

Water and It's Treatment

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1 Boiler Troubles:

The water fed into the boiler for the production of steam is called boiler feed water. Boiler feed water should be free from turbidity, oil, dissolved gases, alkali and hardness causing substances. Using hard water for boilers may result in :

- I. Formation of scale and sludge in boiler
- II. Priming and Foaming
- III. Caustic embrittlement
- IV. Boiler corrosion

BOILER TROUBLES (OR) DISADVANTAGES OF
USING HARD WATER IN BOILERS

Boiler-feed water should correspond with the following composition:

- Its hardness should be below 0.2 ppm.
- Its caustic alkalinity (due to OH⁻) should be between 0.15 and 0.45 ppm.
- Its soda alkalinity (due to Na₂CO₃) should be 0.45 – 1 ppm.

Specification of boiler feed water:

- I. Boiler feed water should have zero hardness.
- II. It must be free from dissolved gases like O₂, CO₂.
- III. It should be free from dissolved salts and alkalinity
- IV. It should be free from oil and turbidity.
- V. It should be free from suspended impurities.
- VI. It should be free from total dissolved solids.

1.1 Scale and Sludge formation

When hard water is boiled in the boiler to generate steam the water starts evaporating. The hardness causing salts are preset in the dissolved form. On evaporation of water the concentration of these dissolved salts increases. But at certain point the dissolved salt starts forming precipitate i.e. no further amount of salt can be dissolved. This is called saturation point. This precipitate has been divided into two forms based on their nature :

1.1.1 Sludge:

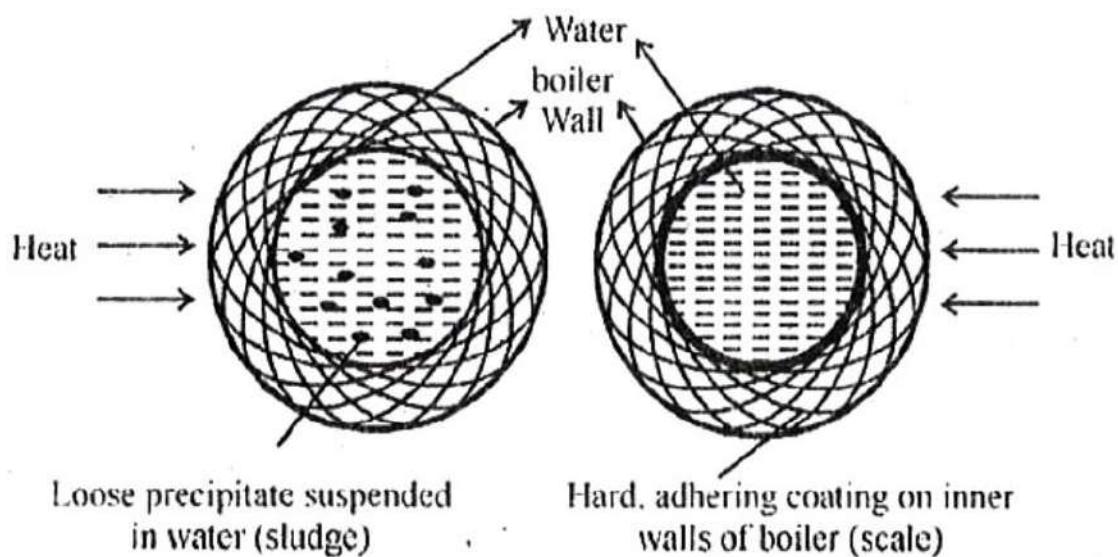
It's a soft, loose, slimy substance formed in cold water or relatively colder parts of the boiler. They are also formed at places where the flow of water is slow. They have high solubility in hot water thus they are collected at the parts where flow of water is slow.

Disadvantage: These are removable and poor conductors of electricity and light therefore causing choking of pipes.

Sludge's are formed by substances like MgCO₃, MgCl₂, MgSO₄ and CaCl₂.

Prevention of sludge formation:-

- i. By using softened water
- ii. By frequent 'blow-down operation' i.e. partial removal of concentrated water through a tap at the bottom of boiler, when extent of hardness in the boiler becomes alarmingly high and 'Make-up' water is addition of fresh softened water to boiler after blow down operation.



1.1.2 Scale:

Scales are hard deposits firmly sticking to the inner surfaces of the boiler. They are difficult to remove, even with the help of hammer and chisel, and are the main source of boiler troubles. Scales are formed by substances like $\text{Ca}(\text{HCO}_3)_2$, CaSO_4 and $\text{Mg}(\text{OH})_2$.

Disadvantages of Scale formation:

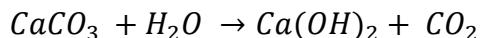
- i. Scales decrease the efficiency of the boiler: Rate of heat transfer is greatly reduced due to poor conductivity of scales. Overheating is required for steady supply of heat hence fuel consumption increases.
- ii. Deposition of scales in valves and condensers choke them partially & decreases the efficiency of boiler
- iii. Danger of Explosion: Due to uneven deposition of the thick scales results in formation of large steam & develops high pressure. It may cause explosion of boiler. When the scale cracks, water suddenly comes in contact with the overhead boiler metal. This causes the formation of a large amount of steam suddenly. So, sudden high pressure is developed, which may even cause the explosion of the boiler. (any crack developed on the scale leads to explosion.)

Scales are mainly formed by:

- i. Decomposition of Temporary Hardness like magnesium bicarbonate, calcium bicarbonate:-



However, scale composed chiefly of calcium carbonate is soft and is the main cause of scale formation in low-pressure boilers. But in high-pressure boilers, $CaCO_3$ is soluble due to the formation of $Ca(OH)_2$.



- ii. Deposition of calcium sulphate:- The solubility of $CaSO_4$ in water decreases with increase in temperature. $CaSO_4$ is soluble in cold water, but almost completely insoluble in super-heated water. It may be due to increase ionization at high temperature so $K_{sp} < K_{ionic\ product}$ and less availability of water molecules for solvation at high temperature. Consequently, $CaSO_4$ gets precipitated as hard scale on the hotter parts, of the boiler. This type of scale causes troubles mainly in high pressure boilers. Calcium sulphate scale is quite adherent and difficult to remove, even with the help of hammer and chisel.
- iii. Hydrolysis of magnesium salts:- Dissolved magnesium salts get hydrolyzed at prevailing high temperature inside the boiler, forming magnesium hydroxide precipitate, which forms a soft type of scale, e.g.
$$MgCl_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HCl$$
- iv. presence of silica:- Even if a small quantity of SiO_2 is present, it may deposit as calcium silicate ($CaSiO_3$) and / or magnesium silicate ($MgSiO_3$). These deposits adhere very firmly on the inner side of the boiler surface and are very difficult to remove. One important source of silica in water is the sand filter.

Removal of scale from Boiler:

- i. At the initial stage, scales can be removed using scraper, wire brush etc. Loosely adhering scales are removed with the help Scraper/wire brush.
- ii. If scales are brittle, they can be removed by thermal shocks
- iii. Loosely adhering scales are removed by frequent blow down operation (frequently removing precipitates)
- iv. Adherent & hard scales are removed by dissolving them by adding chemicals
 $CaCO_3$ scales - 5-10% HCl $CaSO_4$ scales – EDTA

Differences between Sludge and Scale :

S.No.	Scale	Sludge
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1.	Scale is a hard, adherent coating	Sludge is a loose, slimy and non-adherent precipitate
2.	The main scale forming substances are $\text{Ca}(\text{HCO}_3)_2$, CaSO_4 , $\text{Mg}(\text{OH})_2$	The main sludge forming substances are MgCO_3 , MgCl_2 , MgSO_4 and CaCl_2 etc
3	Disadvantages: Scales act as thermal insulators. It decreases the efficiency of boiler. Any crack developed on the scale, leads to explosion.	Disadvantages: Sludge's are poor conductors of heat. Excess of sludge formation decreases the efficiency of boiler.
4	Prevention (i) Scale formation can be prevented by dissolving using acids like HCl , H_2SO_4 (ii) Scale formation can be removed by (a)External treatment. (b)Internal treatment. (iii) They can also be removed by applying thermal shocks, scrapers, wire brush, etc.	Prevention (i)Sludge formation can be prevented by using softened water. (ii)Sludge's can also be removed by blow-down operation. (iii) Blow-down operation is a process of removing a portion of concentrated water by fresh water frequently from the boiler during steam production.

1.2 Priming and Foaming

Priming:

During the production of steam in boilers, some water droplets get carried away along with the steam. This process where the steam contains water droplet along (Wet steam formation) is called *priming*.

Wet steam = Steam + Water Drops

These droplets of liquid water carry with them some dissolved salts and suspended impurities to super heater and turbine blades, where they get deposited as water evaporates. This deposit decreases the efficiency of boiler. This phenomenon is called carry over. It occurs due to priming and foaming. The moisture contained in the steam is expressed in *percentage by weight of steam*.

Causes of Priming:

- i. High steam velocity, enough to carry droplets of water into the steam pipe.
- ii. Very high-water level in the boiler.
- iii. Sudden boiling of water.
- iv. Faulty design of boiler

Prevention:

- i. Maintaining low water levels
- ii. Using softened/treated water
- iii. Fitting mechanical steam purifiers.

- iv. Using well designed boiler
- v. Blowing off any sludge or scale formation regularly.

Foaming:

Foaming is the production of persistent foam or bubbles in boilers, which do not break easily. Foaming occurs due to presence of substance which reduce the surface tension of water; for eg oils and alkalis. These impurities increase the foaming tendency of the liquid. Due to foaming the maintenance of the boiler becomes difficult because of improper judgment of actual height of water column.

Foaming can be avoided by:

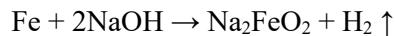
- i. The addition of anti-foaming agents like castor oil which spreads on the surface of water and therefore neutralizes the surface tension reduction.
- ii. The removal of foaming agent like oil from boiler water by using coagulants (eg sodium aluminate) which entrap oil drops.

1.3 Caustic Embrittlement

Caustic embrittlement is a type of boiler corrosion, caused by highly alkaline water in the boilers. Caustic embrittlement means intercrystalline cracking of boiler metal. During the softening of water by lime soda process free Na_2CO_3 is present in small proportions in the softened water. Na_2CO_3 decomposes in the presence of high pressure within the boilers to produce sodium hydroxide and carbon dioxide, this results in making the boiler water caustic. The caustic water reaches the minor hairline cracks within the boiler through capillary action.



The water evaporates leaving behind caustic soda , whose concentration increases progressively. The caustic soda is responsible for attacking the surrounding of boiler by dissolving iron of boiler as sodium ferrate. This causes embrittlement of stressed boiler parts; namely bends, joints, rivets, Causing even failure of boiler



Prevention

Caustic embrittlement can be prevented by

- i. Using sodium phosphate as softening agent instead of sodium carbonate.
- ii. By adding tannin, lignin to the boiler water, which blocks the hair cracks.

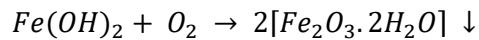
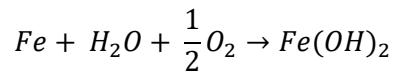
1.4 Boiler Corrosion

Boiler corrosion is “decay” or “disintegration” of boiler material either by chemical or by electrochemical reactions with its environment. Corrosion in boilers occurs chiefly due to the presence of :

- i. Dissolved oxygen.
- ii. Dissolved carbon dioxide.
- iii. Dissolved salts.

- I. **Dissolved Oxygen:** This is the most usual corrosion causing factor. In Boilers, oxygen is introduced through the raw water supply. Water usually contains about 8 ppm of dissolved

oxygen at room temp. As the water is heated, the dissolved oxygen is set free and the boiler starts corroding. Dissolved oxygen reacts with the iron of boiler in presence of water and under prevailing high temperature to form ferric oxide (rust).



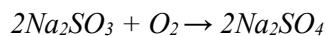
RUST

Removal of dissolved oxygen

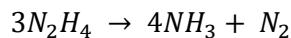
Dissolved oxygen can be removed by chemical (or) mechanical methods.

(a) Chemical method

Sodium sulphite, hydrazine are some of the chemicals used for removing dissolved oxygen.



Hydrazine is an ideal chemical for the removal of dissolved oxygen. It reacts with oxygen, forming nitrogen and water. Nitrogen is harmless. Consequently, hydrazine removes oxygen without increasing the conc. of dissolved solids/salts. Pure hydrazine is not used in water treatment because it is an explosive inflammable liquid so 40% aqueous solution of hydrazine is used which is quite safe. Excess hydrazine must not be used because excess of it decomposes to give NH₃, which causes corrosion of some alloys like brass etc. used in condenser tubes.



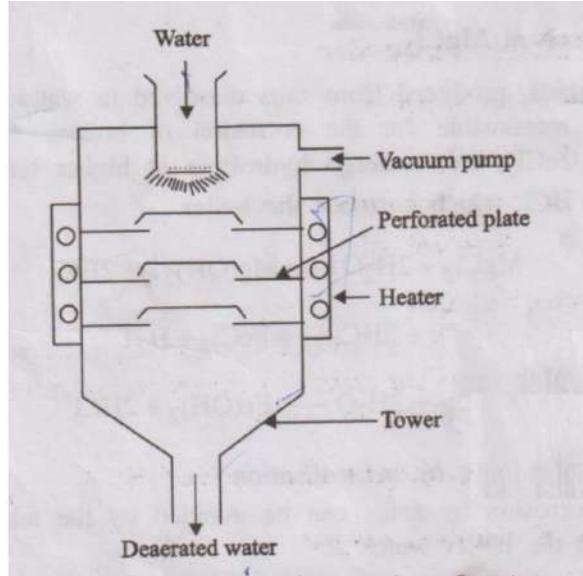
On the other hand, if sodium sulphite or sodium sulphide is used, the sodium sulphate is formed. Under high pressure it decomposes giving SO₂. The SO₂ enters the steam pipes and appears as corrosive sulphurous acid (H₂SO₃) in steam condensate. So as a rule, a very low concentration of 5-10 ppm of Na₂SO₃ in the boiler is maintained, rather adding it intermittently.

(b) Mechanical de-aeration

Dissolved oxygen can also be removed from water by mechanical deaeration.

This process consists of spraying water over preheated perforated plates stacked in a degasifier. Removal of dissolved O₂ is ensured by applying high temperature and vacuum.

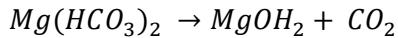
The high temperature and low pressure produced inside the tower reduce the dissolved oxygen content of the water.



Mechanical Degaeration Of Water

II. Dissolved Carbon Dioxide:

There are two sources of CO₂ in boiler water, viz. dissolved CO₂ in raw water and CO₂ is formed by decomposition of bicarbonates in H₂O.

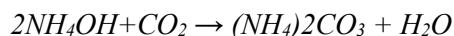


Dissolved carbon dioxide in water also produces carbonic acid, which is acidic and corrosive in nature



Removal of dissolved Carbon dioxide

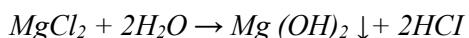
(a) Carbon dioxide can be removed from water by adding a calculated amount of NH₄OH into water.



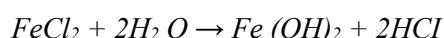
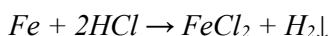
(b) Carbon dioxide along with oxygen can also be removed mechanically by de-aeration method.

III. Dissolved MgCl₂

Acids, produced from salts dissolved in water, are also mainly responsible for the corrosion of boilers. Salts like MgCl₂, CaCl₂, etc., undergo hydrolysis at higher temperature to give HCl, which corrodes the boiler. Magnesium chloride, if present in boiler feed water, can undergo hydrolysis producing HCl.



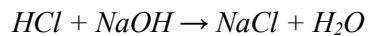
The liberated acid reacts with iron material of the boiler to form ferrous hydroxide which in turn is converted to rust in the following way:



Thus, a small amount of HCl may cause extensive corrosion since HCl is produced in a chain-like manner. Consequently, presence of even a small amount of MgCl₂ causes corrosion of iron to a large extent. As the boiler water is generally alkaline and hence the acid is usually neutralized. In case the amount of acid is more, calculated quantity of alkali is added from outside to neutralize the acid for preventing this corrosion.

Removal of acids by neutralization

Corrosion by acids can be avoided by the addition of alkali to the boiler water.

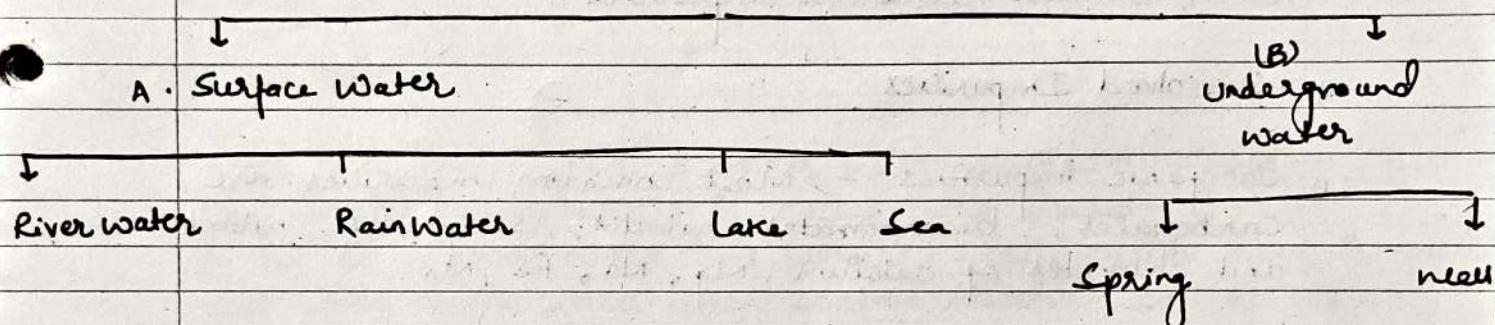


WATER

Water is one of the most abundantly available and most useful resource. It covers nearly $\frac{3}{4}$ th of Earth's crust. Water is essential because it's the basis of survival.

- Engineering use -
 - steam generation
 - coolant
 - production: textile, chemical, paper.

* Sources of water



- Rain water is one of the purest form of water. Because it's obtained as a result of evaporation. During the journey downwards it dissolves industrial gases.

A. SURFACE WATER

- (a) River Water : Rivers are fed by rain and spring water. Water flows over the surface of land and dissolve mineral and sediments.
- (b) Lake water : It has more constant chemical composition. It has more constant organic matter deposition and less mineral.
- (c) Sea Water : Most impure form of natural water. It contains dissolved salts.

- B. Underground Water - A part of the rainwater that reaches the surface of earth, percolates down into the earth. As it reaches into the earth it gets dissolved by mineral salts. Water continues downward until it reaches a hard rock, which doesn't allow further penetration - the water stream retreats upward and results in a spring.

Usually the underground water is more clearer because the water is filtered by the action of soil.

* COMMON IMPURITIES IN WATER

Water is a universal solvent:

water is great solvent as it is and when it acquires acidity or alkalinity by atmospheric gases or earth oxides its dissolving power increases.

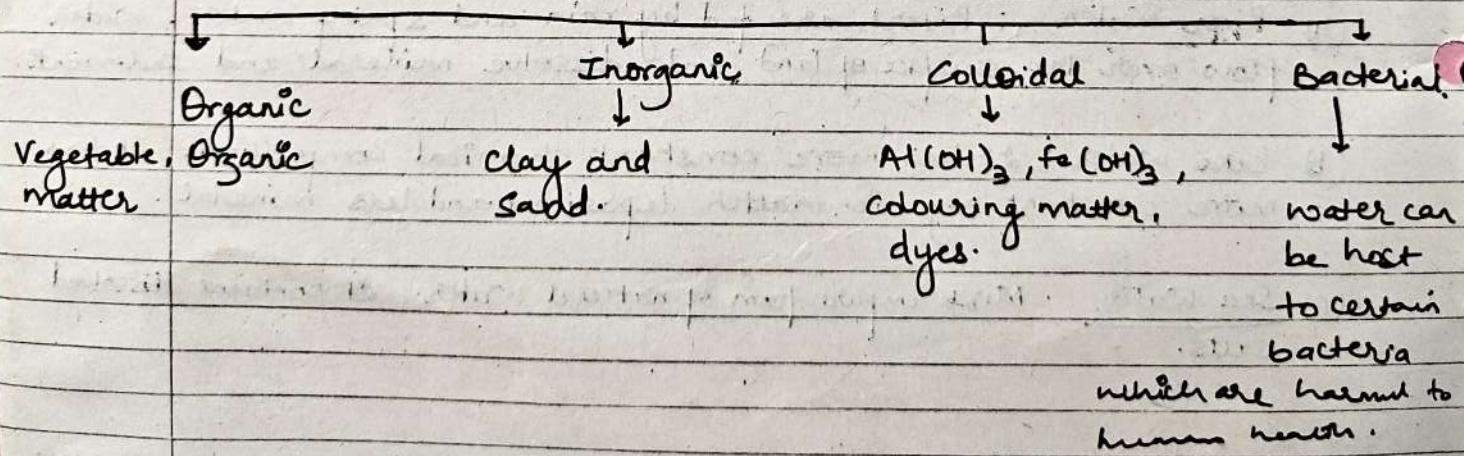
Water contains numerous impurities:

a) Dissolved Impurities

(i) Inorganic impurities - Most common impurities are carbonates, bicarbonates, nitrates, sulphates, nitrates and chlorides of calcium, Mg, Na, Fe, Mn.

(ii) Water is good solvent for gases such as CO_2 , SO_2 , H_2S , NH_3 and oxides of Nitrogen.

(b) Suspended Impurities



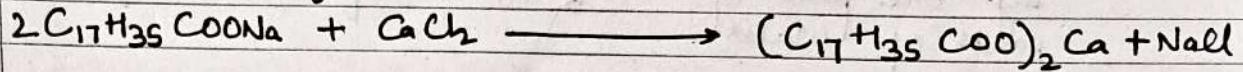
* HARDNESS OF WATER

Hardness in water is that characteristic which prevents the lathering of soap. This is due to the presence in water of certain salts of calcium, Mg and other heavy metals dissolved in it.

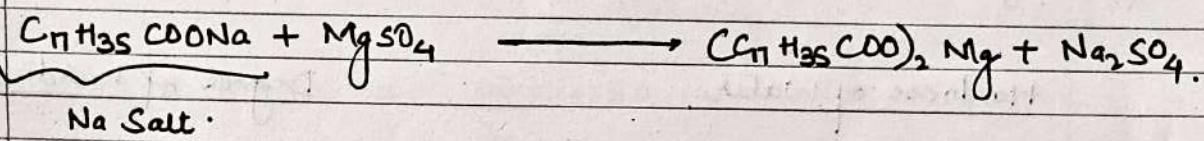
Carboxylic acid with long aliphatic chain which can be saturated or unsaturated.

A sample of hard water when treated with Na/K salts of high fatty acids does not produce lather, but on other hand produces "scum" / precipitate. This precipitate is formed due to formation of insoluble salts of Ca and Mg. The reactions that occur are :

* Soap : Na/K salt + fatty acids.



Sodium Stearate
(Na Salt).



Water that doesn't produce lather with soap form readily; but form white curdy water is called hard water.

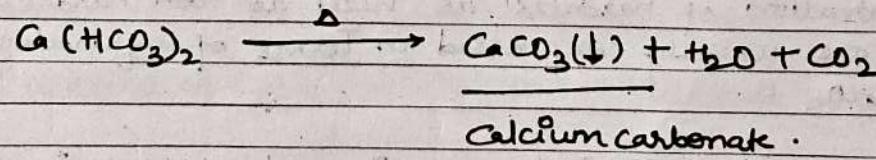
On the other hand water that lathers easily with soap is called soft water. Such water doesn't contain dissolved salt of Ca + Mg.

Now, hardness can be of 2 types :

Temporary hardness

Permanent hardness

(i) Temporary hardness - It's caused by dissolved bicarbonates of Ca, Mg and other heavy metals and CO_3^{2-} of Iron. These can be destroyed by boiling. On boiling, bicarbonates are dissolved decomposed, yielding insoluble carbonates or hydrates which are deposited as crust at bottom of vessel.



(ii) Permanent hardness : It's due to dissolved salts of Cl^- , SO_4^{2-} , NO_3^- of Ca and Mg. This can't be treated on boiling. To remove permanent hardness chemical treatment methods are used.

* Degree of hardness - The hardness of water depends on the amount of calcium and Mg salts present in it. If a sample contains "n" parts of CaCO_3 equiv. per $\frac{1000000}{(\text{million})}$ parts, it possess "n" degree of hardness.

Therefore one degree of hardness is the hardness caused by one part of CaCO_3 or its equivalent in one million parts of water.

The following table shows the reference values for degree of hardness usually ppm.

Hardness of Water

Degree of hardness (ppm)

Soft Water

0-10

Medium hard water

10-20

Hard water

20-30

Very hard water

above 30.

$$\frac{\text{mass of } \text{CaCO}_3}{\text{mass of water}} \times 10^6 \text{ million}$$

Hardness : Equivalent of CaCO_3 . The reason is, it's insoluble in water and doesn't contribute to hardness.

The other is its molecular wt 100 and eq. wt is 50, so for easier calculation.

EQUIVALENT OF CaCO_3

Concentration of hardness as well as non hardness constituents are usually expressed in terms of equivalent amount of CaCO_3 .

The choice of CaCO_3 is because its molecular wt is 100 and its the most insoluble salt that can be participated in water treatment.

Equivalent of CaCO_3 = $\frac{[\text{Mass of hardness producing substance}]}{[\text{Chemical eqv of } \text{CaCO}_3]}$

chemical equivalent of hardness producing substances.

* Chemical eqv of CaCO_3 = 50

Equivalent wt = $\frac{\text{Atomic wt / molecular wt}}{\text{Valency}}$

$$= \frac{100}{2} = 50$$

Hardness of water is represented by the equivalent of CaCO_3 in water.

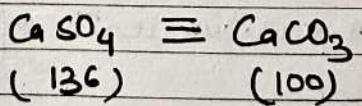
When compared with other material causing hardness it can be represented as following.



$$162 = 100$$

$$x \text{ amount of } \text{Ca}(\text{HCO}_3)_2 = x \cdot \frac{100}{162} \text{ amount of } \text{CaCO}_3.$$

Similarly,



$$(136) \quad (100)$$

$$y \text{ amount of } \text{CaSO}_4 = y \cdot \frac{100}{136} \text{ amount of } \text{CaCO}_3.$$

Similarly, weights of CaCl_2 , MgSO_4 , $\text{Mg}(\text{HCO}_3)_2$ & MgCl_2 actually +wt may be converted in terms of CaCO_3 by multiplying $100/111$, $100/120$, $100/146$ & $100/95$ respectively.

* UNIT OF HARDNESS

(i) Parts per million : It's defined as number of parts by weight of calcium carbonate equivalent present in per million ($10,00,000$) parts by weight of water.

$$1 \text{ PPM} = 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness in } 10^6 \text{ parts of H.O.}$$

(ii) Miligrams per litre (mg/L) - In miligrams per litre the hardness of water is defined as the number of miligram of CaCO_3 equivalent present in litre of water. Thus

$$1 \text{ mg/litre} = 1 \text{ mg of } \text{CaCO}_3 \text{ equivalent in } 1 \text{ L of water.}$$

(iii) Degree french (${}^\circ\text{fr}$) : No. of parts by weight of CaCO_3 equivalent in $100000 (10^5)$ parts weight of water.

$$1 {}^\circ\text{fr} = 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness per } 10^5 \text{ parts of H.O.}$$

(iv) Degree Clark (${}^\circ\text{Cl}$) : This is British system of representing hardness. It's defined as number of grains ($1/700 \text{ lb}$) of CaCO_3 equivalent present in per imperial Gallon ($70,000$ grains or 10 lb) of water.

$$1 {}^\circ\text{Cl} = 1 \text{ grain of } \text{CaCO}_3 \text{ equivalent hardness per gallon of water.}$$

* Relationship between various units of hardness

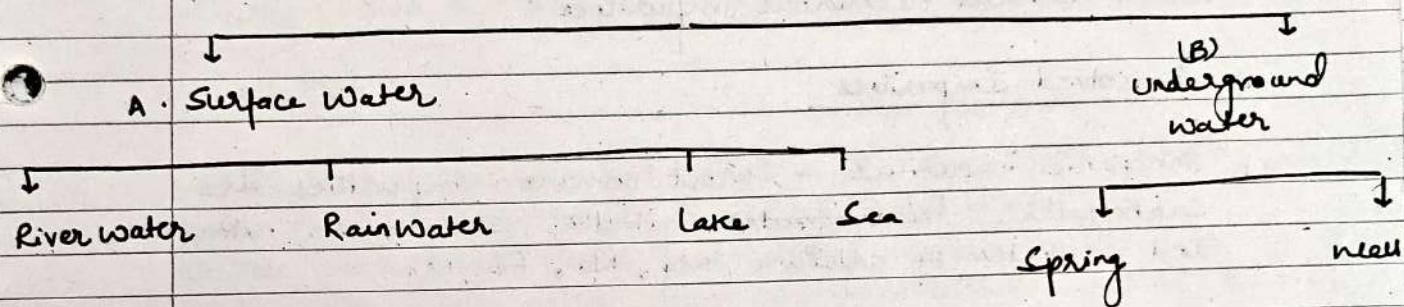
Units	PPM	mg/L	°F	°Cl
PPM	1	1	0.1	0.07
mg/L	1	1	0.1	0.07
°F	10	10	1	0.7
°Cl	14.3	14.3	1.43	1

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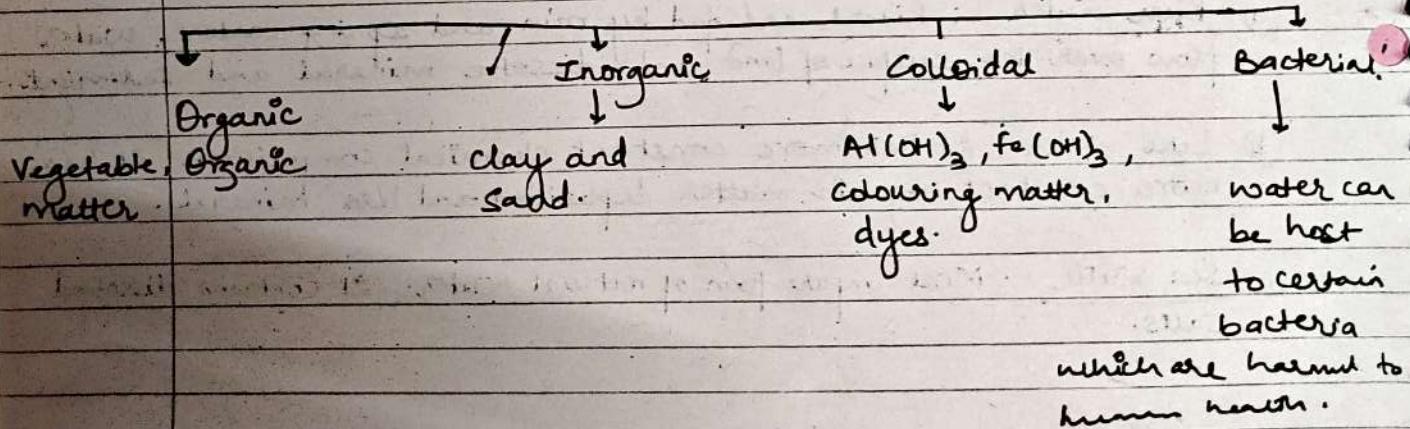
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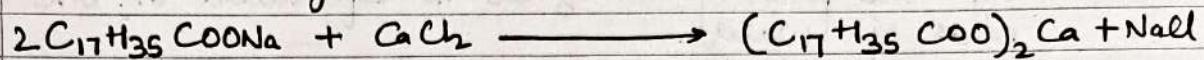
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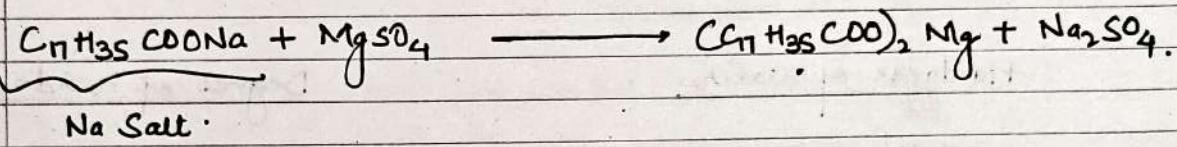
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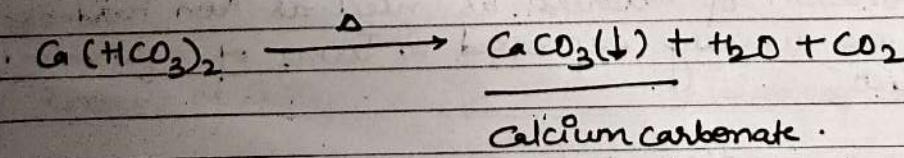
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(ii) Permanent Hardness : It's due to dissolved salts of Cl^- , SO_4^{2-} , NO_3^- of Ca and Mg. This can't be treated on boiling. To remove permanent hardness chemical treatment methods are used.

* Degree of hardness - The hardness of water depends on the amount of calcium and Mg salts present in it. If a sample contains "n" parts of CaCO_3 equiv. per 1000000 parts, it possesses "n" degree of hardness.

Therefore one degree of hardness is the hardness caused by one part of CaCO_3 or its equivalent in one million parts of water.

The following table shows the reference values for degree of hardness usually ppm.

Hardness of Water

Degree of hardness (ppm)

Soft Water

0-10

Medium hard water

10-20

Hard water

20-30

Very hard water

above 30.

$$\frac{\text{mass of } \text{CaCO}_3}{\text{mass of water}} \times 10^6 \text{ million}$$

Hardness : Equivalent of CaCO_3 . The reason is, its insoluble in water and doesn't contribute to hardness. The other is its molecular wt 100 and eq wt is 50, so for easier calculation.

EQUIVALENT OF CaCO_3

Concentration of hardness as well as non hardness constituting ions are usually expressed in terms of equivalent amounts of CaCO_3 .

The choice of CaCO_3 is because its molecular wt is 100 and its the most insoluble salt that can be participated in water treatment.

$$\text{Equivalent of } \text{CaCO}_3 = \left[\frac{\text{Mass of hardness producing substance}}{\text{Chemical eqv of CaCO}_3} \right] \times \left[\frac{\text{Chemical eqv of CaCO}_3}{\text{Valency of CaCO}_3} \right]$$

chemical equivalent of hardness producing substance.

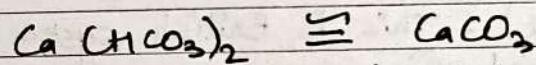
* Chemical eqv of $\text{CaCO}_3 = 50$

$$\text{Equivalent wt} = \frac{\text{Atomic wt / molecular wt}}{\text{Valency}}$$

$$= \frac{100}{2} = 50$$

Hardness of water is represented by the equivalent of CaCO_3 in water.

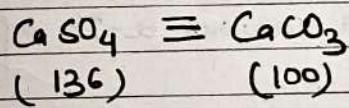
When compared with other material causing hardness it can be represented as following.



$$162 = 100$$

$$x \text{ amount of } \text{Ca}(\text{HCO}_3)_2 = x \cdot \frac{100}{162} \text{ amount of } \text{CaCO}_3.$$

Similarly,



$$(136) \quad (100)$$

$$Y \text{. amount of } \text{CaSO}_4 = Y \cdot \frac{100}{136} \text{ amount of } \text{CaCO}_3.$$

Similarly, weights of CaCl_2 , MgSO_4 , $\text{Mg}(\text{HCO}_3)_2$ & MgCl_2 actually +ve may be converted in terms of CaCO_3 by multiplying $100/111$, $100/120$, $100/146$ & $100/95$ respectively.

* UNIT OF HARDNESS

(i) Parts per million : It's defined as number of parts by weight of calcium carbonate equivalent present in per million ($10,00,000$) parts by weight of water.

$$1 \text{ PPM} = 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness in } 10^6 \text{ parts of water.}$$

(ii) Milligrams per litre (mg/L) - In milligrams per litre the hardness of water is defined as the number of milligram of CaCO_3 equivalent present in litre of water. Thus

$$1 \text{ mg/litre} = 1 \text{ mg of } \text{CaCO}_3 \text{ equivalent in } 1 \text{ L of water.}$$

(iii) Degree french (${}^{\circ}\text{fr}$) : No. of parts by weight of CaCO_3 equivalent in 1000.00 (10^5) parts weight of water.

$$1 {}^{\circ}\text{fr} = 1 \text{ part of } \text{CaCO}_3 \text{ equivalent hardness per } 10^5 \text{ parts of water.}$$

(iv) Degree Clark (${}^{\circ}\text{Cl}$) : This is British system of representing hardness. It's defined as number of grains ($1/700\text{lb}$) of CaCO_3 equivalent present in per imperial gallon. ($70,000$ grains or 10^6) of water.

$$1 {}^{\circ}\text{Cl} = 1 \text{ grain of } \text{CaCO}_3 \text{ equivalent hardness per gallon of water.}$$

* Relationship between various units of hardness

Units	PPM	mg/L	°F	°Cl
PPM	1	1	0.1	0.07
mg/L	1	1	0.1	0.07
°F	10	10	1	0.7
°Cl	14.3	14.3	1.43	1

* DETERMINATION OF HARDNESS BY COMPLEXOMETRIC TITRATION
 (EDTA method).

Hardness in water is represented by CaCO_3 ppm equivalent. The EDTA method is based upon a complexometric titration method. Here, Complexometric reaction of $\text{Ca}^{2+}/\text{Mg}^{2+}$ with Na salt of EDTA is carried out.

Cations like Ni, Cd, Cu, Fe, Al, Ba and Sr interfere in the determination, and thus it's important to mask them. Certain inhibitors are used to mask their trace.

Inhibitors used : Sodium cyanide, Sodium sulphide, hydroxylamine.

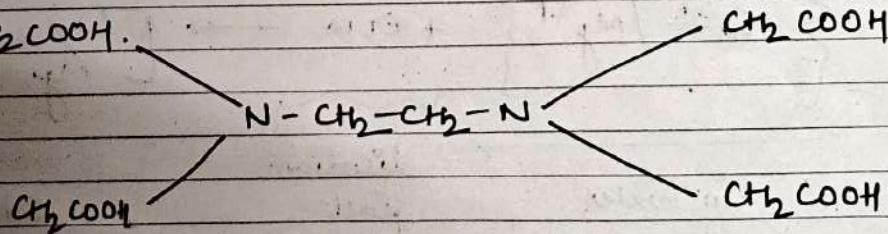
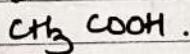
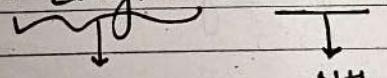
- * All the soln get deteriorated so they should be stored carefully.
- * If there's a dull end point - it may be due to absence of proper inhibitor or old indicator soln.

- pH sensitive method. Range to be maintained $\rightarrow 10-10.01$.
- Temperature : @ room temperature.

why?

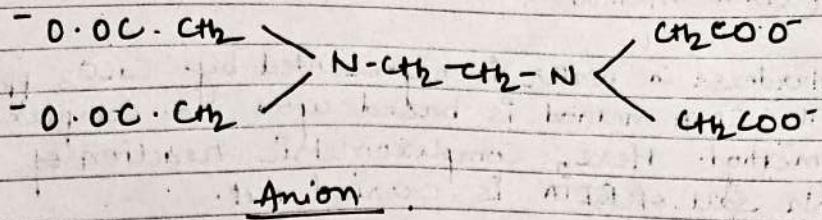
Indicator gets decomposed @ higher temperature

EDTA \rightarrow Ethylenediamine Tetraacetic Acid.

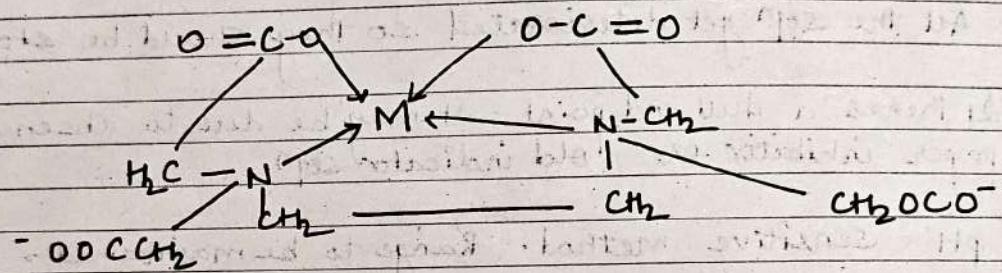


EDTA.

EDTA in the form of Sodium salt yields anion

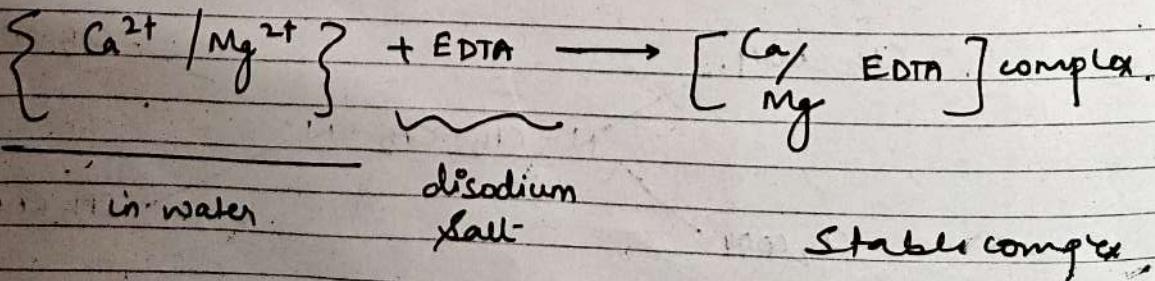


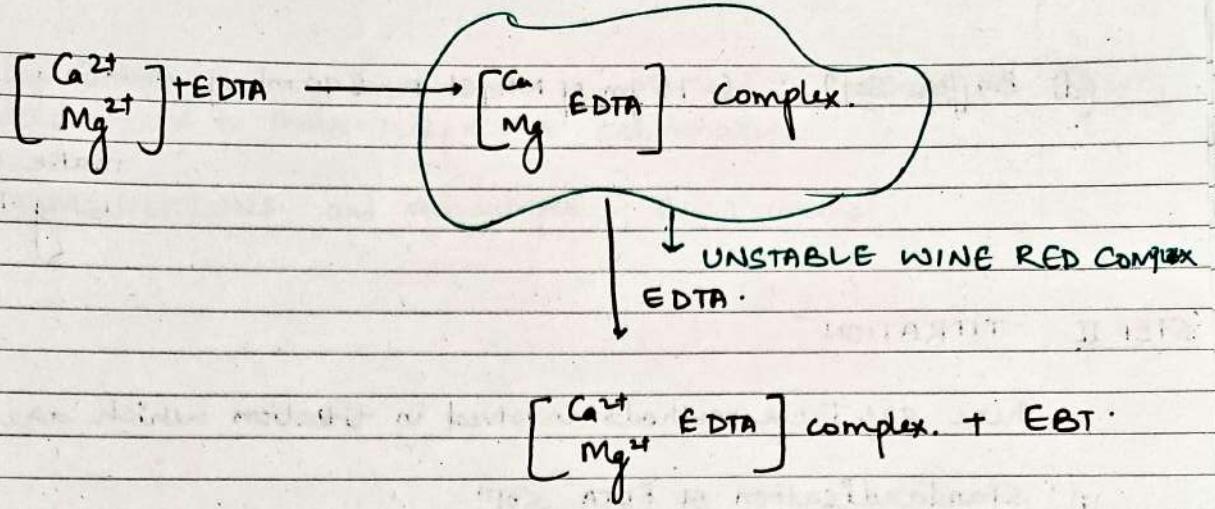
This anion forms complex ion with $\text{Mg}^{2+}/\text{Ca}^{2+}$



$$\text{M} = \text{Ca}, \text{Mg}$$

The titration is carried out in the presence of indicator ERIOCHROME BLACK-T. The indicator when added in small amount to hard water, buffered to a pH value of 10, combines with a few $\text{Ca}^{2+}, \text{Mg}^{2+}$ ions to form weak complexes of WINE RED colour, which changes to blue when an excess drop of EDTA is added.





* Wine red → Blue colour : end point

* Steps of Titration

(i) Preparation of standard hard water - Dissolve 1gm of pure dry CaCO_3 in minimum quantity of dilute HCl and then evaporate the soln to dryness on a water bath. Dissolve the residue.

1 gm of CaCO_3 + dil HCl (min quantity) → China dish

Dissolve residue in DW ← evaporated to dryness (1L)*

* Take minimum water to dissolve and then make up the volm to 1L.

(b) Preparation of EDTA soln

3.7gm of EDTA + 0.1 gm of MgCl_2 → dissolve in water

↓
make upto 1L.

(c) Preparation of Indicator : (EBT)

Eriochrome Black - T.

0.5gm EBT + 100 ml. alcohol

(d) Buffer soln : 6.75 gm of NH_4Cl + 570 ml. of Ammonia soln
↓
make up 1L
using DW.

STEP II TITRATION

There are three methods involved in titration which are :

- Standardisation of EDTA soln
- Estimation of total hardness
- " permanent hardness.

a) Standardisation of EDTA soln

50ml std hard water (conical flask) + 4-5 drop of EBT + 10-15 ml of pH Buffer.

↓
Titrate this whole soln against EDTA

From red colour \rightarrow deep blue colour (End point).

Voln of EDTA — V_1 .

b) Estimation of Total Hardness. (Here value of V_2 will be calc.)

50ml hard water titrated against std EDTA soln. Indicator and buffer are also used.
The voln of EDTA will be V_2 .

c) Estimation of permanent hardness

50ml of hard water \rightarrow boiled for 15 minutes \rightarrow filter \rightarrow dilute it with distilled water to make the voln 50ml.

