



Chemistry Theory Course



Syllabus

Marking Scheme

GROUP : B												
Temporary Course Code	Course Code	Course Title	Nature	Teaching Scheme			Practical		Examination Scheme Marks		Total Credits	Total Marks
				L	T	Lab	Int	Ext	CA	ESE		
T7385	070121101 FY	Engineering Mathematics I	ES	4	2	-	-	-	50	75	5	125
T7540	070121112 FYB	Basic Electrical and Electronics Engineering	C	3	-	-	-	-	30	45	3	75
T7414	070121113 FYB	Engineering Mechanics	C	3	-	-	-	-	30	45	3	75
T7381	070121114 FYB	Chemistry	ES	3	-	-	-	-	30	45	3	75
T7609	070121115 FYB	Engineering Graphics	C	2	4	-	-	-	40	60	4	100
T7383	070121116 FYB	Communication Skills	GP	2	-	-	-	-	50	-	2	50
T7593	070121117 FYB	Basic Electrical and Electronics Engineering Lab	C	-	-	2	10	15	-	-	1	25
T7415	070121118 FYB	Engineering Mechanics Lab	C	-	-	2	10	15	-	-	1	25
T7382	070121119 FYB	Chemistry Lab	ES	-	-	2	10	15	-	-	1	25
T7384	070121120 FYB	Communication Skills Lab	GP	-	-	2	10	15	-	-	1	25
Total				17	6	8	40	60	230	270	24	600

UT1 Marks(20)	UT2 (Marks(20)	Total (40)	Out of 21 (70% of 30)	Present ation marks(10)	Assig n. (10)	Class Test (10)	Total(30)	Total(30)	Out of 9(30 %of 30)	Total (30)	Rounded off
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Annual Examination (45 marks) + Term Work (30) + Lab (Journal + Viva) 25 marks

* Subject to change as per guidelines

Water and water treatment

- ❖ Introduction
- ❖ Characteristic imparted by impurities in water,
- ❖ Analysis of water – alkalinity, hardness and its determination (EDTA method only)
- ❖ Equivalents of calcium carbonates, units of hardness,
- ❖ Disadvantages of hard water, Boiler feed water, boiler problems-

Contents

- ❖ Scale, sludge, priming and foaming,
- ❖ Caustic embitterment and corrosion, their causes and prevention.
- ❖ Water softening processes: Ion exchange method, zeolite method,
- ❖ Drinking water or municipal water,
- ❖ Desalination of brackish water.
- ❖ Numerical problems on alkalinity, hardness, ion exchange method and EDTA method.

Polymer and Composites

Introduction, definition, degree of polymerization (D_p), concept of molecular weight (number average, weight average & numerical based on them), glass transition temperature.

Classification of polymers: polymerization mechanism: (step and chain polymers)

Polymerization Reaction: addition and condensation, thermal behavior: Thermoplastic and thermosetting, types of monomers: linear, branched and cross-linked polymers, homo and copolymers.

Commercial Polymers: synthesis, properties and application, polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), m phenol Formaldehyde (PF), epoxy resin.

Specialty polymers: basic concept applications of conductive polymers, biodegradable polymers, recycling of polymers
Composites: classification, fiber and particle reinforced composites.

Fuels and Combustion

Classification, combustion and chemical principles involved in it. Calorific value: gross and net calorific values and their determination by bomb calorimeter and Boy's gas calorimeter. Numerical based on calorific value calculation.

Solid Fuels: proximate and ultimate analysis of coal and their importance, high and low temperature carbonization.

Liquid Fuels: thermal and catalytic cracking, knocking and chemical structure, octane number and cetane number and their significance.

Rocket propellants: classification of propellants.

Solid State Chemistry

Introduction, unit cell, Bravais lattice, analysis of cubic crystals.

Crystallography: three laws of crystallography- Weiss indices, Miller indices with numerical, X ray diffraction- Bragg's law and numerical.

Crystal defects and imperfections, their effect on properties of crystals.

Preparation of semiconductors. Fullerene and its application.

Phase Rule: introduction, phase rule, one component system.

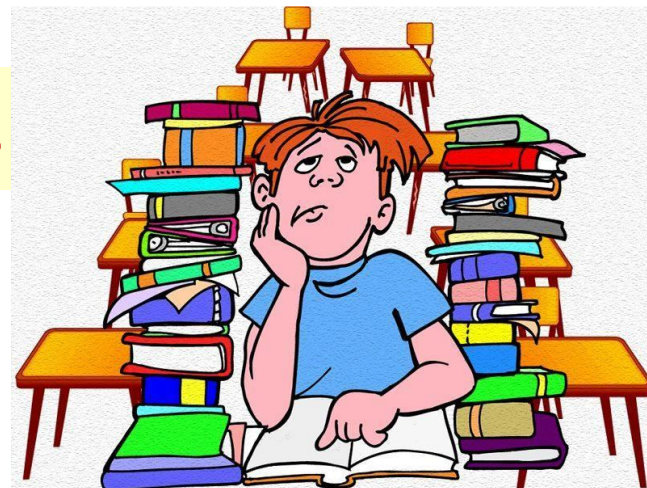
Chemistry In Nanoscience: carbon nanotubes, fullerenes, quantum dots, graphine, synthesis of nanoparticles, uses, application

Analytical Techniques

Spectroscopic techniques: electromagnetic radiations, it's characteristics and interaction with matter. Lambert-Beer Law, principle, working and applications of UV-visible and IR spectroscopy.

Corrosion: introduction of corrosion, dry or chemical corrosion, wet or electrochemical corrosion, galvanic corrosion (Bimetallic), passivity, pitting corrosion, waterline corrosion, stress corrosion, factors influencing corrosion and corrosion control.

Reference Books



- "Engineering Chemistry", [S.K. Singh](#), *New Age Publications.*
- "Engineering Chemistry", [Jain & Jain](#), *Dhanpat Rai Publishing Company*
- "Engineering Chemistry", [S.S. Dara](#), *S Chand & Company*
- "Engineering Chemistry", [M. M. Uppal](#), *Khanna Publishers*
- "Analytical Chemistry", [Douglas A. Skoog](#), *Brooks Cole*
- "Atkins physical chemistry", [Peter Atkins](#), *Oxford University press.*

Water and water treatment

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Water and water treatment

Introduction

Sources of water

Surface Waters



River Water



Lake Water



SeaWater

Sources of water

Underground waters



Well Water

Rain water



characteristic imparted by impurities in water

Impurities in water

There are 4 types of Impurities present in water.

- ❖ Suspended Impurities
- ❖ Colloidal Impurities
- ❖ Dissolved Impurities
- ❖ Biological Impurities.

Suspended Impurities

Particles size is $> 1000 \text{ \AA}$ and these particles are visible

Removal

- ❖ Sand
- ❖ Soil
- ❖ organic wastes
- ❖ Inorganic particles
- ❖ Filtration
- ❖ Sedimentation
- ❖ Settlement Methods

Colloidal Impurities

- ❖ Particles size is in between 10 to 1000Å
- ❖ Very fine organic or inorganic particles
- ❖ Turn water turbid
- ❖ These impurities do not settle and are evenly distributed in water.

Inorganic Impurities	Organic Impurities	Removal
Clay	Finely Divided vegetable or organic matter	Sedimentation followed by
Silt	Oils	a) Coagulation and Filtration
Silica	Fats	b) Coagulation and settling
Ferric Hydroxide	Greases	b) Coagulation and settling and filtration
Calcium Carbonate	Micro Organisms	
Sulphur		

Dissolved Impurities

Gases : All natural water contains dissolved CO_2 . the solubility depends on temp, pressure and dissolved mineral contents of water. Other gases like O_2 , SO_2 , NH_3 , H_2S are also present in water in dissolved form.

Amount of CO_2 present in different water sources.

- ❖ From Air: 0.5 to 2 ppm
- ❖ Surface water : 0 to 5 ppm
- ❖ Ground water: 1 to 50 ppm
- ❖ Well water: 50 to 300 ppm

- ❖ Metal Salts soluble in water
 - ❖ Organic solids like sugar
 - alcohols, carboxylic acids, urea
- ❖ Underground water contains cations like Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Fe^{2+} , Mn^{2+} etc.

Removal

- ❖ Warming the water
- ❖ Aeration Method
- ❖ Inorganic impurities are removed by chemical treatments



Physical Impurities

A) Colour

Usually caused by

- ❖ metallic substances like **Salts of Fe, Mn**
- ❖ Humus materials (the organic component of soil, formed by the decomposition of leaves and other plant material by soil microorganisms)
- ❖ Tannins (organic compound)
- ❖ Peat (partially decayed vegetation or organic matter)
- ❖ Weeds (Undesirable plants)
- ❖ Protozoa (biological organism)
- ❖ Industrial Effluents (like Paper and pulp industry, textile industry)

B) Turbidity

Usually caused by

- ❖ _colloidal and extremely fine suspensions of clay, ash.
- ❖ Finely Divided organic and Inorganic matter
- ❖ Micro Organisms like Palnkton

C) Taste

Usually linked directly with odour but sometimes can be present individually.

- ❖ Presence of dissolved minerals in water produce taste but not odour.
- ❖ Bitter taste: Can be due to presence of Fe, Al, Mn, sulfates or excess of lime
- ❖ Soapy taste: Due to large amount of sodium bicarbonate
- ❖ Brackish taste: Due to presence of large amounts of salts
- ❖ Palatable taste: Due to presence of dissolved gases (CO_2) and minerals (like nitrates) in water

D) Odour

- ