SAQ Short Answer Type Questions

Q. 1. Give specifications of boiler feed water. *(May 2009)*

Ans. The specifications of boiler feed water are as follows :

(*i*) The boiler feed water should be free from salts responsible for hardness *i.e.* salts of Ca and Mg.

(*ii*) The boiler feed water should be free from suspended particles.

(*iii*) The boiler feed water should be free from organic matter.

(*iv*) The boiler feed water should not be acidic or alkaline.

Q. 2. What is lime and soda ? What is their significance ?

Ans. This method involves the treatment of water with lime **$Ca(OH)_2$** and soda **Na_2CO_3**, which results into formation of **insoluble precipitates** of **Ca and Mg**, which can be removed by filtration.

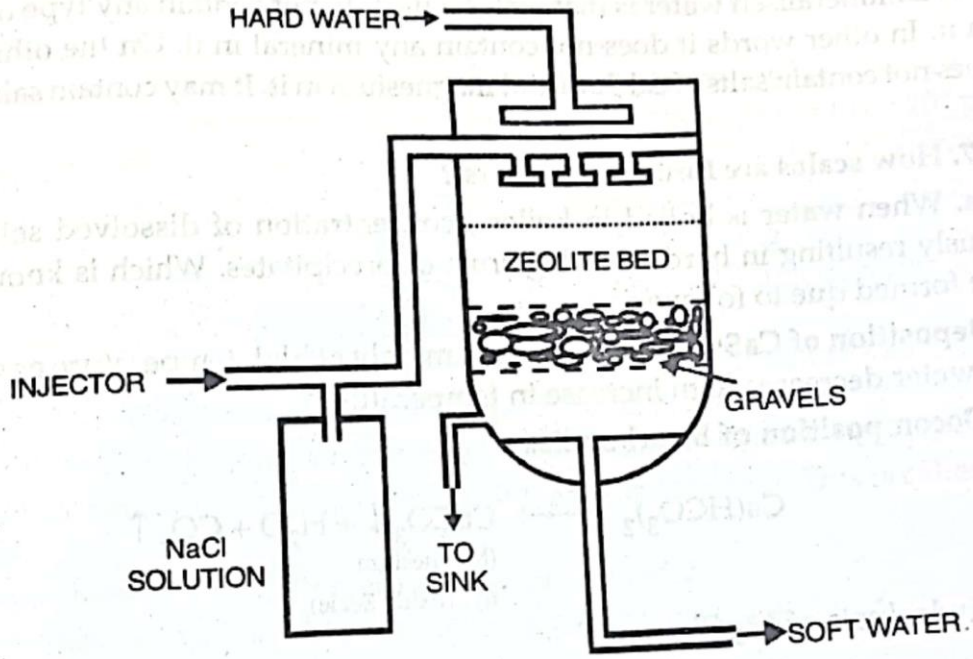
Q. 3. Why does hard water consume lot of soap ? *(Dec. 2007)*

Ans. Hard water consumes lot of soap because it does not form lather with soap rather white scum or precipitate of insoluble salts of calcium and magnesium is formed. Soap is actually sodium or potassium salt of higher fatty acids like stearic or palmitic acid. When these salts of soap react with calcium or magnesium salts present in water it forms insoluble salt of calcium or magnesium.

$$\underset{\text{Sodium stearate (soap)}}{C_{17}H_{35}COONa} + \underset{\text{Calcium chloride (soluble in water)}}{CaCl_2} \longrightarrow \underset{\text{Calcium stearate (insoluble in water)}}{(C_{17}H_{35}COO)_2Ca\downarrow} + 2NaCl$$

Q. 4. What are Zeolites ? Why is water softened by zeolite process unfit for use in boilers ?

Ans. Chemical formula of zeolite is



$Na_2O.Al_2O_3.xSiO_2.yH_2O$; where $x = 2 - 10$, $y = 2 - 6$

Hydrated sodium alumino silicate

or Sodium zeolite.

This is capable of exchanging its Na^+ ions with hardness producing ions (Ca^{2+} and Mg^{2+}) present in hard water.

Zeolites are known as permutit also.

Zeolites are of two types :

(*i*) Natural Zeolites are non-porous *e.g.* **natrolite** $Na_2O.Al_3O_3.4SiO_2.2H_2O$.

(*ii*) Synthetic Zeolites are porous and possess gel like structure.

This method leaves **acidic ions** (HCO_3^- and CO_3^{2-} ions) in soft water which if enters a boiler, generates CO_2 which leads to corrosion.

Q. 5. Why do we express hardness of water in terms of $CaCO_3$ equivalents ?

Ans. The concentration of hardness as well as non-hardness causing ions are expressed in **equivalent amount of calcium carbonate or equivalents of calcium carbonate ($CaCO_3$).** The reason of selecting $CaCO_3$ as a reference standard is that it is **most insoluble salt** that can be precipitated in water treatment and **molecular mass of** $CaCO_3$ **is 100,** which makes the calculations easy as in this method multiplication and division of concentration is involved.

Q. 6. What is dimineralised water ? How it is different from soft water ?

(May 2007, Dec. 2006)

Ans. Dimineralised water is that water which do not contain any type of cation and anion in it. In other words it does not contain any mineral in it. On the other hand soft water does not contain salts of calcium and magnesium in it. It may contain salts of sodium in it.

Q. 7. How scales are formed in boilers ?

Ans. When water is boiled in boilers, concentration of dissolved salts increases continuously resulting in hard adhering crust of precipitates. Which is known as scale. Scales are formed due to following :

(*i*) Deposition of $CaSO_4$: $CaSO_4$ scale is mainly at high temperature as solubility of $CaSO_4$ in water decreases with increase in temperature.

(*ii*) Decomposition of bicarbonates :

$$Ca(HCO_3)_2 \xrightarrow{\Delta} \underset{\text{(Magnesium hydroxide Scale)}}{CaCO_3\downarrow} + H_2O + CO_2\uparrow$$

(*iii*) Hydrolysis of $MgCl_2$

$$MgCl_2(aq) + 2H_2O \xrightarrow{\Delta} Mg(OH)_2\downarrow + 2HCl\,(g)$$

(*iv*) Presence of silica (SiO_2) : Calcium and Magnesium silicates are formed due to presence of silica which are difficult to remove.

Q. 8. A sample of water has the following impurities in mg/lit. Find the temporary and permanent hardness in ppm.

$Ca(HCO_3)_2$ = 10.0 ppm ; $Mg(HCO_3)_2$ = 8.0 ppm ; $CaSO_4$ = 12.0 ppm

Ans. Hardness due to $Ca(HCO_3)_2 = 10 \times \frac{100}{162} = 6.2$ ppm

Hardness due to $Mg(HCO_3)_2 = 8 \times \frac{100}{146} = 5.5$ ppm

Hardness due to $CaSO_4 = 12 \times \frac{100}{136} = 8.8$ ppm

Temporary hardness = Hardness due to $Ca(HCO_3)_2 + Mg(HCO_3)_2$
$= 6.2 + 5.5 = 11.7$ ppm

Permanent hardness = Hardness due to $CaSO_4 = 8.8$ ppm

Q. 9. What is colloidal conditioning of boiler feed water ?

(May 2007, Dec. 2006)

Ans. Chemicals *e.g.* tannin, agar-agar which form a coating on the scale forming

ppts. are added. This leads to formation of sticky, loose deposit which can be removed by blow-down process.

