1) What are boiler troubles? Explain Scales and Sludge formation.

Boiler troubles are 1) Priming & foaming 2) Sludge & Scales3) Caustic embrittlement4) Boiler corrosion

Sludge & Scale formation

In a boiler, water is continuously evaporated and converted into steam. As a result the water becomes saturated due to increase in the concentration of dissolved impurities. Finally a stage is reached where the ionic products of these salts exceeds their solubility product and are thrown out as precipitates on the inner walls of the boiler.

Sludge:

- Soft, loose and slimy precipitate formed within the boiler.
- Formed at comparatively colder portions of the boiler and are collected at the bends.
- Formed by substances which have greater solubility in hot water than in cold water, *e.g.,* $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$, *etc*
- Easily removed with wire brush

Disadvantages of sludge formation

- Sludges are poor conductors of heat, so they tend to waste a portion of heat generated.
- Excessive sludge formation disturbs the working of the boiler.
- Sludge can be removed by using 1) Softened water 2) by blow down operation i.e. drawing off a portion of the concentrated water.

Scales:

- Hard deposits firmly sticking to the inner walls of the boiler.
- Difficult to remove, even with the help of hammer & Chisel.

Formed due to:

i) Decomposition of Calcium bicarbonate:

$$Ca(HCO_3)_2 \longrightarrow CaCO_3\downarrow + H_2O + CO_2$$

Scale

(Soft, formed mainly in low pressure boilers)

In high pressure boilers, CaCO3 is soluble due to formation of $Ca(OH)_2$

$$CaCO_3 + H_2O \longrightarrow Ca(OH)_2 + CO_2\uparrow$$

ii) Deposition of $CaSO_4$:

Solubility of $CaSO_4$ decreases with increase in temperature.

It is completely insoluble in super heated water.

Hard scale formation takes place in high pressure boilers

iii) Hydrolysis of Magnesium salts:

Soft scale formation due to hydrolysis of Mg salts in high pressure boiler.

$$MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2\downarrow + 2HCl$$

iv) Presence of silica:

Even very small amounts of silica leads to deposits of Ca/Mg silicates($CaSiO_3$ & $MgSiO_3$), which adheres firmly to the inner boiler walls. It is difficult to remove.

Disadvantages of scale formation:

i) Wastage of fuel:

Rate of heat transfer is greatly reduced due to poor conductivity of scales

Overheating is required for steady supply of heat hence fuel consumption increases.

ii) Lowering of boiler safety:

To supply steady heat overheating is required, which makes the boiler material weak &soft. Results in distortion of boiler tube & makes the boiler unsafe to bear the high pressure.

iii) Decrease in efficiency of boiler:

Deposition of scales in valves and condensers choke them partially& decreases the efficiency of boiler

iv) Danger of Explosion:

Due to uneven expansion the thick scales gets cracked, results in formation of large steam & develops high pressure. It may cause explosion of boiler.

Removal of scales:

- Mechanical/chemical method
- Loosely adhering scales are removed with the help Scraper/wire brush
- Brittle scales are removed by giving Thermal shocks
- Loosely adhering scales are removed by frequent blow down operation (frequently removing precipitates)

- Adherent & hard scales are removed by dissolving them by adding chemicals

  $CaCO_3$ scales - 5-10% HCl

  $CaSO_4$ scales – EDTA

2) What is meant by Caustic embrittlement?

Caustic embrittlement: The formation of brittle and in crystalline cracks in the boiler shell is called caustic embrittlement.

- It is a type of boiler corrosion, caused by highly alkaline water in the boiler.
- In lime-soda process, it is likely that, some residual Na_2CO_3 is still present in the softened water
- This Na_2CO_3 decomposes to give NaOH and CO_2 due to which the boiler water becomes "Caustic".
- $Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2\uparrow$
- This very dilute caustic water flows into the minute hair cracks in the boiler, by capillary action.
- On evaporation of water, the dissolved caustic soda increases its concentration inside hair cracks.
- This concentrated alkali dissolves iron of boiler as sodium ferroate.
- It causes embrittlement of boiler parts such as bends joints, rivets etc, due to which the boiler gets fail.

$$Fe + NaOH \rightarrow Na_2FeO_2 + H_2$$

Insoluble soluble

Caustic embrittlement can be explained by considering following electrochemical cell

(Anodic site) **Conc NaoH || dil NaoH** (Cathodic site**)**

Iron at Joints &bends Iron at Plane surface

Anodic portion undergoes corrosion and gets dissolved.

