on being heated, when it forms stannic oxide. Tin can be decomposed by many acids, and, as has already been shown, easily alloys with most metals. Tin-plate as used by the sheet-metal worker is not solid tin, but steel-plate thinly coated with tin by a special process. Many of the more important alloys have tin as their principal constituent, some of these alloys are solders. Tin occurs in the form of sulphuret and oxide, but more generally in the form of ore, known as tin-stone. This is smelted either in blast or reverberatory furnaces. In the latter case the treatment is in two stages, one being the actual extraction of the metal and the other the refining. The roasted ore is washed to remove the sulphates, and is then placed in a furnace having an inclined bed and lined with about 8 inches of fireclay. Previous to placing in the furnace, the ore is mixed with anthracite coal and a small quantity of lime and fluor-spar. At the end of five hours more anthracite coal is thrown into the furnace, and in about an hour after that the molten metal can be run off. The re-

maining slag is an iron silicate which contains some oxides. To refine the pig-tin, it is placed in a reverberatory furnace and gradually heated to about 450° Fahrenheit, at this temperature the tin melts, and is drawn off into iron pots. The mass left in the furnace contains for the most part iron. On again melting the tin and stirring it with a pole of green wood, it is caused to boil by the escape of gases, and by this means the impurities, such as iron and arsenic, are brought to the surface, from which they are skimmed. Grain tin is made by allowing the molten metal to fall from a height on to a hard cold surface. To produce what is known as common tin, the metal passes at once to the moulds. Refined tin is the result of using better ores and lengthening the poling process. The purest metal in the mould is the upper portion, the middle portion is the common, and the bottom portion is too impure for use at all, and requires another fusing and poling. The ingots are known as block tin.

Iron and Steel. Iron in a state of purity is comparatively little known, the ores of it are various and abundant. In its commercial forms, as plate or sheet, bar, and cast iron, it is well known. As sheet it can be cut into patterns and bent into desired forms, as bar it can be made hot and wrought, that is, shaped by means of the hammer, and when molten it can be run or cast into all sorts of shapes. Cast iron is brittle, crystalline in fracture, and not workable by the hammer. In sheet and bar form, wrought iron is malleable, mostly fibrous in fracture, and capable of being welded. The presence of impurities in bar iron, that is, the presence of substances not wanted in it at the time being, seriously affects its malleability. Thus the presence of

phosphorus, or tin, renders it brittle when cold, and the presence of sulphur makes it unworkable when hot. Iron quickly rusts if exposed to damp air, as in the case of iron exposed to all weathers, or to air and water, as with vessels in which barely sufficient water is left to cover the bottoms, the rusting being then much more rapid than when the vessels are kept full. Heated to redness and above, scale rapidly forms and interferes greatly with welding. It is impossible to enter here into any consideration of the processes by which iron is prepared from its ores.

The effects of the presence of foreign substances in iron as impurities has been alluded to, but the presence in it of carbon has not been spoken of. This is a substance which in its crystalline form is known as the diamond, and in its uncrystalline form as charcoal. The presence of carbon in iron destroys its malleability, but at the same time gives to it properties so remarkable and useful to mankind, that to say, as a defect, of a piece of iron with carbon in it, that it is not malleable, is simply equivalent to saying that a piece of brass is not a piece of copper. Quite the reverse of being matter in the wrong place, carbon in iron furnishes a compound so valuable on its own account that, if there were other substances not metals, the compounding of which with a metal gave products at all resembling those of iron and carbon, all such compounds would form a class of their own. The iron and carbon compound, however, stands inconveniently alone.

Iron is alloyed with carbon in proportions varying from say $\frac{1}{2}$ to 5 per cent. When in the proportion of from 2 per cent upwards, the compound is cast iron,

that is, iron suitable for casting purposes, in other proportions it is known as steel. In cast iron the metallic appearance is somewhat modified, in steel it is maintained. Originally steel was made by the addition of carbon to manufactured iron, and the word had then a fairly definite signification, meaning a material of a high tensile strength, that by being heated dull red and suddenly cooled could be made so hard that a file would not touch it, that is, would slide over it without marking it; and that could have that hardness modified or tempered by further application of heat. But with the introduction of the Bessemer process of steel making, and of the Siemens' process of making steel direct from the ores, processes by which any desired percentage of carbon can be given, the signification of the word has become enlarged, and now includes all alloys of iron and carbon between malleable iron and cast iron, except that the term mild steel is sometimes applied to those alloys that approach in qualities to malleable iron. Steel plates are now produced equal in toughness, and it is said even excelling the best charcoal plates, and as they are much cheaper, the old process is very generally giving way to the direct process. In practice, however, these plates are found to be more springy than good charcoal plates, and not so soft and easy to work.

As iron is very liable to rust, surface protection is given to it by a coating of tin, or of an alloy of lead and tin, or of zinc. Plates coated with tin are termed tin plates, with lead and tin have the name of terne plates, and if coated with zinc are said to be galvanized. Terne plates are used for lining packing-cases, also for work to be japanned.

