3 METALS & NON-METALS

3.1 INTRODUCTION

Till now, scientists have discovered more than 118 elements. These are classified into metals and Non Metals and metalloids. Metals are electropositive, which are hard, sonorous, melleable, ductile, with tensile strength and good conductor of heat and electricity. Non-metals have just opposite to metals in characterstics. Metalloids are the elements which show the property of both metals and non metals. Metals occur in nature in the free as well as combined state (in minerals). Those minerals from a metal can be extracted profitablly and economically from a metal can be extracted profitablly and economically are called area, process is called metallurgy. Metals also from alloys. We will study all these different aspects of elements in this chapter.

3.1.1 Position of Metal, Non-Metal and Metalloids

The zig-zag line seperating metal and non-metals, the element nearest to zig-zag line are **metalloids** – B, Si, Ge, As, Sb, Te, Po.

Some metals are very important for national economy and defence of any country. They are termed as **strategic metals**.

They and their alloys are used in atomic energy projects , space science projects, jet engines, high grade steels etc.

Some Strategic Metals : Titanium, Chromium, Manganese, Zirconium. They posses following properties which are specific:

(i) High Melting Point / Boiling Point (ii) Resistance to Corrosion. (iii) stronger but lighter than iron, etc.

Metal posseses 1, 2, 3 valence electrons

Non-Metal posseses 4, 5, 6, 7, 8 valence electrons

Metal gets stability by losing electrons and forming cations

Non-metals by gaining electrons form anions and finally achive nearly noble gas configuration.

For eg. : Na → Na^+ like Ne
2, 8, 1 2,8, 2,8
K → K^+ like Ar
2, 8, 8, 1 → 2,8,8 2,8,8

Non-metal, has 4, 5, 6, 7 valence electrons and its has tendency to gain electrons and achive stability to forms electronegative ions.

Question based on basic knowledge required to understand this chapter

1. Which one is a metalloid?
(A) Boron (B) Arsenic (C) Polonium (D) All of the above
2. Mercury is also known as
(A) Orich silver (B) Liquid silver (C) Bright metal (D) Heavy metal
3. Zinc oxide is
(A) Acidic oxide (B) Basic oxide (C) Amphoteric oxide (D) Neutral oxide
4. Metals are
(A) Electropositive in nature (B) Good conductor of heat and electricity
(C) Malleable and ductile (D) All of the above
5. SO_2 if soluble in water
(A) Turn red litmus blue (B) Turn blue litmus red
(C) Both (A) and (B) (D) None of these
6. CO if soluble in water
(A) Turn red litmus blue (B) Turn blue litmus red
(C) Both (A) and (B) (D) None of these
7. Metals possess number of electrons in outermost shell
(A) One (B) Two (C) Three (D) All of the above
8. Non metal is a
(A) Electropositive element (B) Electronegative elements
(C) Always solid (D) Always gas
9. Diamond is a
(A) Metal (B) Non-metal (C) Metalloid (D) None of the above
10. Metals found in native state
(A) Silver (B) Gold (C) Both (D) None of these

	Your Score	**Your Knowledge to understand**
(1)	0 – 4	Unsatisfactory
(2)	5 – 6	Satisfactory
(3)	7 and above	Good

Suggestion: If your knowledge comes under the category of 'unsatisfactory', then go through the following topics from NCERT VIII Metals and Non Metals.

3.2 METALS

All metals are electropositive in nature. Metals have certain characteristic physical properties i.e. they are usually lustrous, ductile, malleable with high melting point, hard usually solid at room temperature, conduct electricity, heat and sound well. Metals play an important role in our life.

Noble metal: Noble metals are metals that are resistant to corrosion or oxidation, unlike most base metals. They tend to be precious metals often due to perceived ? Examples include gold, platinum and rhodium.

Precious Metals: A precious metal is a rare metallic chemical element of high economic value. They are less reactive, high lusturs and high electrical conductivity.

Alloy: An alloy is a mixture of two or more elements in solid solution in which the major component is a metal combining different ratio of metals as alloys modify the properties of pure metals to produce desirable characteristics.

3.2.1 Difference Between Metal & Non-metals

	Metals	Non-metals
1. Physical state	Metals exist in solid state Except: Hg (liq. At room temp.) : Ga : 30º C Cs : 28.5º C Fr : 27º C liquids	: non-metals exist in solid and gaseous state Except: $Br_2 \rightarrow$ is a liquid
2. Lustre	Metals have a shining surface Ex: Al, Mg $\rightarrow$ white Au $\rightarrow$ yellow Cu $\rightarrow$ Reddish brown	They lack of luster. Ex: I_2 & graphite
3. Hardness	Metals are hard in nature Ex: Alkali metals (Na, K, Rb & Cs) (soft-metals-cut by knife)	Soft in nature Ex: Diamond
4. Malleable	Beaten into sheets Au & Ag are more malleable Au: 2×10^{-5}mm thickness foil is derived.	They are brittle in nature
5. Ductile	Drawn into wire Au & Ag are more ductile Au $\rightarrow$ 2 km wire is drawn from 1 g of gold	They lack of malleability & ductility Ex: plastic & sulfur (ductile)
6. Tensile strength	They have very high tensile strength. Ex: Alkali metals	Do not posses tensile strength.
7. Melting & Boiling point	They have high m.p. & b.p. High H.P. = 5650º C (renium – Re) High B.P. = 3380º (wolframite-W) Ex: Alkali metals	Low M.P. & B.P. Ex: Diamond : 3930º C Graphite : 2600º C
8. Density	They have high density Ex: Alkali metals (they float on water)	They have low density
9. Solubility	Soluble in any solvent	Soluble in particular solvents. Ex: sulphur soluble in CS_2
10. Alloy-formation	Ex: Stainless steel alloy of Ni, Cr & Fe : German silver : Cu, Zn & Ni	Do not form Ex: carbon is alloyed with iron to form steel
11. Thermal & electrical conductivity	Metals are good conductors of heat & electricity. Ag, Au > Cu > Al $\rightarrow$ T.C. Ag, Cu > Au , Al > W $\rightarrow$ E.C.	Bad conductor of heat & electricity Ex: graphite & gas-carbon (allotropic forms of carbon)

Illustration 1

How does a metal conduct heat?

Solution

When a metal is heated, its atoms gain energy and vibrate more *vigorously*. This energy is transferred to the electrons, which can move through out the metal, they transfer their energy to other electrons and atoms, and thus, heat is conducted.

Illustration 2

How does a metal conduct electricity?

Solution

Metals have low ionisation potential, so they loose electrons, the free e^- (or) mobile electron, move from one kernal (positive charged ion, Ex: Ag^+) to another kernal, so metal conduct electricity.

Try yourself

1. Define the term electrical conductivity of a metal? Arrange the following metals in order of their decreasing electrical conductivity

   Mercury , Gold, Silver

2. Give one example of a metal which
   (i) is liquid at room temperature
   (ii) can be easily cut out with a knife
   (iii) is the best conductor of heat
   (iv) is the poorest conductor of heat
3. Name two highly malleable metals
4. Name two elements that are alloyed with iron to make strainless steel?

3.2.2 Chemical Properties of Metals

Metals are electropositive elements, so they ionise by loss of electrons and from positive ions (cations)

$K \rightarrow K^+ + e^-$, $Mg \rightarrow Mg^{+2} + 2e^-$

The electropositive character of metals gives a certain characteristic chemical properties, these are discussed below.

(A) Reaction of Metals with Oxygen

All the metals combine with oxygen, and form basic oxides

$4Na + O_2 \rightarrow 2Na_2O$

$2Cu + O_2 \rightarrow 2CuO$

But magnesium combine with oxygen as well as nitrogen and forms oxide & nitride

$2Mg + O_2 \rightarrow 2MgO$

$6Mg + 2N_2 \rightarrow 2Mg_3N_2$ (Magnesium nitride)

Aluminium & zinc are metals. These metals combine with oxygen and form amphoteric oxide. (Amphoteric oxides reacts with acids and bases)

$2Al + 3O_2 \rightarrow 2Al_2O_3$

$2Zn + O_2 \rightarrow 2ZnO$ Amphoteric oxides

$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$

$Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$ (sodium aluminate)

Alkali (I A group) & Alkaline earth metal (II A group) oxides are soluble in nature and forms metal hydroxides.

Na_2O (s) + H_2O (l) $\rightarrow$ 2NaOH (Aq)

MgO (s) + H_2O (l) $\rightarrow$ $Mg(OH)_2$

But most of the metal oxides are insoluble in nature.

$\Rightarrow$ Different metals show different reactivities towards oxygen.

Na & K – catches fire when they placed in moist air, So Na & K are kept in kerosene.

$\Rightarrow$ Mg, Al, Zn & Pb reacts with oxygen and forms metal oxide. This oxide layer is called protective oxide layer, it prevent the further oxidation.

Pb, Ag & Au – do not react with oxygen even at high temperature (Pb, Ag & Au – do not reacts with acids & bases so they called noble metals).

Anodising: is a process of forming a thick oxide layer of aluminium. During anodising, a clean aluminium article is made the anode and is electrolysed with dilute H_2SO_4. The oxygen gas evolved at the anode reacts with aluminium to make a thicker protective oxide layer. This oxide layer can be dyed easily to give Al – articles to an attractive finish.

Metals react with water and produce a metal oxide and hydrogen gas. Metal oxides that are soluble in water dissolve in it to further form metal hydroxide. But all metals do not react with water.

Metal + Water $\longrightarrow$ Metal oxide + Hydrogen

Metal oxide + Water $\longrightarrow$ Metal hydroxide

Metals like potassium and sodium react violently with cold water. In case of sodium and potassium, the reaction is so violent and exothermic that the evolved hydrogen immediately catches fire.

$2K\ (s) + 2H_2O\ (l) \longrightarrow 2KOH\ (aq) + H_2\ (g)$ + heat energy

$2Na\ (s) + 2H_2O\ (l) \longrightarrow 2NaOH\ (aq) + H_2\ (g)$ + heat energy

The reaction of calcium with water is less violent. The heat evolved is not sufficient for the hydrogen to catch fire.

$Ca\ (s) + 2H_2O\ (l) \longrightarrow Ca(OH)_2\ (aq) + H_2\ (g)$

Calcium starts floating because the bubbles of hydrogen gas formed stick to the surface of the metal.

Magnesium does not react with cold water. It reacts with hot water to form magnesium hydroxide and hydrogen. It also starts floating due to the bubbles of hydrogen gas sticking to its surface.

Metals like aluminium, iron and zinc do not react either with cold or hot water. But they react with steam to form the metal oxide and hydrogen.

$2Al\ (s) + 3H_2O\ (g) \longrightarrow Al_2O_3\ (s) + 3H_2\ (g)$

$3Fe\ (s) + 4H_2O\ (g) \longrightarrow Fe_3O_4\ (s) + 4H_2\ (g)$

Metals such as lead, copper, silver and gold do not react with water at all.

(B) Reaction With Acids

All metals do not react with dilute hydrochloric acid and sulphuric acids. But when a metal reacts with any of these acids, a salt is formed and hydrogen gas is evolved. The metal replaces the hydrogen atoms in the acid to form a salt.

Metal + dilute acid $\longrightarrow$ Metal salt + Hydrogen

$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

$2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$

Hydrogen gas is not evolved when a metal reacts with nitric acid. It is because HNO_3 is a strong oxidising agent. It oxidises the H_2 produced to water and is itself reduced to any of oxides of nitrogen (N_2O, NO, NO_2). But Mg and Mn react with very dilute HNO_3 to evolve H_2 gas.

The rate of formation of bubbles was the fastest in the case of magnesium. The reaction was also the most exothermic in this case. The reactivity decreases in the order Mg > Al > Zn > Fe. In the case of copper, no bubbles were seen and the temperature also remained unchanged. This shows that copper does not react with dilute HCl.

Aqua regia, (Latin for 'royal water') is freshly prepared mixture of concentrated hydrochloric acid and concentrated nitric acid in the ratio 3 : 1. It can dissolve gold, even though neither of these acids can do so alone. Aqua regia is a highly corrosive, fuming liquid. It is one of the few reagents that is able to dissolve gold and platinum.