Prevention methods:

- By using sodium phosphate as softening reagent in the external treatment of boiler water.
- By maintaining pH value of water and neutralization of alkali.
- By adding Tannin or lignin or **Sodium Sulphate** to block the hair cracks thereby preventing the infiltration of caustic soda solution

3) Explain internal treatment methods for removal of scales.

Internal treatment (Sequestration):

- In this method some chemicals reagents are added directly to the boiler water for removing dangerous scale forming salts.
- The chemicals convert the scale forming impurities into sludge or more dissolved compounds.
- This method is generally followed by blow down operation.

Important internal conditioning/treatment methods:

Carbonate conditioning:

Reagent added is **sodium carbonate.**

In low pressure boilers scale formation can be avoided by adding sodium carbonate to boiler water

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

Sludge

Deposition of $CaSO_4$ as scale doesn't takes place and calcium is precipitated as loose sludge of $CaCO_3$ which can be removed by blow down operation.

Phosphate conditioning:

Reagent added is **sodium phosphate.**

In high pressure boilers scale formation can be avoided by adding sodium phosphate. It reacts with hardness of water forms non adherent, easily removable soft sludge of Ca / Mg phosphates.

$$3CaCl_2 + 2Na_3PO_4 \longrightarrow Ca_3(PO_4)_2\downarrow + 6NaCl$$

Sludge

We can use different phosphates based on P^H of water

- Na_3PO_4 (alkaline in nature) is used when alkalinity is low.
- Na_2HPO_4 (weakly alkaline) is used when alkalinity is sufficient.
- NaH_2PO_4 (acidic) is used when alkalinity is high

Calgon conditioning:

Reagent added is Calgon.

Calgon = sodium hexa meta phosphate

The process involves the addition of calgon to boiler water.

It prevents scale and sludge formation by forming highly soluble calcium hexa meta phosphate complex compound with $CaSO_4$.

$$Na_2[Na_4(PO_3)_6] \longrightarrow 2Na^+ + [Na_4(PO_3)_6]^{2-}$$
$$2CaSO_4 + [Na_4(PO_3)_6]^{2-} \longrightarrow [Ca_2(PO_3)_6]^{2-} + 2\,Na_2SO_4$$

Highly Soluble complex ion

4) Describe the demineralization process of softening of hard water.

Ion exchange or deionization or demineralization process:

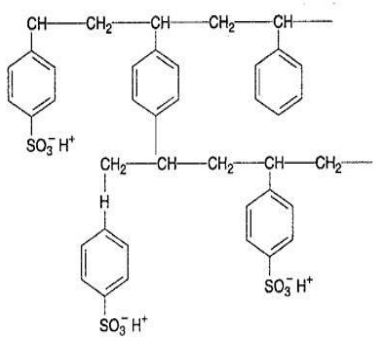
- **Principle:** A reversible exchange of ions takes place between the stationary ion exchange phase and the external liquid mobile phase**.**
- Ion exchange resins are insoluble, cross linked, porous, high molecular weight, organic polymers and the functional groups attached to the chains are responsible for the ion exchange properties.
- Ion exchange resins are generally copolymers of Styrene- divinyl benzene
- Ion exchange resins are of two types
  - Cation exchange resins
  - Anion exchange resins

Cation exchange resins (RH^+):

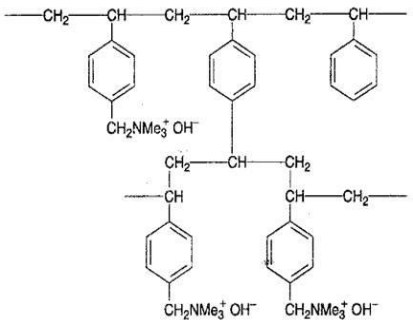
- These are capable of exchanging H^+ ions with the cations.
- It is mainly styrene divinyl benzene copolymer
- They have acidic functional groups like $-SO_3H$, -COOH etc

Anion exchange resin (ROH^-)

- These are capable of exchanging OH^- ions with the anions.
- It is nothing but a copolymer of styrene divinyl benzene
- They contain basic functional groups like quartenary ammonium ion.
- On treatment with dil NaOH they have capability to exchange its OH^- ions with anions in the water