Q. 10. How is hardness of water expressed ? Prove that *mg/l* of hardness is same as hardness in ppm of water.

Ans. Hardness of water is expressed in equivalents amount of calcium carbonate ($CaCO_3$) ppm = parts of calcium carbonate equivalent hardness present per 10^6 parts of water *i.e.* 1 ppm = 1 part of $CaCO_3$ equivalent hardness in 10^6 parts of water. mg/*l* is number of $CaCO_3$ equivalent hardness present per litre of water.

$$1 \text{ kg} = 1000 \text{ g} = 1000 \times 1000 \text{ mg} = 10^6 \text{ mg}$$

$$1 \text{ mg}/l = 1 \text{ mg of } CaCO_3 \text{ equivalents}/10^6 \text{ mg of water} = 1 \text{ ppm}$$

Q. 11. What is Caustic Embrittlement ?

Ans. This is a type of boiler corrosion caused by using alkaline water or caustic water in boiler. The inner walls of boiler have hair cracks always . Alkali passes through these cracks by capillary action and moves in body of boiler. As water evaporates alkali concentration increases and dissolves the iron boiler into its ferrate. This is called Caustic Embrittlement.

Q. 12. How caustic embrittlement can be prevented ?

Ans. (*i*)By not using Na_2CO_3 for softening of water instead sodium phosphate should be used.

(*ii*) By adding **Tannin or Lignin** to water because these **block the hair line cracks.**

(*iii*) By adding sod. sulphate **Na_2SO_4** it also **blocks the cracks.** The conc. of Na_2SO_4 should be so that the $\frac{Na_2SO_4 \text{ conc.}}{NaOH \text{ conc.}} = 1:1, 2:1$ or $3:1$ at the pressure upto 10, 20 and above 20 atmosphere respectively. *(May 2009)*

Q. 13. What is priming and foaming ?

Ans. When the boiler is steaming.

(*a*) Some particles of the liquid water are carried along with the steam, which makes wet steam, it is called Priming.

Cause. (*i*) presence of dissolved solids.
(*ii*) high steam velocity.
(*iii*) Sudden boiling
(*iv*) sudden increase in steam production.

(*b*) **Foaming.** Formation of bubbles or foam in the boiler, continuously is called foaming.

Cause. If oil is present which decreases surface tension of water.

Priming and foaming usually occur together.

Q. 14. Specify advantages of ion exchange resin over zeolite process in dimineralizion of water.

Ans. With help of zeolite method only Ca^{2+} and Mg^{2+} ions are removed while acidic impurities like HCO_3^- and CO_3^{2-} ions can't be removed. So soft water of 10-15 ppm

hardness from zeolites can't be used in high pressure boilers but soft water from ion exchange process does not have acidic or any other type of impurities, so it can be used in high pressure boilers. Moreover soft water with hardness as low as 2 ppm is obtained by ion exchange resin process.

Q. 15. Define Break Point Chlorination and give its significance. *(May 2010)*

Ans. Chlorination of water to the extent of converting all the NH_3 to NCl_3 or N_2 is referred to as break point chlorination. After this free residual chlorine appears in water which destroys the pathogens. Usually all the tastes and odour disappear at this stage.

Significance of Break Point Chlorination.

The chlorine dosage higher than this point means that chlorine demand of the chlorine reactable material has been completely met with and free chlorine residual are available for bacterial action. It also

- signifies complete decomposition of NH_3.
- removal of colouring matter and odour of water.

Q. 16. What is desalination of water ? Name different methods used for desalination of water.

Ans. The process of removing common salts from the water is called desalination of water. Different methods for desalination of water are :—

1. Electrodialysis
2. Reverse Osmosis
3. Distillation of water.

Q. 17. What are lime and soda ? Why does magnesium carbonate require double amount of lime for softening of water ? *(May 2007, Dec. 2006)*

Ans. Lime is calcium hydroxide $Ca(OH)_2$ and soda is Sodium Carbonate Na_2CO_3. These are used for removal of hardness present in water. Lime and soda are added to hard water which is due to salts of calcium and magnesium. Lime and soda combines with these salts of calcium and magnesium and forms insoluble precipitates which can be removed by filteration. In this way lime and soda helps in removing the hardness present in water.

e.g.

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

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + Na_2SO_4$$

Magnesium bicarbonate require double dmount of lime for softening of water because of the following reactions.

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow + Ca(HCO_3)_2$$

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

Overall reaction :

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

So one mole of $Mg(HCO_3)_2$ requires 2 moles of lime.

Q. 18. Differentiate between hot and cold lime soda process.

(Dec. 2009, Dec. 2008, May 2007, Dec. 2006)

Ans.

	Hot Lime Soda	Cold Lime Soda
1.	Mixing of lime and soda is done at the boiling point of water.	Calculated amount of lime and soda is added in tank at room temperature.
2.	Rate of reaction is fast.	Rate of reaction is slow.
3.	No coagulant is required.	Coagulant $Al_2 (SO_4)_3$ is added.
4.	Better method than cold lime soda process.	Inferior method than hot lime soda process.

Q. 19. What is calgon conditioning of boiler feed water ? *(Dec. 2011)*

Ans. Calgon conditioning is an internal treatment method for prevention of scale formation in the boiler feed water. Calgon is sodium hexametaphosphate. Its addition in hard water results into formation of highly soluble complexes of Ca salts which prevents scale formation in the boilers.

Q. 20. Softening of water is essential, Explain. *(May 2008)*

Ans. Hard water (having soluble salts of Ca and Mg) has disadvantages in domestic as well as industrial use.

As in domestic use it results into wastage of lot of water in bathing and washing; as hard water does not form lather with soap, instead it forms a sticky scum. Due to dissolved salts of Ca and Mg, boiling point of water is elevated. So more heat and time is consumed in working.

Industrial use of hard water may result into scale and sludge formation, corrosion, priming and foaming, caustic embrittlement etc.

Q. 21. Why should water be softened before use in boilers ? *(May 2009)*

Ans. Otherwise the impurities present in water will cause :

(*i*) Scale and sludge formation.

(*ii*) Priming and foaming.

(*iii*) Boiler corrosion.

(*iv*) Caustic embrittlement in the boilers.

Q. 22. Differentiate between temporary and permanent hardness. *(May 2008)*

Ans.

	Temporary Hardness	Permanent Hardness
1.	It caused by bicarbonates of Ca and Mg.	It is caused by sulphates and chlorides of Ca and Mg.
2.	It can be removed by boiling water.	It can be removed by Lime soda, zeolite or ion exchange method.

Q. 23. What happens when temporary hard water is boiled. *(Dec. 2010)*

Ans. Temporary hardness caused by $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ is removed on boiling hard water. This can be shown as :

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 \downarrow + CO_2 + H_2O$$

$$Mg(HCO_3)_2 \xrightarrow{\Delta} Mg(OH)_2 \downarrow + 2CO_2$$

$CaCO_3$ and $Mg(OH)_2$ so produced is insoluble in water.So filtrate obtained is soft water.

Q. 24. Why should presence of CO_2 in boiler feed water be avoided ? *(Dec. 2008)*

Ans. Because CO_2 reacts with water to produce carbonic acid which causes corrosion of boiler walls.

Q. 25. Cause of alkalinity of sea water. *(Dec. 2009)*

Ans. Alakalinity means basic water *i.e.* pH > 7. Sea water is alkaline because of dissolved salts of bicarbonates, carbonates and hydroxides.

Q. 26. What are advantages and limitations of lime-soda method.

Ans. Advantages : (1) This method gives water of 15-20 ppm hardness.

(2) It is a fast process as setting rate of impurity is very high.

(3) It is a cheap method.

Disadvantages :

(1) Unreacted Na_2CO_3 if left in water, makes water caustic, which cuases caustic Embrittlement of boiler,if this water is fed to boilers.

Q. 27. Specifications for water to be used for drinking purpose. *(Dec. 2009)*

Ans. Specifications for water to be used for drinking purpose :

1. It should be odourless
2. It should be pleasant in taste.
3. Turbidity should not be more than 10 ppm.
4. It should be free from objectionable gases like H_2S.
5. It should be free from objectionable minerals as Pb, As, Cr and Mn salts.
6. Its pH value should be around 8.0.
7. It should be reasonably soft.
8. It should be free from micro oranisms.

