ATOM STRUCTURE AND BONDING OF METALS

The atom is composed of a small, central nucleus, which contains protons and neutrons. Shells, or energy levels of electrons surround this nucleus. These electrons have a very low mass compared with protons and neutrons so the nucleus therefore makes up a large percentage of the atom's mass. An element is generally defined as a pure substance in which all atoms have the same atomic number, that is, the same number of protons in the nucleus. Atoms also occur as isotopes, isotopes are atoms with the same atomic number but different mass numbers (number of protons and neutrons in the nucleus).

In order to become stable, an atom must have a complete outer shell, this is achieved though the gain or loss of electrons. In a neutral atom the positive charge in the nucleus is equal to the total negative charge of the electrons. However if a neutral atom loses one or more electrons then the positive charge of the nucleus becomes greater than that of the electrons. We call this a cation. Alternatively the atom may gain electrons; the negative charge of the electrons will then be greater than the positive charge of the nucleus. This is called an anion.

The structure of a metal generally consists of positively charged ions arranged in a regular three-dimensional pattern called a continuous lattice. Moving throughout this lattice are delocalised electrons. These have been lost from the outer shell and belong to the lattice as a whole. It is the attraction between the positive metal ions and the delocalised electrons that stabilise the lattice.

Metals usually have high melting and boiling points, as large amounts of energy are required to break the strong forces that exist between the particles in the metallic lattice. Metals also have high densities; this is due to the way in which the atoms are tightly packed in the lattice. Electrical and thermal conductivity are also high due to the freely moving electrons, which are able to carry a charge through the lattice. Other typical properties of metals include high malleability and ductility and high lustre.

REACTIVITY OF METALS

The reactivity of metals can be determined by observing the speed of reaction of the metals with substances such as water, oxygen and dilute acids. The ease with which various compounds of metal can be thermally decomposed tells us a lot of information about reactivity.

The reactivity of a metal has to do with the ease with which it can lose electrons from its outer shell to form a stable ion. In order to remove an electron from an atom, energy must be supplied. This energy is called the ionisation energy. There are several factors, which affect the ease of removal of electrons from the atom. These are

- The distance of the electrons from the nucleus
- The size of the nuclear charge
- The presence of shielding inner shell electrons

By examining all of these it is possible to draw up a list of common metals according to their reactivities. This is known as the activity series of metals.

ACTIVITY SERIES

MOST REACTIVE
Potassium
Sodium
Barium
Calcium
Magnesium
Aluminium
Chromium
Zinc
Iron
Cobalt
Nickel
Tin
Lead
Copper
Mercury
Silver
Platinum
Gold
LEAST REACTIVE

METAL EXTRACTION AND USE

People have utilised metals for thousands of years for everything from jewellery to weapons to cooking utensils. It is the unique properties of metals that make them suitable for such a variety of purposes. Gold and copper were the first elements to be used by humans. They was extracted as early as 6 000 years ago, by the ancient Egyptians. Other metals however were not discovered until long after this, titanium, for example, was not discovered in it's pure form until 1887. So why is it that metals such as copper and gold have been known for centuries and other metals have only recently been discovered? By examining the hypothesis that metals were discovered in order of the ease of their extraction it is possible to find the answer to this question.

Gold, which as mentioned earlier, was one of the earliest metals known to man. It was found as nuggets in eroded hillsides and in streams and it is believed that it's bright yellow colour would have attracted people to find and use it. It was used mainly for ornamental and religious purposes by the ancient Egyptians. Gold is very stable and resistant to corrosion, so therefore can be found free in nature. The simplest way of isolating it is panning. This technique relies on the high density of gold being far greater than that of the sand and other particles that are also found in alluvial deposits. Gold is commonly found with quartz, pyrite and other minerals, in ancient times slaves were forced to dig deep shafts to extract the metal from quartz veins. The gold-bearing quartz was then crushed and water was used to separate the quartz powder from the gold dust and granules. Finally this was melted and shaped into rings. By referring to the activity series, we can see that gold is the least reactive of the listed metals, it is this property that would have made gold easiest to locate for ancient civilisations. The fact that it can not only be found relatively easily, but can be found in its native state.

Copper, another metal which was known to early civilisations also sits low on the activity series. This suggests that it, like gold is quite stable and resistant o corrosion. Many copper ores have their origin in the mineral called chalcopyrite (Cu S.Fe S), which is located in deep hydrothermal deposits. However if it becomes oxidised and weathered at the Earth's surface then other mineral deposits such as malachite (CuCo .Cu(OH)) can form. Malachite was commonly mined by the ancient Egyptians and converted to copper by smelting with carbon. It is this ease with which some of copper's compounds can be decomposed in a hot charcoal fire that is responsible for copper's early discovery.