Cation exchange resin



Anion exchange resin

Process:

- The hard water is passed first through cation exchange column
- The cation exchanger removes all the cations like Ca^{+2}, Mg^{+2} from it
- and equivalent amount of H^+ ions are released from the column to water.

$$2RH^+ + Ca^{2+} \longrightarrow R_2Ca + 2H^+$$
$$2RH^+ + Mg^{2+} \longrightarrow R_2Mg + 2H^+$$

- The hard water is now passed through anion exchange column,
- which removes all the anions like SO_4^{-2}, Cl^- from it
- and equivalent amount of OH^- ions are released from the column to water.

$$R'OH^- + Cl^- \longrightarrow R'Cl + OH^-$$
$$2R'OH^- + SO_4^{2-} \longrightarrow R'_2SO_4 + OH^-$$

- H^+ and OH^- ions are released from the cation exchange and anion exchange columns respectively get combined to produce water molecule.

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

Water coming out from the exchanger is free from cations and anions and is known as deionized or demineralized water

Regeneration of exhausted bed:

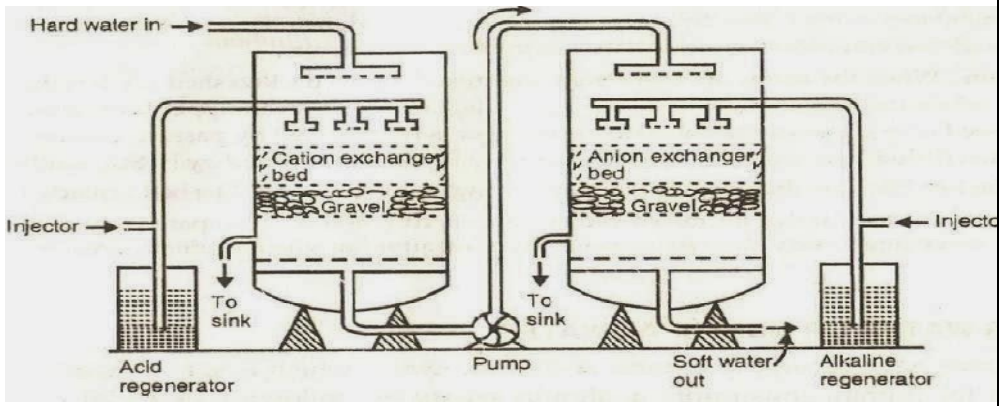
- When the beds are getting exhausted (capacity to exchange H^+ & OH^- ions are lost) then they are regenerated
- The exhausted cationic exchanger is regenerated by washing with acids like HCl, H_2SO_4 etc

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

The exhausted anion exchanger is regenerated by washing with bases like NaOH

$$R'_2SO_4^{2-} + 2OH^- \rightarrow 2R'OH^- + SO_4^{2-}$$

The columns are washed with deionized water and washings are passed to sink or drain. Now they are ready for softening process.



Demineralization of water

Advantages

- Produce water of very low hardness (2ppm)
- The process can be used to soften highly acidic or highly alkaline waters.
- Water produced by this process water can be used in high pressure boilers

Disadvantages

- High capital cost and chemicals & equipment are costly
- If water contains turbidity efficiency of the process decreases.

5) What is meant by Desalination of brackish water? How it is carried out by Electro dialysis?

Desalination: The process of removing salts like sodium chloride from the water is known as desalination.

Commonly employed methods for desalination of brackish water are:

i) Electro dialysis ii) Reverse osmosis

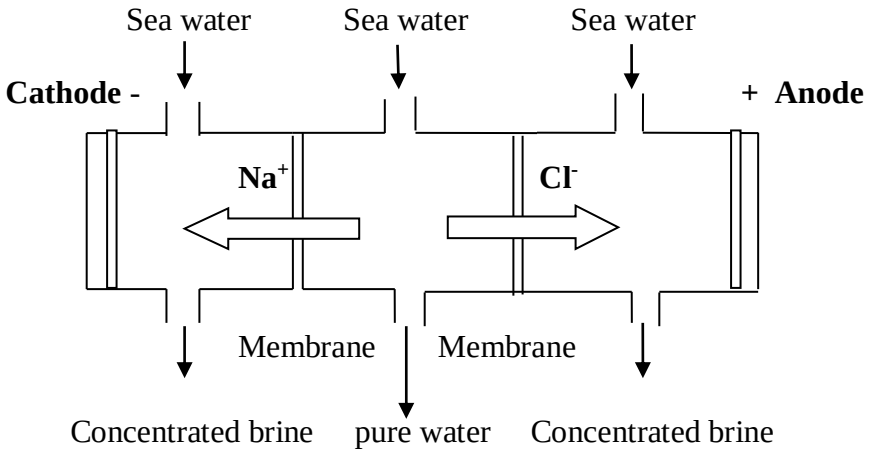
i) Electrodialysis:

