Ion Exchange Resin

Ion-exchange Resins (IER): IER are cross-linked organic co-polymers (e.g., styrene-divinyl benzene or amine-formaldehyde) with a porous structure attached with some functional groups (FGs) like –OH, $-SO_3H$, -COOH, $-NH_2$, etc. responsible for reversibly exchange with ions (e.g., Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-}, etc.) present in hard water.

Types of Ion-exchange resins:

Depending on the nature of FG attached to the polymer, they are of two types: (1) Cation exchange resin (CER), and (2) Anion exchange resin (AER)

Cation Exchange Resins (CER): They are mainly styrene-divinyl benzene copolymers containing sulphonic acid ($-SO_3H$) or carboxylic acid (-COOH) FG. The acidic FG having hydrogen ions ($-H^+$) are *exchange with cations* like Ca^{2+}, Mg^{2+} etc. present in the hard water. It means these hardness causing cations are retained by the resin.

Some commercial cation exchange resins are **Amberlite IR-120 and Dowex-50**.

Anion Exchange Resins (AER): They are mainly styrene-divinyl benzene or amine-formaldehyde copolymers containing basic FG like amino or quaternary ammonium or quaternary phosphonium. As such they are of no use. To act as an *anion exchange resin*, it is treated with dil. NaOH solution to convert it to hydroxide form. The OH^- ion of AER is capable of *exchange with anions (Cl^-, NO_3- etc.)* of water.

Some commercial anion exchangers are **Amberlite IR-400 and Dowex-3**.

Softening of hard water using polymeric ion-exchangers

An ion-exchanger consists of two vertical columns: (1) cation exchanger and (2) anion exchanger column.

The hard water is first passed through the cation exchange column so that all cations are removed from it and equivalent amount of H^+-ions are released from the column to water. Let us represent the cation exchange resin as **$Res\text{-}H^+$.** Here the loosly bound H+ ions are capable of exchanging with cations like Ca^{2+} and Mg^{2+}.

$$\mathbf{2Res\text{-}H^+ + Ca^{2+} \rightarrow (Res)_2Ca + 2H^+}$$

$$\mathbf{2Res\text{-}^{-}H^+ + Mg^{2+} \rightarrow (Res)_2Mg + 2H^+}$$

After passing through the first column, the water is passed through anion exchange column to remove all the anions like Cl^-, NO_3^-, SO_4^{2-}, etc. present in the water and an equivalent amount of –OH- ions are released from the column to the water. Let us represent this resin as **Res-OH⁻.**

$$\text{Res-OH}^- + \text{Cl-} \rightarrow \text{Res-Cl} + \text{OH}^-$$

$$\text{Res-OH}^- + \text{NO}_3^- \rightarrow \text{Res-NO}_3 + \text{OH}^-$$

Now the outgoing water is free from all ions so it is ion-free or *deioinized* water. This water also called as *de-mineralized* water. This water is free from any acidic or alkaline masses. Finally the ion-free water is passed through a *de-gasifier* maintained at about 100 ^{0}C to remove dissolved gases like O_2, CO_2, etc.

Regeneration of ion exchange resins

After working for some time, the ion-exchange resins lost their ion-exchange capacity and are said to be exhausted.

The exhausted cation exchange resin column can be regenerated by washing with a solution of dil. HCl or H_2SO_4.

$$\text{(Res)}_2\text{Ca} + 2\text{H}^+ \text{ (from HCl)} \rightarrow 2\text{Res-H}^+ + \text{Ca}^{2+}$$

The exhausted anion exchange resin column can be regenerated by washing with a solution of dil NaOH or KOH.

$$\text{Res-Cl} + \text{OH}^- \text{ (from NaOH)} \rightarrow \text{Res-OH}^- + \text{Cl}^-$$

The regenerated resins are then used again for softening.

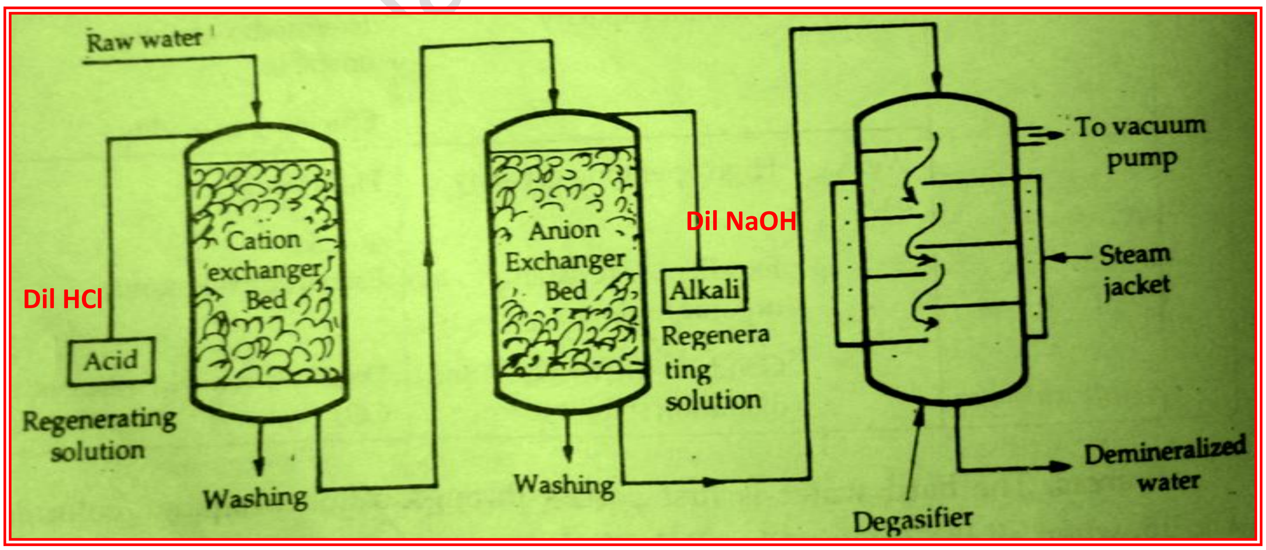

Fig. Polymeric ion-exchanger

Advantages:

1. This process can be used for softening highly acidic and alkaline waters.
2. Residual hardness lies between 0-2 ppm.
3. De-gasifier removes dissolved gases
4. Water is germ free

Limitations:

1. It is an expensive process
2. Turbid water causes problem
3. Water is not fit for human consumption. (we need minerals like Ca)

Q. 1 What is the use of a de-gasifier in ion-exchange resin softener?

Ans. It is a device used to remove unwanted dissolved gases like O_2, CO_2, etc from the soften water.

Q. 2 Differentiate between soften water and de-mineralized/de-ionised water

Sl. No.	Soften Water	De-mineralized Water
1	its hardness lies between 10- **60 ppm and are not ion free**	Hardness lies between 0-2 ppm but free from ions.
2	May be used for domestic use	Not recommended as such for drinking purpose. Used by many industries.
3	Obtain using L-S or zeolite process	Made by distillation or resin process
4	Not suitable for boiler	Fit for boiler operation

Q 3. Mention some advantages of resin process.

Ans.

1. This process can be used for softening even for highly acidic and alkaline waters.
2. Residual hardness lies between 0-2 ppm. So, fit for boiler operation.
3. De-gasifier removes dissolved gases
4. Water is germ free
5. Water can be used in R& D purpose

Q. 4. Mention some limitations of resin process.

Ans.

1. It is an expensive process
2. Turbid water causes problem

3. Water is not fit for human consumption. (we need mineral like Ca)

Q.5 How to regenerate an exhausted cation-exchange resin?

Ans. The exhausted cation exchange resin column can be regenerated by passing a solution of dil HCl or H_2SO_4.

$$\mathbf{(Res)_2Ca\ (Exhausted\ resin) + 2H^+\ (from\ HCl) \rightarrow 2Res\text{-}H^+ + Ca^{2+}}$$

Q.6 How to regenerate an exhausted anion-exchange resin?

Ans. The exhausted anion exchange resin column can be regenerated by passing a solution of dil NaOH or KOH.

$$\mathbf{Res\text{-}Cl\ (Exhausted\ resin) + OH^-\ (from\ NaOH) \rightarrow Res\text{-}OH^- + Cl^-}$$

Q7. What is an ion exchange resin? Give an example.

Ans. Ion exchange resin are insoluble, cross-linked organic co-polymers with a porous structure attached with some functional groups (FG) like –OH, $-SO_3H$, -COOH, $-NH_2$, etc. responsible for reversibly exchange with ions (e.g., Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-}, etc.) present in hard water.

Example: Styrene-divinyl benzene with $-SO_3H$ group attached to it.

Q8. Differentiate between Zeolite and Resin process.

Ans. Do it yourself (DIY)

Q9. Diffrenetiate between CER and AER.

Ans. DIY

Numerical:

An exhausted CER needs 1,000 L of HCl of strength 100 g/L. One million liters of water was softened by the resin process. Find the hardness of water as $CaCO_3$ eq.

Soln. HCl as $CaCO_3$ Eq. = (100 x 1000 mg/L) x (100/2x36.5) = 136986 mg/L

Now, $S_{HCl} \times V_{HCl} = S_{H2O} \times V_{H2O}$

- ⇨ $136986 \times 1000 = S_{H2O} \times 10^6$
- ⇨ $S_{H2O} = (136986 \times 1000) / 10^6 = 136.98$ ppm.