Titrate the whole soln against EDTA - V_3 .

By boiling, any bicarbonate of Mg and Ca would have been decomposed to their respective carbonates.

* CALCULATIONS and Advantages of EDTA method.

* Municipal Water Supply

Municipal water supply has to be essentially made potable and safe to drink. Potable water should satisfy the following conditions.

- i) Colourless
- ii) odourless
- iii) The temp of water should be cold.
- iv) free from toxic substances
- v) Optimum pH
- vi) free from disease producing bacteria
- vii) Fluoride content should be less than 15 ppm.
- viii) Total dissolved solids should be less than 500 ppm
- ix) free from harmful gases
- x) Turbidity shouldn't exceed 10 ppm.

- Purification of water for domestic use

Natural water from rivers or canals does not confirm to all required specification of drinking water. Different impurities require different form of treatment methods.

↓
Removal of suspended
impurities

↓
Removal of
microorganism

(A) Removal of Suspended Impurities

The treatment method adopted depends on the nature of impurities present in raw water.

- | | | | |
|-------------------|---|------|-------------------------|
| I. Screening | } | SSF. | — floating materials |
| II. Sedimentation | | | — suspended impurities |
| III. filtration | | | — colloidal impurities. |

I. SCREENING - The raw water is passed through a screen having large number of holes. The floating material are retained by them.

II. SEDIMENTATION - It's a process where water is allowed to stand still / undisturbed in huge tanks about 5m deep. Most of the suspended material settle down at bottom due to gravity. Most of the suspended material settle down at the bottom due to. The clear supernatant fluid is then drawn from tank with the help of pumps. Retention period is 2-6 hours.

Sedimentation can be further classified in two types :-

- Plain Sedimentation
- Sedimentation with coagulants

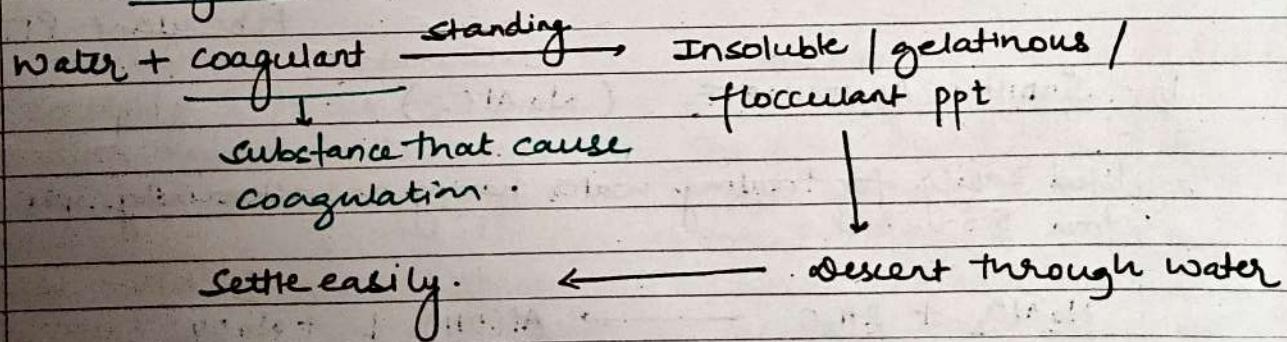
(i) PLAIN SEDIMENTATION - It's the process where which requires retention of water for a certain amount of time in a tank or to flow quietly at velocities.

Softer particles heavier than water tend to settle down with gravitational force. The tanks are usually 5m deep. Retention period may vary from hours to days. Plain sedimentation makes the treatment of water easier for subsequent process.

(ii) Sedimentation with Coagulation → The process of changing to semisolid.

When water contains fine clay particles and colloidal matter it becomes necessary to apply sedimentation with coagulation for removing such impurities.

Sedimentation with coagulation is the process of removing fine suspended and colloidal matter by addⁿ of requisite chemical called coagulant before sedimentation.

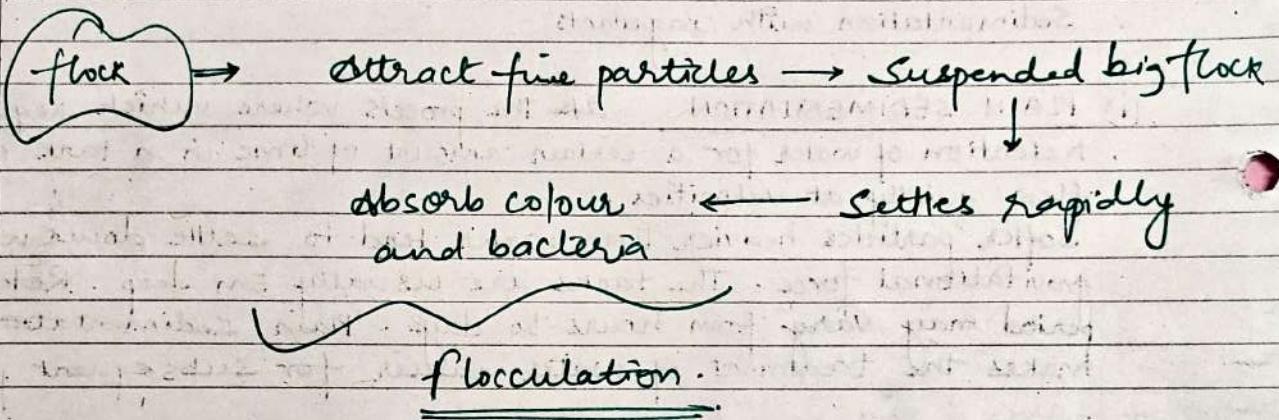


Coagulant when added to water forms an insoluble gelatinous, flocculant precipitate which descent through the water, absorb and entangle very fine suspended impurities forming bigger flocs which settle down easily.

COAGULANT + ALKALINE SALTS \longrightarrow FLOCK

{ loosely
clumped
mass of fine
particles }

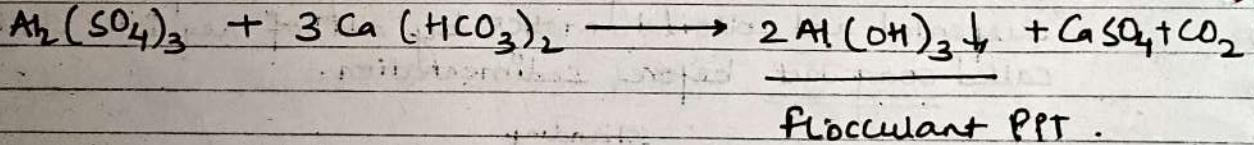
Flock : flock has a property of attracting fine suspended particles to form big flock which settles relatively rapidly by absorbing colour and carrying bacteria. This process is called flocculation.



COMMONLY USED COAGULANTS

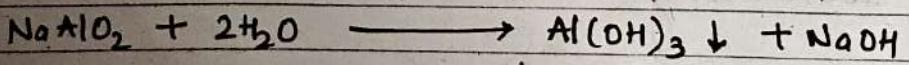
a) ALUM $[K_2(SO_4) \cdot Al_2(SO_4)_3 \cdot 24H_2O]$

widely used in water treatment plants. Alum reacts in water in the presence of alkalinity of water.



b) SODIUM ALUMINATE ($NaAlO_2$)

Used easily for treating water having no alkalinity. pH ranges from 5.5 to 8.0

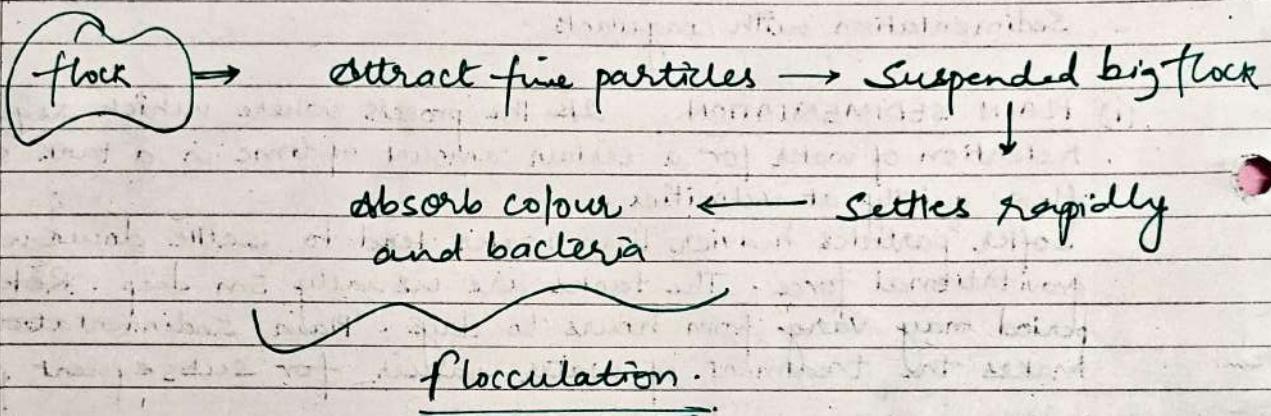


$\underbrace{\hspace{10em}}$
gelatinous floc of aluminium hydroxide.

COAGULANT + ALKALINE SALTS \longrightarrow FLOCK

{ loosely
clumped
mass of fine
particles }

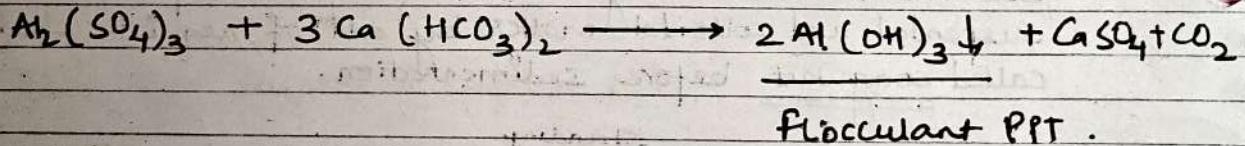
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COMMONLY USED COAGULANTS

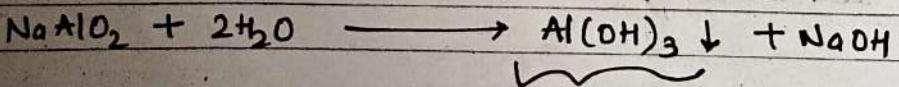
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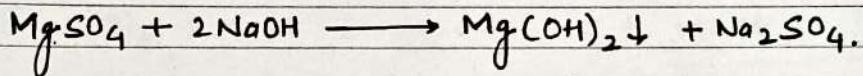
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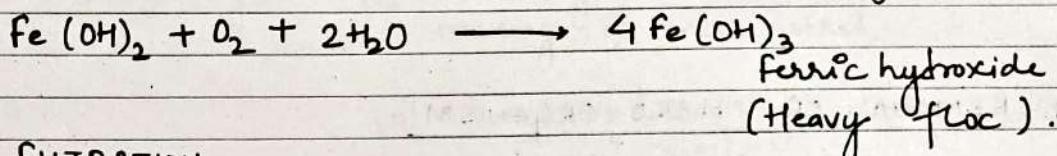
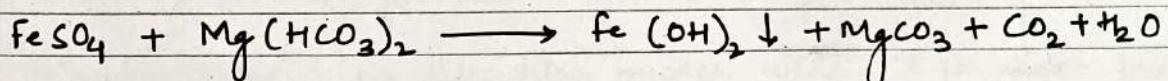
$\underbrace{\hspace{10em}}$
gelatinous floc of aluminium hydroxide.

- Aluminium hydroxide $[Al(OH)_3]$ floc causes sedimentation.
- NaOH precipitates magnesium salts as $Mg(OH)_2$.



c) Ferrous Sulphate ($FeSO_4 \cdot 7H_2O$)

Responsible for good results over pH 8.



III FILTRATION

Sedimentation with or without coagulation does not make water free from suspended matter and bacteria. A clear water is obtained by further treatment of filtration. Filtration removes almost all suspended matter. Filters are divided into 2 subclasses:

a) Gravity Sand filter

b) Pressure filter.

FILTERS

GRAVITY SAND FILTER

Carried out in large tank - rectangular in shape consisting of porous medium known as filter medium which retains solid particles but allow the passage of water.

Common filter media: fine sand at top and coarse sand below. Gravel @ bottom to depth of 1-2 meters. Water from sedimentation tank comes at top of filter plant and seeps through layers.

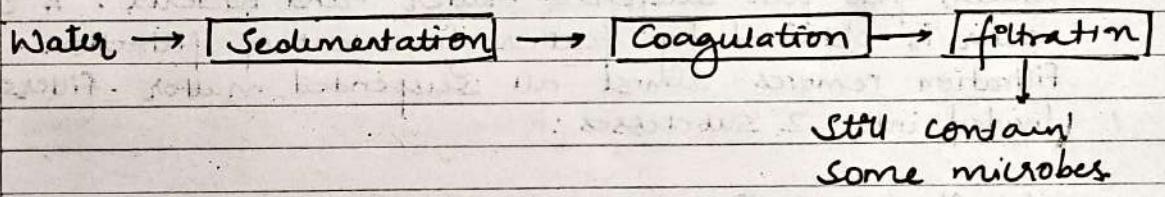
In gravity filter water passes through the bed @ an atm P. due to gravity.

PRESSURE FILTER.

Arrangement similar to filter media as gravity filter. The filter media is kept in closed cylinder and water is forced through filter bed under P. Filter can be installed on supply line so that repumping of water can be avoided.

B REMOVAL OF MICRO-ORGANISM

Disinfection : The process of removal of micro-organisms



Water used for drinking purpose must be free from disease causing bacteria from water and making it safe for use is called disinfection.

The chemical substances which are added to water for killing the bacteria are called disinfectants.

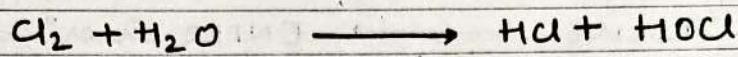
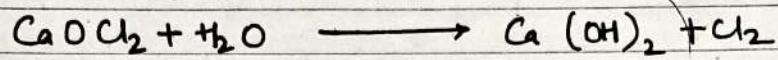
Disinfection of water can be carried out by following methods:

a) By boiling : Boil water for 10-15 minutes → disease producing bacteria are killed.

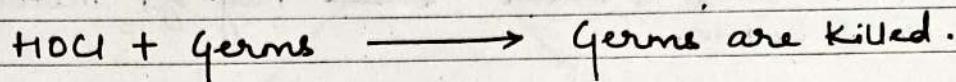
+ This method is responsible for killing of germs that at the time of boiling. It doesn't guarantee prevention of contamination.

(b) Adding Bleaching powder - In small water tanks usually about 1 kg of bleaching powder is added (per 1000KL of H_2O) and allowed to stand undisturbed for several hours.

The chemical action produces hypochlorous acid (germicide)



hypochlorous Acid

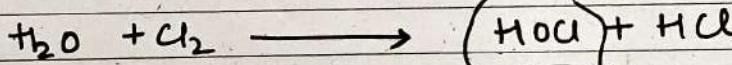


Bleaching powder provides chlorine for production of HOCl.

Disadvantages : (i) Bleaching powder adds Cl in water thus making it more hard.

(ii) Excess of bleaching powder adds to bad taste and smell.

(C) Chlorination : chlorine (either gas / concentrated soln) forms hypochlorous acid . which is powerful germicide.



Powerful Germicide.

