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JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

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Year & Sem. – B. Tech I year, Sem.-I
Subject –Engineering Chemistry
Unit – I (Zeolite &Ion-exchange Process)
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Designation - Associate Professor & Head
Department - Chemistry

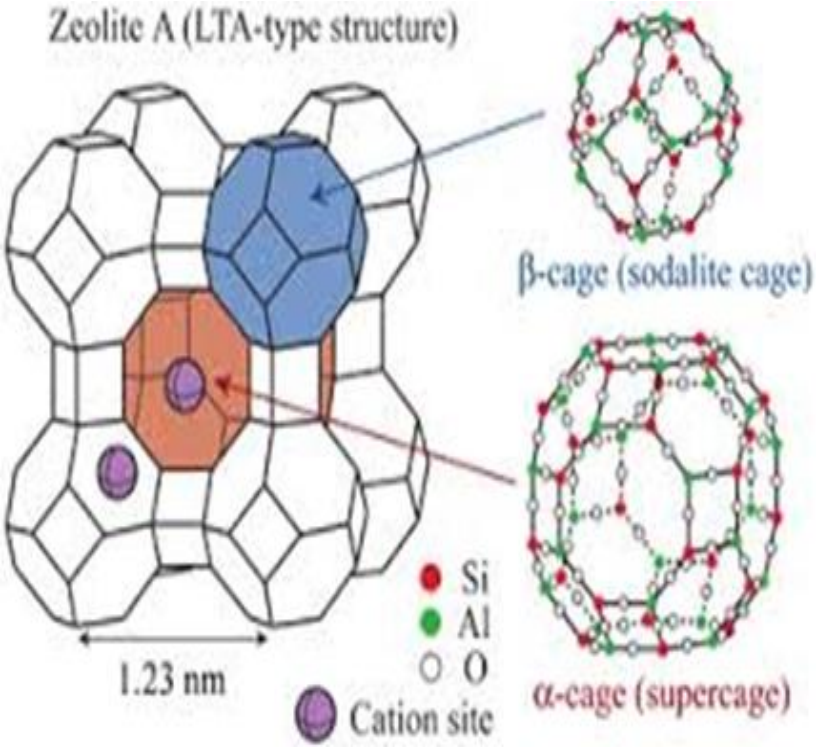
Softening Methods
Zeolite Process (Permutit Method)

Zeolites are hydrates of sodium aluminium orthosilicate and it is represented as :

$Na_2O.Al_2O_3.xSiO_2.yH_2O$

Where X=2-10, Y= 2-6

Zeolite Structure



Types of Zeolite

Zeolites are of two types:

1. Natural Zeolites:

Derived from natural sources like green sand and Nonporous
Example Natrolite

2. Synthetic or Artificial Zeolite:

Prepared in laboratory and porous. Posses a gel like structure, more efficient so common in use

Principle of Zeolite Process:

$Na_2Ze + Ca(HC0_3)_2 \text{-------} \rightarrow CaZe + 2NaHCO_3$

$Na_2Ze + Mg(HCO_3)_2 \text{-------} \rightarrow MgZe + 2NaHCO_3$

$Na_2Ze + CaCI_2 \text{ or } CaSO_4 \text{-------} \rightarrow CaZe + 2NaCI \text{ or } Na_2SO_4$