- It is a membrane process, during which ions are transported through semi permeable membrane, under the influence of an electric potential.

Principle:

- When direct current is passed through saline water using electrodes, salt ions present in saline water migrates towards their respective electrodes through ion selective membrane, under the influence of applied emf.

Apparatus: The electro dialysis unit consists of a chamber, two electrodes a cathode and an anode. The chamber is divided into three compartments with the help of thin, ion selective membranes which are permeable to either cation or anion



Process:

- When direct electric current is passed through saline water, the Na^+ ions moves towards cathode (-ve pole) and the chloride ions moves towards anode (+ve pole) through membrane.
- The concentration of brine decreases in the central compartment, where as the concentration in outer compartments increases.
- Desalinated brine (pure water) is removed from time to time, while concentrated one is replaced by fresh brine.
- Ion selective membranes are employed for more efficient separation, which has permeability for one kind of ions.
- Cation selective membrane (which possesses functional groups such as RSO_3^-) is permeable to cations only.
- Anion selective membrane (possess functional groups such as $R_4N^+Cl^-$) is permeable to anions only

Electrodialysis cell:

- It consists of a large number of paired sets of rigid plastic membrane.
- Saline water is passed at a pressure of 5-6 kg m^{-2} between membrane pairs.
- Electric field is applied to the direction of water flow
- Fixed +ve charges inside the membrane repel +ve charge ions (Na^+) and permits –vely charged ions.
- Fixed -ve charges inside the membrane repel -ve charge ions (Cl^-) and permits +vely charged ions.
- Alternative streams of pure water and brine water are obtained.

Advantages:

- It is a compact unit, economical.
- Best suited if electricity is easily available.

6) What is meant by Desalination of brackish water? How it is carried out by Reverse Osmosis?

Desalination: The process of removing salts like sodium chloride from the water is known as desalination.

Commonly employed methods for desalination of brackish water are:

i) Electro dialysis ii) Reverse osmosis

Reverse osmosis. (R.O)

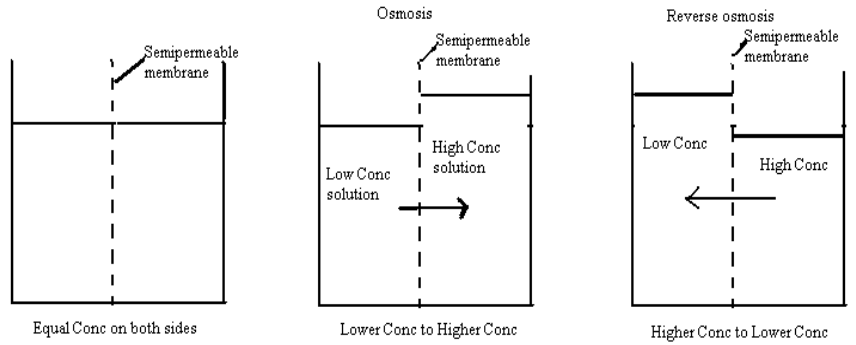
Reverse osmosis is one of the membrane filtration processes. The process is used to remove salts and organic micro pollutants from water.

Principle:

Osmosis: When two solutions of different concentrations are separated by a semi permeable membrane, solvent flows from region of low concentration to region of high concentration. This is called **Osmosis**.

The Pressure developed on the membrane is called **osmotic pressure**.