* Mechanism of Action -

It was believed that disinfecting action of chlorine was due to nascent oxygen (Something that's either freshly formed or in process of forming). which oxidises harmful bacteria.

But the death of micro-organism was due to chemical rxn of HOCl with enzymes in the cell of organism.

So, HOCl causes inactivation of enzymes (in the cell of mo) which result in death of micro organism.

Therefore, death of micro-organism result due to inactivation of enzymes which are responsible for metabolism in micro-organism..



hypochlorite

Hence chlorine is a more effective disinfectant at lower pH. Apparatus used for chlorination is called chlorinator.

WATER + CHLORINE → ENTER Chlorinator from top

Treated water is taken ← They get thoroughly mixed out @ bottom.

Diagram: Chlorinator

Advantages -

- i) Effective and economical
- ii) Requires very less space for storage
- iii) Used at low and high temperatures
- iv) Stable and doesn't deteriorate.

Disadvantages

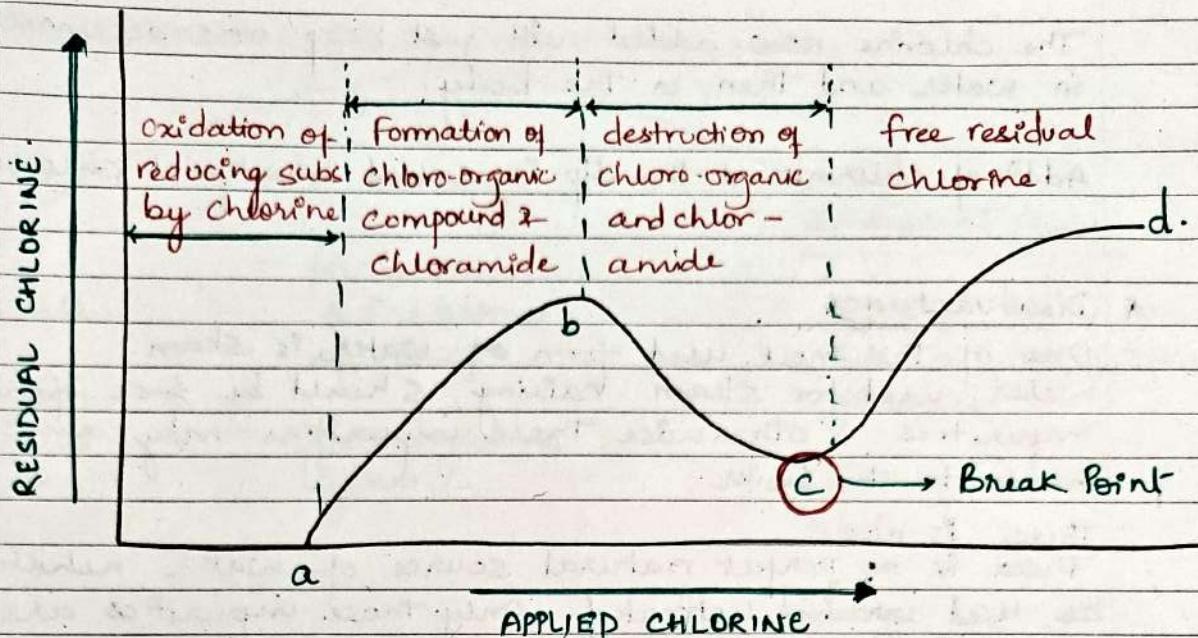
- i) Excess of chlorine produces unpleasant taste and smell.
- ii) Causes irritation of mucous membrane.

Graph + Break Point Chlorination

When chlorine is added to water its used for different rxn such as -

- Oxidation of any reducing substance
- Chlorination of any organic substances
- Disinfection of pathogen and free from ammonia.

In chlorination we have studied that by addⁿ of chlorine we can successfully disinfect the water. But it's essential to figure out the amount of chlorine that has to be added. Breakpoint chlorination helps in figuring out the amount of chlorine that has to be added for successful disinfection of water.



- Chlorination of water to such an extent that not only kills all bacteria but also destroy all living organism present in water.
- The graph has been plotted between residual chlorine and applied chlorine.

Step I : When we add chlorine in water, there is no residual chlorine. All the chlorine has been used for the oxidation of all the reducing components.

Step II : As the dose of applied chlorine is increased, value of residual chlorine also increases. All the chlorine is being used for the formation of chloro-organic compound and chloramine.

Step III : The residual chlorine increases on the rise of applied chlorine. This happens because of all the chloro-organic compound that were formed earlier will now be destroyed.

Step IV : The amount of residual chlorine increases from here because all the chlorine added here after will be of no use because all the impurity has been destroyed.

The chlorine now added will just keep on accumulating in water and then in the body.

Addn of chlorine at the dip is called breakpoint chlorination.

* Disadvantages

One of the most used form of water is steam. Water used for steam raising should be free from impurities. Otherwise these impurities may cause trouble to the boiler.

There is no perfect natural source of water which can be used untreated. Only those impurities are removed which lead to objectionable phenomenon. Unsuitable water may cause troubles to the boiler.

The major troubles are :

- i) Scale and sludge formation
- ii) Priming and foaming.
- iii) Caustic embrittlement
- iv) Boiler corrosion.

... Continued in the print version.

A comparison between sludges and scales

S.No.	Sludges	Scales
1.	Generally, sludges form less adherent coating, these can be removed by mechanical means.	Scales forms a firmly adherent coating and can not be removed easily.
2.	These are soft and less impermeable.	These are hard and more impermeable.
3.	Sludges, to some extent, can transfer heat and are less troublesome.	The scales are bad conductors of heat, so these are more troublesome.
4.	Usually, sludges get deposited where flow rate is low or where bends in the lines.	Scales are formed throughout the surface.
5.	These are formed in one place and get deposited at other place.	Scale are formed in place on surfaces in contact with water.

or efficiency of the water treatment.

Prevention of Scale Formation :

The scale formation is prevented by subjecting boiler feed water to certain chemical treatments. Treatment of water before feeding to the boiler is known as external treatment. Treating the raw water inside the boiler is known as internal treatment or sequestration.

Internal Treatment Methods :

Broadly classified, there are two types of processes to prevent the impurities in boiler water from getting deposited in the form of scale.

- (a) Appropriate chemicals are added to precipitate the scale forming impurities in the form of sludge which can be removed by blow down operation.
- (b) The problem causing cations are converted in to highly soluble compounds or complexes which will stay in dissolved form in boiler water without causing any deposition of scale.

The internal treatment methods are generally followed by blow down operation, so that accumulated sludge is removed. Important internal conditioning/treatment method are

(i) **Carbonate conditioning** : This method can be practised in low-pressure boilers. Any scale forming salt like CaSO_4 present in water is precipitated in the form of insoluble CaCO_3 by addition of Na_2CO_3

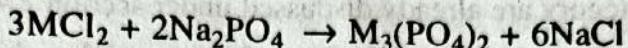


The loose sludge of CaCO_3 formed can be removed by blow down operation.

(ii) **Colloidal Conditioning** : In low pressure boilers, scale formation can be avoided by adding organic substances like kerosene, tannin, agar-agar etc. which get coated over the scale forming precipitate, thereby

ielding non-sticky and loose deposits which can easily be removed by pre-determined blow down operation.

(iii) Phosphate conditioning : In high-pressure boilers, scale formation can be avoided by adding sodium phosphate, which reacts with hardness of water forming non adhement and easily removable, soft sludge of calcium and magnatium phosphates, which can be removed by blow down operation e.g.,



Where $M = Ca^{2+}$ or Mg^{2+}

Calcium can be properly precipitated only at a pH of 9.5 or above. So the exact choice of the phosphate salt depends upon the alkalinity of boiler feed water. The phosphate chosen should be adjusted to the pH of an optimum value 9.5-10.5. If the pH is to be reduced, then mono sodium phosphate is used which is acidic in nature. If the alkalinity of boiler water is adequate for phosphate precipitation, then disodium phosphate is used. If the alaklinity of boiler water is low, it has to be raised to a pH value of 9.5-10.5 by the addition of trisodium phosphate which is highly alkaline in nature.

(iv) Treatment with Sodium Aluminate ($NaAlO_2$) : When Sodium Aluminate is added to the boiler water, it gets hydrolysed.



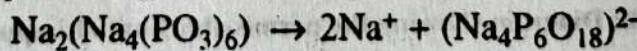
Gelatenous
precipitate

The Sodium Hydroxide formed as per the above reaction precipitates any magnesium salts presents

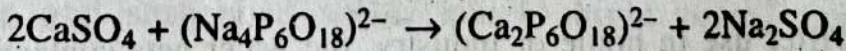


Both $Al(OH)_3$ and $Mg(OH)_2$ are flocculent precipitates and they easily trap any finely suspended and colloidal impurities such as silica and oil. These loose precipitates can then be removed by blow down operation.

(v) Calgon Conditioning : This involves the addition of sodium hexa meta phosphate (Calgon) to boiler water. It prevents the scale and sludge formation by forming soluble complex



Calgon



(vi) Electrical conditioning : Sealed glass bulb, containing mercury connected to a battery, is set rotating in the boiler. When water

boils, mercury bulbs emits electrical discharges, which prevents scale forming particles to stick together to form scale.

External Treatment Methods :

Water used for industrial purposes, such as, for steam generation, should be sufficiently pure. It should, therefore, be freed from hardness producing salts before put to use. The process of removing hardness producing salts from water, is known as softening of water. The various processes under this category are already discussed under section 2.4.

2.7.5 Permissible Limits of Impurities in Boiler Water :

These figures vary widely for individual boiler types and the advice of manufacturers should be taken into consideration. The permissible impurities depend on the permissible limits of boiler drum contents. The graph shown in Fig. 2.20 represents the quality of water generally acceptable to a boiler. It can, therefore, be used together with the analysis of fresh water to calculate the percentage blow down required to keep the drum contents within permissible limits. In turn, this will give an idea about the make up requirements.

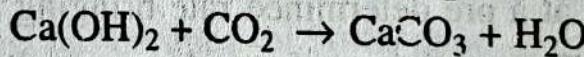
2.4.3 Lime-Soda Process :

If the temporary and permanent hardness are present together, then water can be softened by lime and soda method which is oldest method of water softening. It is the combination of Clark's method and washing soda method. Though the both types of hardness can be removed by later method, but the excess use of washing soda will then be expensive. Moreover, by the addition of only sodium carbonate the hardness due to magnesium salt will not be completely removed because the precipitate of the magnesium carbonate formed is somewhat soluble, which can be converted into insoluble magnesium hydroxide by the addition of extra lime.

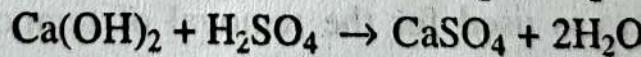
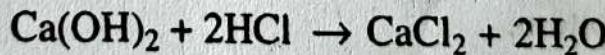
The basic principle in this method is to convert all the soluble hardness causing constituents in to insoluble precipitates by appropriate chemical treatment and then removing them.

In this process, a suspension of calcium hydroxide (lime) and sodium carbonate (soda) is added to water in calculated quantities based on the concentration of impurities expected to be and their nature and stoichiometry of chemical reactions. The reaction of lime and soda with various removed constituents present in water are given below in the form of equation.

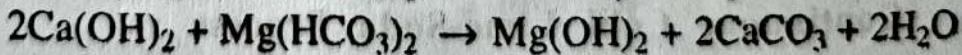
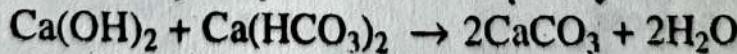
(a) Removal of dissolved gases CO_2 and H_2S .



(b) Neutralization of free mineral acids



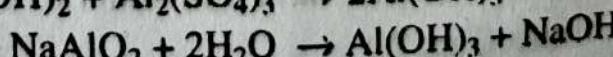
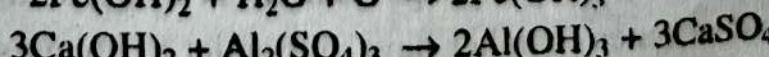
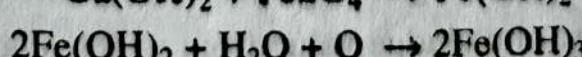
(c) Removal of temporary hardness completely



(d) Removal of permanent magnesium hardness

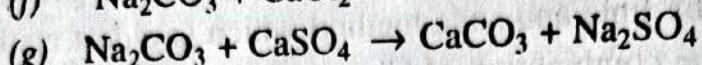
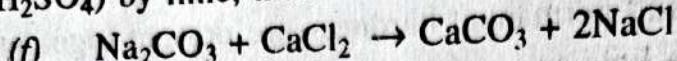


(e) Removal of dissolved iron and aluminium salts



Reactions of sodium carbonate :

Soda removes all the calcium permanent hardness (original calcium hardness + hardness introduced during the removal of Mg^{2+} , Fe^{2+} , Al^{3+} , HCl , H_2SO_4) by lime, thus



It is seen from the equations that lime removes temporary hardness without introducing any soluble salts into the water. Since lime is cheap, it is economical to use for removing temporary hardness. Both magnesium hydroxide and calcium carbonate produced as per the reactions given above are insoluble and precipitate as sludge. Addition of a coagulant like alum helps in the faster settling of sludge which can then be removed easily.

Water softened by this process contains considerable quantities of soluble salts like $NaCl$ and Na_2SO_4 , and hence, cannot be used in high pressure boilers.

The process may be carried out in batches or continuously. In batch process, the chemicals and hard water are added in batches in tank, stirred for required time and the precipitates allowed to settle down and filtered. Fresh water is again taken into the tank and the operation is repeated. In continuous process, water together with lime and soda solution enters in tank continuously at a pre determined rate bringing the correct amount of material together. The precipitates formed as a result of chemical reactions settle down. Clear soft water is removed continuously from the top and sludge from the bottom.

This process is used for the removal of temporary hardness and permanent hardness and has been divided in to the cold lime-soda and hot lime-soda process.

Continuous Cold Lime-Soda Process :

Construction of apparatus : There is continuous flow of raw water and chemicals and uninterrupted out flow of soft water from it. This softener consists of steel tanks having two concentric chambers. The inner chamber is small with open bottom and is provided with stirrer with paddles. The outer chamber is big with larger cross-section. The lower end of outer chamber consist of a sludge valve from which sludge is taken out. The upper end of outer chamber have an outlet to obtain soft water after passing through filters (Fig. 2.1).

Water and its Treatment |

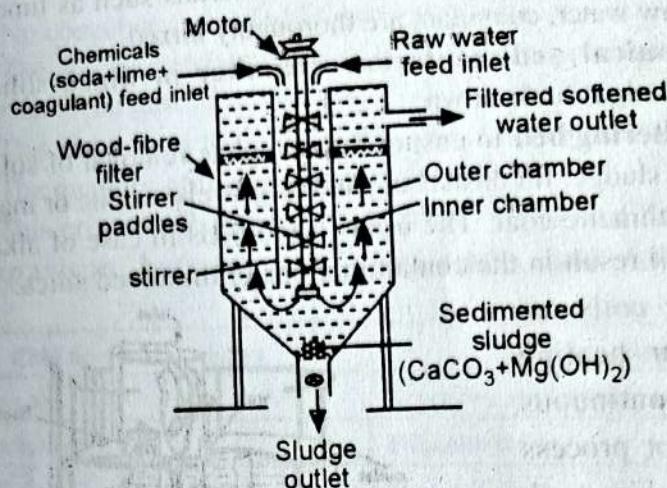


Fig. 2.1 : Continuous Cold Lime-Soda Process

Method : The hard water and calculated amount of lime and soda with coagulants are added through upper end of the inner chamber fitted with stirrer having paddles. As water flows down, there is thorough mixing and due to the various chemical reactions taking place in this process, softening is achieved. The softened water rises upwards through the outer co-axial chamber. The sludge settles in to the bottom of conical portion of the outer chamber. The softened water is made to pass through the filters to make sure complete removal of sludge. The filtered soft water is withdrawn out continuously through the outlet at the top of outer chamber. Sludge from the bottom is periodically removed through the sludge valve. The soft water obtained for this process has hardness of 50-60 ppm.

