Hard and Soft Water

Water which produces lather with soap solution readily is called soft water. For example, rain water, distilled water etc. Water which does not produce lather with soap solution readily is called hard water. eg: sea water, water from certain rivers.

Hardness of water is due to the presence of bicarbonates, chlorides and sulphates of calcium and magnesium. The calcium and magnesium ions present in hard water form insoluble salts with soap and prevent the formation of lather. For example, soap containing sodium stearate reacts with hard water to precipitate calcium and magnesium stearate.

$$\underset{}{M^{2+}} + \underset{\text{(soap)}}{2C_{17}H_{35}COONa} \longrightarrow \underset{\text{(insoluble precipitate)}}{(C_{17}H_{35}COO)_2\,M} + 2Na^+ \quad (M = Mg \text{ or } Ca)$$

(a) Temporary hardness

This type of hardness of water is caused by the presence of bicarbonates of calcium and magnesium dissolved in it. Temporary hardness can be removed by merely boiling the water. When boiled, the soluble bicarbonates are decomposed into insoluble carbonates. These are precipitated and can be removed by filteration.

$$M(HCO_3)_2 \xrightarrow{heat} MCO_3 + H_2O + CO_2 \quad \text{where } M = Mg, Ca$$

Temporary hardness of water can also be removed by adding calculated amount of lime ($Ca(OH)_2$) whereupon Mg and Ca ions are precipitated as insoluble carbonates.

It is known as **Clark's process.**

$$Mg\,(HCO_3)_2 + 2Ca\,(OH)_2 \longrightarrow 2CaCO_3 + Mg\,(OH)_2 + 2H_2O$$

$$Ca\,(HCO_3)_2 + Ca\,(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$$

(b) Permanent hardness

Permanent hardness of water is caused by the presence of chlorides and sulphates of calcium and magnesium dissolved in it. Permanent hardness cannot be removed by boiling. Permanent hardness of water can be removed by the following methods.

(i) By using washing soda

The sample of hard water is treated with calculated amounts of washing soda ($Na_2CO_3.10H_2O$) to convert the chlorides and sulphates of calcium and magnesium into their respective insoluble carbonates.

$MgSO_4 + Na_2CO_3 \rightarrow MgCO_3 + Na_2SO_4$;

$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$

(ii) Calgon process

In this process, the calcium and magnesium ions are made ineffective by the addition of sodium hexametaphosphate (known as calgon). The ions of Ca and Mg form soluble complexes with calgon which remain in solution, but does not react with soap.

$$\underset{Calgon}{Na_6P_6O_{18}} \longrightarrow 2Na^+ + [Na_4P_6O_{18}]^{2-}$$

$$[Na_4P_6O_{18}]^{2-} + M^{2+} \longrightarrow \underset{\text{soluble complex ion}}{[Na_2MP_6O_{18}]^{2-}} + 2Na^+$$

[Here $M^{2+} = Ca^{2+}$ or Mg^{2+}]

(iii) Inorganic ion-exchange method (Permutit process)

Hydrated sodium aluminium silicate ($NaAlSiO_4 . xH_2O$) known as Zeolite or Permutit is capable of exchanging its sodium ions with calcium and magnesium ions of hard water. For simplicity, permutit is represented as NaZ.

$$2NaZ + M^{2+}(aq) \longrightarrow 2Na^+(aq) + MZ_2(s)$$

After some time, the whole of permutit gets exhausted due to its conversion of into calcium and magnesium permutit. It is regenerated by treating it with an aqueous solution of $NaCl$.

$$MZ_2(s) + 2NaCl(aq) \longrightarrow 2NaZ(s) + MCl_2(aq)$$

(iv) Synthetic resin method

Synthetic cation exchange resins consist of a high molecular weight organic compound containing acidic $-SO_3H$. The resins can exchange H^+ ions with the cations present in hard water and the hard water thus gets softened.

Resins containing basic groups can exchange OH^- ions with the anions present in hard water and are called *anion exchange resins*. They may be generally represented as $R\overset{+}{N}H_3\ OH^-$ where R represents a giant hydrocarbon network.

The hard water sample is passed through a bed of cation exchange resin when all the cations in water get exchanged with H^+ ions of the resin. This sample is then passed through a bed of anion exchange resin where the anion (Cl^- and SO_4^{2-}) of water exchange with OH^- ions in the resin. The

H^+ ions formed in the first step combine with OH^- ions formed in the second step to form water. The water so formed is free from all types of cations and anions and is known as *deionised water.*

HEAVY WATER (D_2O)

Ordinary water contains very trace quantity of D_2O (About 6000 parts of ordinary water contains one part of D_2O. It is prepared by exhaustive electrolysis of ordinary water.

Heavy water is chemically similar to ordinary water because both H and D contain the same number of protons and electrons. But it has higher density, melting and boiling point than ordinary water. It is used in the preparation of other deuterium compounds

(i) $CaC_2 + 2D_2O \longrightarrow C_2D_2 + Ca(OD)_2$
(deuteroethyne)

(ii) $SO_3 + D_2O \longrightarrow D_2SO_4$ (deuterosulphuric acid)

(iii) $Al_4C_3 + 12D_2O \longrightarrow 4Al\,(OD)_3 + 3CD_4$ (Deuteromethane)

Heavy water is used as a **moderator** in nuclear reactors and in exchange reactions for the study of reaction mechanisms.

Liquid hydrogen as fuel

Due to extensive use, our reserves of fossil fuels are fast depleting. A prospective alternative in this regard is what is known as **hydrogen economy**. The major idea behind hydrogen economy is the storage and transportation of energy in the form of gaseous and liquid hydrogen. Advantage of hydrogen economy is that energy is carried in the form of dihydrogen and not as electric power. Hydrogen fuel can release more energy per unit weight of the fuel than our conventional fuels. Hydrogen oxygen fuel cells can be used for generating power in automobiles. Liquid hydrogen has already been used as rocket fuel along with liquid oxygen. About 5% of H_2 has now been mixed with CNG (condensed natural gas) for use in vehicles.