Q. 28. Milliequivalent per litre of hardness =_____ppm. Explain. *(May 2012)*

Ans. $1\ kg = 1000g = 1000 \times 1000\ mg = 10^6\ mg$

$1mg/L = 1\ part/10^6\ parts.$

Q. 29. What is standard hard water ? *(Dec. 2011)*

Ans. Standard hard water is prepared in lab during soap titration method. When 1.0 g of dry $CaCO_3$ is dissolved in minimum quantity of HCl (dilute). Then it is heated to dryness and the residul is dissolved water to make 1L solution. This water is called standard hard water. Its hardness is 1 mg/ml.

LAQ Long Answer Type Questions

Q. 1. Discuss the treatment of ground water to be used for domestic purposes.

Ans. The water to be used for domestic purposes should be free from hardness, suspended particles, microorganisms, undesirable salts. It is treated with different methods before its supply for domestic purposes. These methods for treatment of water are :

(a) Screening : This process is used for removal of various suspended impurities present in water. In this method, water is allowed to pass through various screens having holes. The suspended particles are retained in the holes and water is pass through the screens.

(b) Sedimentation : This process is used for removing the large suspended solids present in water. The water with these impurities is left undisturbed in large reservoir or tanks for a week or few days or few hours depending on the nature of impurities. The impurities present in water settle down at the bottom due to the gravitation pull acting downwards. The supernatent water is then collected from the tanks. Sedimentation only removes 70-75% of suspended impurities.

(c) Coagulation : Coagulation is used for removal of impurities which are colloids in nature like emulsions, gels, fine clay, silica etc. and sedimentation is not enough for the removal of colloidal impurities. As these colloidal particles are negatively charged, they do not amalgamate easily due to mutual repulsions. Certain chemicals having positively charged particles are added to neutralize the charged particles. This process to neutralize the charged particles by adding chemicals processing opposite charged particles is known as coagulation. The chemicals which are added for coagulation are known as coagulents. e.g. aluminium sulphate $Al_2(SO_4)_3$, Sodium aluminate ($NaAlO_2$), ferrous Sulphate ($FeSO_4$) and potash alum.

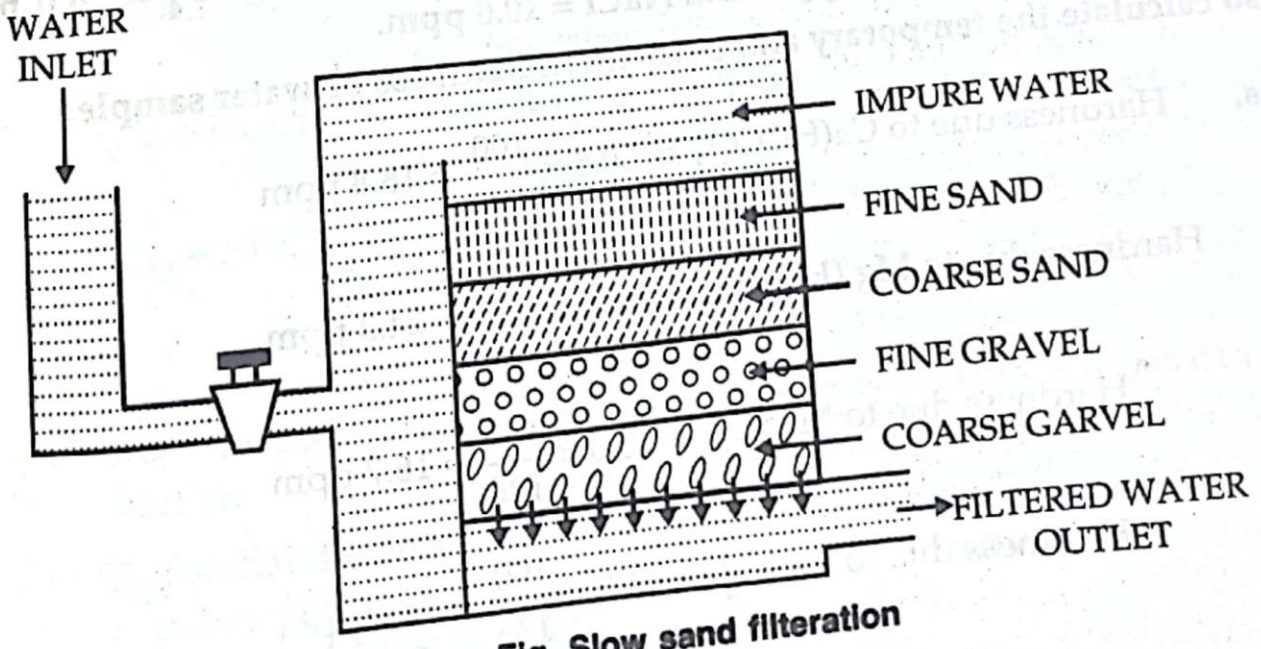


Fig. Slow sand filteration

(d) Filteration : Filteration is carried out to remove the micro organisms, odour, colour, fine suspended impurities and bacterias. In general, it is the processof water clarification by allowing the water to pass through the porous material capable of retaining the impurities in its pores and on its surface. The porous material used for filteration is called filtering medium *e.g.* quartz sand, porous clay etc. The equipment employed for filteration is known as filter *e.g.* slow sand filter, pressure filter and rapid gravity filter.

In case of slow sand filteration with the help of slow sand filter, the water is allowed to pass through beds of fine sand (upper layer), coarse sand, fine gravel and finally coarse gravel (bottom layer) lying in large tank. The tank is equipped with inlet for water and outlet for filter water at the bottom of the tank. The water distributed uniformally over the fine sand pass through all the beds due to gravity. The rate of sedimentation or filteration gets slowed down with the time because impurities are accumulated in the capillaries or pores of the beds. The beds are cleaned by scrapping the sand bed and replacing it with fresh sand. The scrapped layer of sand can be used again after washing it with water.

(e) Disinfection : Disinfection is very important process of purification of water, as the water treated by sedimentation, coagulation, filteration is not free from all the impurities. It may contain many pathogenic bacterias *i.e.* disease producing bacterias. **The complete removal of all micro-organisms present in water is known as sterlisation.** On the other hand, **killing the micro-organisms is known as disinfection.** The following processes are employed for the disinfection of water :

(*i*) Boiling (*ii*) By adding bleaching powder (*iii*) By chloroamine (*iv*) By ozonolysis (*v*) By chlorination (*vi*) By UV light (*vii*) By $KMnO_4$.

Q. 2. Calculate the amount of Lime (91% pure) and soda (97.2% pure) required for softening one million litres of water containing *(Dec. 2007)*

$Ca(HCO_3)_2$ = 30.5 ppm ; $Mg(HCO_3)_2$ = 35.5 ppm ; $MgSO_4$ = 20.0 ppm ; $CaSO_4$ = 24.0 ppm; $CaCl_2$ = 25.0 ppm and NaCl = 10.0 ppm.

Also calculate the temporary and permanent hardness of water sample.