Continuous Hot lime-soda process : A typically hot lime-soda water softening unit is shown in Fig. 2.2(A). The unit consist essentially of three parts :

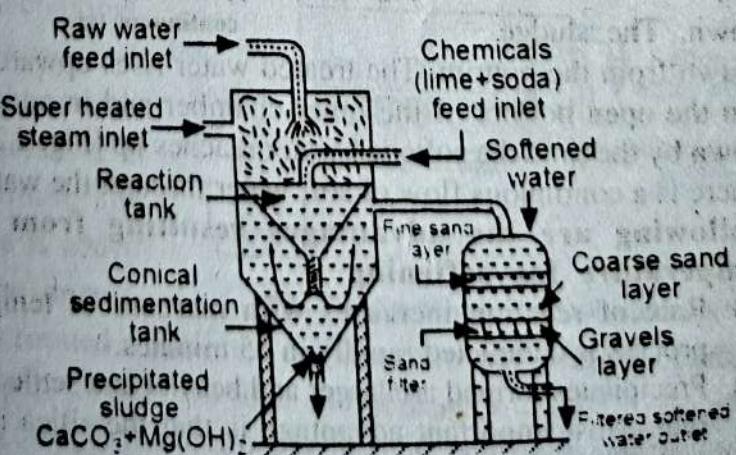


Fig. 2.2(A) : Continuous Hot Lime-Soda Process

- (i) **reaction tank** in which raw materials such as lime and soda, raw water, coagulant are thoroughly mixed.
- (ii) **conical sedimentation chamber** in which solid particles (sludge) settle down.
- (iii) **filtering bed** to ensure the complete removal of solid particles or sludge. It consists of sand or gravels, calcite or magnetite and anthracite coal. The use of sand beds in case of alkaline water will result in the contaminations of dissolved silica.

Heating coils are used in it for heating water. The continuous softener for hot process consists of a big tank having inner circular vertical chamber, the upper end of which is in the form of funnel, while lower end is open. Hard water, lime $\text{Ca}(\text{OH})_2$ and soda (Na_2CO_3) are fed in to the funnel and get mixed. Steam is then passed through the steam inlet. As the mixture goes down, the reaction is complete. When water goes up in the tank, the sludge separates out and settles down. The sludge is withdrawn from the bottom.

The treated water rises upwards in the outer tank from the open bottom of the inner chamber and in outer tank sludge settles down by the time the softened water reaches up [Fig. 2.2(B)].

There is a continuous flow of soft water through the water outlet. Following are the advantages resulting from the use of high temperature for softening :

- (1) Rate of reaction increases with increase of temperature, the process is completed rapidly in 15 minutes.
- (2) Precipitates formed are larger and heavier and settle at more rapid rate. Most important advantage is that the silica in water also gets.
- (3) Precipitated by adding magnesium oxide at 50°C .

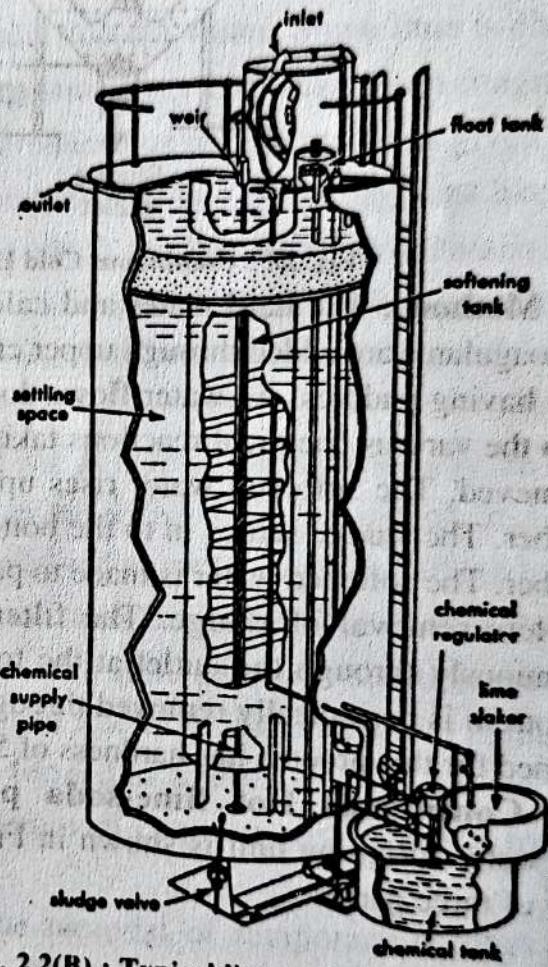


Fig. 2.2(B) : Typical lime-soda water softener - continuous type.

- (4) No coagulant is needed for precipitation.
- (5) The process can be operated in the plant of smaller size.
- (6) Dissolved gases such as CO_2 , H_2S are expelled out of water.
- (7) The viscosity is decreased and so filtration is faster.
- (8) The quantity of the reagents used is lesser.
- (9) This process produces a soft water of 15-30 ppm hardness.

Comparison between cold lime-soda and hot lime soda process :

	Cold lime-soda process	Hot lime soda process
1.	Reactions are slow.	Reactions are fast, and complete.
2.	Filtration is slow.	Filtration is fast.
3.	Less efficient.	Very efficient.
4.	Softening capacity is low.	Softening capacity is high.
5.	Use of coagulant is necessary.	No coagulants are required since the bigger precipitates are formed.
6.	Requirements of lime consumption is as per stoichiometry.	Lesser quantity of lime is required as temporary hardness, CO_2 and H_2S are removed at higher temperature.
7.	Steam is not used.	Steam has to be used. Hence there is fuel consumption.
8.	Residual hardness of soft water produced is 50-60 ppm.	Residual hardness of soft water produced is 15-30 ppm.

Advantages of Lime and Soda Process :

- (1) Less amount of coagulants are required if this process is combined with sedimentation.
- (2) The pH of the soft water produced is higher, which prevents the corrosion of the distributions pipes.
- (3) Amount of impurities such as iron and manganese are also decreased.
- (4) Water produced after treatment, is of alkaline nature. The amount of microorganisms are also reduced.
- (5) It is very economical method.

Disadvantages of Lime and Soda Process :

- (1) This process can not be used for domestic purpose because it is difficult to know how much of $\text{Ca}(\text{OH})_2$ and Na_2CO_3 should be added and then how to filter off the precipitates.
- (2) It is not suitable for many industrial purposes, because soft water obtained is supersaturated with CaCO_3 . This can be serious in laundry, where CaCO_3 may end up on the clothing.
- (3) Skilled and careful supervision is required for efficient and economical operation.
- (4) It creates the problem of disposal of sludge.
- (5) The hardness of water is not completely removed, so there is always, to some extent, possibility of scale and sludge formation.

2.4.5. Zeolites (Permutit) Process :

This is the modern process of removing both temporary and permanent hardness of water. Zeolites in Greek means “boiling stone”. A Swedish geologist first used this word to mean a certain group of naturally occurring mineral which released their water of hydration in the form of steam. The formula of sodium zeolite is Na_2Z .

This may be regarded as a hydrated sodium aluminosilicate which is capable of reversibly exchanging its sodium ions with the alkaline earth group cations generally present in water. Zeolite is also known as permutit. Zeolites are of two types :

- (i) **Natural Zeolites** : Are nonporous and are derived from green sands by washing, heating and treating with NaOH. The most commonly used natural zeolite is natrolite ($\text{Na}_2\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) and it possesses good durability (Fig. 2.5).

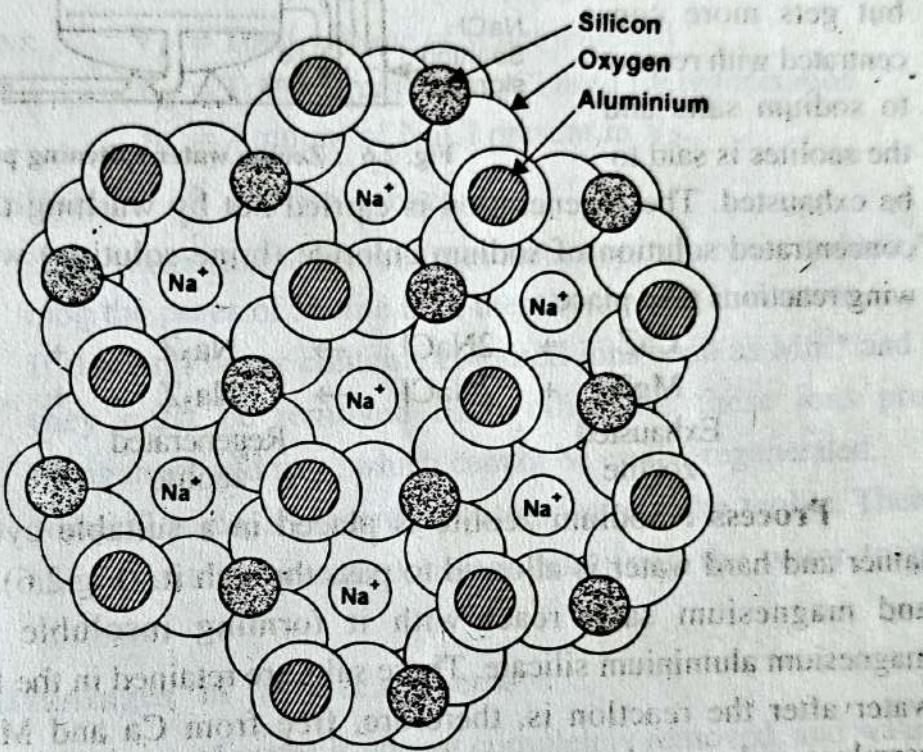
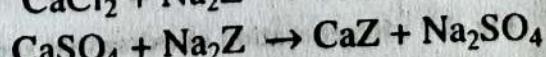
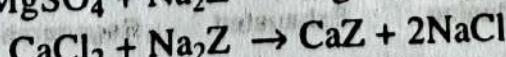
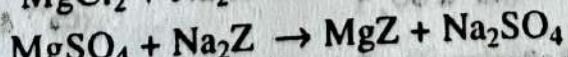
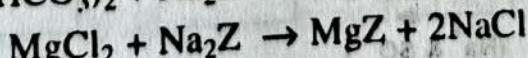
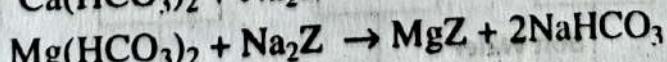
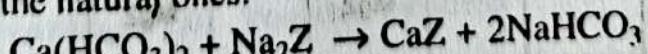


Fig. 2.5 : Structure of naturally occurring zeolite, NaAlSiO_4 .

The sodium ions are loosely held in holds in the lattice.

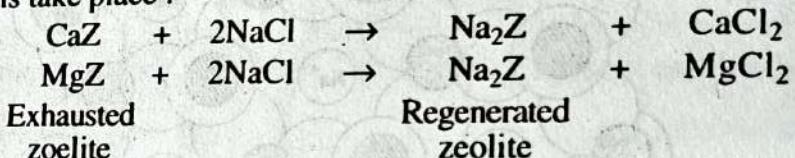
- (ii) **Synthetic Zeolite** : The gel structured synthetic zeolites are porous and they can be prepared by heating together solutions of sodium silicate, aluminium sulphate and sodium aluminate. Synthetic zeolites possess higher exchange capacity per unit weight when compared to the natural ones.



It is seen that sodium zeolite is converted to calcium and magnesium zeolites.

In the process, the water becomes free from Ca^{2+} and Mg^{2+} , the main hardness producing cations, but gets more concentrated with respect to sodium salts and the zeolites is said to

the zeolites is said to be exhausted. The regeneration is carried out by washing the bed with a concentrated solution of sodium chloride (brine solution) when the following reactions take place :



Process : Sodium zeolite is placed in a suitable cylindrical container and hard water is allowed to pass through it. (Fig.2.6). The calcium and magnesium salts react with it forming insoluble calcium and magnesium aluminium silicate. These salts are retained in the filter bed. The water after the reaction is, therefore, free from Ca and Mg salts. Only harmless sodium salts are left in the water. The reactions takes place as mentioned above.

Regeneration : When the process is continued for long time, the

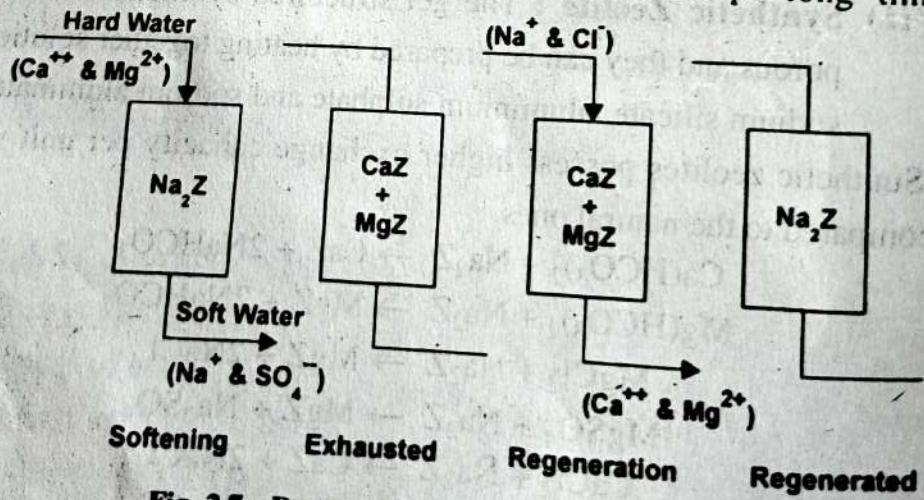


Fig. 2.7 : Regeneration of exhausted zeolite

zeolite is completely converted in calcium and magnesium zeolite (Ca^{++} and Mg^{++}) and it ceases to soften water, i.e., it gets exhausted. At this stage, the supply of hard water is stopped and exhausted zeolite is regenerated by treating it with 10% NaCl solution. Thus whole process involves alternate cycle of softening run and the regeneration (Fig. 2.7).

Thus from the equation, knowing the amount of NaCl consumed for regeneration of exhausted zeolite, the hardness of water may be found out.

$$\text{Hardness (H)} = \frac{50 \times m \times V_2 \times 10^3}{58.5 \times V_1}$$

where V_1 = Total volume of water softened

V_2 = Total volume of NaCl used for regeneration

m = Amount of NaCl present in V_2 .

Limitation of zeolite process :

- (1) Hard water should be free from turbidity, otherwise turbidity will clog the pores of zeolite bed, thereby making it inactive.
- (2) If the hard water contains coloured ions such as Mn^{2+} and Fe^{2+} , they must be removed first, otherwise these ions produce manganese and iron, which cannot be easily, regenerated.
- (3) Mineral acids, if present in water, destroys the zeolite. Therefore, they must be removed before admitting the water to zeolite softener.

