METALS AND THEIR PROPERTIES.

BY ARCHIBALD M'KILLOP.

It is usual to divide all elementary substances into metals and metalloids, or non-metals. This division is not a very clear one, and it would be difficult to draw a strict line of demarcation between the two kinds of bodies.

A metal is usually defined as an elementary substance possessing power of conducting heat and electricity, opacity, and peculiar metallic lustre. These three properties are usually the marks of metallic bodies. Taking the third property first, i. e., peculiar metallic lustre, we find that this lustre is not confined to metals. If we look merely to lustre, it would be difficult to exclude graphitic carbon, crystalline silicon, etc., from the list of metals. Arsenic is seen in the form of a mirror, and possesses metallic lustre, but in its chemical deportment it is very like phosphorus, and phosphorus is, by general consent, considered non-metallic. And if we lose sight of the metallic lustre which arsenic possesses, and look to its more stable and unchangeable properties, we should at once call it non-metallic.

The property of lustre is sometimes lost. When a solution of arsenic chloride is treated with ferrous sulphate, the metallic gold is got in a different condition from that in which we ordinarily see it. If we filter the product, we obtain gold as a powder, void of metallic lustre; but if this powder be dried, and rubbed with a pestle, the gold will acquire its metallic lustre again. Metallic lustre depends upon the molecular arrangement of the metal.

Carbon is found in nature in two allotropic forms which possess lustre—the diamond and graphite. But it is also found in forms possessing no lustre, and these different forms of carbon vary in their power of conducting heat and electricity; ordinarily it is an indifferent conductor; heated it is a good conductor—a feature that enables us to make use of carbon points in the voltaic arc.

Metals only possess the power of conducting heat and electricity when the arc is in a compact form. Hence, in the case of those rarer metals that have never been solidified and those that exist only as powder, this property is unknown. The power of conducting electricity varies in metals with the temperature, the power of conduction growing less as the temperature rises. Upon this law Siemens has invented the pyrometer. In passing from one degree of temperature to another, some metals assume a pasty, or adhesive form; this condition has been found extremely useful, and it is owing to this property that iron can be so easily welded.

Although silver has the greatest power of conducting electricity copper is the metal used, because of its cheapness.

The smallest trace of impurities lessens the conducting power of the metals. It is at present a field for research—the action of small quantities of one metal upon large quantities of others. Why traces of impurities affect metals as they do, is a point not yet thoroughly understood.

Opacity varies with the thickness of the metal. Gold may be beaten out so thin that a considerable amount of light of a green color will pass through it.

In chemical work, the changes the bodies undergo are of two kinds—physical and chemical. The former changes are too often overlooked; the attention cannot be too strongly directed to them. The physical properties, such as crystalline structure, color, hard ness, etc., and physical changes should by very carefully noted.

Certain metals have a distinct color. Most of them have a more, or less deep grey color. This grey approaches more nearly to white with polishing. In all metals the color is improved by polishing. Some metals are white, as silver, platinum, and magnesium. Zinc and lead are bluish, calcium a pale yellow, copper and bismuth reddish, and gold a bright yellow.

Another property, although not a very important one, which some metals possess is their odor. Some metals, as iron, tin, etc., have a distinct and characteristic odor.

Mode of fracture is another property that should be attended to. Different metals have different kinds of fracture, as crystalline, fibrous, conchoidal. In specular iron we have crystalline fracture. The same mode of fracture is observed when iron is allowed to cool very slowly in a blast furnace. If a bar of wrought iron were broken across we would have an example of fibrous fracture.

The fusing point of an alloy is always lower than the fusing points of the metals employed. This is well shown in alloy called fusible metals, which may be prepared by heating two parts of lead, four of bismuth and one of tin, or more fusible still, eight of lead, fifteen of bismuth, four of tin and three of cadmium. This substance is fusible in boiling water. Another example of this property of alloys is seen in an alloy of potassium and sodium. Neither of these elements is liquid at the ordinary temperature, but the alloy is.

An amalgam is a compound of mercury with some other metal. Some of these are soft and semi-solid and others firm. The amalgams and alloys appear to be definite chemical compounds.

The utility of a metal depends upon its toughness and tenacity, the plentifulness of the supply of its ores. If a new metal were found these would be the crucial tests put to it, and unless it possessed some advantage on the metals presently in use, it would not be manufactured. Any metal largely used must possess these properties. In the iron group of metals, iron is more generally applied than any of the other metals, because of its cheapness· and toughness.

Brittle metals have no tenacity; they are used as alloys in arts. Type metal, an alloy of antimony, is a very important alloy of a brittle metal. All of the metals, with the single exception of mercury, are solid bodies at the ordinary temperature. They differ very widely in their fusibility. Thus some are fusible below the boiling point of water; others, as zinc, tin and lead, are fusible redness, copper, silver and gold are fusible in furnaces, while cast iron requires a temperature of 1,500°, wrought iron 1,800°, and cobalt and nickel require the strongest heat of the furnace to fuse them. The platinum group require the oxyhydrogen flame or voltaic arc to fuse them.