Large iron sheets of various gauges coated with tin and having the same appearance as tin plate are called tinned iron. But the latter term is more generally applied to sheets of iron which are coated with lead and tin, and are dull like terne plates.

Iron coated with zinc is not so easily worked as when ungalvanized. In galvanizing, the zinc alloys with the surface of the iron, and this has a tendency to make the iron brittle. Galvanized iron is useful for water tanks and for roofing purposes, as the zinc coating prevents rust better than a tin coating. For roofing, however, terne plates are largely used, and, kept well painted, are found to be very durable. Owing to the ease with which zinc is attacked by acids, galvanized iron is not suitable for vessels exposed to acids or acid vapors.

Copper. This, the only red metal, is malleable, tenacious, soft, ductile, sonorous, and an excellent conductor of heat. For this reason, and because of its durability, it is largely made use of for cooking utensils. It is found in numerous states of combination with other constituents, as well as native. Its most important ore is copper pyrites. Copper melts at a dull white heat and becomes then covered with black crust. It burns when at a bright white heat with a greenish flame. No attempt at explanation of its manufacture will here be made, as any description not lengthy would be simply a bewilderment. For the production of sheet copper it is first cast in the forms of slabs which are rolled, and then annealed and re-rolled, this annealing and re-rolling being repeated until the copper sheet is brought down to the desired thickness. In working ordinary sheet copper, it is hammered to stiff-

fen it, and close the grain. Hard-rolled copper is, however, nowadays produced that does not require hammering.

In the course of the manufacture of copper it undergoes a process termed poling to get rid of impurities. We mention this because we shall find a similar process gone through in preparing solders. The poling of copper consists in plunging the end of a pole of green wood, preferably birch, beneath the surface of the molten metal, and stirring the mass with it. Violent ebullition takes place, large quantities of gases are liberated, and the copper is thoroughly agitated. It is doubtful if this poling process is fully understood, for, though it is quite obvious that there may be insufficient poling, it is not easy to explain overpoling. But overpoling, as a fact, is fully recognized in the manufacture of copper, and the metal is brittle, both if the poling is too long continued or not long enough. If duly poled, the cast slab when set displays a comparatively level surface, if underpoled a longitudinal furrow forms on the surface of the slab as it cools, if overpoled, instead of a furrow, the surface exhibits a longitudinal ridge. Copper, duly poled, is known as best selected.

Zinc. Of this metal, known also very commonly as spelter, calamine is a very abundant ore, another abundant ore is blende. The metal is extracted from its ores by a process of distillation, the metal volatilizing at a bright red heat, and the vapor, passing into tubes, condenses, and is collected from the tubes in powder and in solid condition. If required pure, further process is necessary. Zinc is hardened by rolling, and requires to be annealed at a low temperature to

restore its malleability. Until the discovery of the malleability of zinc when a little hotter than boiling water, it was only used to alloy copper with, and sheet zinc was unknown. Zinc expands $\frac{1}{40}$ th by heating from the freezing to the boiling point of water. The zinc of commerce dissolves readily in hydrochloric and in sulphuric acid, pure zinc only slowly. If zinc is exposed to the air, a film of dull grey oxide forms on the surface, it suffers afterwards little further change. Zinc alloys with copper and tin, but not with lead, it also alloys with iron, for which it is largely used as a coating, iron so coated being known as galvanized iron.

Lead. Another metal that is prepared in sheet is lead. This metal was known in the earliest ages of the world, it is soft, flexible, and has but little tenacity. One of its principal ores is galena. Being a soft metal, it is worked by the plumber into various shapes by means of special tools, which often saves the making of joints. As it is comparatively indestructible under ordinary conditions, it is largely used for roofing purposes and for water cisterns. It is also used for the lining of cisterns for strong acids, in which case the joints are not soldered in the ordinary way with plumber's solder, but made by a process termed autogenous soldering or lead burning. Lead prepared in sheet by casting is known as cast lead, but when prepared by the more modern method of casting a small slab of the metal and then rolling it to any desired thickness is called milled lead.

Alloys. An alloy is a compound of two or more metals. Alloys retain the metallic appearance, and whilst closely approximating in properties to the metals compounded, often possess in addition valuable prop-

erties which do not exist in either of the constituent metals forming the alloy. An alloy of copper and zinc has a metallic appearance and working properties somewhat similar to those of the individual metals it is made up of, and so with an alloy of gold, or silver, and a small percentage of copper. But the latter alloys have the further property of hardness, making them suitable for coinage, for which gold, or silver, unalloyed, is too soft. Like to this addition of copper to gold or silver is the addition of antimony to lead and, to tin, by which alloys are obtained harder though more brittle than either lead or tin by itself. The alloy of lead and antimony is used for printer's type, for which lead alone is too soft.