Ans. Hardness due to $Ca(HCO_3)_2 = 30.5 \times \frac{100}{162} = 18.8$ ppm

Hardness due to $Mg(HCO_3)_2 = 30.5 \times \frac{100}{146} = 24.3$ ppm

Hardness due to $MgSO_4 = 20.0 \times \frac{100}{120} = 16.7$ ppm

Hardness due to $CaSO_4 = 24.0 \times \frac{100}{136} = 17.6$ ppm

$$\text{Hardness due to } CaCl_2 = 25.0 \times \frac{100}{111} = 22.5 \text{ ppm}$$

Amount of lime required

$$= \frac{74}{100} \times [Ca(HCO_3)_2 + 2 \times Mg(HCO_3)_2 + MgSO_4] \times \frac{100}{91} \times 10^6$$

$$= \frac{74}{100}[18.8 + 2 \times 24.3 + 16.7] \times \frac{100}{91} \times 10^6 = 68.38 \text{ kg}$$

$$\text{Amount of soda required} = \frac{106}{100} \times [CaCl_2 + CaSO_4 + MgSO_4] \times \frac{100}{97.2} \times 10^6$$

$$= \frac{106}{100} \times [22.5 + 17.6 + 16.7] \times \frac{100}{97.2} \times 10^6 = 61.96 \text{ Kg}$$

Temporary hardness = Hardness due to $Ca(HCO_3)_2 + Mg(HCO_3)_2$

= 18.8 + 24.3 = 43.1 ppm

Permanent hardness = Hardness due to $CaCl_2 + CaSO_4 + MgSO_4$

= 22.5 + 17.6 + 16.7 = 56.8 ppm

Q. 3. What is break point chlorination ? Explain different zones. What are the advantages of break point chlorination.

Ans. Break Point Chlorination : The disinfection action of Cl_2 is not simple. It form HCl, HOCl with water. The disinfection form of chlorine are Cl_2 and HOCl. Being an oxidizing agent it first oxidises **organic mater** and other **reducing agents** *e.g.* NH_3, H_2S etc. *e.g.*

$$HOCl + NH_3 \longrightarrow \underset{\text{Monochloroamine}}{NH_2Cl} + H_2O$$

$$NH_2Cl + HOCl \longrightarrow \underset{\text{Dichloroamine}}{NHCl_2} + H_2O$$

$$NHCl_2 + HOCl \longrightarrow \underset{\text{Trichloroamine Or (Nitrogen Trichloride)}}{NCl_3} + H_2O$$

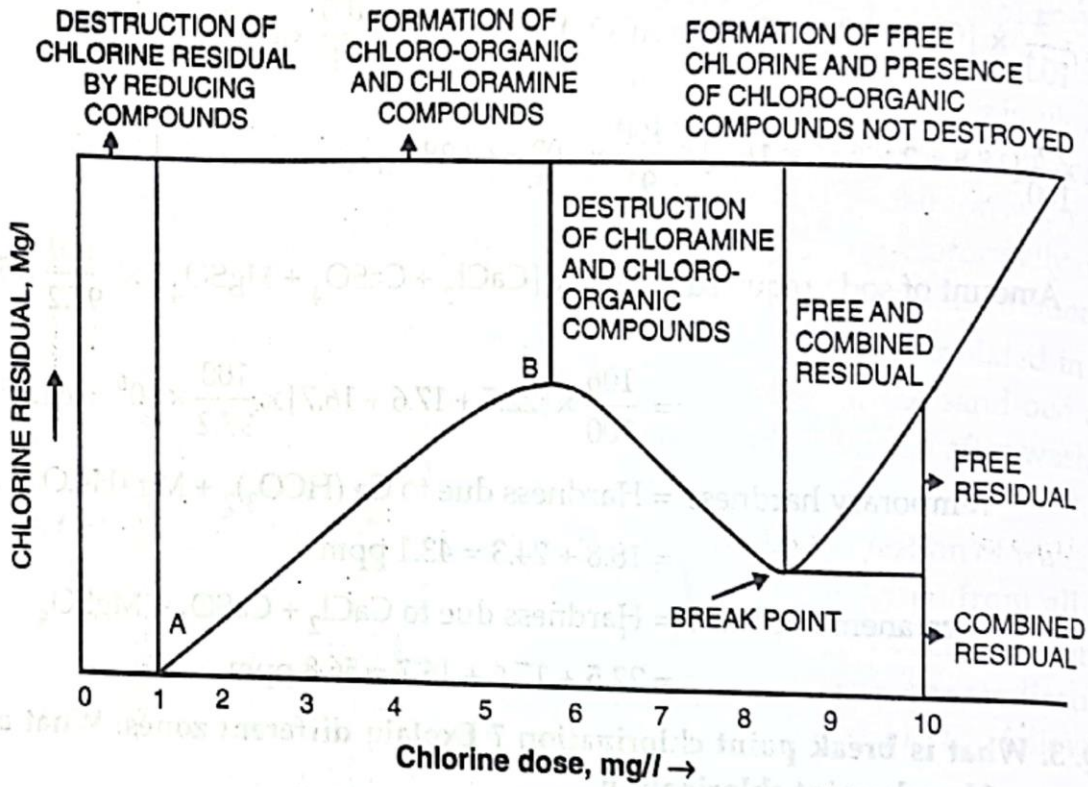
These **chloroamines** formed above act as **chlorine reserve, kill the organism** which were not killed earlier.

The free Cl_2 for disinfection becomes available only after the requirement for Cl_2 by other reacting substances is met with. It is important to know the **difference** between **free chlorine** and **combine chlorine** residue.

(For efficient disinfection, a greater conc. of combined chlorine is required)

Free chlorine residue is Cl_2 and HOCl. Combined chlorine residue is chloramines.

The effect of passing Cl_2 into water can be represented as :



Chlorination of water to the extent of converting all the NH_3 to NCl_3 or N_2 is referred to as break point chlorination. After this free residual chlorine appears in water which destroys the pathogens. Usually all the tastes and odour disappear at this stage.

Significance of Break Point Chlorination.

The chlorine dosage higher than this point means that chlorine demand of the chlorine reactable material has been completely met with and free chlorine residual are available for bacterial action. It also

- signifies complete decomposition of NH_3.
- removal of colouring matter and odour of water.

An overdose of chlorine produce unpleasant taste and odour, irritation of mucus membrane. So information regarding break point of water sample being chlorinated is useful in the following respects.

(*i*) It indicate complete oxidation of organic matter responsible for imparting colour bad smell and unpleasant taste of water.

(*ii*) It ensure complete destruction of pathogens.

(*iii*) It prevent presence of excess chlorine which may impart bad taste or odour.

Q. 4. A sample of water was analysed and found to contain temporary Mg hardness 25 mg/l. Permanent magnesium chloride hardness is 15 mg/l and permanent $CaSO_4$ hardness is 20 mg/l. Calculate lime and soda required for softening 30,000 l of hard water.

Ans.

$$\text{Amount of lime required} = \frac{74}{100} \times [2 \times \text{Temp } Mg^{2+} + \text{Permanent } MgCl_2] \times 30000$$

$$= \frac{74}{100} \times [2 \times 25 + 15] \times 30,000$$

$$= \frac{74}{100} \times 65 \times 30,000 = 1.443 \text{ kg}$$

$$\text{Amount of soda required} = \frac{106}{100} \times [\text{Pem } MgCl_2 + \text{Pem } CaSO_4] \times 30,000$$

$$= \frac{106}{100} \times [15 + 20] \times 30,000$$

$$= \frac{106}{100} \times 35 \times 30,000 = 1.113 \text{ kg.}$$

Q. 6. Calculate the amount of lime (84% pure) and soda (92% pure) required for treatment of 20,000 l of water, whose analysis is as follows : $Ca(HCO_3)_2$ = 40.5 ppm; $Mg(HCO_3)_2$ = 36.5 ppm ; $MgSO_4$ = 30.00 ppm; $CaSO_4$ = 34.0 ppm ; $CaCl_2$ = 27.75 ppm and NaCl = 10.00 ppm. Also calculate the temporary and permanent hardness of water.

