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WATER TREATMENT

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- Rainwater is purest form of natural water.
- sea water is most impure form of natural water.

Types of Impurities →

1. Dissolved Impurities

(a) ~~at~~ Inorganic salts.

Cations

Anions.

(b) Gases (O_2, O_2 , etc.)

(c) Organic Matter.

Inorganic e.g. clay & sand

2. Suspended impurities

Organic, e.g. oil globules, veg-etc.

3. Colloidal impurities ($10^{-4} - 10^{-6}$ mm) e.g. clay & finely divided silica colloidal particles.

4. Micro-organisms e.g. Bacteria, fungi, algae etc.

Effect of Impurities →

→ Colour

→ Taste & odour.

→ Micro-organisms.

→ Turbidity & sediments

→ Dissolved minerals matter

(a) hardness

(b) Alkalinity

(c) total solids

(d) corrosion

→ Dissolved gas

→ Silica contents

#

~~10%
10%
0%
0%~~

Hardness of Water: defined as soap consuming capacity of water sample. (Soap consuming capacity is mainly due to Ca, Mg & other heavy metals dissolved in it.)

Oleic, Palmitic & stearic

Soap → consist Na salts of fatty acids

Ca & Mg reacts with Na salts of long chain to form insoluble scums of Ca & Mg soaps.

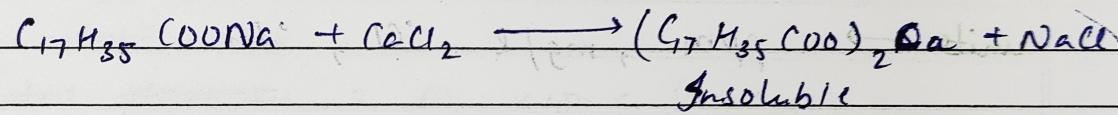
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Hard Water

→ does not produce lather or foam with soap.

→ consume more soap.

contains HCO_3^- , Cl^- & also chlorides & SO_4^{2-} of Ca & Mg.



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Soft Water

→ Soft water when treated with Soap produce more lather & consume less soap as there is absence of dissolved salts of Ca & Mg.



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Temporary Hardness.

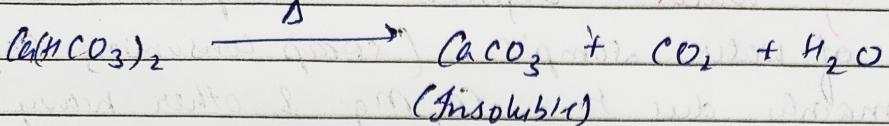
→ caused due to presence of dissolved Mg & Ca HCO_3^-

→ can be destroyed by boiling of water.

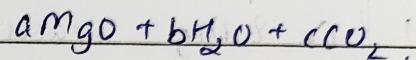
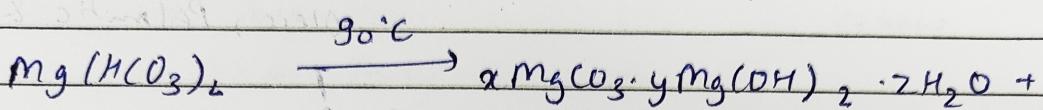
Permanent Hardness.

→ due to presence of Cl^- & SO_4^{2-} of Ca & Mg

→ Temporary Hardness.



(Deposited at bottom of vessel)



Hardness :-

Equivalent of CaCO_3 = Mass of hardness producing substances $\times \frac{100}{80}$

Chemical equivalent of hardness producing substances

units \rightarrow ppm, mg/l, °F.H., °C.I.

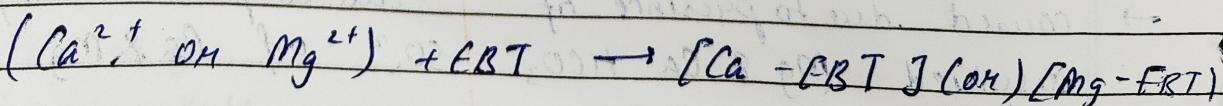
$$1\text{ppm} = 1\text{mg/l} = 0.1^\circ\text{F.H.} = 0.07^\circ\text{C.I.}$$

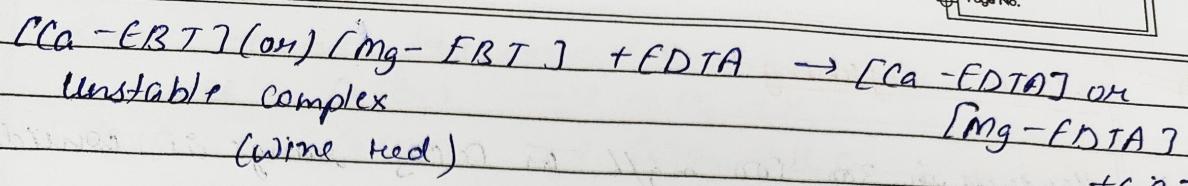
Estimation of Hardness:

① EDTA Method:

→ Eriochrome Black-T (EBT) → indicator.
pH at 9 - 10 maintain.

→ end point colour change wine red - blue.





$$M_2 = \frac{M_1 V_1}{V_2}$$

$M_2 \times 10^5 \Rightarrow$ ~~Temporary~~
permanent hardness
when boiled.

M_1 = Molarity of Standard Hard water

V_1 = Volume of standard hard water

M_2 = Molarity of EDTA

or V_2 = Volume of EDTA

Determination of Total Hardness:

$$M_3 (\% \text{ Molarity of Hard Water}) = \frac{(M_2 \cdot V_1)}{V_3}$$

M_3 = Molarity of Hard Water

M_1 = Molarity of EDTA = M_2

or V_3 = Volume of Sample Hard water

or V_1 = Volume of EDTA

permanent hardness

$$\text{Total Hardness} = M_3 \times 100 \times 1000 (\text{ml}) \\ = M_3 \times 10^5 \text{ ppm}$$



$$\text{Temporary hardness} = \text{Total hardness} - \text{Permanent hardness.}$$

Water softening :-

→ Hardness in 300 - 500 mg/L as CaCO_3 range is considered excessive & leads to:

→ High soap consumption

→ Scaling in heating vessels & pipes.

→ even $> 150 \text{ mg/L}$ may result in consumer objection.

→ 60 - 120 mg/L as CaCO_3 is considered a moderate amount.

External Treatment

→ lime - soda

→ Zeolite

→ Ion exchange

Internal Treatment

→ phosphate

→ Calcogen

LIME-SODA process :-

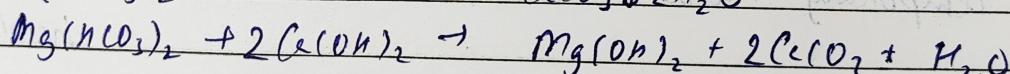
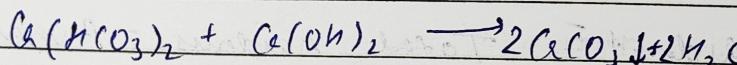
all soluble hardness-causing impurities are converted to insoluble which may be removed by filtration.

(i)

Lime removes the temporary

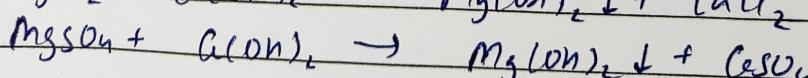
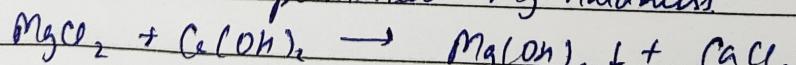
(calculated amount of Ca(OH)_2 & Na_2CO_3 is added).

reduces.



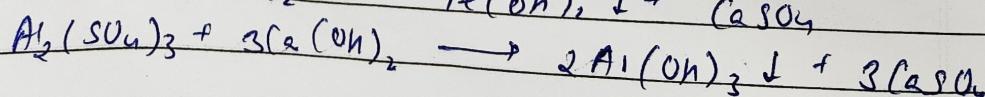
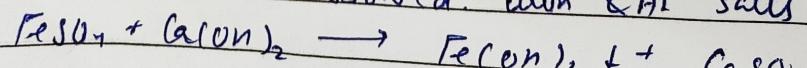
(ii)

Lime removes permanent Mg hardness

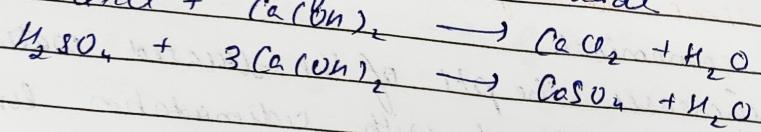


(iii)

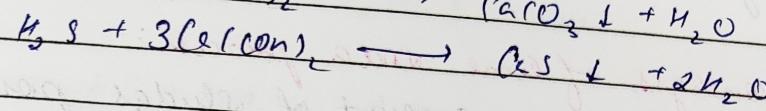
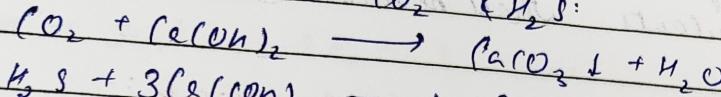
Lime removes the dissolved iron & Al salts