Those metals which are volatile at a low temperature can be purified by distillation. Mercury is purified in this way.

Many of the metals show the property of malleability, i. e., the property of being permanently extended in every direction by heating or hammering. Some of them possess it to a remarkable degree. The metal gold can be beaten so thin that 250,000 sheets of it, piled one above another, are only one inch in thickness. In this process there is a change in the molecular arrangement of the particles of the metal. Some metals may be rendered hard and brittle, and if the process of hammering were continued, the metal would crack. To prevent this the manufacturers have recourse to the annealing process—reheating the metal. By this process the particles of the metal again take their natural position, and the process of hammering can be again repeated. This process is very necessary in the manufacture of copper. The furnaces are generally heated with gas, which produces a more equable temperature and admits of a better result. The gas may be coal gas, or the carbonic oxide of Siemens' furnaces.

Some metals, again, are brittle as antimony or arsenic; the slightest blow can break up antimony.

Ductility is another property of metals. It is closely allied to, though different from malleability. It is more closely related to tenacity. Ductility is the power of being drawn out; the property of withstanding a tensile force.

The following table shows the relative position of the more important metals on this point:

Tenacity.		Order of Malleability.	Order of Ductility.
Lead	1	Gold	Gold
Tin	1	Silver	Silver
Zinc	2	Copper	Platinum
Palladium	12½	Tin	Iron
Gold	12	Platinum	Copper
Silver	12½	Lead	Palladium
Platinum	15	Zinc	Aluminium
Copper	18	Iron	Zinc
Iron	25½		Tin
Steel	42		Lead

The tenacity of a metal varies with the purity. We would be led to anticipate this, from the comparative tenacities of iron and steel. It also depends upon the molecular arrangement and the temperature. This a point of practical importance, for we sometimes find railroad accidents taking place in winter, possibly caused by a change of molecular arrangement, caused by the lowering of the temperature. The tenacity of a metal is determined by putting a weight to the end of a wire of the metal, and increasing the weight till the wire snaps. It is found that the tenacity decreases as the temperature increases. Hardness of metals is another point worthy of consideration. Some metals are soft as wax, as sodium, potassium. Others can be marked with the nail, as lead; while others, like steel and chromium, are hard enough to scratch glass like diamonds. The hardness of some metals is affected by alloying them with non-metallic bodies, as carbon, silicon, boron. Of late years artificial diamonds have been produced by the union of aluminium and boron.

The chemical character and relation of metals and non-metals show differences as great as their physical relations. The power of combining chemically is varied by their temperature and state of aggregation. Some metals, in the form of powder, have great power on combining chemically. It is found that bodies most opposite in their chemical relations have the greatest power of combining chemically. The more electro-positive element precipitates the less electro-positive one.

Some of the basilous elements are very firmly combined with the chlorous elements; so firmly, indeed, that for thousands of years they resisted the efforts of chemists to disunite them. Humphrey Davy had to employ the most powerful batteries in order to decompose them. It is found, however, that the basilous character of the elements is not absolute; in fact, there is nothing absolute in the properties of elementary bodies. It is all relative. The same element may be basilous when compared with one, and chlorous when compared with another element. Compound substances possess basilous or chlorous characteristics, according to the preponderance of one or the other kind of matter present in its substance; therefore the character of the compound varies with the quantity of matter of one kind present.

Berzelius thought that when he discovered this classification he would be able to explain all the laws of chemical action by means of it, but when it was found that electro-negative elements combined among themselves his theory was upset. Although this classification cannot explain all changes, it is still of very great value.

DISCUSSION.

PROF. ORTON.—I am pleased at the scientific attainments and literary skill displayed in this paper, It is an interesting review of a subject of great importance. But I regret that Mr. McKillop did not choose a subject for discussion touching the many and interesting geological problems which abound in the Corning region. Mr. McKillop is Mining Engineer for the Ohio Central Coal Company, and is perfectly familiar with the geology of the Corning district. It is the knowledge of such problems worked out by ourselves which will give the chief value to our meetings.

PRESIDENT ROY.—Mr. McKillop's paper was forwarded at my urgent request, the writer being unable, owing to professional duties, to be present at our meeting. Mr. McKillop attached little value to the paper, knowing it contained nothing new, and he desired me to withhold it in case I felt it would not interest the Institute.

EDWARD ORTON, JR.—This paper treats on a subject with which Mr. McKillop is very conversant. While at school he excelled in the study of chemistry, and was awarded a prize for his proficiency in this branch. He is a young man of great modesty, but is a thoroughly practical mining engineer, and his paper embodies his own researches in the field of Mining Engineering.