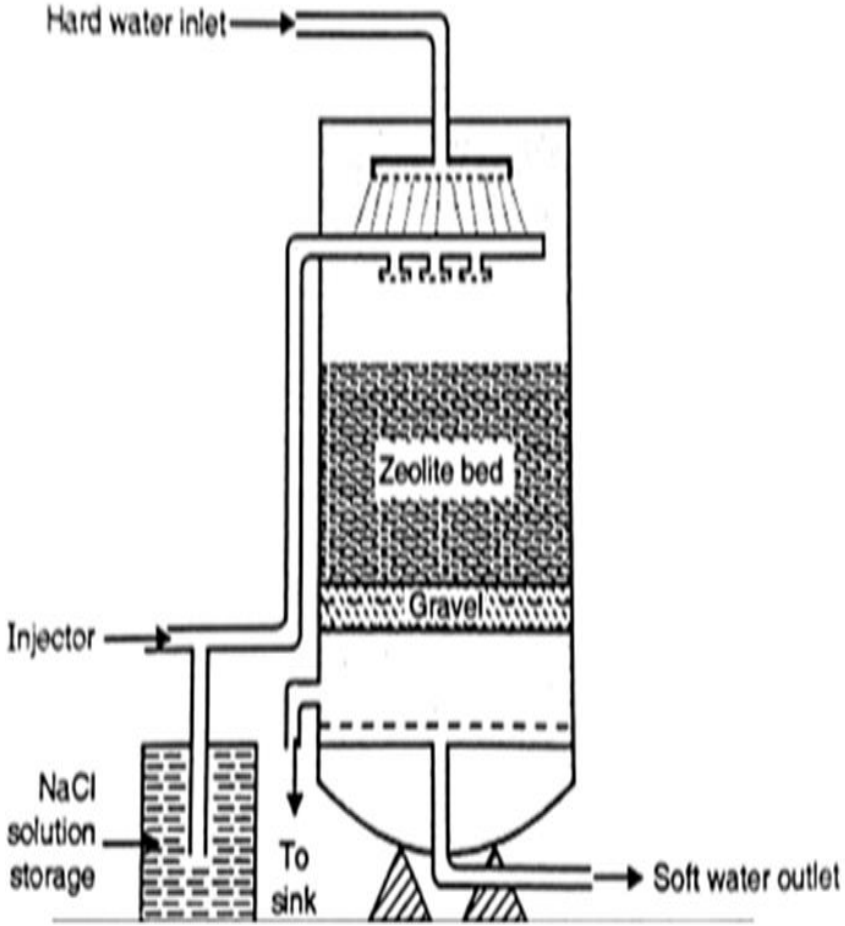
$Na_2Ze + MgCl_2 \text{ or } MgSO_4 \text{------} \rightarrow MgZe + 2NaCI \text{ or } Na_2SO_4$

Zeolite Hardness

Water is thus softened because sodium salts do not cause hardness but total dissolved solids increase as Ca and Mg ions are replaced by Na ions

Process:

- Hard Water is percolated at a specified rate through zeolite bed.
- Zeolite holds sodium ions loosely and can be represented as Na_2Z
- The hardness causing ions (Ca^{2+} / Mg^{2+}) are retained by the zeolite as calcium or magnesium zeolite.
- The outgoing water contains sodium salts.
- The soft water can be obtained from the tap at bottom.



Limitations of zeolite process:

- If the supplied water is turbid, the suspended matter must be removed before the water is fed to the zeolite bed. Otherwise the pores of the zeolite bed will get clogged by the turbidity, thereby making it inactive.
- If water contains large quantities of coloured ions like Mn^{2+} and Fe^{2+}, they must be removed because these ions produce manganese and iron zeolites that cannot be regenerated easily.
- If mineral acids are present in water, they destroy the zeolite bed and hence they must be neutralized with soda in advance, before feeding the water into the zeolite bed.

Advantages.

(*i*) Hardness of water can be removed completely upto about 10 ppm;

(*ii*) The equipment used is small and easy to handle;

(*iii*) It requires less time for softening;

(*iv*) There is no sludge formation, hence the process is clean;

(*v*) Easy to regenerate;

(*vi*) Any hardness can be removed without any adjustment of the process.

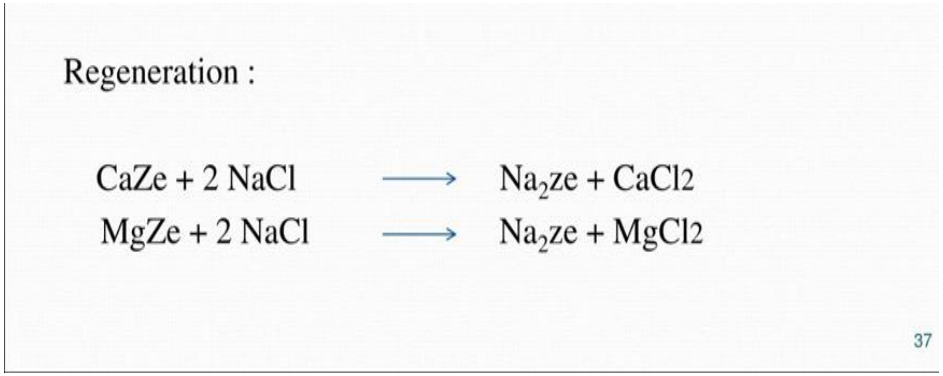
Disadvantages.

(*i*) Coloured water or water containing suspended impurities cannot be used before filtration;

(*ii*) Water containing acid cannot be used for softening since acid may destroy the zeolite;

Regeneration

Exhausted Zeolite can be regenerated by treating with a concentrated (10%) brine (NaCl) solution . The regenerated zeolite bed thus obtained is used again for softening operations



Zeolite Process reduces water of hardness up to 15 ppm

Calculation of Hardnesss:

$$\text{Hardness (ppm)} = \frac{m \times v_2 \times 50 \times 10^3}{V_1 \times 58.5}$$

Ion –Exchange/ Demineralization/ De-ionization Process

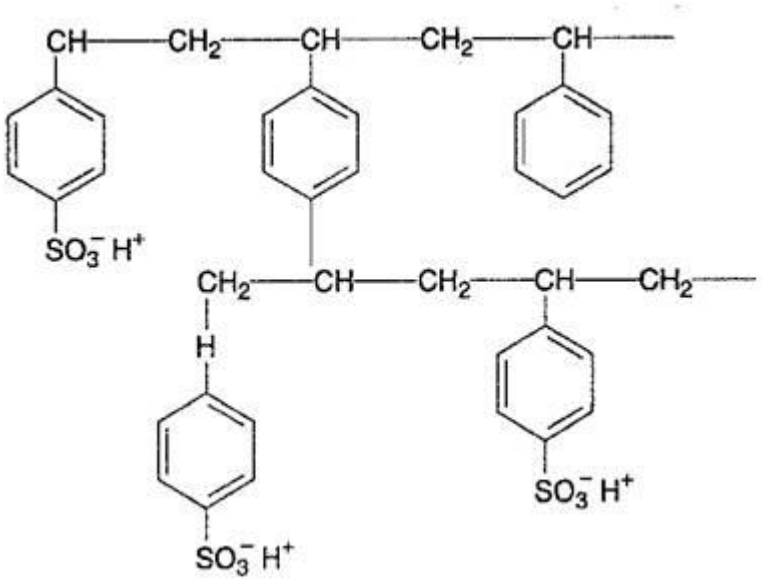
Ion exchange is a process by which ions causing hardness in water are exchanged with ions of exchange resigns (chemicals) used in the process.
All the cations and anions are removed in this process , therefore it is known as de-ionization or ion-exchange process.
Ion-exchange resigns are organic cross linked insoluble polymers carrying functional groups which are responsible for the ion exchanging properties.

Ion-exchange resigns can be classified as:

(a) Cation Exchange Resigns
(b) Anion Exchange Resigns

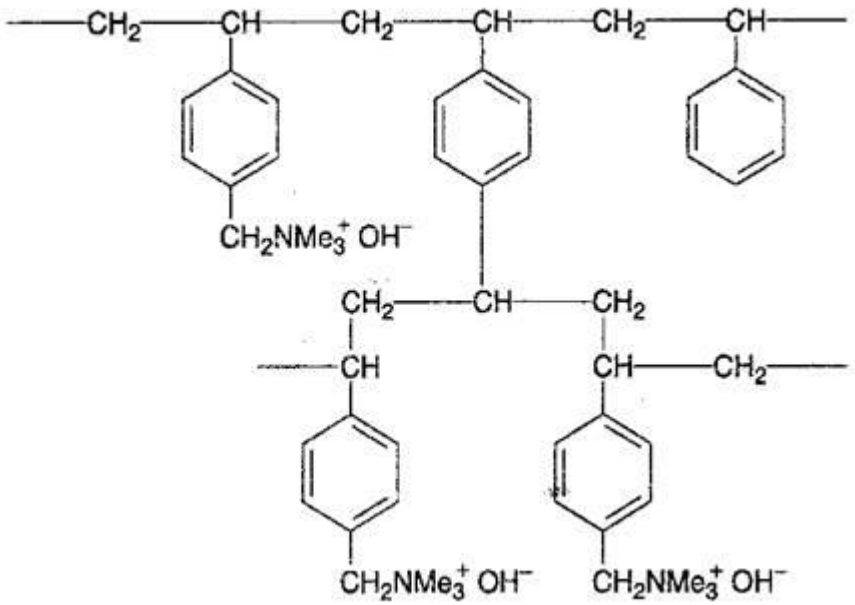
Cation Exchange Resign:

These are mainly derivatives of styrene di vinyl benzene copolymers which on sulphonation or carboxylation acquire ability to exchange their H^+ ions with other cations present in the water.