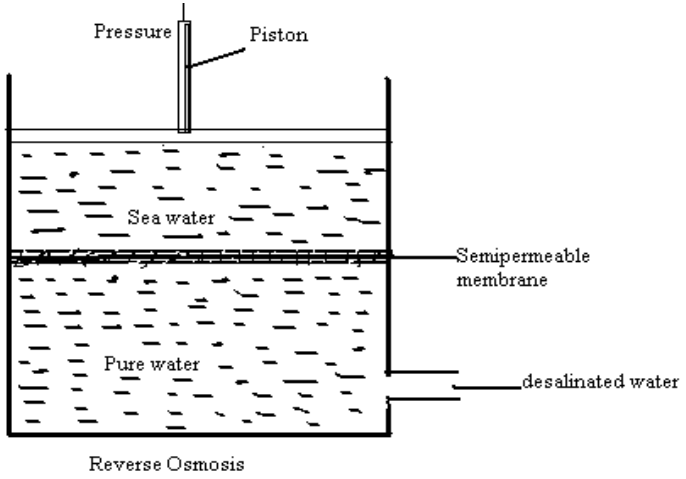
If the pressure higher than osmotic pressure is applied on the concentrated side, then the solvent flows in reverse direction i.e from higher concentrated region to lower concentrated region. This is called reverse osmosis.



In this process pure solvent (water) is separated from its contaminants, rather than removing contaminants from water. Sometimes it is also called super/hyper filtration.

Method:

- Reverse osmosis cell consists of a chamber fitted with a semi permeable membrane above which, sea water or impure water is taken.
- Pressure (of the order 15-40 kg cm^{-2}) is applied to the sea water/impure water.
- The pure water is forced through the semi permeable membrane.
- The membrane consists of very thin films of cellulose acetate/ superior membrane made of polymethacrylate and polyamide polymers, affixed to either side of the perforated tube.



Reverse Osmosis

Advantages:

- Removes ionic and non-ionic colloidal particles and high molecular weight organic matter.
- It removes colloidal silica
- The life time of semi permeable membrane is high.
- Membrane can be replaced within few minutes.
- Low capital and operating cost & high reliability

10. Explain the different steps involved in Municipal water treatment.

There are 2 steps

1) Removal of suspended matter.

2. Removal of microorganisms- Disinfection.

Type of impurity	Process to be employed
Floating matter(leaves, wood pieces)	Screening
Suspended (Clay, Sand)	Plain sedimentation
Fine suspended inorganic matter	Sedimentation with coagulation
Micro organisms & colloidal impurities	Filtration
Pathogenic bacteria	Disinfection

1) Removal of suspended matter:

Screening:

- The raw water is passed through screens which contain large number of holes where floating matter is retained.

Sedimentation:

- Suspended impurities are removed by allowing the water to stand undisturbed for few hours (about 2-8 hr) in big tanks (5m deep).
- Due to force of gravity most of the particles settles down at the bottom of the tank.
- About 70-75% of the suspended matter can be removed.

Sedimentation with coagulation:

- Plain sedimentation can't remove finely divided silica, clay and organic matter.
- Sedimentation with coagulation is a process of removing fine particles by addition of chemicals (coagulants) before sedimentation.

- Commonly used coagulants are Alum (K_2SO_4 $Al_2(SO_4)_3.24H_2O$), Sodium aluminate ($NaAlO_2$) etc.

$Al_2(SO_4)_3 + H_2O \rightarrow 2Al(OH)_3 \downarrow + 3H_2SO_4$

$Al(OH)_3$ acts as flocculent (enormous surface area) and removes the impurities either by neutralizing the charge or by adsorption and mechanical entrainment.

- Coagulant aids (lime, fuller's earth, poly electrolytes) are added to increase the efficiency of the process.
- Generally coagulants are added in solution form with the help of mechanical flocculators for through agitation.
- Substantial reduction of bacteria also takes place during this process. (O_2 i.e. released by some coagulants destroys some bacteria, breaks up some organic compounds, partial removal of color &taste producing organisms.)

Filtration:

- It is the process of clarification of water by passing the water through a porous material, which is capable of retaining coarse impurities on its surface & in the pores. [Porous material used – filtering media, equipment used – filter]
- Common materials used as filtering media: quartz sand(0.5-1.0mm),crushed anthracite(0.8-1.5mm), porous clay
- Slow sand filtration (2gal/Sqft/hr) is generally employed in municipal water treatment.
- **Process:**
- A typical sand filter consists of a tank with abed containing fine sand (top layer), coarse sand, coarse gravel (bottom layer).
- It is provided with inlet for sedimented water and under drain channel at the bottom for exit of filtered water
- Sedimented water is distributed uniformly over the bed and flows slowly through various layers.
- Rate of filtration slowly decreases due to retention of impurities in the pores.
- Top layer is scrapped and replaced with clean sand to increase the efficiency of process.