(C) Reaction of Metals with Solutions of Other Metal Salts

Reactive metals can displace less reactive metals from their compounds in solution or molten form.

We have seen in the previous sections that all metals are not equally reactive. We checked the reactivity of various metals with oxygen, water and acids. But all metals do not react with these reagents. So we were not able to put all the metal samples we had collected in decreasing order of their reactivity.

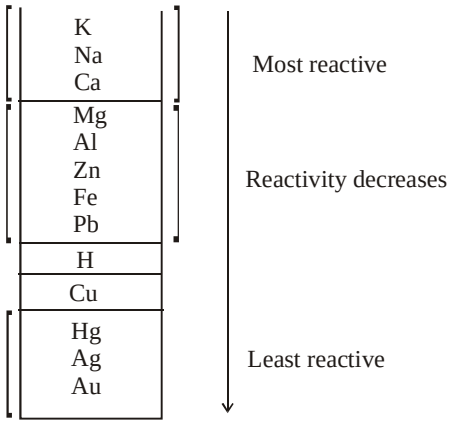
It is simple and easy if metal A displaces metal B from its solution, it is more reactive than B.

Metal A + Salt solution of B $\longrightarrow$ Salt solution of A + Metal B

ACTIVITY/REACTIVITY SERIES OF METALS

The reactivity of metals differs from metal to metal. Some of the metals are reactive, while others are less reactive towards chemical reagents. The elements that can lose electrons easily and form positively charged ions are more reactive. The elements that cannot lose electrons easily are less reactive.

Metals can be arranged in the decreasing order of their reactivity in a series. This series is called the reactivity or activity series of metals. The series has been derived from the reactions discussed above and many other similar reactions.



1. The activity series of metals provides a list of metals arranged in order of their decreasing chemical activity. The most active metal, potassium is at the top of the list and the least active metal, gold, is at the bottom.

2. The ease with which a metal loses electrons and forms positive ions in solution, decreases as we do down the activity series from potassium to gold.
3. Hydrogen is included in the activity series even though it is not a metal. The hydrogen ion (H^+), like other metal ions, has a positive charge in most chemical reactions.

Significance of Activity Series

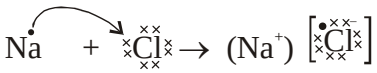
1. The metals above hydrogen in the activity series have greater tendency than hydrogen to give up electrons in their solutions. Such metals are called electropositive metals.
   For example, potassium (K), the first metal in the series is the most electropositive, while gold (Au), the last metal of the series is the least electropositive.
2. The metals above hydrogen in the series can liberate hydrogen when treated with an acid solution. Thus, magnesium and zinc react with dilute solutions of sulphuric acid to produce hydrogen gas.
   $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$; $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
3. A more electropositive metal can replace a less electropositive metal from the solution of a salt of the less electropositive metal. For example, when an iron rod is dipped into a solution of copper sulphate, reddish coloured copper is deposited on the iron rod.
   $Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$
   This is because iron is more electropositive than copper.

(D) Reaction of Metals with Non-Metals

We learnt that noble gases, which have a completely filled valence shell, show little chemical activity. We, therefore, explain the reactivity of elements as a tendency to attain a completely filled valence shell.

We know that a sodium atom has one electron in its outermost shell. If it loses the electron from its M shell then its L shell now becomes the outermost shell and that has a stable octet. The nucleus of this atom still has 11 protons but the number of electrons has become 10, So there is a net positive charge giving us a sodium cation Na^+.On the other hand chlorine has seven electrons in its ourtermost shell and it requires one more electron to complete its octet. If sodium and chlorine were to react, the electrons lost by sodium could be taken up by chlorine.After gaining an electron, the chlorine atom gets a unit negative charge, because its nucleus has 17 protons and there are 18 electrons in its K, L and M shells. This gives us a chloride anion $C1^-$. So both these elements can have a give and take relation between them as follows.

Na	$\longrightarrow Na^+ + e^-$
2, 8,1	2, 8
	(Sodium cation)
$Cl + e^-$	$\longrightarrow Cl^-$
2, 8,7	2,8,8
	(chloride anion)



Sodium and chloride ions, being oppositely charged, attract each other and are held by strong electrostatic forces of attraction to exist as sodium chloride (NaCl). It should be noted that sodium chloride does not exist as molecules but aggregates of oppositely charged ions.

Let us see the formation of one more ionic compound, magnesium chloride

Mg	$\longrightarrow Mg^{2+} + 2e^-$
2,8,2	2,8
	(Magnesium cation)

$Cl + e^- \longrightarrow Cl^-$

2,8,7 2,8,8

(Chloride anion)

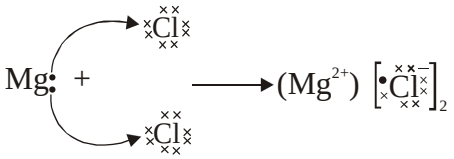


Illustration 3

The element A and B having electronic configuration 2,8,1 and 2,8,7 respectively. Which one of them is a metal and which is a non-metal?

Solution

The element A has only one electron in its outermost shell (All inner shells being complete). Therefore, the element A is a metal.

The element B has seven electron in its outermost shell (all inner shells being complete). Therefore, the element B is a non-metal.

Try yourself

5. Which of the following is a metal

(A) ${}^{7}_{3}X$ (B) ${}^{3}_{1}Y$ (C) ${}^{10}_{9}Z$

6. Which of the following replace the H_2 from acid to form salts ?

S, P, Na, Si

7. Name any two metal oxide which are amphoteric

3.3 OCCURENCE OF METALS IN NATURE

A metal is said occur native or free when it is found in nature in the metallic state. Those metals which remain unaffected by moisture, oxygen and carbon dioxide of the air can occur native or free.

The reactive metals, i.e., the metals which react with moisture, oxygen, carbon dioxide or other chemical reagents, are not found in nature in free state, but in combined state in the form of compounds.

Occurrence of metals in nature

In free state	In combined state
(gold, platinum, silver, mercury, etc.)	(sodium, calcium, potassium, aluminium, lead, copper, etc).

3.3.1 Minerals and Ores

Minerals: Metal-bearing substances, found in the earths crust, are called minerals. In other words, the solid compounds of metals occuring in nature are called minerals.

Metals can also be classified in terms of their nature and behaviour. For example, metals resembling iron in properties like manganese, chromium, nickel are ferrous metals. They have a similar magnetic behaviour like iron and can be used for preparing **magnets**.

Ores: The minerals from which metals can be obtained on a commercial scale are called ores. In other words, the minerals from which metals can be extracted profitably are called ores.

(i) All ores are minerals, but all minerals are not ores.

(ii) An ore is rich in the amount of the metal. The amount of foreign materials or impurities is low in an ore.

Flux : A flux is a substance that is added to the furnace charge (roasted or calcined ore and coke) during the process of smelting to remove the nonfusible impurities present in the ore.

Slag : Flux combines with the nonfusible impurities to convert them into a fusible substance known as slag. Impurities present in metal oxides may be acidic or basic. For acidic impurities, such as SiO_2 or P_2O_5, a basic flux (e.g., CaO) is added to the mixture during smelting. If basic impurities such as MnO are present, silica is added to the flux.

Impurity		**Flux**	**Slag**
SiO_2	+	CaO	$\longrightarrow CaSiO_3$
P_2O_5	+	3CaO	$\longrightarrow Ca_3(PO_4)_2$
MnO	+	SiO_2	$\longrightarrow MnSiO_3$.

Classification of Ores / Minerals

(1) Sulphide minerals of metals

Metal	Name of mineral	Formula
1. Copper	Chalocite	Cu_2S
	Chalcopyrite	$CuFeS_2$
	Copper glance	CuS
2. Lead	Galena	PbS
3. Mercury	Cinnabar	HgS
4. Zinc	Zinc blende	ZnS

(2) Oxide minerals of metals

Metal	Name of mineral	Formula
1. Aluminium	Bauxite	$Al_2O_3 \cdot 2H_2O$
2. Copper	Cuprite	Cu_2O
3. Iron	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
4. Lead	Litharge	PbO
5. Manganese	Pyrolusite	MnO_2
6. Thorium	Monazite	ThO_2
7. Uranium	Pitchblende	U_3O_8
8. Zinc	Zincite	ZnO

(3) Carbonate minerals of metals

Metal	Name of mineral	Formula
1. Calcium	Limestone	$CaCO_3$
2. Copper	Malachite	$CuCO_3 \cdot Cu(OH)_2$
3. Iron	Siderite	$FeCO_3$
4. Lead	Cerussite	$PbCO_3$
5. Magnesium	Magnesite	$MgCO_3$
6. Zinc	Calamine	$ZnCO_3$

(4) Chloride minerals of metals

Metal	Name of mineral	Formula
1. Magnesium	Carnallite	$KCl \cdot MgC_{12} \cdot 6H_2O$
2. Silver	Horn silver	AgCl
3. Sodium	Rock salt (halite)	NaCl

(5) Sulphate ores of Metal

Name	Name of mineral	Formula
1. Barium	Barytes	$BaSO_4$
2. Lead	Anglesite	$PbSO_4$

(6) Silicate ores of metal

Name	Name of mineral	Formula
1. Silicon	Asbestos	$CaMg_3Si_4O_{12}$
2. Silicon	Mica	$KAl_3H_2Si_3O_{12}$

Gangue or Matrix

The ore mined from the earth's crust contains some unwanted substances or impurities, such as sand, rocky or clay materials. These substances ae called **gangue or matrix.**

3.4 METALLURGY

The process of extracting metals from their ores and refining them for use is known as metallurgy. In other words, the process of obtaining a metal from its ores is called metallurgy of the metal.

Metallurgical Operations

The various steps used in metallurgy are :

(i) Enrichment or dressing of the ore.

(ii) Conversion of the enriched ore into the oxide of metal.

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(iii) Extraction of metal from the metal oxide.
(iv) Refining or purification of the metal.

3.4.1 Enrichment of Ores

Ores mined from the earth are usually contaminated with large amounts of impurities such as soil, sand,etc., called **gangue**. The impurities must be removed from the ore prior to the extraction of the metal. The processes used for removing the gangue from the ore are based on the differences between the physical or chemical properties of the gangue and the ore. Different separation techniques are accordingly employed.

(A) Extracting Metals Low in the Activity Series

Metals low in the activity series are very unreactive. The oxides of these metals can be reduced to metals by heating alone. For example, cinnabar (HgS) is an ore of mercury. When it is heated in air, it is first converted into mercuric oxide (HgO). Mercuric oxide is then reduced to mercury on further heating.

$$2HgS\ (s) + 3O_2\ (g) \xrightarrow{Heat} 2HgO\ (s) + 2SO_2\ (g)$$

$$2HgO\ (s) \xrightarrow{Heat} 2Hg\ (l) + O_2\ (g)$$

Similarly, copper which is found as Cu_2S in nature can be obtained from its ore by just heating in air.

$$2Cu_2S + 2O_2\ (g) \xrightarrow{Heat} 2Cu_2O\ (s) + 2SO_2\ (g)$$

$$2Cu_2O + Cu_2S \xrightarrow{Heat} 6Cu\ (s) + SO_2\ (g)$$

(B) Extracting Metals in the Middle of the Activity Series

The metals in the middle of the activity series such as iron, zinc, lead, copper, etc., are moderately reactive. These are usually present as sulphides or carbonates in nature. It is easier to obtain a metal from its oxide, as compared to its sulphides and carbonates. Therefore, prior to reduction, the metal sulphides and carbonates must be converted into metal oxides.

The process of obtaining metals from their compounds is known as reduction.Before reduction the ore is subjected to **roasting and calcination.** The sulphide ores are converted into oxides by heating strongly in presence of excess of air. The process is known as **roasting**. The carbonate ores are changed into oxides by heating strongly in absence of excess of air.

Roasting

$$2ZnS(s) + 3O_2\ (g) \longrightarrow 2\ ZnO(s) + 2\ SO_2\ (g)$$

Calcination

$$ZnCO_3\ (s) \longrightarrow ZnO\ (s) + CO_2\ (g)$$

3.4.2 Extraction of Metal From The Concentrated Ore

(i) Conversion of Concentrated Ore into its oxide
(ii) Reduction of metal oxide into Metal by Suitable Reagent.

Calcinations	Roasting
1. $Al_2O_3.2H_2O \rightarrow Al_2O_3 + 2H_2O$ It is to convert hydrated ore into non-hydrated ore.	$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2 \uparrow$ It is used for sulphide ores.
2. $ZnCO_3 \rightarrow ZnO + CO_2 \uparrow$ Calamine $PbCO_3 \rightarrow PbO + CO_2 \uparrow$ Cerussite It is generally used for carbonate.	Galena (PbS) is converted into litharge (PbO) by roasting. $2PbS\ (s) + 3O_2\ (g) \rightarrow 2PbO\ (s) + 2SO_2\ (g)$ Cinnabar (HgS) is roasted to convert it directly into mercury (Hg). $HgS\ (s) + O_2\ (g) \rightarrow Hg\ (I) + SO_2\ (g)$ It is generally used for sulphide ore.
3. It is use to remove volatile impurities.	It is use to remove volatile impurities. Moisture is removed
4. Carbonate ore into oxide ore.	Sulphide ore into oxide ore.
5. In the absence of O_2.	In the presence of O_2.

3.5 METALLURGY IN DETAIL

3.5.1 Concentration of ore

The process of removal of the gangue particle from the ore is called dressing (or) concentration (or) benafaction.

It can be classified into various types, depending upon the nature of impurities

(a) Hand picking

(b) Hydraulic washing (or) gravity separation (or) levigation

(c) Magnetic separation

(d) froth flotation

(e) Leaching (or) chemical separation

(A) Hand picking

If ore particles and impurities (gangue) are different in size & shape, hand picking process can be used to separate it.

For example, Haematite ore is purified by this method

(B) Hydraulic washing (or) gravity separation (or) levigation

This method is based on the difference in specific gravity of the ore & gangue particle. Gangue particles are lighter than the ore particles.

In this method the ore is mixed with water (or) washed with an upward stream of running water, the lighter gangue particles are washed heavy leaving the ore-particles.

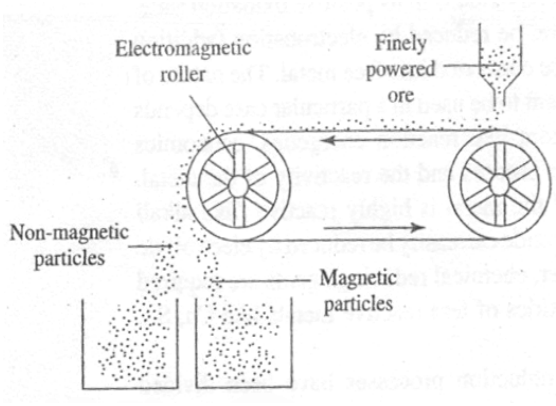
For example, this method is used for concentration of the oxide ores of Iron (Haematite), Tin (Tinstone), Au & Ag etc.

(C) Magnetic separation

If ore or gangue particles are having magnetic nature, then it is concentrated by this method.

Ex: A magnetic ore of chromium (chromate – FeO, Cr_2O_4) is separated from non-magnetic impurities and a non magnetic ore of Tin (casseterite – SnO_2) is separated from magnetic impurities of Iron & chromium, Tungstates.

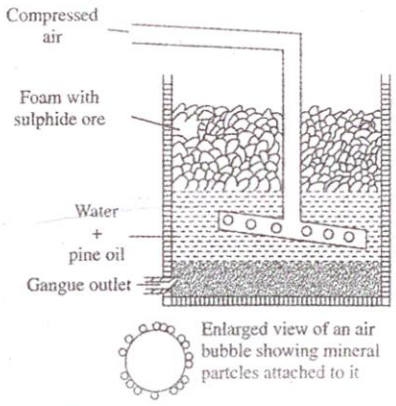
In this method, the powdered, impure ore is dropped over a trevelling belt moving around two rollers, one of which has a magnet attached to it. As the impure ore particles roll over the left, the magnetic particles are attracted by the magnetic roller & ore collected just below the magnetic roller, But the non-magnetic particle fall away from the magnetic rollers.



(D) Froth flotation process

It is used for separating impurities from the sulfide ores. Copper pyrities ($CuFeS_2$), galena (PbS) & zinc blende (ZnS) are concentrated by using this method.

This process based upon the fact that the surface of sulphide ore is wetted by oils, while grangue is wetted by water.



Froth floatation method.

The ore is crushed into a fine powder & mixed with water to form suspension in a tank. Collectors like pine oil, xanthates & fatty acids. Froth stabilisers like cresols & Aniline are added.

agitation, the froth formed of oil & air rises to the surface along with the ore particles, the gangue particles being wetted by water, settle at the bottom of the tank, the froth is skimmed off & it is dried for the recovery of concentrated mineral particles.

Exception: NaCN is used as a depressant to separate P&S ore from ZnS ore. NaCN forms a complex on the surface of ZnS & hence prevent it from forming the Froth due to presence of NaCN

$4NaCN + ZnS \longrightarrow Na_2[Zn(CN)_4] + Na_2S$

(sodium Tetracyano zincate)

(E) Leaching (or) chemical separation

The process consists of treatment of the powdered ore with a suitable reagent (such as acids, base (or) other reagents) which can Salectively dissolve, the ore but not the impurities.

Ex: Baeyer's process: pure aluminium oxide is obtained from the Bauxite ore (containing Fe_2O_3 & silicates) by leaching. The powdered ore is treated with concentrated solution of NaOH (base) when Al_2O_3 dissolves as sodium aluminate leaving behind the impurites.

$Al_2O_3\,(s) + 2NaOH\,(aq) + H_2O\,(l) \longrightarrow 2Na[Al(OH)_4]\,(aq) + 4H_2O\,(l)$

sodium aluminate

Sodium aluminate on dilution (or) by neutralisation with CO_2 gives Auminium hydroxide (ppt).

$Na[Al(OH)_4]\,(aq) \xrightarrow[(or)CO_2]{\text{Dilution}} Al(OH)_3\,(s)\downarrow + NaOH\,(aq)$

white ppt

$Al(OH)_3$ on heating gives pure alumina.

$2Al(OH)_3 \xrightarrow{1473\,K} Al_2O_3 + 3H_2O$

Leaching is also used for extracting metals like Au & Ag by converting these metals (or) their ores into soluble complexes with the help of NaCN (or) KCN (Dilute solution)

$Ag_2S + NaCN \longrightarrow 2Na[Ag(CN)_2] + Na_2S$

sodium dicyano argentate (I)

(soluble complex)

Illustration 4

Define Mineral, Ore and Gangue

Solution

Mineral: The inorganic compounds which occurs naturally in the earth crust are known as minerals for example, $CuFeS_2$, Copper pyrites

Ore: The minerals from which metals can be profitably and conveniently extracted are known as ore, for example, Fe_2O_3 haematite

Gangue: The impurities of sand and rochy material present in ore is known as gangue for example, SiO_2

Try yourself

8. Which process is used for the enrichment of
   (i) Sulphide ore (ii) Oxide ore
9. Define the term metallurgy.
10. Name the oil used in froath floatation process.

3.5.2 Chemical Reduction

(I) Before reduction the ore is subjected to roating and calcination (as dicussed earlier)

It is carried by using carbon (or) hydrogen (or) aluminium as reducing agents.

(A) Carbon as a reducing agent (i.e. smelting)

The reduction of metal oxides with carbon is known as smelting. The roasted (or) calcined ore mixed with carbon (in the form of coal, coke (or) charcoal) and heated to a temperature above its melting point in a furnace.

$MO + C \longrightarrow M + CO$

Ex: $ZnO\ (s) + C\ (s) \longrightarrow Zn\ (s) + CO\ (g) \uparrow$

$SnO_2\ (s) + 2C\ (s) \xrightarrow[1573K]{1437\ to} Sn + 2CO\ (g) \uparrow$

Cassiterite

The carbon monoxide produced can also bring about the reduction of metal oxide to free metal.

Ex: $ZnO + CO \longrightarrow Zn + CO_2 \uparrow$

$Fe_2O_3 + CO \longrightarrow 2FeO + CO_2 \uparrow$

$FeO + CO \longrightarrow Fe + CO_2 \uparrow$

Important application for carbon reduction is to extract the Iron which is carried out in a blast furnace.

(B) Hydrogen as a reducing agent

Metals like W, Mo $\rightarrow$ Cannot be reduced by carbon

$\downarrow$ Molybdnum

wolframite

They can be reduced by passing a current of hydrogen

$NiO + H_2 \longrightarrow Ni + H_2O$

Hydrogen is rarely used as reducing agent, because it is highly expensive & also inflammable.

(II) Reduction with aluminium:

The process of reduction of a metal oxide to the metals, with help of Al powder as the reducing agent is called **Alumino thermic reduction** or **Aluminothermy** (or) **Goldschmidt thermic process**.

Cr_2O_3, Mn_3O_4 & Fe_2O_3 are reduced by Al (there are not reduced by carbon).

In thermit process, Al-powder is mixed with metal oxide. (The mixture is called thermite).

Mg-ribbon (or) piece is inserted in a mixture of Mg-powder barium peroxide (The mixture is called) ignition. it is present above thermite in a crusible.

When Mg-ribban is ignited, aluminium reacts with metal oxide and metalic oxide is converted into molten-state. It is used to weld two Iron objects together, cracked machine parts, railway tracks etc.

$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

$Cr_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Cr$

(III) Auto-Reduction or self reduction (or) self-electronation

In certain cases no reducing agent is required. Sulphide ores of the less reactive metals like Hg, Cu, Pb etc. are roasted in excess of air. A part of them is converted into metal & the rest is converted into oxide (O^{-2}) (or) sulphate (SO_4^{-2}). These oxides or sulphates reduce the rest of the metal sulphide. This is known as self-reduction.

$2PbS + O_2 \longrightarrow 2PbO + 2SO_2$

$2PbO + PbS \longrightarrow 2Pb + SO_2$

or $PbS + 2O_2 \longrightarrow PbSO_4$

$PbSO_4 + PbS \longrightarrow 2Pb + 2SO_2$

$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$

$2Cu_2O + Cu_2S \longrightarrow 6Cu + 2SO_2$

(IV) Displacement Method

Some less reactive metals are reduced by displacement by a more reactive metal from their complexes.

Ex: Au (gold) & Ag (silver) are obtained from their cyanide complex with Zn metal

$2[Ag(CN)_2]^- + Zn \longrightarrow [Zn(CN)_4]^{-2} + 2Ag$

(V) Electrolytic Reduction

The oxides or hydroxides or chlorides of highly electropositive elements like Alkali metals, Alkali metals, Alkali earth metals & Al etc. cannot be reduced by carbon, hydrogen & aluminium, these metals are extracted by the electrolysis of its fused or molten self this is known as Electrometallurgy. In this process, the electrons serve as the Reducing agent.

$2NaCl\ (Fused) \rightarrow 2Na^+ + 2Cl^-$

$2Cl^- \rightarrow Cl_2 + 2e^- \rightarrow Anode$

$2Na^+ + 2e^- \rightarrow 2Na \rightarrow Cathode$

simply $2NaCl \xrightarrow{Electrolysis} 2Na + Cl_2$

3.5.3 Refining (or) purification of metals

The process of purifying the crude metal is called refining depends upon nature of the metal & nature of impurities following methods are used

(a) Distillation (b) Liquation (c) Oxidation (d) Electro-refining

(e) Zone refining (f) Fractional crystallisation (g) Vapour phase refining

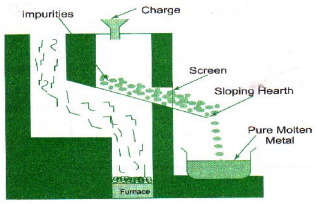
(a) Distillation: Based upon boiling point difference

Distillation is a method of heating impure liquid to its point & cooling the vapours to get the pure liquid.