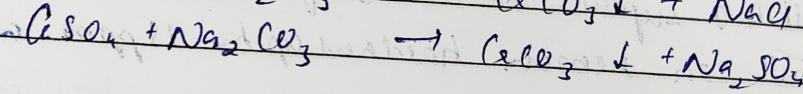
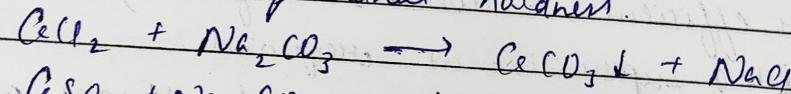
(iv) lime removes few mineral acids
steel + $\text{Ca}(\text{OH})_2 \rightarrow \text{CaO}_2 + \text{H}_2\text{O}$



(v) lime removes dissolved CO_2 & H_2S :



(vi) Soda removes all Ca permanent hardness.



Lime required for softening

$$\Rightarrow \frac{74}{100} (\text{Temp. Ca}^{2+} + 2 \times \text{Temp. Mg}^{2+} + \text{pH} / \text{Mg}^{2+} + \text{Fe}^{2+} + \text{Al}^{3+}) + (\text{CO}_2 + \text{H} + f \text{ HCl or H}_2\text{SO}_4) + \text{HCO}_3^-]$$

Soda required for softening

$$= \frac{106}{100} (\text{pH} / (\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Fe}^{2+} + \text{Al}^{3+}) + (\text{CO}_2 + \text{H} + (\text{HCl or H}_2\text{SO}_4) - \text{HCO}_3^-)]$$

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Cold lime soda process:-

Use of NaAlO_2 as coagulant also helps the removal of Silice as well as oil if present in water.



Advantages of high temp.

- rxn proceeds faster
- softening capacity is increased
- Much of dissolved gaseous are driven out of water
- Viscosity of soft water is less, so filtration of water becomes easier.

- **Advantages of lime soda process:-**
- It is very economical.
- The process increases the pH of the treated water.
- If the process is combined with sedimentation lesser amount of coagulants shall be needed.

⇒ **Disadvantages of lime soda process:-**

- Disposal of large amount of sludge poses a problem.
- for efficient & economical softening, careful operation & skilled supervision is required.
- This can remove hardness up to 15 ppm which is not good for boilers.

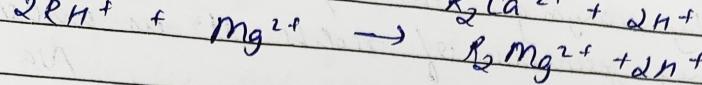
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WATER SOFTENING:

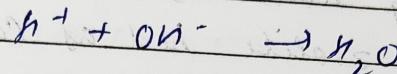
Ion exchange or deionization or demineralization process:-

- Ion-exchange resins are insoluble, cross linked, long chain organic polymers with microporous structure. & the functional groups attached to the chains are responsible for ion exchange properties.
- ⇒ Resins containing acidic functional groups (-COOH, -SO₃H) are capable of exchanging their H⁺ ions with other cations known as cation exchange resins (RH⁺).
e.g. Styrene-divinyl benzene copolymer on sulphonation.
- ⇒ Resins containing basic functional groups (-NR₃⁺, OH⁻) are capable of exchanging their anions with other anions which comes in their contact known as anion exchange resins (R-OH⁻).
e.g. Styrene-divinyl benzene on treatment with aq. NaOH.

process →

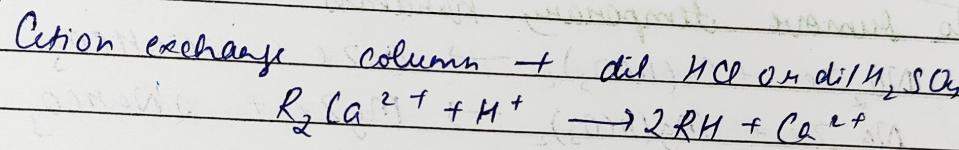


(remove all the cations)

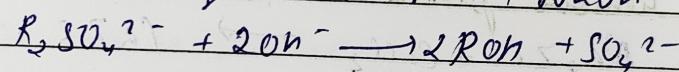


Gon free water → deionized water.

Regeneration →



Exhausted Anion exchange column + dil NaOH



Advantages.

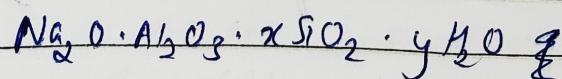
- Can be used to soften highly acidic or alkaline water.
- It produces water of very low hardness.

