Chapter_06

General Principles and Processes of Isolation of Elements

1. Naturally occurring chemical substances in the earth's crust obtainable by mining are called **minerals**.
2. The minerals from which a metal can be extracted conveniently and profitably are called **ores**. e.g. bauxite is an ore of aluminium.
3. The substance which is added in the ore to convert non-fusible gangue to fusible compound, (called slag) is called **flux**. The flux may be acidic (like SiO_2) or basic (like CaO, MgO etc).
4. **Concentration of Ores**

   Various methods are as follows:

   - **Gravity separation or hydraulic washing or levigations** : This method is based on the difference in the specific gravities or densities of the ore and gangue and usually employed for oxides and carbonate ores. Cassiterite or tin stone, chromite and haematite are concentrated by this method.
   - **Magnetic separation** : This method is based on the difference in magnetic properties of minerals. If either the ore or the gangue is attracted by a magnetic field, it can be concentrated to yield a sample which is rich in metal iron, e.g. magnetite (Fe_3O_4), haematite (Fe_2O_3), wolframite ($FeWO_4$), chromite ($FeO \cdot Cr_2O_4$) and illmenite ($FeO \cdot TiO_2$) are separated from non-magnetic impurities by this method.
   - **Froth-flotation process** is used to concentrate sulphide ores because of the preferential wetting of ore with pine oil. Here, collectors (like pine oil, xanthates etc.) enhance the non-wettability of mineral particles, while froth stabilisers like cresols, aniline etc. stabilise the froth.
   - **Leaching** is used when ore is soluble in some suitable solvent, while impurities remain insoluble e.g. leaching of alumina from bauxite by Baeyer's process. Al_2O_3 is leached out as sodium aluminate when treated with NaOH.

     $$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \longrightarrow 2Na[Al(OH)_4](aq)$$

   - Gold or silver ore is leached with dil. NaCN solution in the presence of air to give a metal complex, from which metal is displaced by zinc. This process is called **cyanide process**.

     $$4M(s) + 8CN^-(aq) + 2H_2O(aq) + O_2(g) \longrightarrow 4[M(CN)_2]^-(aq) + 4OH^-(aq)$$

     $$2[M(CN)_2]^-(aq) + Zn(s) \longrightarrow [Zn(CN)_4]^{2-}(aq) + \underset{\text{Metal}}{2M(s)} \quad [M = \text{Ag or F}]$$

5. **Extraction of metal from concentrated ore** involves two major steps, i.e. conversion to oxide and reduction of oxide to metal.
   - The process of heating of metal ore in the absence of air is called **calcination**. By calcination, ore is converted into oxide.

     e.g. $CaCO_3 \cdot MgCO_3(s) \longrightarrow CaO(s) + MgO(s) + 2CO_2(g)$

   - The process of heating of metal ore below its melting point in the presence of air is called **roasting**. By sulphide roasting, ore is converted to oxide.

     $$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2\uparrow$$

   - The process of reduction of metal oxide into crude metal by C or CO is called **smelting**.
6. **Ellingham diagram** helps in predicting the feasibility of thermal reduction of an ore.

   According to this, the sum of $\Delta G°$ of the two reactions (oxidation of reducing agent and reduction of metal oxide) should be negative.
   - At lower temperature, CO is a better reducing agent than C but at higher temperature (983 K or above), C is the better reducing agent.
   - For the reduction of a molten metal salt, electrolysis is done that should follow the equation $\Delta G° = -nFE°$.
7. **Refining** Metal extracted by any method is usually contaminated by some impurities. To obtain metal of high purity, several techniques are used such as distillation, liquation, electrolytic refining etc. Some important techniques are as follows :
   - Low boiling metals are refined by **distillation**. For e.g. Zn and Hg. **Liquation** is used to refine low melting metals that are separated from higher melting impurities by allowing them to flow on a sloping surface, e.g: Sn.
   - **Zone refining** is based on the principle that the impurities are more soluble in the molten metal than in the solid state of the metal. Metals like, Si, Ge, Ga, B etc., are refined by this process.
   - **Vapour phase refining** is based on the principle that the impure metal is first converted into its volatile compound and collected elsewhere. The volatile compound on decomposition gives pure metal. e.g. Ni.

     (a) **Mond's process** is used to refine nickel.

     $$\underset{\text{Impure}}{Ni} + 4CO \xrightarrow{330\text{-}350\ K} \underset{\substack{\text{Volatile}\\\text{compound}}}{Ni(CO)_4} \xrightarrow{450\text{-}470\ K} \underset{\text{Pure}}{Ni} + 4CO$$

     (b) **van-Arkel process** is used to refine zirconium and titanium.

     $$\underset{\text{Impure}}{Zr} + 2I_2(g) \longrightarrow \underset{\text{Metal iodide}}{ZrI_4(g)} \xrightarrow[\text{Tungsten filament}]{1800\ K} \underset{\text{Pure}}{Zr(s)} + 2I_2$$

   - **Chromatography** is the most advanced technique used for separation or metallurgical purposes. It is based on the principle that different components of a mixture are adsorbed differently on an adsorbent.
   - Copper and zinc are refined by **electrolytic method**, where impure metal is made to act as anode and a strip of pure metal acts as cathode. Here, the salt solution of the metal to be extracted is generally used as electrolyte.
8. Bauxite ($Al_2O_3 \cdot 2H_2O$) is an important ore of aluminium, haematite (Fe_2O_3) and magnetite (Fe_3O_4) are the important ores of iron. Copper pyrites ($CuFeS_2$) is an important ore of copper.
9. Copper is extracted from low grade ores by leaching through acid or bacteria or by treating the ore with scrap Fe or H_2.
10. Cast iron, wrought iron, steel, alloy steel, nickel steel are some useful alloys.