Low boiling metal like, Zn, Hg, Cd etc can be refined by this method. The impure metal is heated so it is converted into liquid & the pure metal is converted into vapors, leaving the non-volatile. Impurities in the container, the pure metal vapours on cooling condensed into pure metal.

(b) Liquation process: Based upon melting point difference

When the M.P. of the metal lower than the impurities, this technique is used.



Low melting point metals such as Bi, Hg, Sn, Pb etc are refined by the process.

The crude metal is heated in an inert atmosphere of carbon monoxide on slopping hearth. The metal, metals & flows down the hearth, leaving behind the high melting impuries.

(c) Oxidation process: If impurities have greater affinity for oxygen (or) impurities are oxidised more readily than the metal.

Ex: Cu, Ag etc.

(i) Bassemerisation: This is carried out in a specially designed furnace called bassemer converter. The impure metal is melted & a hot blast of air is passed through it. Impurities are removed as volatile oxides which escapes out.

(ii) Cupellation: This method is used, when the impure metal contain the impurities of other metals, which form volatile oxides. The crude metal is taken in a wpel (a boat shaped pan) and a blast of air is blown into it. The impurities are converted into volatile oxides which escapes.

This process is used for removing the impurities of lead from silver.

(iii) Poling: If crude metal contains impuries of the oxide of the metal itself. The crude metal is melted in a big container and is stirred with green poles of wood. Gaseous hydrocarbons (CH_4, C_2H_6 etc.) released from the green poles reduce the oxides of the metal to the pure state by taking up oxygen.

Crude copper (i.e. blister copper) having the impurities of

$Cu_2O + CH_4 \rightarrow 6Cu + 2H_2O + CO$

$\Rightarrow$ Stannic oxide is also purified by this method.

(d) Electro-refining: Used for Cu, Au, Ag, Pb, Zn & Al. In this method

The impure metal act as Anode & pure metal strip is taken as Cathode (both are same metals), these electrodes are suspended in an electrolyte, (soluble salt of the same metals).

On passing electric current, metal ions from the electrolyte are reduced to metal, which is deposited on the cathode in the form of pure metal & an equivalent. Amount of metal from the anode goes into the electrolyte solution.

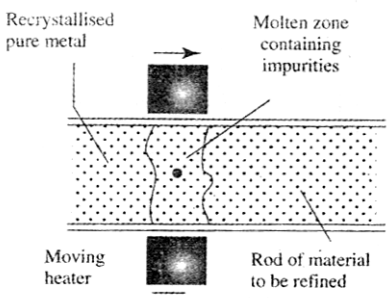
At Anode: $M(Impure) \rightarrow M^{n+} + ne^-$

At Cathode: $M^{n+} + ne^- \rightarrow M$ (pure)

Ex: In the electrolysis of coper, metals like Zn remains in the solution as cations.

Where as metals such as Au, Ag etc form the Anode mud.

(e) Zone refining (or) Fractional distillation: The method is based on the principle that when an impure metal in the molten state is allowed to cool. Only the metal crystallises, while the impurities remain in the molten mass (or) melt (Impurities are more soluble).



Zone refining.

This method gives high purity, metals like Ga, In, Si which are used in semi conductors are purified by this method.

$\Rightarrow$ The impure metal is converted into a rod, which is heated at one end with a moving circular heater. As the heater is slowly moved along the length of the rod. The pure metal crystallises out of the melt, where as the impurites pass into the adjacent molten zone, this process is repeated no of times till the impurities are driven completely towards one end and the pure metal towards the other end.

The entire process is carried out in an inert atmosphere to prevent the oxidation of the metal.

(f) Vapour phase refining: The crude metal is heated with specific reagent at low temperature, so that it is converted into unstable volatile compound, leaving behind the impurities. The unstable voltatile compound is decomposed at a high temperature to give the pure metal.

It is two types:

(i) Mond process: Mond process is used for refining of Nickle. Impure Nickle is heated with carbon monoxide to form volatile Nickle carbonyl, leaving behind the impurities.

$$\underset{\text{(Impure)}}{Ni} + 4CO \xrightarrow{330\text{-}350\ K} \underset{\text{vapor}}{[Ni(CO)_4]} \xrightarrow{\Delta} \underset{\text{pure}}{Ni} + 4CO$$

(ii) Van-Arkel method: The impure metal heated with Iodine-vapors at high temperature to give vapors of metallic tetra iodide, (unstable). At high temperature these are decomposed to give pure metal.

$\Rightarrow$ Zirconium (Zr) & Titanium (Ti) are purified by this method

$$\underset{\text{Im pure}}{Ti} + \underset{\text{Vapours}}{2F_2} \xrightarrow{500k} \underset{\text{Vapours}}{TiI_4} \xrightarrow{1700k} \underset{\text{pure metal}}{Ti} + 2I_2$$

Illustration 5

Name two metals which can be purified by liquation method

Solution

Tin, Lead

Try yourself

11. Name two methods for obtaining metals of high purity.
12. For the reduction of a metallic oxide.Suggest a reducing agent cheaper than aluminium.

3.6 ALLOYS

The homogeneous mixture of two or more metals, or a metal and a nonmetal is called an alloy. For examples, brass is an alloy of copper (Cu) and zinc (Zn). Similarly, steel is mainly an alloy of iron (Fe) and carbon (C).

Preparation

Alloys are commonly prepared by melting the desired metals in proper proportions. The melt is allowed to cool and solidify. The solid substance formed is called an alloy.

Properties of Alloys

Alloys have certain characteristic properties :

1. They are harder than their constituents but less ductile and malleable.
2. They are resistant to corrosion.
3. The melting point of an alloy may be higher or lower than any of its constituents.
4. The properties of an alloy are much more improved and pronounced than those of its constituents. For example, aluminium is a light metal and it is not very strong. But Duralumin, an alloy of Aluminium, is light and very strong.
5. The colour of an alloy is different from the metals from which it is formed. For example, both Silver and zinc are almost white but the alloy formed from them are pink in colour.

S.No.	Alloy	Composition	Uses
1.	Brass	Cu = 80%, Zn = 20%	Harder than pure Cu and Zn ; used for making utensils, cartridges, etc
2.	Bronze	Cu = 90%, Sn = 10%	For making statues, medals, ships coins, machines, etc.
3.	Solder (common)	Sn = 50%, Pb = 50%	For joining metals, soldering wires, electronic components, etc.
4.	Duralumin	Al = 95.5%, Cu = 3 % Mn = 1%, Mg = 0.5 %	In bodies of aircraft, kitchenware, automobile parts, etc.
5.	Magnalium	Al = 90%, Mg = 10% Cu = 3%	Balance beams, light instruments, etc.
6.	German Silver	Cu = 60%, Zn = 20%, Ni = 20%	For making utensils, ornaments, etc.

Alloys of Gold

The purity of gold is expressed in carats. 24 carat gold is pure gold. But pure gold is very soft and, therefore, cannot be used in making ornaments or coins. It is generally alloyed with copper or silver to make it hard and useful. 22 carat gold means that the alloy contains 22 parts of gold in 24 parts of the alloy.

Amalgam

An amalgam is an alloy of mercury and one or more metals. Most of the metals form amalgam with mercury. But iron and Platinum are noticable exceptions. Therefore, amalgams can be stored in iron bottles.

Some of the amalgams are definite intermetallic compounds, such as sodium amalgam ($NaHg_2$), magnesium amalgam (MgHg), silver amalgam (Ag_5Hg_8), etc. Amalgams of sodium and aluminium are good reducing agents. Amalgam of silver, tin, Cadmium and copper have been utilized as dental fillings.

Amalgams may be solid or liquid.

Alloy Steels

Steel : Steel is an alloy of iron and carbon, the carbon content being 0.15–1.7%. Small quantities of other elements such as manganese, silicon, chromium, Molybdenum, cobalt and nickel are added to impart desirable mechanical and chemical properties that cannot be obtained by using carbon alone. Such steels are known as **alloy steels.**

Stainless Steel : Steel that contains over 11–12% of chromium is known as **stainless steel**. Stainless steel does not rust or stain. It is, therefore, used to serve a variety of purposes in industrial, chemical and domestic fields.

A particularly useful alloy is the steel known as 18–8 which contains Cr (18%), Ni (8%) and C (0.08%). It is now apparent that the ingredient which is instrumental in influencing the properties of steel is carbon.

The wonder of ancient Indian metallurgy

The iron pillar near the Qutub Minar in Delhi was made around 400 BC by the iron workers of India. They had developed a process which prevented wrought iron from rusting. This is likely because of formation of a thin film of magnetic oxide (Fe_3O_4) on the surface, as a result of finishing treatment given to the pillar, painting it with a mixture of different salts, then heating and quenching. The iron pillar is 8 m high and weighs 6 tonnes (6000 kg).

3.7 CORROSION OF METALS

Slow destruction of metals due to chemical reactions on their surface by oxygen, carbon dioxide, moisture, sulphur dioxide, hydrogen sulphide, etc., of the atmosphere,is known as **corrosion of metals**.

Due to corrosion, small holes appear on the surface of the metal and the strength of the metal goes on decreasing. The process of corrosion is caused by the reaction of the metal with oxygen of air or with oxygen dissolved in water.

In corrosion, the metal atoms give up electrons (i.e. they are oxidized) and are converted into ions.

$$M \rightarrow M^{+} + e$$

The ions move from one part of the metal to another more easily in the presence of moisture. This is because moisture provides the medium through which ions can flow.

Factor Determining the Rate of Corrosion

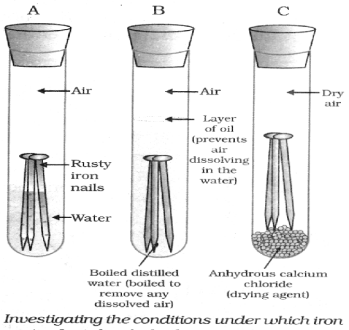
The process of corrosion is speeded up in the following circumstances.

1. The metals are in contact with each other

The corrosion of a more electropositive metal is speeded up when it is in contact with a less electropositive metal. Two metals form an electrochemical (galvanic) cell in the presence of moisture. Electrons begin to flow from the more electropositive (or more reactive) to the less electropositive (or less reactive) metal. Thus, the more electropositive metal is lost as ions. For example, when iron and copper are in contact, electrons flow from iron to copper because iron is more electropositive than copper. Thus, the more reactive metal iron forms ions. The process of iron going away as ions is slower in the absence of copper.

2. Polluting materials in air

The air near industrial units is generally polluted with CO_2, SO_2, H_2S etc. Gases coming out of chimneys contain these gases in abundance. We know that these gases are also responsible for the corrosion of metals. Therefore, the process of corrosion is speeded up in presence of these pollutants.



Investigating the conditions under which iron rusts. In tube A, both air and water are present. In tube B, there is no air dissolved in the water. In tube C, the air is dry.

(a) Silver articles become black some time when exposed to air. This is because it reacts with sulphur in the air to form a coating of silver sulphide.

(b) Copper reacts with moist carbon dioxide in the air and slowly loses its shiny brown surface and gains a green coat. This green substance is basic copper carbonate.

(c) Iron when exposed to moist air for a long time acquires a coating of a brown flaky substance called rust.

(d) **Activity**

Take three test tubes and place clean iron nails in each of them. Label these test tubes A, B and C. Pour some water in test tube A and cork it.

Pour boiled distilled water in test tube B, add about 1 mL of oil and cork it. The oil will float on water and prevent the air from dissolving in the water.

Put some anhydrous calcium chloride in test tube C and cork it. Anhydrous calcium chloride will absorb the moiture, if any, from the air.

Leave these test tubes for a few days and then observe (figure). You will observe that iron nails rust in test tube A, but they do not rust in test tubes B and C. In the test tube A, the nails are exposed to both air and water. In the test tube B, the nails are exposed to only water, and the nails in test tube C are exposed to dry at.

Preventive measures

The metallic surface can be coated with appropriate chemicals (ex: bisphenol, oxides etc.)

• Points are very good corrosion-inhibitors. If they contain red lead zinc chromate or lead chromate. Since these forms the protoctive coatings.

• Concrete coating & phosphate coating (Fe & Mn-phophates) are very effective against atmopheric corrosion.

• Steel plants & nuclear plants etc are protected by the method of Anodic potential

• Anodised 'Al' is resistant to corrosion. it is the reason that the bodies of the buses & cars have 'Al' strips around it.

• Glycol in coolant for automobiles is good corrosion inhibitor addition of small quantity of cyanovanador to the thermostats (or) radictors of cars can protect them from corrosion.

• Copper & Brass items can be protected by covering them with p-chlorobenzohydroxamic Acid

Illustration 6

What is 24 carat gold? How will you convert it into 18 carat gold?

Solution

24 carat gold is pure gold. It is very soft for which reason it can not be used for making jewellery. To make it 18 carat, 18 parts of pure gold in alloyed with 6 parts of either silver or copper.

Illustration 7

What is rust ? Write its chemical formula?

Solution

The deposition of brown, flasy substance on the surface of air is known as rust. Rust is mainly hydrated iron(III) oxide $[Fe_2O_3.xH_2O].Fe(OH)_3$

$Fe + H_2O + O_2 \rightarrow Fe_2O_3.xH_2O + Fe(OH)_3$

Try yourself

13. Brass is an alloy of copper and

(A) Silver (B) Iron (C) Aluminium (D) Zinc

14. Why does aluminium not corrode or rust through

15. Explain why iron sheets are coated with zinc?

Comparison of Pig Iron, Wrought Iron and Steel

Pig Iron	Wrought Iron	Steel
Composition		
1. Iron : upto 94 % 2. Carbon : 2.5–4.0% 3.Impurities : Less than 2% (Si, P, S, Mg)	Almost pure iron Carbon : 0.1 – .25% Impurities : negligible	Less pure than wrought iron Carbon : 0.1–1.7% Impurities : negligible
Properties		
1. Hard, brittle, non-malleable, non-ductile. 2. Lacks tensile strength Cannot be welded, forged, tempered or shaped by hammering even while hot. 3. Does not rust easily. 4. Has a low melting point (1200°C)	Soft, tough, malleable, ductile, does not crack under strain. Can be welded, forged, tempered and by hammering while hot but has less strength than steel. Resists corrosion better than pig iron. Melting point around 1500°C.	Hardness depends on the carbon content, malleable and ductile. Can be welded, forged, tempered and shaped by hammering while hot. Has maximum tensile strength. Ordinary steel rusts. Hence alloyed. Melting point ranges between 1200 – 1500°C.

3.7.1 Rusting

When iron is exposed to moist air, a reddish-brown coating of a mixture of ferric oxide (Fe_2O_3) and ferric hydroxide ($Fe(OH)_3$) is deposited on the surface of the metal. The slow conversion of iron into a mixture of Fe_2O_3 and $Fe(OH)_3$ by water and atmospheric oxygen is known as **rusting.**

Rusting of iron is an oxidation reaction that occurs due to the attack of water and oxygen. It has been found that rusting does not take place in air-free water. It also does not occur in presence of oxygen alone. Both water and oxygen are essential for rusting. Thus, the following conditions are necessary for rusting :

(i) Presence of oxygen or air (ii) Presence of water or moisture

The process of rusting is continuous. The strength of iron decreases gradually and finally the metal is destroyed completely.

(A) Prevention of Rusting

Iron can be prevented from rusting by the following ways :

1. Rusting of iron can be prevented by covering its surface with paint, grease, enamel, that does not allow air and moisture to come in contact with it and no rusting occurs. This is known as **barrier protection**.
2. Rusting of iron can be prevented by **galvanization**. Zinc metal does not corrode on exposure to air. So zinc coating protect iron from rusting. Zinc itself forms a protective coating of basic zinc carbonate [$Zn(OH)_2.ZnCO_3$].
3. Rusting can be prevented by coating the surface of iron object with chromium, tin, nickel or aluminium. These metals resist corrosion. Hence, they protect iron from rusting. They may be coated by **electro-plating**.
4. Rusting can also be prevented by converting it into an alloy with chromium and nickel. This alloy is called **stainless steel**.
5. Rusting of iron can be prevented by coating it surface with iron(II, III) oxide, Fe_3O_4.
6. Rusting is prevented by **sacrificial protection** in which a more reactive metal is connected to iron objects so that the more reactive metal gets oxidized in preference to the iron object. For example, Mg or Zn being more reactive than Fe are connected to Fe, which are oxidized and said to be scarified. Iron pipes beneath the soil are protected by connecting them to rolls of magnesium (Mg) or Zinc sheets by Sacrificial Protection.

(B) Uses of Iron

1. Iron find wide application in house construction, eg. in the **reinforcement** of roofs and other parts of buildings.
2. Wrought iron and cast iron are largely used in the manufacture of locomotives, railway lines, springs, cubes, etc.
3. Iron has its important therapeutic uses in the treatment of **hypochromic anemias.** The iron deficiency condition impair the formation of haemoglobin and many other functions of red blood cells. Any of iron compounds may be used in therapy and inorganic salts are equally effective for the purpose.
4. All plants, animals and human beings require iron to live. The largest percentage of iron in human beings is present in red blood cells, which are main part of **haemoglobin**. Small quantities of iron are also found in muscles and tissues.
5. Iron is the basic material for thousands of manufactured goods from small pins to mammoth buildings. Iron combines readily with various non-metals such as sulphur and oxygen. Enormous quantities of iron metal is used producing **alloys**, eg. steel (one of the most useful and cheapest metals) is produced by adding a small amount of carbon to iron. Several precious stones, including topaz, turquoise and spinel also contain iron.

(C) Prevention of Corrosion

(i) By painting (ii) Self-prevention (iii) By coating iron with zinc

3.8 USES OF METALS

Metals are used in the form of pure metals, alloys and in the form of metal compounds.

Use of Pure Metals

Zinc: (i) It is used to galvanise iron to prevent it from rusting.

(ii) It is used in making alloys such as brass and bronze.

Iron: It is used as a catalyst in the manufacture of ammonia by the Haber's Process.

Mercury: It is used in preparing amalgams.

Silver and Gold: (i) Both are used in making ornaments and jewellary.

(ii) Both are used in making coins.

Chromium and Nickel: (i) Both these metals are used in electroplating, cycle, motorcycle and other automobile parts.

(ii)They are mixed with other metals to prepare useful alloys.

Titanium: Titanium is a light metal. It has a high melting point and boiling point. It is highly resistant to corrosion and has a high tensile strength, even higher than that of steel. Due to these properties, it has the following uses :

(i) Preparing steel for defence installations (military hardware) marine instruments, aircraft frames. Hence referred to as a **'strategic element'**.

(ii) Titanium is used in nuclear reaction.

(iii) Titanium is used for making strong structures for construction of buildings.

Some important metals compounds used in daily life :

1. **Silver Nitrate ($AgNO_3$)** : It is also known as lunar caustic It is colourless, transparent, crystalline solid and soluble in water.

   Uses :

   (i) As laboratory reagent,

   (ii) In preparation of marking inks,

   (iii) In photography

   (iv) In silvering of mirror,

   (v) In manufacturing of other salts of silver.

2. **Silver Bromide (AgBr)**: It is pale yellow coloured crystalline compound, insoluble in water.

   Uses : In photography

3. **Potash Alum** : $(K_2SO_4.\ Al_2(SO_4)_3\ 24H_2O)$

   Potash alum is a double salt of aluminum sulphate and potassium sulphate. It is soluble in water. In potash alum crystalline water is found in large amount, so on heating it expands in volume.

   Uses: In softening of water.

4. **Blue Vitrol or copper sulphate ($CuSO_4.5H_2O$)** :

   Copper sulphate is also known as blue vitrol. It is blue coloured, crystalline substance. On heating it gradually releases the crystalline water

   $$CuSO_4.5H_2O \xrightarrow{373\,K} CuSO_4.H_2O \xrightarrow{413K} CuSO_4 \xrightarrow{443K} CuO + SO_2$$

   Uses :

   (i) In electroplating

   (ii) In electric batteries.

   (iii) The mixture of $CuSO_4$ and lime is known as bordeaux mixture, it is used as fungicide,

(iv) In dyeing of clothes

(v) In preservation of wood

Illustration 8

In the manufacture of iron lime stone added to the blast furnace why?

Solution

Limestone mixed with charge get decomposed in to CaO and CO_2. Calcium oxide reacts with silica present in the ore to produce fusible slag.

$CaO + SiO_2 \rightarrow CaSiO_3$

Lime Silica Slog (Calcium silicate)

Illustration 9

Give the formation of slag in the metallurgy of copper

Solution

$FeO + SiO_2 \rightarrow FeSiO_3$

Impurity flux Slag

Try yourself

16. Which of the following is not an ore

(A) Bauxite (B) Malachite (C) Zinc blende (D) Pig iron

17. Carbonates and sulphide ores are usually converted into oxide ores why?

18. Write down the chemical formula of compound

(i) Potash alum (ii) Blue vitrol (iii) Lunar caustic

3.9 NON-METALS

Non-Metals : Only 22 nonmetallic elements, of which 11 are gases, one is a liquid and the rest 10 are solids. Nonmentals are placed on the right-hand side of the periodic table.

At room temperature, non-metals are either solids or gases, except bromine, which is a liquid. Hydrogen (H_2), nitrogen (N_2), oxygen (O_2), chlorine (Cl_2) etc., are example of some gaseous non-metals. Carbon, sulphur (S_8), phosphorus (P_4), etc., are solids. **They play an important role in our daily life.**

Physical Properties

1. Non-metallic solids are **brittle**. If they are hammered or stretched, they break into pieces. Carbon in the form of graphite is very soft.
2. Non-metals **do not have any lustre**, i.e., they do not have a shining surface. But **iodine**, which has a lustrous appearance, is an exception.
3. Non-metals are generally soft elements, except diamond (an allotropic form of carbon), which is the hardest known substance.
4. Non-metals do not conduct heat and electricity because unlike metals, they have no free electrons. But there is an exception. Graphite, an allotropic form of carbon, is a good conductor of electricity.

Chemical Properties

Due to energy considerations, non-metals cannot form positively charged ions by the loss of electrons. In fact, they form negatively charged ions (anions) by the gain of electrons. Hence, they are known as electronegative elements.

$Cl + e^- \rightarrow Cl^-$; $O + 2e \rightarrow O^{2-}$

$S + 2e^- \rightarrow S^{2-}$.

(a) Reaction with Oxygen

Non-metals combine with oxygen to form oxides. These oxides are either acidic or neutral. They never form basic oxides. The non-metallic oxides are formed by sharing of electron pairs between the atoms of non-metal and oxygen. Hence, these are convalent compounds.

$C(s) + O_2(g) \rightarrow CO_2(g)$

$S(s) + O_2(g) \rightarrow SO_2(g)$

Both carbon dioxide (CO_2) and sulphur dioxide are acidic oxides. They dissolve in water to form acids.

$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$

Carbonic acid

$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$

Sulphurous acid

The solutions of both CO_2 and SO_2 in water turn blue litmus red. Examples of neutral oxides are carbon monoxide (CO), nitrous oxide (N_2O), etc.

(b) Reaction with Acids

Non-metals do not displace hydrogen from dilute acids. For example, carbon or sulphur does not react with dilute acids. Hydrogen can only be displaced from dilute acids if electrons are supplied to the H^+ ions of the acid.

$H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$

$2H^+(aq) + 2e^- \rightarrow H_2(g)$

A non-metal is an electron acceptor. It cannot supply electrons to H^+ ions. Therefore, it does not displace hydrogen from dilute acids.

(c) Reaction with Chlorine

With chlorine, non-metals form covalent chlorides. The covalent chloride is generally a volatile liquid or a gas. For example, phosphorus trichloride.

$P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(g)$ (phosphorus trichloride)

(d) Reaction with Hydrogen

Non-metals combine with hydrogen to form hydrides. For example, ammonia (NH_3), methane (CH_4), hydrogen sulphide (H_2S), water (H_2O), etc. These hydrides are stable compounds and are formed by sharing of electron pairs between the non-metal and hydrogen.