Lead, like gold and copper is resistant to corrosion, however tarnishes upon exposure to air. Lead was used to make pipes by the early Romans. Lead can be isolated quite simply from the sulphide, PbS. The process involves burning and then the resulting oxide is reduced with carbon. However this generally produces laed which is contaminated with metals such as arsenic, gold, silver, zinc and copper. Removing these requires a fairly complex process. So it was not pure lead used by the early Romans, as technologies were not in existence at their time which enabled lead to be purified completely.

Approximately 5.1% of the weight of the Earth's crust is comprised of Iron. Iron has been known since about 3000 BC, when samples of meteoric iron were collected and turned into ornaments and weapons. Unlike copper which could be easily smelted, iron required a much higher temperature to smelt it from its ores. It could not be isolated in a simple hot charcoal fire, this explains why it was not discovered earlier. Iron became commonly used between 1500 and 1200 BC when the first iron smelters were established. The use of iron also lead to the discovery and production of steel, which was an instrumental development in the advancement of several human technologies.

Aluminium is an abundant element in the earth's core and yet is not found free in nature. Aluminium was not discovered until 1825 as it requires electrolysis to free it from its compounds. Aluminum is mined in huge scales as bauxite (Al O .2H O). Obtaining pure aluminium from bauxite involves a complex process, known as the Bayer process. This involves treatment with sodium hydroxide solution, which results in a solution of sodium aluminate and sodium silicate. When CO_2 is blown through the resulting solution, the sodium silicate stays in solution while the aluminium is precipitated out as aluminium hydroxide. Pure aluminium is obtained from the pure Al_2O_3 by an electrolytic method.

The first impure sample of calcium was prepared in 1808, however it wasn't until 1898 that a pure sample was prepared. Calcium does not occur free in nature, however it's compounds are very common. Calcium tarnishes rapidly when exposed to air and reacts directly with water. Calcium is mainly utilised in its compounds such as calcium chloride and calcium carbonate. However it can be produced in it's pure state by the electrolysis of molten calcium chloride or through the reduction of calcium oxide with aluminium.

Potassium is the most reactive metal in the activity series, it is this high reactivity that makes it hard to isolate in pure form. It oxidises very rapidly in air and decomposes in water. Potassium is made by the reaction of molten sodium with molten potassium chloride at 850℃. Potassium was first produced in its pure form in 1807.

CONCLUSION

Technological advancements and metal-extracting skills within society have in turn affected each other greatly. Over the years advancements in technology have often required the extraction of certain metals, the reverse is also true. Metal-extracting requires advancements in technology. It seems that this results in a “chicken or the egg” scenario. Which came first? Which is more important? Which had a greater effect on the other? It seems clear that generally the less reactive and more stable an element is, the easier it is to extract and the earlier it was discovered. However this still fails to answer whether it was advancing technology that resulted in improved metal-extraction or whether it was infact the improving metal-extraction that promoted technological advancements. Without delving much deeper into metallurgy it is perhaps impossible to find a solution to this dilema, however several generalisations can be made.

Metals which could be readily found free in nature, such as copper and gold were the first to be discovered and utilised. It is likely that the investigation of such metals led to an understanding of the basic properties of metal, and in turn resulted in an improvement of extraction techniques, and the discovery of more metals. It is evident that as the number of metals known to man increased so too did our knowledge and understanding, and in turn more metals were discovered.

Early metal extracting skills resulted in only compounds of metals being produced. This was because whilst isolating the compound from its environment may have been relatively simple, identifying and then removing contaminants was not as easily achieved. However, realising that metal compounds could serve purposes that their pure counterparts could not was a positive result of this.

Electricity, was perhaps the greatest step forward in the advancement of both technology and metal-extracting skills. It alowed the breaking down of compounds that had previously been impossible. This lead to an astonishing increase in the metal elements known to and used by humans. These include potassium and sodium. Electricity enabled people to produce electric charges, perform electroysis and create temperatures higher than ever before. All of which were significant in the discovery of the more reactive metals.

Whilst it is difficult, perhaps even impossible to decide which aided the other most, technological advances of metal-extracting skills, it is clear that neither could exist as we know them today without the other.

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