2. Removal of microorganisms- Disinfection:

Removal of pathogenic (Disease causing microorganism) is known as disinfection.

a) Boiling

When water is boiled the harmful bacteria and virus cannot survive at this temperature

But this process can be applicable only on house hold, municipalities cannot apply

b)Bleaching powder($CaOCl_2$):

By adding bleaching powder disinfection of water is done

$CaOCl_2 + H_2O \rightarrow Ca(OH)_2 + Cl_2\uparrow$

$Cl_2 + H_2O \rightarrow HCl + HOCl$(Hypo chlorous acid which kills germs)

When bleaching powder is added to water first cl_2 is liberated along with $Ca(OH)_2$

Cl_2 reacts with water& forms Hcl&Hocl(Hypochlorous acid).

HOCl is a germicide which kills bacteria or germs present in water

Limitations:

It is unstable, difficult to store

It introduces calcium in water which increases hardness of water when used in excess

c) Addition of chlorine – (Chlorination)

Disinfection is done by addition of liquid chlorine or gaseous chlorine.

Chlorine produces hypochlorous acid [HOCl] which kills microorganisms.

$Cl_2 + H_2O \rightarrow HCl + HOCl$

$HOCl \rightarrow H^+ + OCl^-$

$HOCl \rightarrow$ Kills Germs

Initially it was found that nascent oxygen[o] from Hocl [Hypochlorous acid] is killing the microorganisms, but later on two scientists found that Hocl is causing death of micro-organisms. Chlorine is good disinfectant at a PH of 6.5.

Chlorination depends upon

- **Time of contact:** Number of Micro-organisms destroyed by chlorine per unit time is proportional to number of microorganisms remaining alive. So death rate is maximum at starting.
- **Temperature of water:** Higher the temperature, the rate of reaction is faster & killing of microorganisms increase.
- **PH value of water:** Lower the PH value ,the reaction is faster & a small contact period is required.

Advantages:

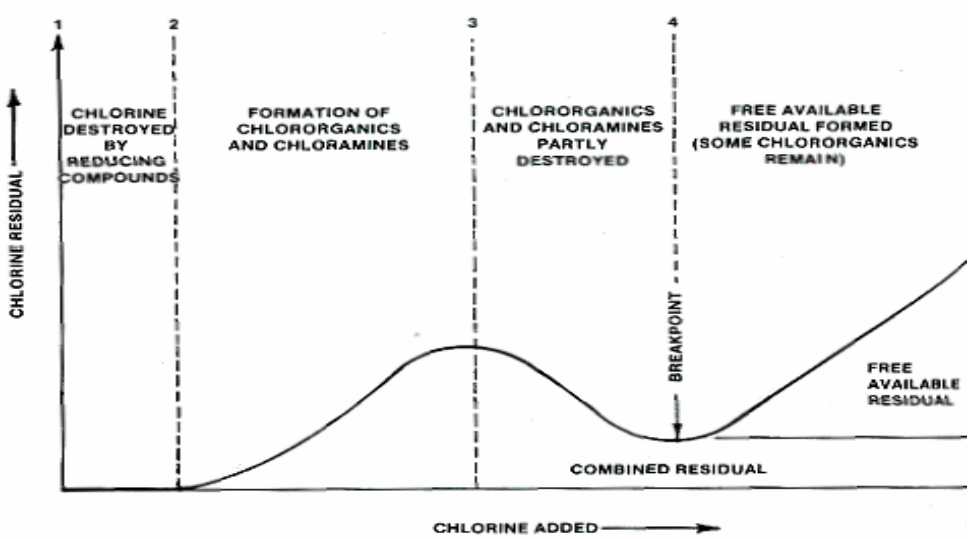
- Effective & economical
- It requires very little space.

Disadvantages:

- Excess of chlorine produces unpleasant odour&taste.
- Free chlorine should not exceed 0.1-0.2ppm
- It is more effective below 6.5 &less effective at higher PH values.