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

$H_2(g) + S(s) \rightarrow H_2S(g)$

Difference between Metal & Non-metal

Property	Metals	Non – Metals
1. Action with mineral acids	Metals generally react with dilute mineral acids to liberate H_2 gas	Non-metals do not displace hydrogen on reaction with dilute minerals acids
2. Nature of oxides	They form basic oxides. These oxides are ionic in nature. Some oxides like Al_2O_3 are amphitricha also.	Non-metals form acidic or neutral oxides. These oxides are covalent in nature.
3. Combination with hydrogen	Only a few metals combine with hydrogen to form hydrides. These hydrides are ionic in character.	Non-metals combine with hydrogen to form stable hydrides. These hydrides are covalent.
4. Combination with halogens	They combine with halogens to form well defined and stable crystalline solids. For example, NaCl, KBr, etc.	Non-metals form halides which are unstable and undergo hydrolysis readily. For example, PCl_5, PCl_3, etc.
5. Electrochemical behavior	Metals are electropositive in character. They form cations in solutions and are deposited on the cathode when electricity passed through their solutions.	Non-metals are electronegative in character. They form anions in solutions and are liberated at the anode when electricity is passed through their solutions. Hydrogen is an exception. It usually forms positive ions and is liberated at cathode.
6. Oxidising or reducing behaviour	Metals behave as reducing agents. This is because of their tendency to lose electrons.	Non-metals generally behave as oxidizing agents since they have the tendency to gain electrons.

3.9.1 Non-metal Sulphur

Atomic number of sulphur is 16. atomic mass is 32, electronic configuration is $Is^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$, symbol is $_{16}S^{32}$, valencies are + 2, + 4 and + 6 while in some compounds -2.

Sulphur is known to man since ancient time. Sulphur emerged out with lava when volcanoes are erupted. Sulphur compounds arc also found in water of many streams, wells, ponds etc. Ancient Indian physicians used sulphur for preparation of various drugs In Sanskrit, sulphur is known as sulvcri which means de-stroyer of copper'. Infact when copper is heated with sulphur its properties are lost. Lavoisier studied its properties and identified it as an clement Sulphur is found in nature in free state and in the form of different compounds.

Allotropes of sulphur

Allotropes and allotropy : Two or more forms of an element which have different structure and other physical properties but have same chemical properties are known as allotropes of the element This property of elements is known as allotropy .

Sulphur has two allotropes the crystalline and non crystalline.

(A) **Crystalline allotropes**: Crystalline sulphur is found in two allotropic forms.

(i) **Rhombic sulphur** : This allotrope of sulphur is also known as α (alfa) sulphur At normal temperature this allotrope of sulphur is highly stable. It is insoluble in water but soluble in carbon disulphide When it is heated at 368.6 K (95 6° C), it is converted into other allotrope, monoclinic sulphur

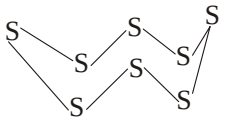
(ii) **Monoclinic sulphur** : It is also known as β (beta) sulphur. It is found in the form of needle shaped crystals. Thus it is also known as prismatic sulphur. It is insoluble in water and soluble in carbon disulphide. This allotrope of sulphur is stable above 368.6 K temperature Below this temperature it is converted to α sulphur Both allotropcs of sulphur coexist at 368.6 K This temperature is known as transition temperature.

Rhombic sulphur $\underset{}{\overset{368.6K}{\rightleftharpoons}}$ monoclinic sulphur

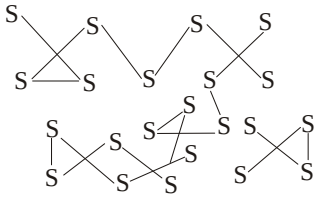
Both these allotropes of sulphur have 58 structure that forms a distorted ring.

(B) **Non crystalline sulphur** : This sulphur is found in three allotropic forms

(i) **Plastic sulphur** : When boiling sulphur is poured in cold water a soft rubber like substance is obtained which is known as plastic sulphur. This is an unstable allotrope of sulphur which gets converted slowly, into rhombic sulphur, It is also known as γ (gamma) sulphur. Plastic sulphur is unsynchronized chain structure.



Distorted ring of S_8 molecle in rhombic and monoclinic sulphur



Chain of S. molecules in plastic sulphur.

Allotropes of sulphur

(ii) **δ (delta) sulphur or milk of sulphur**: It is white coloured non crystalline sulphur It is used for preparing medicines.

(iii) **Collidial sulphur** : This allotrope of sulphur is obtained by passing H_2S gas in dilute nitric acid solution.

$$H_2S + 2HNO_3\,(\text{dilute}) \rightarrow 2NO_2 + 2H_2O + S$$

This sulphur is soluble in Carbon disulphide but insoluble in water. On heating or after some times, this sulphur gets transfonned into rhombic sulphur.

It is also used in preparation of medicines.

Use of sulphur:

(i) sulphur is extensively used for industrial production ofsulphuric acid.

(ii) It is used in gun powder and in manufacturing of match sticks.

(iii) It is used as powerful insecticide.

(iv) Sulphur is used in preparation of medicines, sulphur contain ing medicines are useful for skin diseases and blood purification,

(v) It is used in vulcanization of rubber.

3.9.2 Phosphorus

Atomic number 15, atomic mass is 31, electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ symbol is $^{31}_{15}P$, valencies are + 3,+ 5 brand, a German scientist discovered phosphorus in 1669. He obtained this element for first time by distillation of a mixture of urine, sand and coal As this element glows in dark, hence the name phosphorus was given.

It is not found in free state in nature because it is highly reactive. In combined state, it is found in the form of phosphate compounds.

Allotropes of phosphorus : There are many allotropes of phosphorus, they are as follows.

(i) White or yellow phosphorus,

(ii) Red phosphorus,

(iii) Black phosphorus,

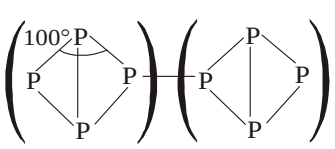
(iv) Violet / purple phosphorus,

(v) Dark red phosphorus.

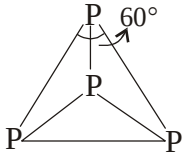
Out of these white, red and black phosphorus are more common.

White phosphorus is of white colour when it is pure but gradually it turns yellow. It has garlic like smell and is poisonous. It is a molecular solid having tetrahedral P_4 units. In this arrangement P-P-P bond angle is 60° and the structure is more strained. Due to this while phosphorus is more reactive. It catches fires in presence of air thus it is kept in cold water. It is soft and can be easily cut with knife.

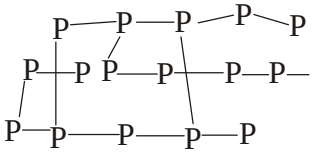
Red phosphorus: It has a complex chain structure. It is odourless and its ignition point is high. In red phosphorus, P-P-P bond angle is 100°.



Red phosphorus



White phosphorus



Black Phosphorus

Black phosphorus: Due to its layered structure it is more stable. In this allotrope many layer of phosphorus atoms are interconnected. Similar to red phosphorus, it is also odourless.

Interconvesion of white to black and red phosphorus can be explained by following reaction.

Uses :

(i) White phosphorus is used to prepare smoke clouds, fire balls, presentation of fire game and to manufacture coloured match sticks.

(ii) Red phosphorus is used to prepare match sticks,

(iii) Red Phosphorus is used to prepare phosphorus bronze alloy. This alloy contains copper, tin and phosphorus.

(iv) Compounds of phosphorus like zinc phosphide and calcium phosphide are used to kill rats.

3.9.3 Some Important Compounds of Non-Metals

1. **Ozone(O_3)**: Ozone is a allotrope of oxygen.Nascent oxygen is obtained from this compound, so it is a strong oxidizing agent. A layer of ozone is also found in the atmosphere. This layer prevents the harmful U.V. radiations coming from sun. Thus act as a protective layer. Following are important industrial uses of ozone gas.

   (i) In production of artificial silk, (ii) As bleaching agent.

   (iii) As disinfectant. (iv) For purifying drinking water.

   (v) Ozone used as disinfectant and also for purifying air.

   (vi) Used for preparation of potassium permangnate.

2. Hydrogen peroxide (H_2O_2)

   It's chemical structure is H–O–O–H.

   It exhibit both oxidizing and reducing properties. Usually its oxidizing properties are more Its important uses are as follows :

   (i) The oxidizing property is employed in rejuveniling (re-brightening) of old paintings whose original lead coating has turned dirty due to its reaction with H_2S present in atmosphere, resulting in formation of PbS Hydrogen peroxide oxidises this yellow lead sulphide to white lead sulphate

   $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

   yellow white

   (ii) Dilute solution of hydrogen peroxide is used as a disinfectant for wounds.

   (iii) Concentrated H_2O_2 is used as rocket fuel oxidant.

   (iv) The main industrial application of it is the bleaching of silk, hair, ivory, wool, wood etc

   (v) It is used in medicine, cosmetics etc.

3. **Ammonia (NH_3)** : Structure of ammonia is $\begin{matrix} H- & N & -H \\ & | & \\ & H & \end{matrix}$.

   (i) Ammonia is used for manufacturing of nitrogen containing fertilizers (like ammonium nitrate, urea . ammonium phosphate and ammonium sulphate)

   (ii) Ammonia is used for manufacturing of nitric acid.

   (iii) It is used as freezing agent thus it is also used in ice factories

   (iv) Used in synthesis of artificial silk.

   (v) Used for producing explosives.

   (vi) It is useful in removing stains of fats, oils, grease etc. from clothes.

   (vii) Dilute ammonia is used in medicines and cosmetics.

4. **Nitric acid (HNO_3)** : Structure of nitric acid is $\begin{matrix} & O & \\ & \uparrow & \\ O = & N & - OH \end{matrix}$.

   Nitric acid is a strong oxidizing agent Its main industrial applications are as follows.

   (i) Nitric acid is used for preparation of ammonium nitrate which is used as fertilizer,

   (ii) It is also useful for preparation of other nitrates which are used in explosives and fire crackers. For example - potassium nitrate (KNO_3), nitroglycerine, trinitrotoluene etc are explosive.

EXERCISE-I

EX: A1

1. Which of the following is a metal ? (i) $_3X^7$ (ii) $_9Y^{10}$
2. Which of the following will replace H_2 from acids to form salt. S, P, Na, Si.
3. Name the reducing agent in the following chemical reaction, $3MnO_2 + 4Al \rightarrow 3Mn + 2Al_2O_3$.
4. Name an element which shows property of catenation other than carbon.
5. Sodium & potassium are not found in free state in nature. Give one reason.
6. Which metal occurs in free state as well as in combined state?
7. What happen to the electrical conductivity when a metal is heated?
8. Which colour appears on the surface of aluminium when it is kept in air for sometimes?
9. Which property of copper and aluminium makes them suitable for making boilers and cooking utensils?
10. A copper coin is kept immersed in a solution of silver nitrate for sometime.What will happen to the coin and the colour of the solution?
11. The element Al has atomic number (Z) equal to 13. How many electrons should be lose to form a positive ion? How will you represent it?
12. The electronic configuration of an element 'A' is 2, 8, 6. Will it like to lose six electrons or gain two electrons?
13. Does the atomic number of an element change when it forms ion?
14. What is the major source of metals?
15. Why do gold and platinum always exist in free state?
16. A metal is found to be present in vitamin B –12. Name the metal.
17. Suggest a method to remove gangue impurities from haematite ore.
18. Which metal acts as anode during the electrolytic refining?
19. Name an alloy of copper used for making utensils.
20. Which process is used for the enrichment of (a) sulphide ore (b) oxide ore?
21. What is rust? Write its chemical formula.
22. Why do not non - metals conduct electricity.
23. Write the names of two oxides which are neither acidic nor basic.
24. Name two metals which do not react with oxygen.
25. Name a metal which combines with hydrogen gas. Name the compound formed.