Disadvantages.

- equipments costly
- expensive chemicals are needed.
- Output of process is reduced if water contains turbidity.

Zeolite (Pernosit) method of softening of water :-

→ Zeolite (N.S.A.S), capable of exchanging reversibly its sodium ions for hardness producing ions in water.



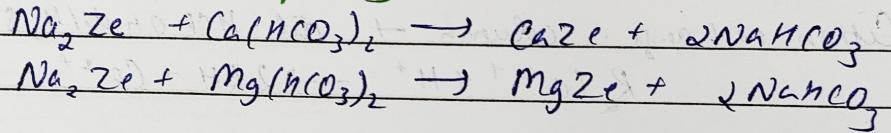
- porosity or cavity size of synthetic zeolite st can be controlled by varying the Si / Al ratio.
 - Ion - exchange process of zeolite st is associated with Na ions.

Process of softening of by zeolite method :-

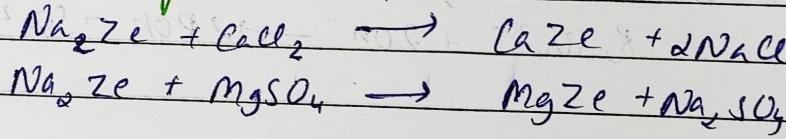
- The hardness causing ions such as Ca^{2+} , Mg^{2+} , are retained by the zeolite bed as CaZe & MgZe .

The following processes take place during softening process.

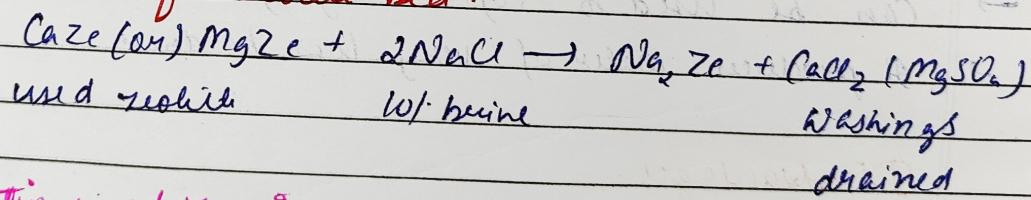
To remove temporary hardness



To remove permanent hardness



Regeneration of Zeolite bed



Limitations of Zeolite process :-

- If H_2O is turbid : then the turbidity causing particles clogs the pores of the zeolite & making it inactive.
 - The ions such as Mn^{+2} & Fe^{+2} forms stable complex zeolite which can not be regenerated that easily by both.
 - Any acid present in H_2O (acidic water) should be neutralized with soda before admitting the water to plant.

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Advantages of Zeolite process:

- Soft water of 10-15 ppm can be produced by this method
- The equipment occupies less space
- No impurities are precipitated
- It does not require more time & more skill.

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Disadvantages of Zeolite process:

- ① Soft water contains more Na salts than in lime-soda process
- ② It replaces only Ca^{2+} & Mg^{2+} with Na but leaves all the other ions like HCO_3^- & CO_3^{2-} in the softened water.
- ③ It also causes caustic embrittlement when Na_2CO_3 hydrolysis gives NaOH .

Internal Treatment
phosphate conditioning → Calgon

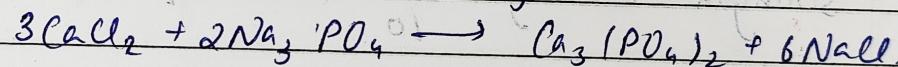
Colloidal

Conditioning

⇒

phosphate conditioning

Scale formation can be avoided by



non-adherent & easily removable soft sludge of Ca & Mg phosphate.

Trisodium phosphate → alkalinity

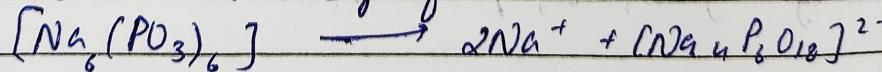
Disodium " → alkalinity suff.

Monosodium " → alkalinity of boiler water ↑

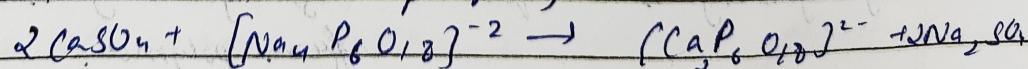
⇒

Calgon Conditioning

prevents the scale & sludge formation.



Calgon (Sodium hexameta phosphate)



Soluble complex ion.

⇒

Colloidal conditioning:

Scale formation can be avoided by adding organic substances like keratin, tannin etc. which get coated on over the scale forming precipitate yielding non-sticky & loose deposits.