(May 2007, Dec. 2006)

Ans. Hardness due to $Ca(HCO_3)_2 = 40.5 \times \frac{100}{162} = 25$ ppm

Hardness due to $Mg(HCO_3)_2 = 36.5 \times \frac{100}{146} = 25$ ppm

Hardness due to $MgSO_4 = 30.0 \times \frac{100}{120} = 25$ ppm

$$\text{Hardness due to } CaSO_4 = 34.0 \times \frac{100}{136} = 25 \text{ ppm}$$

$$\text{Hardness due to } CaCl_2 = 27.75 \times \frac{100}{111} = 25 \text{ ppm}$$

$$\text{Amount of lime required} = \frac{74}{100} \times [25 + 2 \times 25 + 25] \times \frac{100}{84} \times 20{,}000$$

$$= \frac{74}{100} \times [100] \times \frac{100}{84} \times 20000$$

$$= 1.76 \text{ kg}$$

$$\text{Amount of soda required} = \frac{106}{100} \times [25 + 25 + 25] \times \frac{100}{92} \times 20{,}000$$

$$= \frac{106}{100} \times [75] \times \frac{100}{92} \times 20{,}000$$

$$= 1.72 \text{ kg}$$

Temporary hardness = hardness due to $Ca(HCO_3)_2 + Mg(HCO_3)_2$

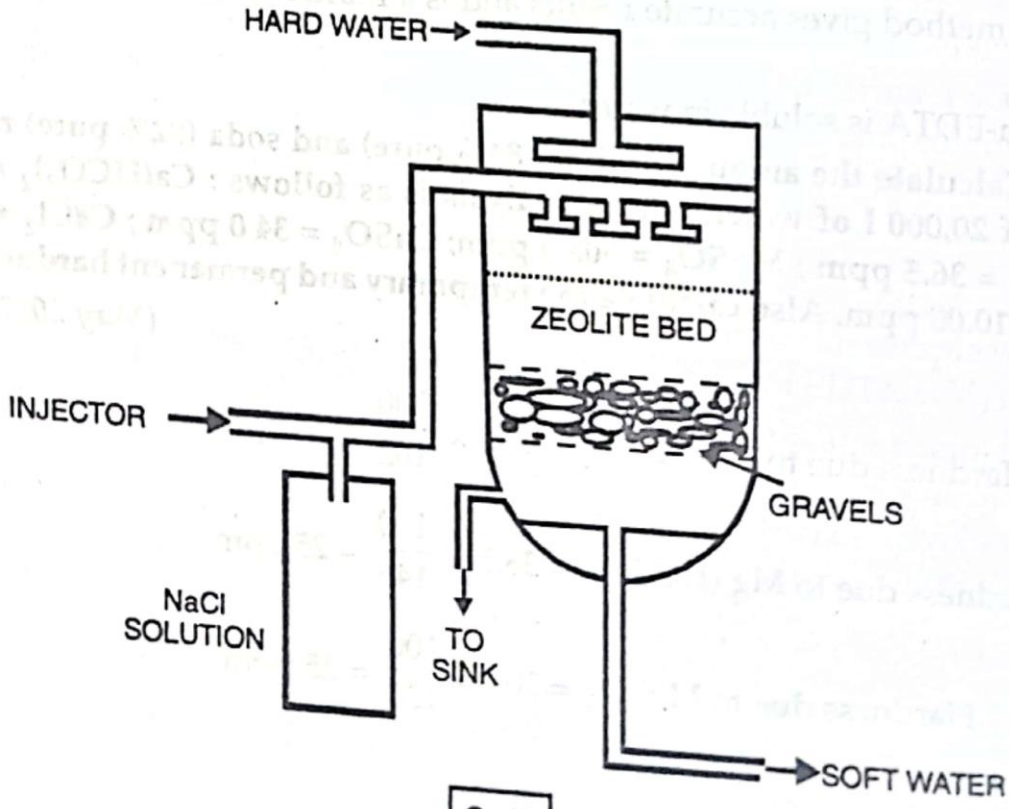
$= 25 + 25 = 50$ ppm

Permanent hardness = Hardness due to $MgSO_4 + CaSO_4 + CaCl_2$

$= 25 + 25 + 25 = 75$ ppm.

Q. 7. What are Zeolites ? How do they function in softening of water ? What are their merits and demerits ? *(Dec. 2010, May 2009)*

Ans. Zeolite or Permutit Process. This is a very effective method. Chemical formula of zeolite is



$Na_2O.Al_2O_3.xSiO_2.yH_2O$; where $x = 2 - 10$, $y = 2 - 6$

Hydrated sodium alumino silicate

or Sodium zeolite.

This is capable of exchanging its Na^+ ions with hardness producing ions (Ca^{2+} and Mg^{2+}) present in hard water.

Zeolites are known as permutit also.

Zeolites are of two types :

(i) Natural Zeolites are non-porous *e.g.* **natrolite** $Na_2O.Al_3O_3.4SiO_2.2H_2O$.

(ii) Synthetic Zeolites are porous and possess gel like structure.

Softening Process. Water is passed through zeolite beds. The Ca^{2+} and Mg^{2+} ions in the water are replaced by Na^+ ions of the zeolite bed *i.e.* Zeolite retains Ca^{2+} and Mg^{2+} ions of hard water and gives away its Na^+ to water. Although conc. of Na^+ ions of Na salts is increasing in the water, but these salts are not responsible for hardness of water (Remember hardness of water is caused by Ca & Mg salts/ions).

$$\underset{\text{Sodium zeolite}}{Na_2Ze} + \underset{\substack{\text{salt causing}\\ \text{hardness of water}}}{Ca(HCO_3)_2} \longrightarrow CaZe + \underset{\text{(to water)}}{2NaHCO_3}$$

$$\underset{\text{Sodium zeolite}}{Na_2Ze} + \underset{\substack{\text{salt causing}\\ \text{hardness of water}}}{Mg(HCO_3)_2} \longrightarrow \underset{\text{(to water)}}{2NaHCO_3} + MgZe$$

Regeneration. After some time all the Na^+ ions of zeolite are replaced by Ca^{2+}/Mg^{2+} ions. And hence zeolite is no more effective. So to remove this saturation 10% NaCl soln (brine solution) is passed through the used zeolite.

$$\underset{\text{Brine}}{CaZe + NaCl} \longrightarrow Na_2Ze + CaCl_2$$

$$MgZe + NaCl \longrightarrow Na_2Ze + MgCl_2$$

So in this way used up zeolite is regenerated to sodium zeolite and $CaCl_2$ and $MgCl_2$ formed are removed from the zeolite softener to sink.

Limitations

1. If **suspended particles** are present in water, these must be removed first otherwise, these will clog the pores of zeolite.
2. If **Mn^{2+} or Fe^{2+}** ions are present in water, these must be removed completely otherwise these will replace Na^+ of zeolite permanently to form **Mn or Iron zeolite, whose regeneration is not possible.**
3. **Mineral acids** must be removed, if present in water. Because these can **destroy the zeolite bed.**

Advantages of Zeolite Process

1. The equipment used is **compact.** So time saving.
2. **No impurities are ppted,** so no sludge.
3. **Less time** for softening.
4. **Less** skill for **maintainence.**

Disadvantages

1. **Treated water** has more of **Na^+ ions.**
2. This method leaves **acidic ions** (HCO_3^- and CO_3^{2-} ions) in soft water which if enters a boiler, generates CO_2 which leads to corrosion.
3. **Turbid** water can't be made soft by this process because it leads to clogging of the holes of zeolite bed.

Q. 8. Explain the process of desalination of water by giving any one method. **(Dec. 2010)**

Ans. Reverse Osmosis : *When two solutions of unequal concentration are separated from each other by semipermeable membrane, flow of the solvent from lower conc. to high conc. take place. This is called Osmosis.*

Semipermeable membrane. Selective membrane which does not allow the solute to pass through if a hydrostatic pressure is applied to such a situation provided hydrostatic pressure is greater than osmotic pressure.

Then flow of solvent is reversed *i.e.* It flows from high conc. to low conc. of the solution. This is called Reverse **Osmosis.**

So by using reverse osmosis, pure water is extracted out of salty water, instead of extracting salt from water.

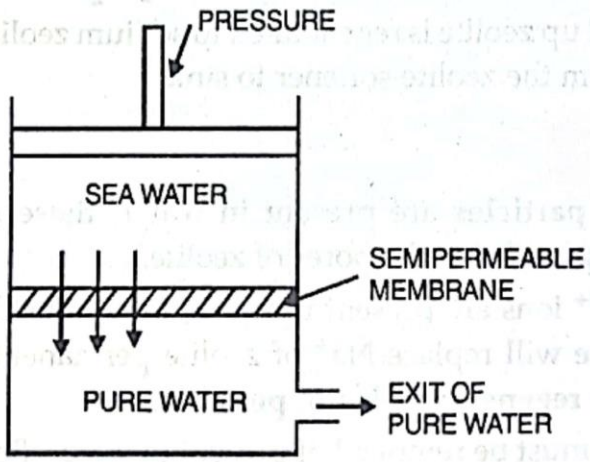


Fig. Reverse Osmosis Cell

Pressure is applied to lime water passing through semipermeable membrane which leaves behinds the dissolved solids.