Break point chlorination or Dip point (Free residual chlorine):

- The addition of sufficient amount chlorine to oxidize Organic matter, reducing substances, free ammonia leaving behind free chlorine killing pathogenic bacteria is called break point chlorination.
- The addition of sufficient amount of chlorine to satisfy chlorine demand is called break point chlorination
- When a graph is drawn between the added chlorine to residual chlorine a dip or break is formed in the graph called break point chlorination.
- The addition of chlorine at the dip or break is called as Breakpoint chlorination. After this dip or break point chlorination, free residual chlorine is present.
- Usually all tastes and odors disappear at break point.
- **Advantages:** Break point chlorination gives idea of amount of chlorine required to add for chlorination
- It i) oxidizes completely organic matter, NH3 and reducing agents, ii) removes colours in water, iii) destroys completely all the disease producing bacteria, iv) removes odour from water, v) prevents if any growth of weeds in water.
- **Disadvantages:** If excess chlorine is added it leave residual or free chlorine which impart bad taste and odour
- Dechlorination must be done in order to remove free chlorine.
- **Dechlorination:** Dechlorination is done by passing SO2 &sodium sulphite.



d) By using chloramines

When chloramines are added into water they produce HOCl which act as germicide

Chloramines can be prepared by passing chlorine gas into ammonia chamber

Now a day's municipalities are using this process.

$$Cl_2+NH_3 \rightarrow NH_2Cl+HCl$$

$$NH_2Cl+H_2O \rightarrow HOCl + NH_3$$

e) Disinfection by ozone (OZONIZATION).

By sending raw water through ozonizer, where the nacent oxygen liberated from ozone act as a germicide and kills the microorganisms.Ozone is unstable so easily decomposes to

O3→O+O2

Disadvantages : Equipment is Expensive

Advantages: It removes chlorine odour (smell) taste etc.if ozone is in excess, it is not harmful.

Short answer questions.

1. Name the chief sources of water.
2. What are the different types of impurities present in water?
3. Distinguish between hard water and soft water?
4. Define hardness of water.
5. What are the different types of hardness?
6. What are the salts responsible for the temporary and permanent hardness of water?
7. How hardness is expressed?
8. Why do we express hardness in terms of $CaCO_3$ equivalents?
9. Mention common units used for expressing hardness of water.
10. Why is Calgon conditioning is better than Phosphate conditioning?
11. What is meant by softening of water?
12. What is the main advantage of reverse osmosis over ion exchange process?
13. What are the requisites for potable water?
14. What is sedimentation with coagulation?
15. What is meant by break point chlorination?
16. What are the advantages of break point chlorination?
17. What is electro dialysis and reverse osmosis?

1. Name the chief sources of water.

A) The chief sources of water are rain water, surface water, ground water& sea water.

2. What are the different types of impurities present in water?

A) Different types of impurities are

i) Dissolved impurities:

a) Inorganic salts

i) Cations: Ca^{+2},Mg^{+2}, Na^{+},K^{+},Fe^{+2}, Al^{+3} traces of Zn^{+2} etc
ii) anions: Cl^{-},SO_4^{2-}, NO_3^{-},HCO_3^{-}&sometimes F^{-} &NO_2^{-}
b) Gases: CO_2,O_2, N_2 oxides of N_2&sometimes NH_3,H_2S
c) Organic salts.

ii) Suspended impurities
a) Inorganic: Clay and sand
b) Organic: Oil globules, Vegetable and Animal matter

iii) Colloidal impurities: Finely divided Clay & Silica, Products from organic waste

iv) Bacterial impurities: Bacteria, other microorganisms and other forms of animal &vegetable life

3. Distinguish between hard water and soft water?

A) **Soft water-**which produces lather easily on shaking with soap due to absence of calcium and magnesium salts

Hard water- which doesn't produces lather (forms white curd) or very less lather difficultly with soap due to presence of Ca^{+2}& Mg^{+2}

4. Define hardness of water.

A) Hardness is defined as characteristic property of water that prevents the lathering of soap.

It is also defined as **soap consuming capacity of water.**

It is mainly due to the presence of calcium and magnesium ions, which react with sodium salts of long chain fatty acids present in the soap to form insoluble scums of calcium and magnesium soaps (don't have detergent value)

$2C_{17}H_{35}COONa + CaCl_2 \rightarrow (C_{17}H_{35}COO)_2 Ca + 2NaCl$

Sodium stearate — calcium stearate

Soap (soluble) — calcium soap (insoluble)

5. What are the different types of hardness?

A. There are two types of hardness

1. Temporary hardness or carbonate hardness

2. Permanent hardness or non carbonate hardness

Total Hardness = Temporary hardness + Permanent hardness

6. What are the salts responsible for the temporary and permanent hardness of water?

A.**Temporary hardness:** $Ca(HCO_3)_2$, $Mg(HCO_3)_2$

Due to presence of dissolved bicarbonates of Ca^{+2}& Mg^{+2}

It is removed by mere boiling of water.

$Ca(HCO_3)_2 \rightarrow CaCO_3\downarrow + H_2O + CO_2\uparrow$

$Mg(HCO_3)_2 \rightarrow Mg(OH)_2\downarrow + 2\,CO_2\uparrow$

Permanent hardness: $CaCl_2$, $MgCl_2$,$CaSO_4$,$MgSO_4$,$FeSO_4$,$Al_2(SO_4)_3$ etc

Due to presence of dissolved chlorides and sulphates (Cl^{-} & SO_4^{-2}) of Ca^{+2}& Mg^{+2}

It cannot be destroyed by boiling.

7. How hardness is expressed?

A. Generally the concentration of hardness of water is usually expressed in terms of equivalents of $CaCO_3$.

Equivalents of $CaCO_3$ = [Mass of hardness causing substance] x [Molecular weight of $CaCO_3$] / Molar mass of hardness causing substance

8. Why do we express hardness in terms of $CaCO_3$ equivalents?

Reason for choosing CaCO3: It is most insoluble salt that can be precipitated in water treatment.

This mode permits easy addition and subtraction of concentration of hardness causing constituents since its molecular weight is 100(equivalent mass=50).

9. Mention common units used for expressing hardness of water.

A. parts per million (ppm) or milligrams per liter (mg/L)

10. Why is Calgon conditioning is better than Phosphate conditioning?

A. In Calgon conditioning, the added calgon forms soluble complex compound with $CaSO_4$, thereby it prevents the scale and sludge formation in boiler. Since the complex formed is soluble, so it does not cause any problem to the boiler.

$2CaSO_4 + [Na_4(PO_3)_6]^{2-} \longrightarrow [Ca_2(PO_3)_6]^{2-} + 2\ Na_2SO_4$
Soluble complex

On the other hand, in phosphate conditioning, sodium phosphate is added to boiler water so that precipitate of calcium phosphate is formed. Although this precipitate is non adherent and soft yet it has to be removed by frequent blow down operation.

$3CaCl_2 + 2Na_3PO_4 \longrightarrow Ca_3(PO_4)_2 \downarrow + 6Nacl$
Sludge

Hence Calgon conditioning is better than Phosphate conditioning

11. What is meant by softening of water?

A. The process of removing hardness causing salts from water is called water softening.

12. What is the main advantage of reverse osmosis over ion exchange process?

A. Reverse osmosis removes all ionic, non ionic, colloidal and high molecular weight organic matter

13. What are the requisites for potable water?

A. Potable water: means the water which is safe to drink.

Essential requirements: The water should be

- clear
- Colorless and Odorless
- Pleasant in taste
- It should not have turbidity (not exceed 10 ppm)
- pH should be in the range of 7.0-8.5
- Free from gases like H_2S & minerals like Pb, As, Cr & Mn salts
- Total hardness should be less than 500 ppm
- Free from disease producing bacteria

14. What is sedimentation with coagulation?

A. The process of removing fine suspended and colloidal impurities by adding required amount of coagulant to water before sedimentation.

15. What is meant by break point chlorination?

A. It involves addition of sufficient amount chlorine to oxidize Organic matter, reducing substances, free ammonia leaving behind free chlorine killing pathogenic bacteria.

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A. It i) oxidizes completely organic matter, NH3 and reducing agents, ii) removes colours in water, iii) destroys completely all the disease producing bacteria, iv) removes odour from water, v) prevents if any growth of weeds in water.

17. What is electro dialysis and reverse osmosis?

A. **Electro dialysis:** A process in which the ions of the salts present in water are pulled out by passing direct current , using electrodes and a thin rigid plastic membrane pair.

Reverse osmosis: A process by which pure solvent is separated from its contaminants by using semi permeable membrane and applying high pressure on concentrated side.