Anion Exchange Resign:

These contains basic functional groups such as amino or quaternary ammonium. These are capable of exchanging their anions with other anions , which comes in their contact. After treatment with dil. NaOH solution, become capable of exchanging their OH^- ions with other anions present in the water.



Principle:

$$2R^{-}H^{+} + Ca^{2+}/\ Mg^{2+} \longrightarrow R_2Ca/R_2Mg + 2H^{+}$$

$$R^{+}OH^{-} + Cl^{-} \longrightarrow R^{+}Cl^{-} + OH^{-}$$

$$H^{+} + OH^{-} \longrightarrow H_2O$$

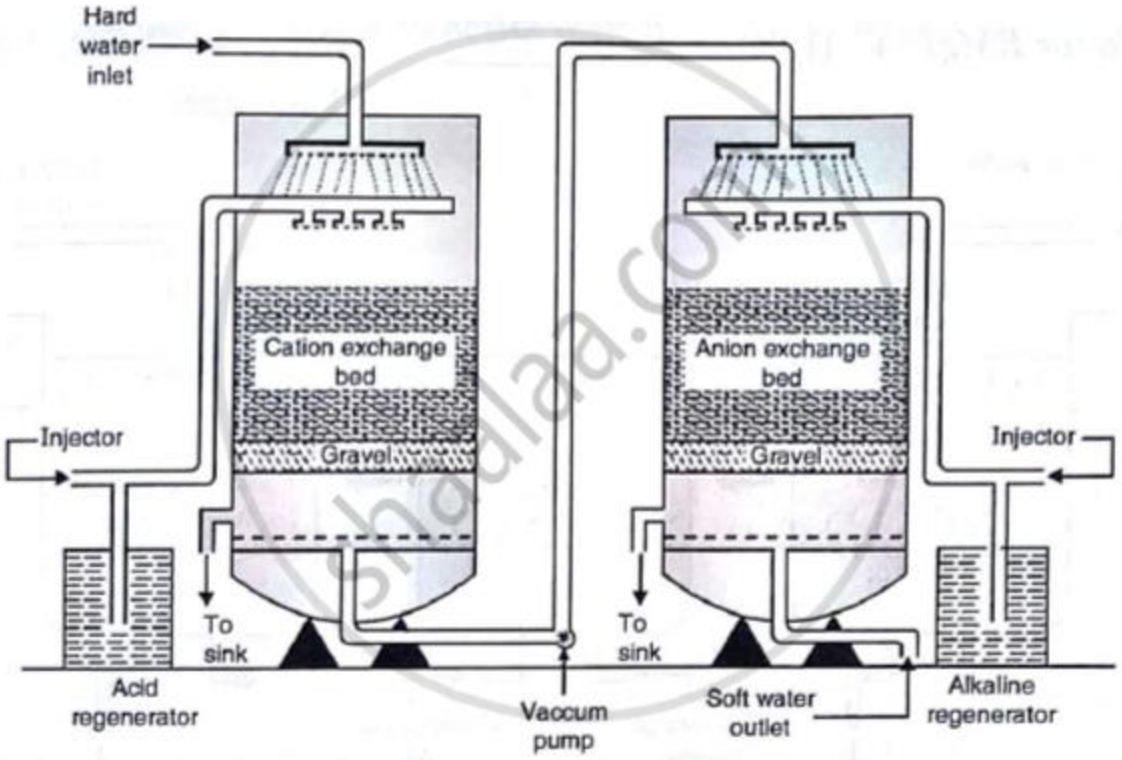
Regeneration:

$$R_2SO_4 + 2OH^{-} \qquad 2ROH + SO_4^{2-}$$

$$R_2Ca/R_2Mg + H^{+} \longrightarrow 2R^{-}H^{+} + Ca^{2+}/\ Mg^{2+}$$

The exhausted cation and anion beds can be regenerated by passing dil. HCl and dil. NaOH to these beds

Process:



Ion-Exchange Plant

Process:

1. First the hard water is passed through cation exchange bed
2. It removes all the cation present (Ca^{2+}/ Mg^{2+}) from water
3. And equal amount of H^+ ions are released from this column to water.
4. Then hard water is now pumped to anion exchange resign bed.
5. Where all the anions like Cl^-, SO_4^{2-} are removed and equal amount of OH^- ions are released to water.