Membrane is a film of **ceclulose acetate,** affixed to either side of the perforated tube.

Other option can be : Cellulose Membrane made of poly meth acrylate and polyamide polymers

Advantages

The advantages of reverse osmosis are :

1. Useful not only to remove NaCl, but ionic, nonionic, colloidal or high molecular weight organic matter.
2. It removes colloidal silica, which is not removed by demineralization.
3. Life time of membrane is 2 years. So it is an economical econcept.
4. Replacement of water takes few seconds only, so continuous supply of water can be maintained.

Q. 9. What are ion exchange resins ? How soft water can be obtained by using these resins ? What are its advantages and disadvantages ?

(Dec. 2010, May 2010, 2008, Dec. 2007)

Ans. Ion exchange resins are insoluble, cross linked, long chain **organic polymers** with micropores (very small pores). The functional group attached to the ion exchange resin are responsible for its ion exchange properties.

(i) Cation Exchange Resin is generally represented as RH^+ *e.g.* styrene-divinyl benzene copolymer. Resins containing acidic functional group —COOH, —SO_3H (after treatment of sulphonation or carboxylation) are capable of exchanging their H^+ ions with cations of water (means cations of salts responsible for hardness of water) which comes in their contact.

(ii) Anion exchange polymer is generally represented as R'OH$^-$. *e.g.* styrene-divinyl benzene or amine formaldehyde copolymer. These after treatment with dil. NaOH solution become capable of exchange their OH^- with anion of H_2O. These are having basic functionalities *e.g.* —NH_2 or —OH exchange their anion with anion of water (means anions of the salts responsible for hardness of water).

Process. The hard water is passed through cation exchange column. Which remove all the Ca^{2+}/Mg^{2+} ions present in hard water as shown.

$$\underset{\text{Cation exchange Resin}}{2RH^+} + \underset{\text{Hard water}}{Ca^{2+}} \longrightarrow \underset{\text{Cation exchange Resin}}{R_2Ca^{2+}} + \underset{\text{Soft water}}{2H^+}$$

$$\underset{\text{Cation exchange Resin}}{2RH^+} + \underset{\text{Hard water}}{Mg^{2+}} \longrightarrow \underset{\text{Cation exchange Resin}}{R_2Mg^{2+}} + \underset{\text{Soft water}}{2H^+}$$

After this **same water is passed through anion exchange column, which removes all the SO_4^{2-} or Cl^- etc.**

$$\underset{\text{Anion Exchange Resin}}{R'OH^-} + \underset{\text{Hard water}}{Cl^-} \longrightarrow \underset{\text{Anion exchange Resin}}{R'Cl^-} + \underset{\text{Soft water}}{OH^-}$$

$$\underset{\text{Anion Exchange Resin}}{2R'OH^-} + \underset{\text{Hard water}}{SO_4^{2-}} \longrightarrow \underset{\text{Anion exchange Resin}}{R_2SO_4^{2-}} + \underset{\text{Soft water}}{2OH^-}$$

$$\underset{\text{Anion Exchange Resin}}{2R'OH^-} + \underset{\text{Hard water}}{CO_3^{2-}} \longrightarrow \underset{\text{Anion exchange Resin}}{R_2CO_3^{2-}} + \underset{\text{Soft water}}{2OH^-}$$

The H^+ and OH^- released respectively, combine to form H_2O.

The water coming out of the ion exchanger is called de-ionized/de-mineralized water.

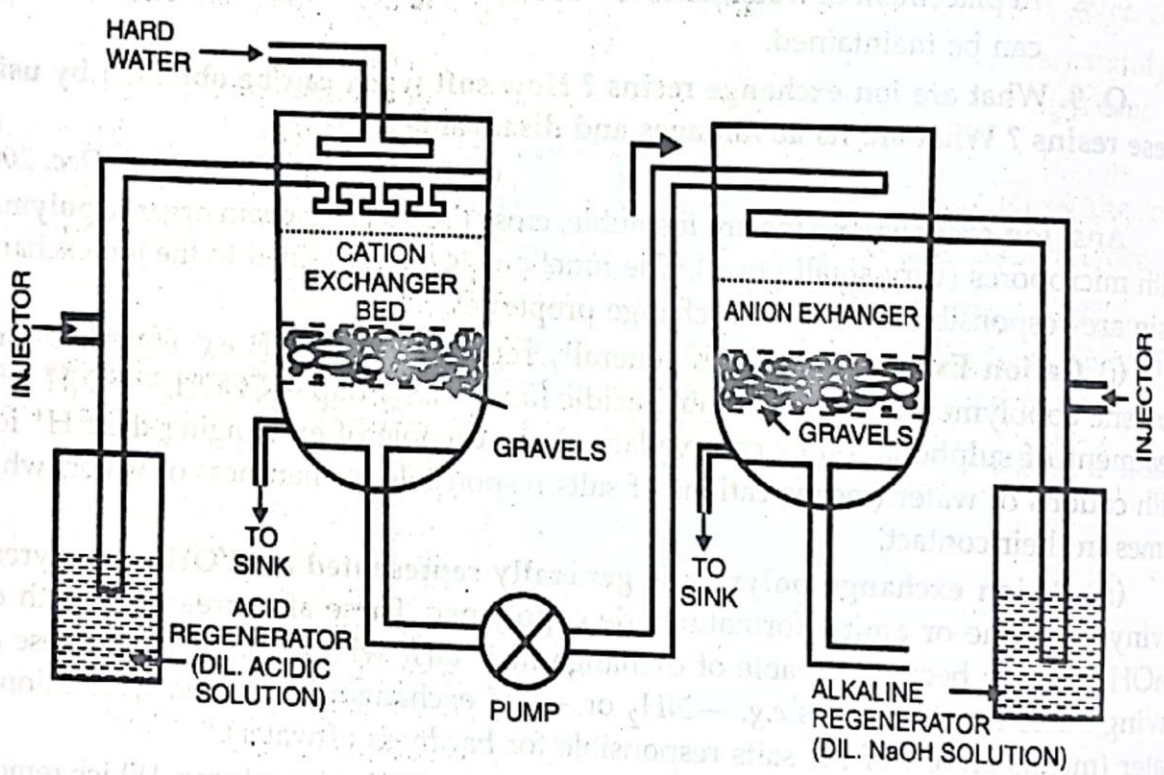


Fig. Ion Exchange Process

When capacity of cation and anion **exchanger to exchange H^+ and OH^- is lost,** they are said to be **exhausted.** It is when ion exchange resin has given all its H^+ and OH^- ions to hard water and had only cations and anions which it has got from water during ion exchange process. Its regeneration in required.

Regeneration of Cation Exchange Column.

On passing a solution of HCl/H_2SO_4 (dil.) through cation exchange column, regeneration of the H^+ ions take place as follows :—

$$R_2Ca^{2+} + 2H^+ \longrightarrow 2RH^+ + Ca^{2+}$$

Saturated cation exchange resin — dil. acidic solution — Re-generated Cation Exchange resin — Washings

The column is washed with de-ionized water and Ca^{2+} moves out with this washing.

Regeneration of Anion exchange column.

It is done by passing dil. NaOH solution through it.

$$R_2SO_4^{2-} + 2OH^- \longrightarrow 2R'OH + SO_4^{2-}$$

Saturated anion exchange resin — dil. NaOH solution — Regenerated anion exchange columns

Again column is washed with de-ionized water and SO_4^{2-} goes out with washings.

Advantages.

1. This process is very good to **soften very acidic or alkaline water.**
2. It produces water of very low hardness.

Disadvantages.