EX: A2

1. Name two metals obtained from their metal oxides by electrolytic reduction.
2. Name two metals which do not corrode.
3. In the redox reactions : $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$.
   (i) Which one of Cu & Fe is more reactive. (ii) Which one of the 2 is oxidised.
4. Why do silver ornaments tarinish after some time?
5. Name two non - metals which exist in the solid state and two non- metals which exist in the gaseous state.
6. How will you show that metal oxides are basic in nature?
7. What are active metals? Give list of three acitve metals.
8. Give the reaction if any when the following metals are treated with copper sulphate solution:
   (i) Pt, (ii) Zn, (iii) Ag
9. An element X combines with oxygen to form an oxide XO. The oxide is electrically conducting. Give the following information.

(i) How many electrons would be present in the valence shell of the element X?

(ii) Write the formula of the compound when element X combines with chlorine.

10. Give reasons for the following :
    (i) Metals replace hydrogen from dilute acids whereas non - metals do not
    (ii) Carbonate and sulphide ores are usually converted into oxides.
11. All ores are minerals while all minerals are not ores. Elaborate.
12. Name the products obtained when (a) zinc sulphate is roasted (b) lime stone is calcined.
13. Enlist the main factors which promote corrosion.
14. Iron nails are not rusted if kept in boiled distilled water for a long time. Explain.
15. Oxides of the metals which are high in the activity series are not reduced by carbon. How will you account for it?
16. Metals at the top of the activity series do not occur in the free state. Explain.

EX: A3

1. Differenciate between calcination & roasting.
2. Name a non-metal which (i) is liquid at room temp. (ii) is good conductor of heat & electricity (iii) has metalliclustre.
3. What do you mean by metallurgy? What are the various processes involved during metalluragy?
4. A group of students looked at different metals and metal sulphate solutions given in a tabular form. From the data answer the following:
   (a) Which metal reacted with all other metal sulphate solutions?
   (b) Which metal did not react with any other metal sulphate solution?
   (c) Put the metals in decreasing order of reactivity.
   (d) Iron is slightly more reactive then cobalt.With which other metal sulphate solution, will it react?

Metal	Metal sulphate solution	Colour
Chromium	Chromium sulphate	Green
Cobalt	Cobalt sulphate	Pink
Copper	Copper sulphate	Blue
Magnesium	Magnesium sulphate	colourless

5. (i) Choose one metal from the reactivity series which will not react with steam.
   (ii) Choose one metal from the reactivity series which will safely react with dilute sulphuric acid.
   (iii) Name the salt formed when your chosen metal in (ii) react with sulphric acid.
6. From the options given along the side of each statement, select the most appropriate.
   (i) A metal that gets covered with a protective film of its oxide : Al, Cu, Ag
   (ii) A metal which burns in air will golden flame : Zn, K, Na
   (iii) A metal which can displace hydrogen from boiling water as well as steam : K, Zn, Fe
   (iv) A metal that does not react with air at room temperature. : Na, Mg, Ca
7. Complete and balance the following :
   (i) $MgO + HCl \rightarrow$
   (ii) $Na + H_2O \rightarrow$
   (iii) $Al_2O_3 + HCl \rightarrow$
8. Which of the following reactions are not possible and why?
   (a) $Fe\ (s) + ZnSO_4\ (aq) \rightarrow FeSO_4\ (aq) + Zn\ (s)$

(b) $Cu\ (s) + 2\ AgNO_3\ (aq) \rightarrow Cu\ (NO_3)_2\ aq + 2Ag\ (s)$

(c) $Cu(s) + H_2SO_4\ (dil) \rightarrow CuSO_4\ (aq) + H_2(g)$

(d) $Zn\ (s) + CuSO_4\ (aq) \rightarrow ZnSO_4\ (aq) + Cu\ (s)$

9. Suggest various ways to check the rusting of iron.
10. (a) What is a thermit reaction?
    (b) In the electrolytic refining of a metal M, name the anode, cathode and the electrolyte.

11. Name an alloy of
    (i) Aluminium used in construction of air crafts
    (ii) Lead in joining metals for electric work.
    (iii) Copper used in household vessels.
12. E is an element which is one amongst copper, zinc, aluminium and iron. It shows following properties
    (a) One of its ores is rich in E_2O_3
    (b) E_2O_3 is not attacked by water.
    (c) it forms two chlorides ECl_2 and ECl_3
    Name the element and justify your answer.
13. You are provided with three metals: Sodium, magnesium and copper. Using only water as the reactant, how will you identify them?
14. Name with examples three common forms in which metals occur in nature. How do the metals interact with dilute acids?
15. Write one point of difference between electrolytic reduction and reduction with carbon. Give one example of each.

EX: A5

1. (a) Name two metals which are liquids.
   (b) Name a metal other than mercury which lacks malleability
   (c) What is the nature of Al_2O_3?
   (d) Name a metal which forms a mixed oxide on reacting with steam. Also give the name of the oxide.

EXERCISE-II

(Boards)

EX: B1

1. Why do ionic compounds have high melting points?
2. What chemical process is used for obtaining a metal from its oxide?
3. Which of the following methods is suitable for preventing an iron frying pan from rusting?
   (i) Applying grease (ii) Applying paint
   (iii) Applying a coating of zinc (iv) All of the above.
4. An element reacts with oxygen to give a compound with a high melting point. This compound is also soluble in water. The element is likely to be
   (i) calcium (ii) carbon (iii) silicon (iv) iron.
5. Food cans are coated with tin and not with zinc because
   (i) zinc is costlier than tin. (ii) zinc has a higher melting point than tin.
   (iii) zinc is more reactive than tin. (iv) zinc is less reactive than tin.
6. Why is sodium kept immersed in kerosene oil?
7. Name two metals which are found in nature in the free state.
8. Which metals do not corrode easily?

9. What are alloys?
10. Give reasons
    (a) Platinum, gold and silver are used to make jewellery.
    (b) Sodium, potassium and lithium are stored under oil.
    (c) Aluminium is a highly reactive metal, yet it is used to make utensils for cooking,
    (d) Carbonate and sulphide ores are usually converted into oxides during the process of extraction.
11. Why are stainless steel cooking pans often given a copper outer bottom? (CBSE 1998)
12. Which chemical element is alloyed with copper to make bronze? (AISB 2001)
13. Name the two metals which are best conductors of electricity. (HSB 2002)
14. Name the metal which is poorest conductor of electricity. (HSB 2002)
15. Name the major metal used for making of aircraft. (HSB 2002)
16. Which one of the metal in the following group are (a) most reactive (b) least reactive : Au, Na, Cu, Ca? (DSB 2003)
17. Name one metal and one non-metal which are in liquid state at room temperature. (AISB 2004)
18. Name two metals both of which are very ductile as well as very malleable. (AISB 2005)
19. Why is tungsten metal selected for making filaments of incandescent lamp bulbs ? (DSB 2005)
20. A green layer is gradually formed on a copper plate left exposed to air for a week in a bathroom. What could this green substance be? (DSB 2005)
21. Why is it necessary to concentrate an ore before processing? (CBSE 2001)

EX: B 2

1. Give reasons for the electricity :
   (i) Reaction of nitirc acid with metals generally does not evolve hydrogen gas.
   (ii) For making gold ornaments, 22-carat gold is preferred over 24-carat gold. (DSB 2004)
2. An element reacts with oxygen to form an oxide which dissolves in dilute hydrochloric acid. The oxide turns solution of red litmus blue. Is it a metal or non-metal? Explain with the help of suitable example. (AISB 2001)
3. An athlete won a bronze medal in a race competition. After some days he found that the metal has lost its lusture due to formation of greenish layer on its surface. Name the metals present in the metal. What is the reason for appearance of greenish layer on its surface? (AISB 2002)
4. A copper plate was dipped into a solution of $AgNO_3$. After sometime, black layer was deposited on the copper plate. State the reason for it. Write the chemical equation of the reaction involved. (Delhi 2002)
5. Why gold and platinum often occur in free state? (PSB 2004)
6. Why metals are good conductors of heat and electricity? (PSB 2004)
7. Explain the meanings of malleable and ductile.
8. Write equations for the reactions of
   (i) iron with steam (ii) calcium and potassium with water.
9. Which gas is produced when dilute hydrochloric acid is added to a reactive metal? Write the chemical reaction when iron reacts with dilute H_2SO_4.
10. What would you observe when zinc is added to a solution of iron (II) sulphate? Write the chemical reaction that takes place.
11. You are given a hammer, a battery, a bulb, wires and a switch.
    (i) How could you use them to distinguish between samples of metals and non-metals?
    (ii) Assess the usefulness of these tests in distinguishing between metals and non-metals.
12. What are amphoteric oxides? Give two examples of amphoteric oxides.
13. Name two metals which will displace hydrogen from dilute acids, and two metals which will not.

14. In the electrolytic refining of a metal M, what would you take as the anode, the cathode and the electrolyte?
15. State two ways to prevent the rusting of iron.
16. What type of oxides are formed when non-metals combine with oxygen?
17. Which of the following pairs will give displacement reactions?
    (i) NaCl solution and copper metal (ii) $MgCl_2$ solution and aluminium metal
    (iii) $FeSO_4$ solution and silver metal (iv) $AgNO_3$ solution and copper metal
18. Give reasons why copper is used to make hot water tanks and not steel (an alloy of iron).

EX: B 3

1. Give reasons for the following :
   (i) Germanium is known as a metalloid.
   (ii) Inspite of high reactivity, aluminium can be used for making household utensils. (DSB 2004)
2. Give reasons for the following :
   (i) Silicon is counted among metalloids.
   (ii) Na, K and Ca metals form hydrides by combination with hydrogen gas, but most other metals donot.
   (iii) Carbon is not used for making aluminum form aluminium oxide. (AISB 2004)
3. Write chemical equations for reactions taking place when :
   (i) Zinc carbonate is calcined. (ii) Manganese dioxide is heated with aluminium powder.
   (iii) Cinnabar is heated in air. (AISB 2004)
4. Write chemical equation for the reactions taking place when :
   (i) Zinc sulphide is roasted. (ii) A piece of calcium metal is placed in water.
   (iii) Steam is passed over red hot iron. (DSB 2004)
5. (a) Why is ZnO called an amphoteric oxide? Name another amphoteric oxide.
   (b) What are alkalies? Give one example of alkalies. (DSB 2005)
6. You must have seen tarnished copper vessels being cleaned with lemon or tamarind juice. Explain why these sour substances are effective in cleaning the vessels.
7. Give an example of a metal which
   (i) is a liquid at room temperature. (ii) can be easily cut with a knife
   (iii) is the best conductor of heat. (iv) is a poor conductor of heat.
8. Samples of four metals A, B, C and D were taken and added to the following solution one by one. The results obtained have been tabulated as follows.

Metal	Iron (II) sulphate	Coppoer (II) sulphate	Zinc sulphate	Silver nitrate
A	No reaction	Displacement		
B	Displacement		No reaction	
C	No reaction	No reaction	No reaction	Displacement
D	No reaction	No reaction	No reaction	No reaction

   Use the table above to answer the following questions about metals A, B, C and D.
   (i) Which is the most reaction metal?
   (ii) What would you observe if B is added to a solution of Copper (II) sulphate?
   (iii) Arrange the metals A, B, C and D in the order of decreasing reactivity.
9. (i) Write the electron - dot structures for sodium, oxygen and magnesium.
   (ii) Show the formation of Na_2O and MgO by the transfer of electrons.
   (iii) What are the ions present in these compounds?

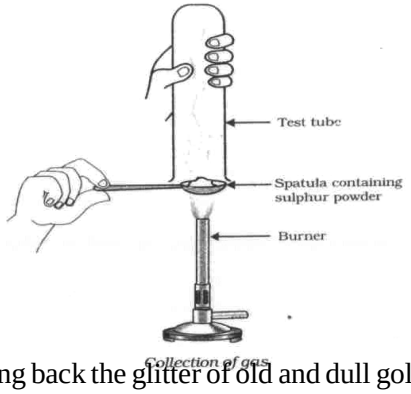
10. Define the following terms
(i) Mineral (ii) Ore (iii) Gangue

11. Metallic oxides of zinc, magnesium and copper were heated with the following metals.

Metal	Zinc	Magnesium	Copper
Zinc oxide Magnesium oxide Copper oxide			

In which cases will you find displacement reactions taking place?