6. H^+ and OH^- ions released from this reaction in equivalent amount, get combined to produce water molecules.
7. Thus treated water is completely free from cations as well as anions so it is known as demineralized or deionized water.

Merits:

1. It can be used to soften highly acidic or alkaline water
2. It produces water of very low hardness (0-2 ppm). So the treated water is very good for use in high pressure boilers.

Demerits:

1. Equipment required are very costly.
2. Chemicals used are expensive.
3. Turbid water can not be treated saisfactorily.

Practice Questions

1. The chemical formula of zeolite is _____
   a) $FeSO_4.7H_2O$
   b) $Al_2(SO_4)_3.18\ H_2O$
   c) $Na_2O.Al_2O_3.xSiO_2.yH_2O$
   d) Na_2Al_2O

2. Which of the following is not naturally occurring zeolite?
a) Na^+
b) Al^{+3}
c) Si^{+4}
d) Ca^{+2}
3. Natural zeolites are _____
a) Non Porous
b) Amorphous
c) Non-durable
d) Possess gel structure
4. Synthetic zeolites possess a higher exchange capacity per unit weight compared to natural zeolites.
a) True
b) False
5. The exhausted zeolite is reclaimed by treating the bed with a _____
a) Conc. NaCl
b) Conc. HCl
c) Conc. H_2SO_4
d) Dil. HCl

6. In zeolite process, the exchange of _____ takes place.
a) Anions
b) Cations
c) Both cations and anions
d) No ions exchange

7. The hardness of 1000 litres of a water sample was removed by passing it through a zeolite softener which required 30litres of NaCl solution containing 1.5 gm/L NaCl for regeneration. The hardness of the water sample will be _____
a) 54.2 ppm
b) 12.9 ppm
c) 45 ppm
d) 38.46 ppm
8. Which of the following cannot be used in place of NaCl?
a) $NaNO_3$
b) KCl
c) HCl
d) KNO_3
9. Natrolite is an example of _____
a) Synthetic zeolite
b) Natural zeolite
c) Calgon
d) Colloid

10. Ion-exchange resin is _____

a) Linear

b) Low molecular weight

c) Organic polymer with porous structure

d) Soluble

11. Which of the following ion get released from the cation exchange column?

a) H^+

b) Na^+

c) K^+

d) Ca^{+2}

12. Which of the following ion get released from the anion exchange column?

a) CO_3^{-2}

b) OH^-

c) Cl^-

d) SO_4^{-2}

13. Ion-free water coming out from the exchanger is known as _____

a) Potable water

b) Disinfected water

c) Coagulated water

d) Demineralised water

14. Which of the following statement is incorrect about the demineralized water?
a) It is as pure as distilled water
b) It is very good for use in high pressure boilers
c) It is fit for domestic use
d) It can be made either by distillation or by using cation and anion exchangers
15. The exhausted cation exchange column is regenerated by passing a solution of _____
a) Dil. HCl
b) Dil. NaCl
c) Conc. HCl
d) Conc. NaCl
16. The exhausted anion exchange column is regenerated by passing a solution of _____
a) Dil. KOH
b) Conc. KOH
c) Conc. NaOH
d) Dil. NaOH
17. The raw water used for ion-exchange process should be turbid.
a) True
b) False

Question Bank

Q1. What are zeolites?
Q2. Write the formula for calculating hardness by zeolite method?
Q3. What will be the residual hardness in Ion-Exchange method?
Q4. What will be the residual hardness in zeolite process ?
Q5. Write the formula for hardness calculation in zeolite process ?
Q6. Draw a labeled diagram of zeolite plant.
Q7. Draw a labeled diagram of ion-exchange plant.
Q8. Write limitations of zeolite process.
Q9. Write merit and demerits of ion-exchange process.
Q10. Write down the principle involved in zeolite process.
Q11. How will you regenerate exhausted zeolite bed ?
Q12. Name the chemicals used for regeneration of cation and anion exchange bed.

Suggested links for video lectures

1. Link for video lecture by Dr. Barkha Shrivastava on Zeolite process (class room recording)
https://youtu.be/KULYEDNqeKk

2. Link for video lecture by Dr. Barkha Shrivastava on Zeolite process (RTU portal e-content)

https://youtu.be/NWBmcgiklgU

3. Link for video lecture by Dr. Barkha Shrivastava on Ion-exchange process (class room recording)

https://youtu.be/C-whmbH0jdY

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Thank you!