1. The Equipment is **costly.**
2. **If water is turbid, output of de-ionization is low.**

Mixed Bed Deionizer. It consists basically of a single cylinderical unit having mixture of cationic and strongly basic anion exchanger. So water comes in contact with cation and anion exchangers alternatively and gets deionized. When mixed bed ionizer gets saturated it also needs regeneration.

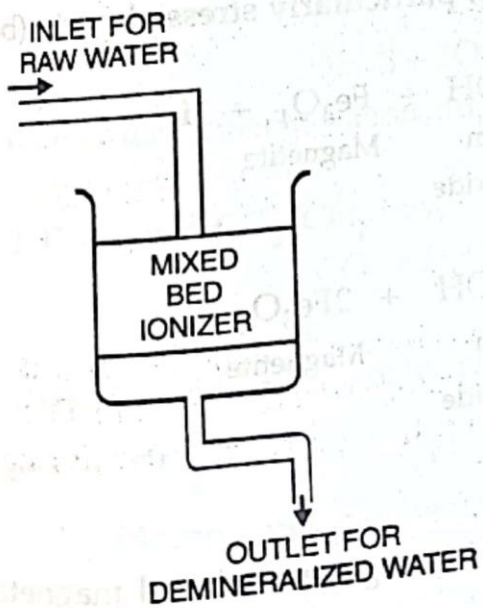


Fig. Mixed Bed Ionizer

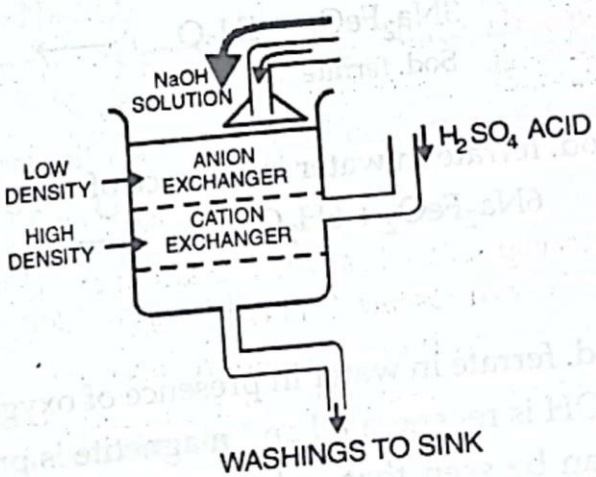


Fig. Regeneration of Mixed Bed Ionizer

Regeneration.

Mixed ion exchanger is **back washed,** which leads to formation of two layers.

Upper Layer is of Anion exchanger because of its low density, which can be regenerated by passing caustic soda through it.

The **Lower layer** is of cation exchanger because of its high density. It can be regenerated by passing dilute sulphuric **acid solution** through it.

Q. 10. What are disadvantages of using hard water in boilers. Explain any two. How these can be prevented ? *(Dec. 2009)*

Ans. For steam generation boilers are used. If hard water is fed to the boilers, then many troubles are to be faced. These are

1. Scale and sludge formation
2. Corrosion
3. Priming and foaming
4. Caustic embrittlement

Caustic Embrittlement : This is a type of boiler corrosion, which is caused by using **alkaline water** (water basic in nature *i.e.* water having pH > 7) in boiler.

Alkali in the water comes while doing **softening of water.** For sofetning of water Na_2CO_3 is added to react with dissolved Ca and Mg salts. Some unreacted Na_2CO_3 in water makes water alkaline as shown :

$$Na_2CO_3 + H_2O \longrightarrow NaOH + CO_2$$

NaOH, so formed in water makes water alkaline or **caustic.** In the **inner wall** of **boiler hair cracks are always present,** this NaOH through the **capillary action** from these hair cracks moves into the body of the boiler. As water evaporates concentration of NaOH increases and hence NaOH moves to body of boiler. It dissolves iron from the body of boiler as sodium ferrate.

This called embrittlement of the boiler parts, particularly stressed parts (bends, joints, rivets, cracks etc.)

$$\underset{\text{Sod. ferrate}}{3Na_2FeO_2} + 4H_2O \longrightarrow \underset{\text{Sodium hydroxide}}{6NaOH} + \underset{\text{Magnetite}}{Fe_3O_4} + H_2$$

(Sod. ferrate in water in absence of oxygen)

$$6Na_2FeO_2 + 6H_2O + O_2 \longrightarrow \underset{\text{Sodium hydroxide}}{12NaOH} + \underset{\text{Magnetite}}{2Fe_3O_4}$$

(Sod. ferrate in water in presence of oxygen)

NaOH is regenerated and magnetite is ppted.

It can be seen that in both the process, NaOH is regenerated and magnetite is precipitated out.

Caustic embrittlement can be explained as :

Iron at cracks bends and joints	Conc. NaOH	Dilute NaOH	Iron present at the boiler
Anode			Cathode

Due to **non-availability of O_2 in the cracks,** the iron here behaves as anode. Boiler walls behave as cathode. Therefore, **Iron in the cracks undergo oxidation and gets corroded.**

Prevention of Caustic Embrittlement

(*i*) **By not using Na_2CO_3 for softening of water** instead sodium phosphate should be used.

(*ii*) By adding **Tannin or Lignin** to water because these **block the hair line cracks.**

(*iii*) By adding sod. sulphate **Na_2SO_4** it also **blocks the cracks.** The conc. of Na_2SO_4 should be so that the $\frac{Na_2SO_4 \text{ conc.}}{NaOH \text{ conc.}} = 1:1, 2:1$ or $3:1$ at the pressure upto 10, 20 and above 20 atmosphere respectively.

Boiler Corrosion : This leads to deterioration of the boiler body by **chemical or electrochemical attack by its environment.** Main reasons for it :

1. Dissolved O_2 (D.O.). Water has **8 ml/litre** dissolved oxygen which attack the boiler body. As boiler is made up of iron.

So $$2Fe + 2H_2O + O_2 \longrightarrow 2Fe(OH)_2 + O_2 \longrightarrow \underset{\text{Rust}}{2[Fe_2O_3.2H_2O]}$$

Removal of D.O. (*a*) **By adding sodium sulphite Na_2SO_3 or hydrazine.** N_2H_4 or Na_2S **sod. sulphide.** Because all these consume O_2 by reacting as :

$$2Na_2SO_3 + O_2 \longrightarrow 2Na_2SO_4$$
$$N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O$$
$$Na_2S + 2O_2 \longrightarrow Na_2SO_4$$

(*b*) **By mechanical de-aeration.** That means by using Vacuum-pump, air is removed from water mechanically.

2. Dissolved CO_2. CO_2 in water, reacts with water to form carbonic acid as :

$$CO_2 + H_2O \longrightarrow \underset{\text{Carbonic acid}}{H_2CO_3}$$

Carbonic acid has corrosive effect on the boiler body.

Removal of CO_2

(*i*) By adding ammonia because ammonia absorb CO_2 as shown :

$$2NH_4OH + CO_2 \longrightarrow (NH_4)_2CO_3 + H_2O$$

(ii) Mechanical Method. By mechanically removing CO_2 using vacuum pump.

3. Acids from dissolved salts. Water has dissolved salts, which on hydrolysis *i.e.* on reacting with water releases acid as :

$$MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 + \underset{\text{Acid}}{2HCl}$$

This acid (HCl) react with boiler body's iron in a chain reaction to produce HCl again.

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2\uparrow$$

$$FeCl_2 + 2H_2O \longrightarrow Fe(OH)_2 + 2HCl$$

So, presence of small amount of $MgCl_2$ may cause corrosion to large extent.