Advantages of zeolite process :

- (1) Hardness of water is almost completely removed, and water of 10 ppm hardness is obtained.
- (2) Equipment used, occupies small space.
- (3) There is no danger of formation of sludge in treated water because impurities are not precipitated.
- (4) Process automatically adjusts itself for variation in hardness of incoming water.

Disadvantages of zeolite process :

- (1) The process only replaces only Ca^{2+} and Mg^{2+} by sodium ions, but leaves all other ions as such in the softened water which are harmful to boilers.
- (2) Turbid water cannot be treated efficiently.
- (3) Treated water contains more sodium salts.

Comparison between lime-soda and zeolite process

S.No.	Lime-soda process	Zeolite process
1.	This process produces soft water having hardness 15–60 ppm.	This process produces soft water of hardness 10–15 ppm.
2.	It is precipitation process. After precipitation, it may take place in distribution system or even in boilers.	It is an ion exchange process.
3.	The plant is comparatively less costly.	It is costly plant.
4.	Plant consists of reaction tank, filter, pressure equipment..	Unit is compact.
5.	Heating is required in hot lime-soda process.	No heating is required, no fuel consumption.
6.	There is no regeneration step in the process, moreover the chemicals and coagulants used are costly.	The exhausted zeolite can be regenerated, hence, operating cost is lower.
7.	Treated water containing less percentage of dissolved solids and lesser amount of sodium salts.	Treated water contains greater amounts of sodium salts and greater percentage of dissolved salts.
8.	The reagent doses must be adjusted according to hardness.	This process adjusts itself to different hardnesses.
9.	This process is free from the limitation as in zeolite process.	This process can not be used for hot water, acidic water, water with turbidity and suspended matter.
10.	Iron containing water can be treated.	Iron containing water cannot be treated because iron is irreversibly exchanged.

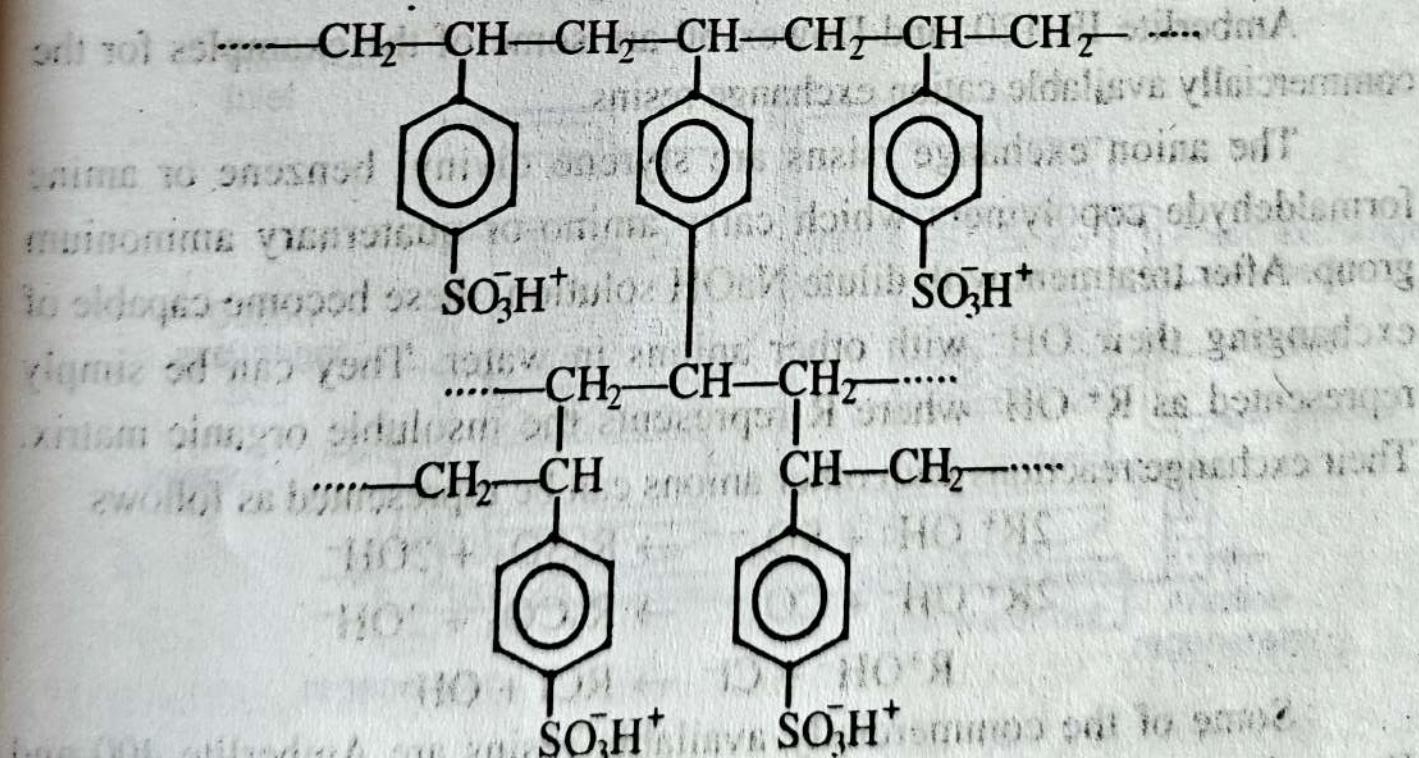
1 litre hard water softened = 64102 litre.

2.4.6 Ion Exchange Process :

This is also known as deionisation or demineralisation since all the cations and anions are completely removed in this process. A large number of synthetic resins (organic compounds) are known which possess a property like permittit to take up certain ions from the aqueous solutions and replace them by others.

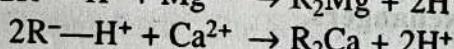
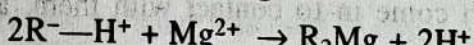
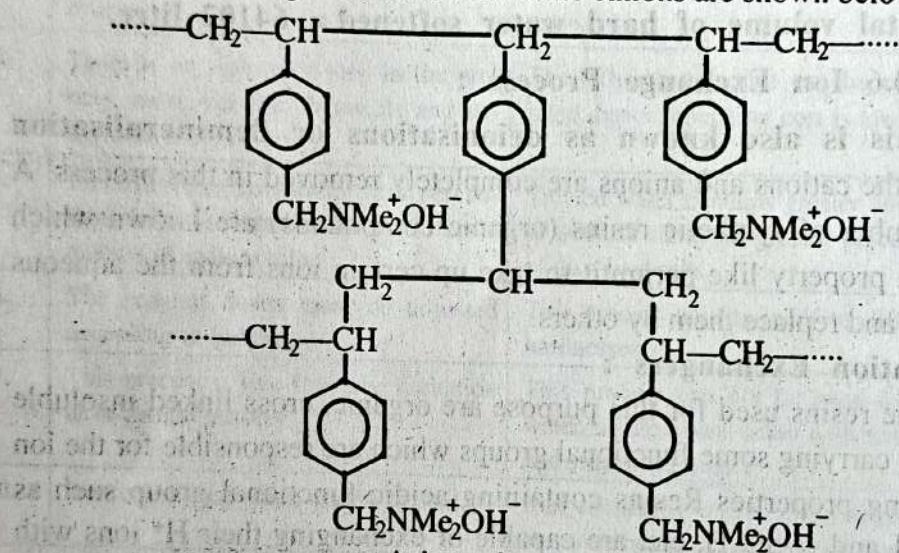
Cation Exchangers :

The resins used for this purpose are organic, cross linked insoluble polymers carrying some functional groups which are responsible for the ion exchanging properties. Resins containing acidic functional group such as —COOH and $\text{—SO}_3\text{H}$, etc. are capable of exchanging their H^+ ions with other cations which come in to contact with them, and hence, they are termed as **cation exchangers**.



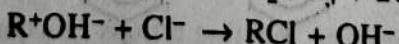
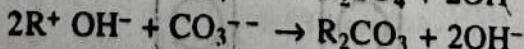
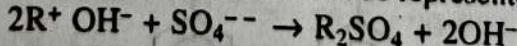
Cation exchange resin

Anion Exchangers : Resins containing basic functional group such as $\text{—NH}_2=\text{NH}$, etc. as hydroxide or hydrochlorides are capable of exchanging their anions with other anions in water and therefore, are known as **anion exchangers**. Based on the extent of capacity and alkalinity, the resins could be further classified in to **strongly acidic, weakly acidic cation exchangers and strongly basic, weakly basic anion exchangers**. Cation exchanger resins are mainly styrene divinyl benzene copolymers which on sulphonation or carboxylation acquire capability to exchange their hydrogen ions with other cations in water. They can be simply represented as R^-H^+ where R represents the insoluble polymeric matrix. Their exchange reactions with other cations are shown below ?



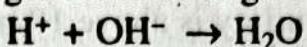
Amberlite IR-120; and Dowex-50 are some of the examples for the commercially available cation exchange resins.

The anion exchange resins are styrene divinyl benzene or amine formaldehyde copolymers which carry amino-or quaternary ammonium group. After treatment with dilute NaOH solution, these become capable of exchanging their OH^- with other anions in water. They can be simply represented as R^+OH^- where R represents the insoluble organic matrix. Their exchange reactions with other anions can be represented as follows



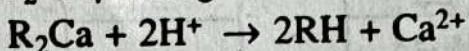
Some of the commercially available resins are Amberlite 400 and Dowex-3.

Process : The schematic diagram of the unit used for this purpose is shown in fig. 2.8. The hard water is passed through the cation exchange column when all the cations like Ca^{2+} , Mg^{2+} , etc. are removed and an equivalent amount of H^+ is released from the resin to water. Subsequently, this water is passed through the anion exchange column when all anions like Cl^- , SO_4^{2-} etc. are removed and an equivalent amount of OH^- is released from the column to water. The H^+ and OH^- released respectively from cation exchangers and anion exchanger combine to give water



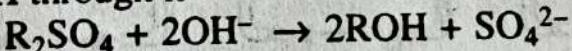
Thus, the water coming out from the exchanger is free from cations as well as anions. **Ion free water is known as deionised or demineralised water.**

When cation and anion exchangers are fully saturated by the absorption of cations and anions, respectively from water, they lose their exchanging capacity and become exhausted and require regeneration. The exhausted cation exchanging column is regenerated by passing through a solution of dilute HCl or H_2SO_4 through it.



Column is washed with deionised water and the washings containing Ca^{2+} , Mg^{2+} , Cl^- , SO_4^{2-} etc. are drained.

The exhausted anion exchanger column is regenerated by passing a dilute solution of NaOH through it



The column is washed with deionised water and the washings containing Na^+ , Cl^- or SO_4^{2-} are drained out. The regenerated exchangers can be used again. The residual hardness of water in this process is 0-2 ppm.

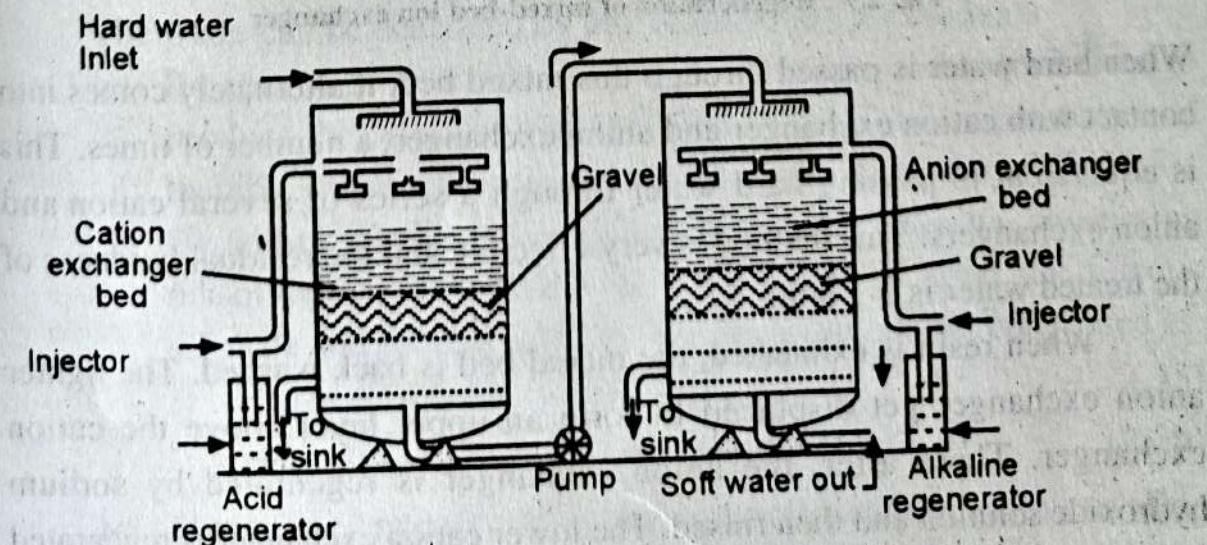


Fig. 2.8 : Demineralization of water

Advantages :

- (1) Highly acid or alkaline water can be softened
- (2) Water of very low hardness is obtained. So it is very good for treating water for use in high pressure boilers.

Disadvantages :

- (1) Expensive chemicals and costly equipment is required.
- (2) If the water contains turbidity, then the output of the process is reduced. If the turbidity is above 10 ppm, it has to be removed first by Coagulation and filtration.

Mixed-bed deionizer :

This consists of a single cylinder containing an intimate mixture of strongly acidic cation exchanger and strongly basic anion exchanger (Fig. 2.9).

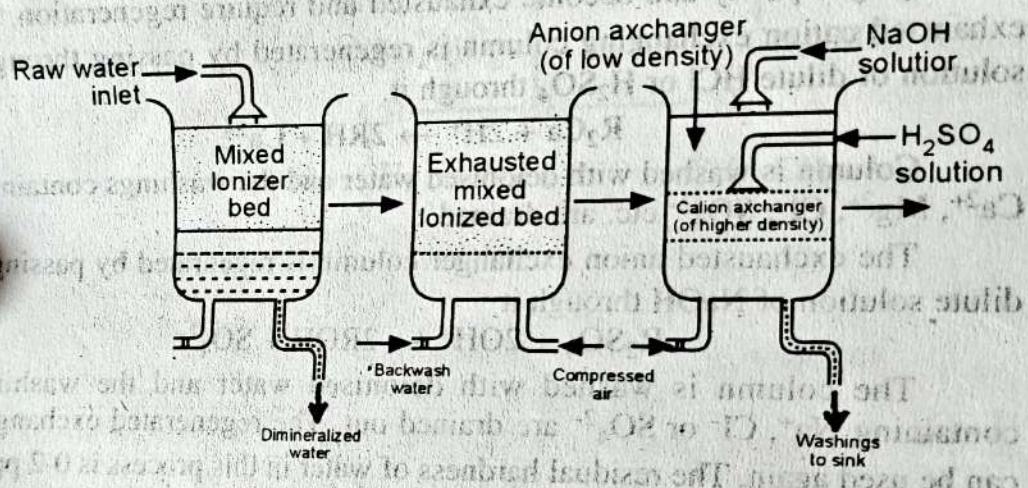


Fig. 2.9 : Regeneration of mixed-bed ion exchanger

When hard water is passed through this mixed bed, it alternately comes into contact with cation exchanger and anion exchanger, a number of times. This is equivalent to passing hard water through a series of several cation and anion exchangers. This method is very effective and the residual hardness of the treated water is 0-1 ppm.