12. Pratyush took sulphur powder on a spatula and heated it.
He collected the gas evolved by inverting a test tube over it, as shown in figure below.
(a) What will be the action of gas on
(i) dry litmus paper?
(ii) moist litmus paper?
(b) Write a balanced chemical equation for the reaction taktng place.



13. A man went door to door posing as a goldsmith. He promised to bring back the glitter of old and dull gold ornaments. An unsuspecting lady gave a set of gold bangles to him which he dipped in a particular solution. The bangles sparkled like new but their weight was reduced drastically. The lady was upset but after a futile argument the man beat a hasty retreat. Can you play the detective to find out the nature of the solution he had used?

EX: B5

1. Define an alloy and an amalgam. State the main constituents of the following alloys. In what property is each of them its main constituent? (i) Stainless steel (ii) Bronze. (AISB 2004)
2. (a) What is an 'activity series' of metals? Arrange the metals Zn, Mg, Al, Cu and Fe in a decreasing order of reactivity.
(b) What would you observe when you put
(i) Some zinc pieces into blue copper sulphate solution?
(ii) Some copper pieces into green ferrous sulphate solution? (AISB 2005)
3. (a) What is corrosion of metals? Name one metal which does not corrode and one which corrodes on being kept in atmosphere.
(b) How will you show that the rusting of iron needs oxygen and moisture at the same time.(DSB 2005)
4. Differentiate between metal and non-metal on the basis of their chemical properties.

EXERCISE-III

SECTION-A

- **Fill in the blanks**

1. Thermit reaction is sometimes called the _____.
2. Stainless steel contains _____, _____ and _____.
3. Phosphorus with chlorine forms two chlorides namely _____ and _____.
4. An alloy of any metal with mercury is called _____and the electrical conductivity of an alloy is _____than that of pure metal

5. German Silver is an alloy of _____ _____ and _____.

SECTION-B

- **Multiple choice question with one correct answers**

1. If an isotope has two neutrons in its atom, the atomic number and mass number will respectively be:
   (A) 2 and 1 (B) 3 and 1 (C) 1 and 1 (D) 1 and 3
2. Oleum is:
   (A) Caster oil (B) Oil of vitriol (C) Fuming H_2SO_4 (D) None of these
3. Sulphur molecule is
   (A) Diatomic (B) Tetra-atomic (C) Triatomic (D) Octa-atomic
4. When a non-metal reacts with chlorine, it forms
   (A) an ionic chloride (B) a covalent chloride (C) a tetrachloride (D) a dichloride
5. Which of the following metals will displace hydrogen from steam, dilute acids and alkalies?
   (A) Iron (B) Mercury (C) Zinc (D) Calcium
6. The final acid obtained during the manufacture of H_2SO_4 by contact process is:
   (A) H_2SO_4 (conc.) (B) H_2SO_4 (dil.) (C) H_2SO_4 (aq) (D) $H_2S_2O_7$
7. A mineral is known as ore if metal
   (A) cannot be produced from it (B) can be produced from it
   (C) can be extracted from it profitably (D) is very costly
8. Out of the following , which cannot be obtained by electrolysis of aqueous solution of the salt?
   (A) Ag (B) Mg (C) Cu (D) Cr
9. A process employed for the concentration of sulphide ore is :
   (A) Froth floatation (B) Roasting (C) Electrolysis (D) Bessemerisation
10. Zone refining is used for the :
    (A) Concentration of an ore (B) Reduction of metal oxide
    (C) Purification of metal (D) Purification of an ore.
11. Which of the following processes is used for the concentration of Bauxite (Al_2O_3. $2H_2O$)?
    (A) Froth floatation (B) Leaching (C) Liquation (D) Magnetic separation
12. The earthly impurities associated with mineral used in metallurgy are called?
    (A) Slag (B) Flux (C) Gangue (D) Ore
13. Most abundant metal on the surface of earth is :
    (A) Iron (B) Aluminium (C) Calcium (D) Sodium
14. In the thermite process, the reducing agent is :
    (A) Nickel (B) Zinc (C) Sodium (D) Aluminium
15. Metal always found in free state is

(A) Gold (B) Silver (C) Copper (D) Sodium

16. Chemically rust is :

(A) hydrated ferrous oxide (B) hydrated ferric oxide

(C) only ferric oxide (D) none of these

SECTION-C

- **Assertion & Reason**

Instructions: In the following questions as Assertion (A) is given followed by a Reason (R). Mark your responses from the following options.

(A) Both Assertion and Reason are true and Reason is the correct explanation of 'Assertion'

(B) Both Assertion and Reason are true and Reason is not the correct explanation of 'Assertion'

(C) Assertion is true but Reason is false

(D) Assertion is false but Reason is true

1. **Assertion:** Auto-reduction of ores is used for cinnabar, copper glance and galena
Reason: The sulphide ores of these metals reacts with their oxides to give metals.

2. **Assertion:** Poling involves reduction of metals oxides of metals
Reason: Green poles of wood release hydrocarbon gases to act as reducing agent.

SECTION-D

- **Match the following (one to one)**

Column-I and **column-II** contains **four** entries each. Entries of column-I are to be matched with some entries of column-II. Only One entries of column-I may have the matching with the same entries of column-II and one entry of column-II Only one matching with entries of column-I

1. Column I	**Column II**
(A) Zn	(P) Cuprite
(B) Hg	(Q) Carnalite
(C) Cu	(R) Calamine
(D) Mg	(S) Cinnabar

EXERCISE-IV

SECTION-A

- **Multiple choice question with one correct answers**

1. Which is used as catalyst in Haber's process?
   (A) Cr (B) Al (C) Ni (D) Fe
2. The percentage of lead in lead pencil is:
   (A) zero (B) 20 (C) 80 (D) 70
3. Which of the following can act both as oxidising and reducing agent?
   (A) SO_2 (B) MnO_2 (C) Al_2O_3 (D) CrO_3
4. SO_2 reacts with Cl_2 in the presence of sun light to form
   (A) Sulphuryl chloride (B) Sulphonyl chloride (C) Sulphur dioxide (D) None of these
5. Sulphur readily dissolves in
   (A) Water (B) sodium hydroxide (C) hydrochloric acid (D) carbon disulphide
6. In the preparation of vanaspati ghee from an cdible oil, the chemical reaction taking place in the presence of Ni catalyst is called.
   (A) oxidation (B) dehydration (C) hydrogenation (D) dehydrogenation
7. Anhydride of H_2SO_4 is:
   (A) SO_2 (B) SO_3 (C) H_2SO_3 (D) $H_2S_2O_7$
8. Sugar reacts with concentrated sulphuric acid to give the smell of burning sugar. It is due to the formation of
   (A) CO_2 (B) SO_2 (C) C (D) both CO_2 and SO_2
9. Concentrated sulphuric acid acts as
   (A) oxidising agent (B) dehydrating agent (C) both (D) none of these
10. When concentrated H_2SO_4 comes in contact with sugar, it becomes black due to:
    (A) Hydrolysis (B) Hydration (C) Decolourisation (D) Dehydration
11. The important ore of iron is
    (A) Siderite (B) Haematite (C) Pyrites (D) Bauxite
12. Which of the following processes is used in the extractive metallurgy of magnesium?
    (A) Fused salt electrolysis (B) Self reduction
    (C) Aqueous solution electrolysis (D) Thermite reduction
13. An alloy which does not contain copper is :
    (A) Solder (B) Bronze (C) Brass (D) Bell metal

SECTION-B

- **Multiple choice question with one or more than one correct answers**

1. Which one of the following is/are a basic flux?
   (A) $CaCO_3$ (B) CaO (C) SiO_2 (D) MgO

2. Electrolytic reduction process is/are used for the extraction of:
   (A) alkali metals (B) alkaline earth metals (C) aluminium (D) none
3. The process of conventing hydrated alumina into anhydrous alumina is called:
   (A) roasting (B) smelting (C) dressing (D) calcination
4. The method(s) of extraction of metal from oxide ores is/are:
   (A) reduction with carbon (B) reduction with hydrogen
   (C) reduction with aluminium (D) electrolytic method
5. Which of the following contain(s) Mg?
   (A) magnetite (B) magnesite (C) asbestos (D) carnalite

6. Calcination is/are used in the metallurgy of:
(A) Magnesite ore (B) Dolomite ore (C) Malachite ore (D) none

SECTION-C

- **Comprehension**

Roasting involves heating of ore (below its melting point) in presence of air or oxygen. It is done in reverberatory furnace or blast furnace. Roasting involves chemical changes with decomposition. It is commonly used for sulphides ores. During roasting moisture and volatile oxides of some metals like Se, As, Sb etc are removed. Sulphure is expelled in the form of SO_2 or SO_3.

1. Roasting is done:
(A) in the absence of air
(B) in the presence of air
(C) in the presence or absence of air
(D) all of the above

2. During roasting
(A) moisture removes
(B) volatile substance removes
(C) S removes in the form of SO_2 or SO_3
(D) All

3. Roasting is done in the
(A) Are furnace
(B) Blast furnace
(C) Reverbenatory furnace
(D) Induction furnace

SECTION-D

- **Match the following (one to many)**

Column-I and **column-II** contains **four** entries each. Entries of column-I are to be matched with some entries of column-II. One or more than one entries of column-I may have the matching with the same entries of column-II and one entry of column-II may have one or more than one matching with entries of column-I

1.

Column I	**Column II**
(A) Self reduction	(P) Pb
(B) Carbon reduction	(Q) Ag
(C) Complex formation & displacement by metal	(R) Cu
(D) Electrolytic reduction	(S) Na

Answers

Knowledge base questions

1.	(D)	2.	(A)	3.	(C)	4.	(D)	5.	(B)
6.	(D)	7.	(D)	8.	(B)	9.	(B)	10.	(C)

Try Yourself

1. The conductivity of electricity is known as electrical conductivity i.e. the property of metals due to which they allow electric current to pass through them is known as electrical conductivity Ag > Au > Hg
2. (i) Mercury (ii) Sodium (iii) Silver (iv) Mercury
3. (i) Silver (ii) Gold
4. Chromium and Nickel
5. (A) 6. Na 7. ZnO, Al_2O_3
8. (i) Sulphide ore: Froath floatation method (ii) Oxide ore: Calcination
9. The process of extracting metal from its ore and its refining is known as metallurgy
10. Pine oil
11. (i) Zone refining (ii) Van Arkel method 12. Carbon 13. (D)
14. This is because first when aluminium get corrode, it form a layer of Al_2O_3, which prevents it from further rusting.
15. This process is called galvanization and is used to prevent rusting of iron.
16. (D)
17. It is easier to reduce oxide as compared to carbonate and sulphide.
18. (i) $K_2SO_4.Al_2(SO_4)_3.24H_2O$ (ii) $CuSO_4.5H_2O$ (iii) $AgNO_3$

****

Exercise-III

Section-A

1. Goldsehmidt Process
2. Iron, Chromium, Carbon
3. PCl_3, PCl_5
4. amalgam, less
5. Cu, Zn and Ni

Section-B

1.	(D)	2.	(C)	3.	(D)	4.	(B)	5.	(C)
6.	(D)	7.	(C)	8.	(B)	9.	(A)	10.	(C)
11.	(B)	12.	(C)	13.	(B)	14.	(D)	15.	(A)
16.	(B)								

Section-C

1.	(A)	2.	(A)

Section-D

1. (A)-(R), (B)-(S), (C)-(P), (D)-(Q)

Exercise-IV

Section-A

1.	(D)	2.	(A)	3.	(A)	4.	(A)
5.	(D)	6.	(C)	7.	(B)	8.	(C)
9.	(C)	10.	(D)	11.	(B)	12.	(A)
13.	(A)						

Section-B

1.	(A,B,D)	2.	(A,B,C)	3.	(D)	4.	(A,B,C)
5.	(B,C,D)	6.	(A,B,C)				

Section-C

1.	(B)	2.	(D)	3.	(C)

Section-D

1. (A)-(P,R), (B)-(P,R), (C)-(Q), (D)-(S)