Removal. Mineral salts can be removed by **adding alkali.** If pH of boiler water is 10.5, **acid will not attack the boiler wall.**

Q. 11. Calculate the amount of lime (91% pure) and soda (97.2 % pure) for softening one million litres of water containing :

H^+ (free acidity) = 1.5 ppm ; HCO_3^- = 396.5 ppm ; Mg^{+2} = 42 ppm ; Ca^{+2} = 90 ppm; $FeSO_4 . 7H_2O$ = 14 ppm

[Given atomic masses of H = 1, Ca = 40, Mg = 24, O = 16, C = 12, S = 32, Fe = 56]

Ans.

Impurities	$CaCO_3$ eq.	Requirement	L	S
H^+	$1.5 \times \frac{100}{1}$	L + S	$1.5 \times \frac{100}{2} = 75$	$1.5 \times \frac{100}{2} = 75$
HCO_3^-	$396.5 \times \frac{100}{61}$	$\frac{L}{2} - \frac{S}{2}$	$396.5 \times \frac{100}{61} \times \frac{1}{2} = 325$	$-396.5 \times \frac{100}{61} \times \frac{1}{2} = -325$
Mg^{2+}	$42 \times \frac{100}{24}$	L + S	$42 \times \frac{100}{24} = 175$	$42 \times \frac{100}{24} = 175$
Ca^{2+}	$90 \times \frac{100}{40}$	S	—	$90 \times \frac{100}{40} = 225$
$FeSO_4.7H_2O$	$14 \times \frac{100}{278}$	L + S	$14 \times \frac{100}{278} = 5.03$	$14 \times \frac{100}{278} = 5.03$
			580.03	**155.03**

$$\text{Line requirement} = \frac{74}{100} \times 580.03 \times \frac{100}{91} = 47.16 \text{ Kg}$$

$$\text{Soda requirement} = \frac{106}{100} \times 155.03 \times \frac{100}{97.2} = 169.0 \text{ Kg}$$

Q. 12. A water sample on analysis give the following : Ca^{2+} = 30 mg/L, Mg^{2+} = 24 mg/L, CO_2 = 24 mg/L, HCl = 50 mg/L, K^+ = 10 mg/L, Calculate the quantities of lime (purity 90%) and soda (purity 94%) required to soften one million litres of water. *(Dec. 2010)*

Ans.

Impurities	Conc.	$CaCO_3$ equivalents	Require-ment	L	S
Ca^{2+}	30 mg/L	$\frac{100}{40} \times 30 = 75$	S	0	75
Mg^{2+}	24 mg/L	$\frac{100}{24} \times 24 = 100$	L + S	100	100
CO_2	24 mg/L	$\frac{100}{44} \times 24 = 54.54$	L	54.54	0
HCl	50 mg/l	$\frac{100}{36.5} \times 50 = 136.98$	$\frac{1}{2}L + \frac{1}{2}S$	68.49	68.49
K^+	10 mg/L	–		223.03	168.49

Lime requirement $= \frac{74}{100} \times 223.03 \times 10^6 \times \frac{100}{90} = 183 \times 10^6$

$= 1833 \times 10^5$ mg

Soda requirement $= \frac{106}{100} \times 168.49 \times 10^6 \times \frac{100}{94}$

$= 1894 \times 10^5$ mg.

Q. 13. Explain priming and foaming in boilers. *(May 2012)*

Ans. Priming and Foaming

When the boiler is steaming.

(*a*) Some particles of the liquid water are carried along with the steam, which makes wet steam, the process being called Priming.

Cause. (*i*) Presence of dissolved solids.

(*ii*) High steam velocity.

(*iii*) Sudden boiling

(*iv*) Sudden increase in steam production.

(*b*) Foaming. Formation of bubbles or foam in the boiler continuously is called foaming.

Cause. If oil is present, it decreases surface tension of water.

Priming and foaming usually occur together.

Disadvantages of Priming and Foaming

1. Salts which are dissolved in water pass onto steam and then to the different parts where the steam goes *i.e.* **to turbine blades** where these salts get deposited as water evaporates. **These deposits reduce the efficiency** of the engine.
2. It is **difficult to maintain proper pressure** in the boiler.
3. The **boiling point of water is increased** which results in wastage of fuel.
4. **Actual water level can't be accessed in the presence of foam.**
5. Due to foaming, **bubbles are carried along with steam to the engine. Hence it decreases the efficiency of the engine.**

Prevention

Priming can be prevented by taking the following precautions :

1. **Priming forming substances should be removed.**
2. **Scale/Sludge should be removed from time to time.**
3. **Boiler water should be changed from time to time.**
4. **Water level should be maintained at the lower level.**
5. Fitting mechanical **steam purifies.**
6. **Avoid rapid change in the steaming rate.**

Foaming can be prevented by :

1. Using antifoaming agents *e.g.* castor oil.
2. Removing oil from boiler water by adding chemicals like sodium aluminate.

Q. 14. Discuss hot lime soda process of water softening. *(May 2012)*

Ans. Hot lime soda process

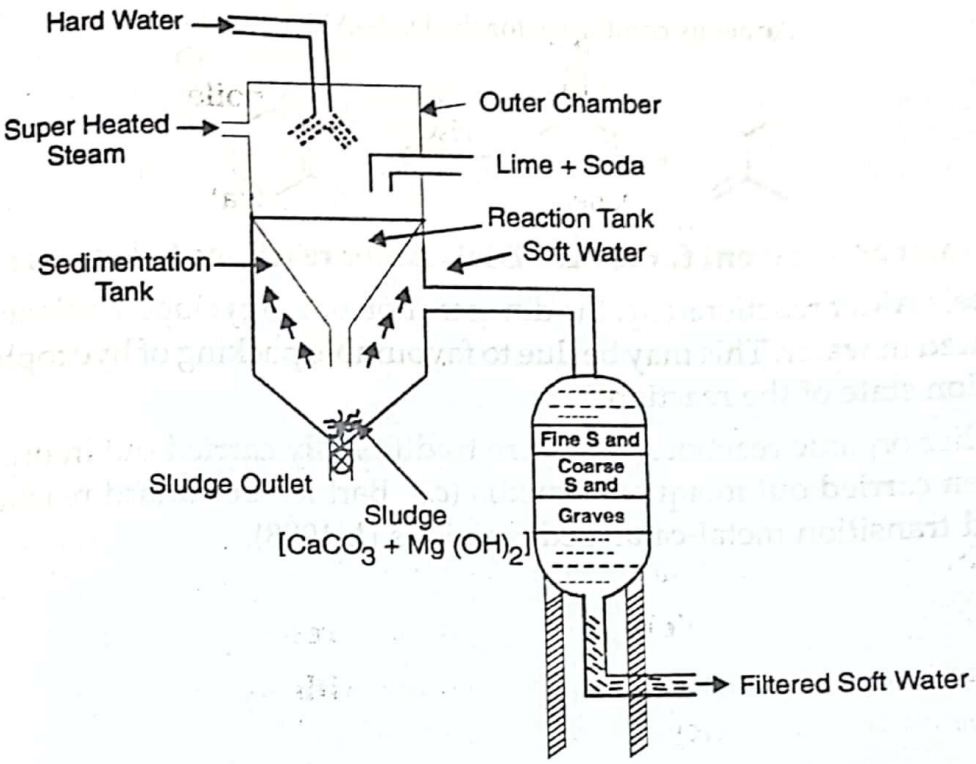


Fig. Hot Lime Soda Process

(*i*) **Reaction tank.** The reactants *i.e.* hard water, steam and chemicals are mixed in outer chamber and moved on to the reaction tank.

(*ii*) **Conical sedimentation tank.** The chemical **reaction is completed** here. The precipitates get settled down and form sludge.

(*iii*) **Sand filter.** Water passes the sand filter and complete removal of sludge takes place.

In this process, the mixing of chemicals is done **near boiling point of water.** Rate of reaction becomes **faster** because of high temperature and **complete precipitation** takes place more **quickly** and thus the **settling rate is also high.** Hence like cold like soda process, **no coagulant is** required.

This is a better method than cold lime soda process because it gives water of **15-20 ppm** hardness as compared to the latter which gives water of **50-60** ppm of hardness.

C **and ad**