When resin is exhausted, the mixed bed is back washed. The lighter anion exchanger get displaced to form an upper layer above the cation exchanger. There after, the anion exchanger is regenerated by sodium hydroxide solution and then rinsed. The lower cation exchanger is regenerated by sulphuric acid.

The both beds are mixed again. The bed is ready to use again.

Comparative statement

Comparison of lime-soda, zeolite (permutit) and ion exchange processes.

S. No.	Lime-soda process	Permutit process	Ion exchange process
1.	Treated water contains 10-15 ppm residual hardness	Treated water contains residual hardness 0-15 ppm	Treated water contains residual hardness 0-12 ppm
2.	Operating expenses are high	Operating expenses are low	Higher operating expenses
3.	Low capital cost process	Cost of material plant is high	Cost is higher than permutit soda lime process
4.	Acidic water can also be treated	Acidic water can not be treated	Resins are very inert. Acidic water can be treated
5.	Raw water can have suspended impurities	Water must be free from suspended impurities	Water should be free from suspended impurities
6.	Coagulation, filtration, removal of sludge is required	Not required	Not required
7.	Hardness of water must be known in advance	Not required	Not required
8.	Treated water contains lesser amounts of dissolved solids	Treated water contains more dissolved solids	No dissolved solids
9.	Plant occupies more space	Plant occupies less space	Plant occupies less space

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

Boiler troubles are 1) Priming & foaming 2) Sludge & Scales 3) Caustic embrittlement 4) 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

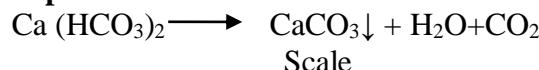
- Sludges are poor conductors of heat, so they tend to waste a portion of heat generated.
- Excessive sludge formation disturbs the working of the boiler.
- Sludge can be removed by using 1) Softened water 2) by blow down operation i.e. drawing off a portion of the concentrated water.

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:



(Soft, formed mainly in low pressure boilers)

In high pressure boilers, $CaCO_3$ is soluble due to formation of $Ca(OH)_2$



ii) Deposition of $CaSO_4$:

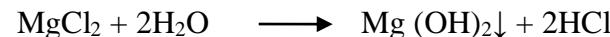
Solubility of $CaSO_4$ decreases with increase in temperature.

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.



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:

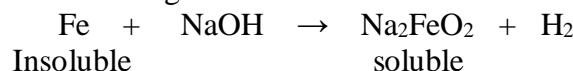
- Mechanical/chemical method
- Loosely adhering scales are removed with the help Scraper/wire brush
- Brittle scales are removed by giving Thermal shocks
- Loosely adhering scales are removed by frequent blow down operation (frequently removing precipitates)

- Adherent & hard scales are removed by dissolving them by adding chemicals
CaCO₃ scales - 5-10% HCl
CaSO₄ 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 Na₂CO₃ is still present in the softened water
- This Na₂CO₃ decomposes to give NaOH and CO₂ due to which the boiler water becomes “Caustic”.
- Na₂CO₃+ H₂O → 2NaOH + CO₂↑
- 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.



Caustic embrittlement can be explained by considering following electrochemical cell



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):

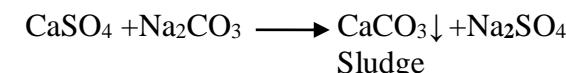
- In this method some chemicals reagents are added directly to the boiler water for removing dangerous scale forming salts.
- The chemicals convert the scale forming impurities into sludge or more dissolved compounds.
- This method is generally followed by blow down operation.

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

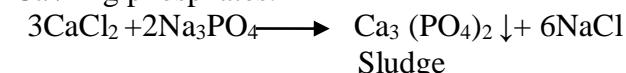


Deposition of CaSO₄ as scale doesn't takes place and calcium is precipitated as loose sludge of CaCO₃ which can be removed by blow down operation.

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.



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

- Na₃PO₄ (alkaline in nature) is used when alkalinity is low.
- Na₂HPO₄ (weakly alkaline) is used when alkalinity is sufficient.
- NaH₂PO₄ (acidic) is used when alkalinity is high

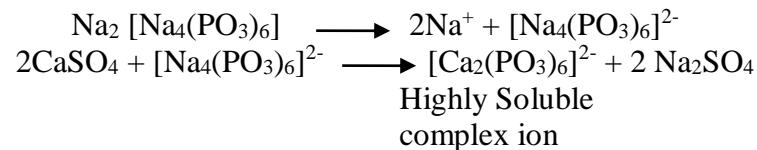
Calgon conditioning:

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 .



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

Ion exchange or deionization or demineralization process:

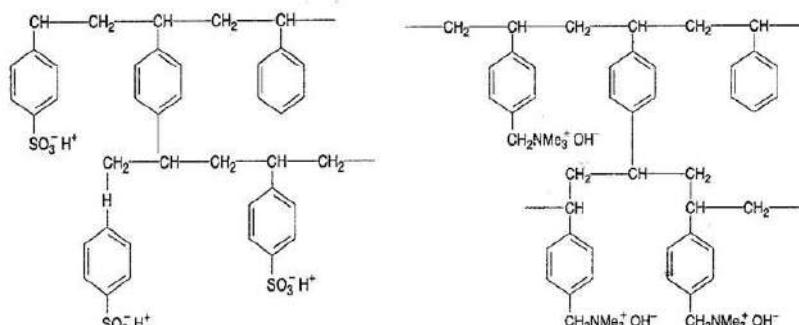
- **Principle:** A reversible exchange of ions takes place between the stationary ion exchange phase and the external liquid mobile phase.
- Ion exchange resins are insoluble, cross linked, porous, high molecular weight, organic polymers and the functional groups attached to the chains are responsible 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 $-\text{SO}_3\text{H}$, $-\text{COOH}$ 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

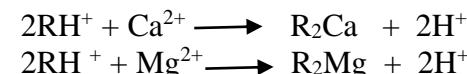


Cation exchange resin

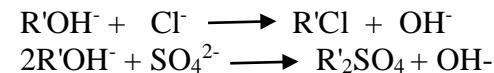
Anion exchange resin

Process:

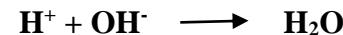
- The hard water is passed first through cation exchange column
- The cation exchanger removes all the cations like Ca^{2+} , Mg^{2+} from it
- and equivalent amount of H^+ ions are released from the column to water.



- 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.



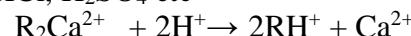
- H^+ and OH^- ions are released from the cation exchange and anion exchange columns respectively get combined to produce water molecule.



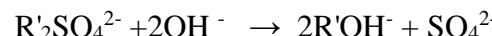
Water coming out from the exchanger is free from cations and anions and is known as deionized or demineralized water

Regeneration of exhausted bed:

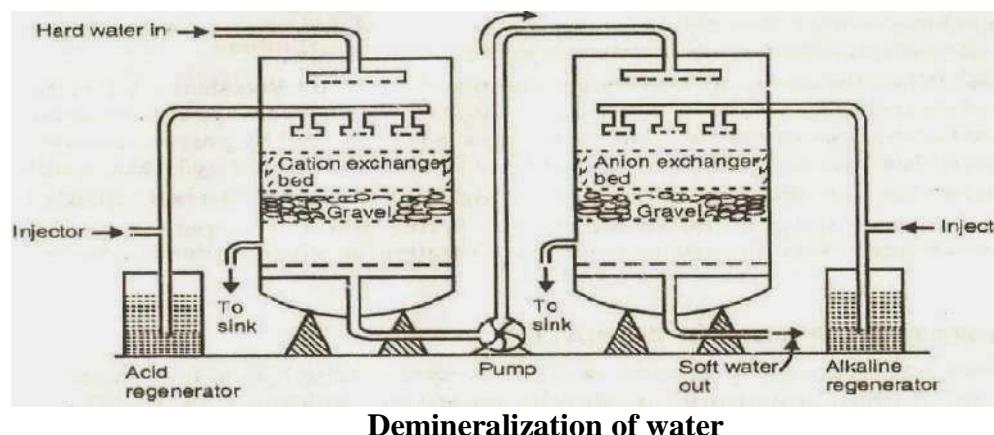
- When the beds are getting exhausted (capacity to exchange H^+ & OH^- ions are lost) then they are regenerated
- The exhausted cationic exchanger is regenerated by washing with acids like HCl , H_2SO_4 etc



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



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

**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:

- Electro dialysis
- Reverse osmosis

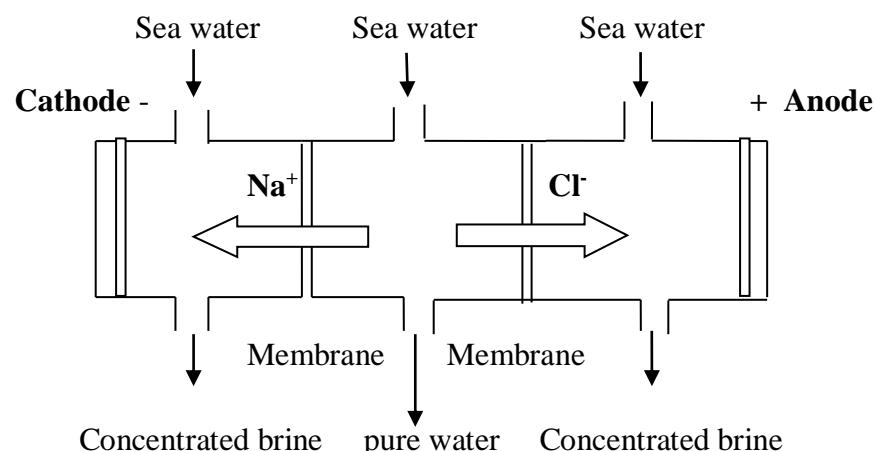
i) Electrodialysis:

- 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, whereas 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 $\text{R}_4\text{N}^+\text{Cl}^-$) 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 $5-6 \text{ kg m}^{-2}$ 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:

- Electro dialysis
- Reverse osmosis

Reverse osmosis. (R.O)

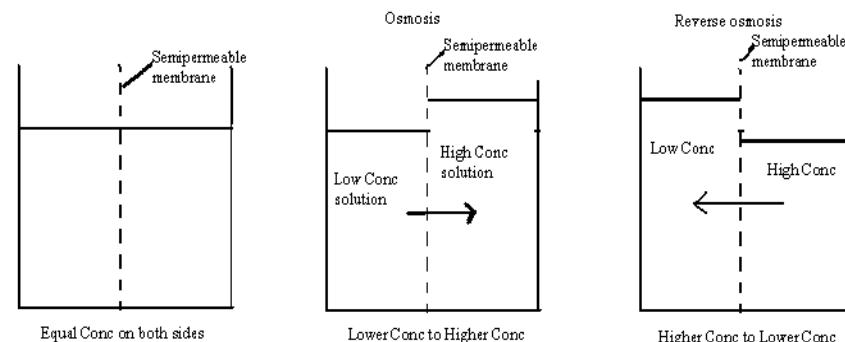
Reverse osmosis is one of the membrane filtration processes. The process is used to remove salts and organic micro pollutants from water.

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**.

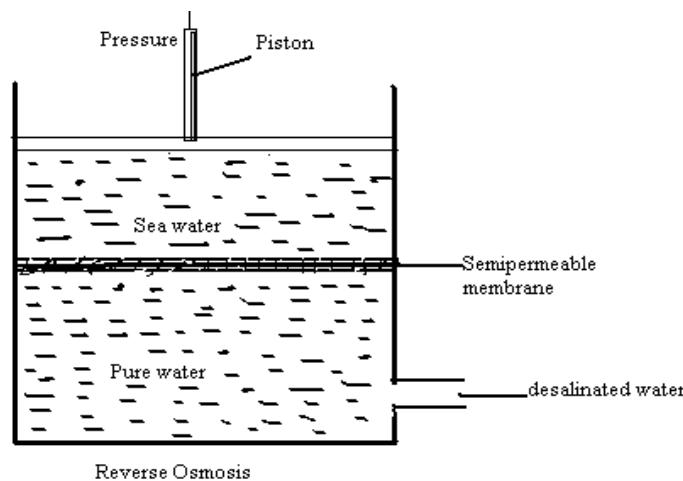
If the pressure higher than osmotic pressure is applied on the concentrated side, then the solvent flows in reverse direction i.e from higher concentrated region to lower concentrated region. This is called reverse osmosis.



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 $15\text{-}40 \text{ kg cm}^{-2}$) 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.

**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 ($K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$), Sodium aluminate ($NaAlO_2$) etc.

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

$Al(OH)_3$ 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 thorough 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 a bed 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.

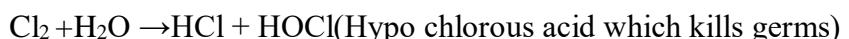
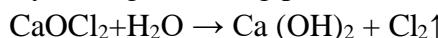
a) Boiling

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



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:

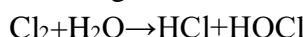
It is unstable, difficult to store

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.



$HOCl \rightarrow$ 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.

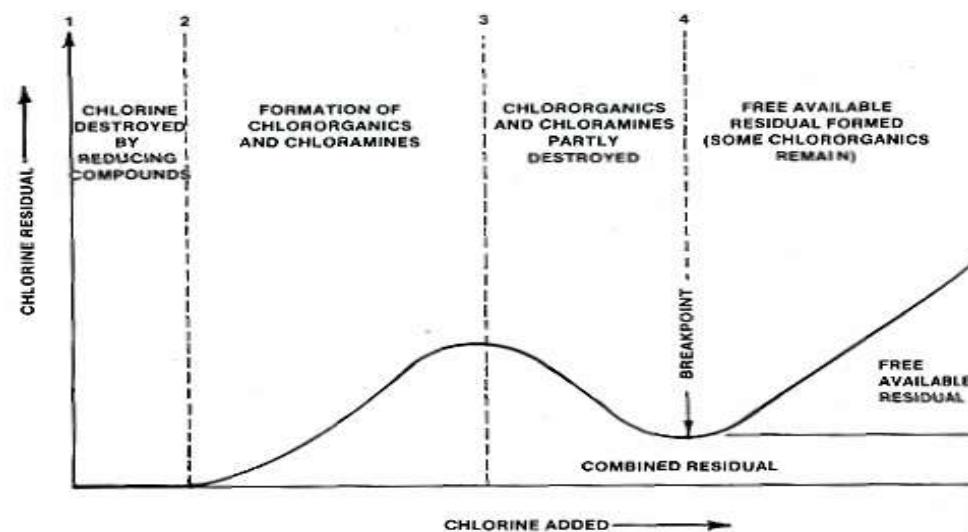
Disadvantages:

- 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.

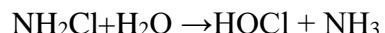
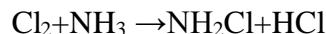


d) By using chloramines

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

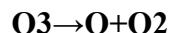
Chloramines can be prepared by passing chlorine gas into ammonia chamber

Now a day's municipalities are using this process.



e) Disinfection by ozone (OZONIZATION).

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



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 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.

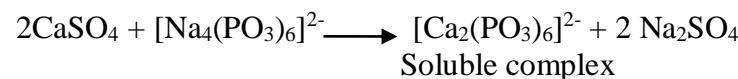
A) The chief sources of water are rain water, surface water, ground water & sea water.

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

A) Different types of impurities are

i) Dissolved impurities:

a) Inorganic salts



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.



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.

The addition of sufficient amount of chlorine to satisfy chlorine demand is called break point chlorination

16. What are the advantages of break point chlorination?

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.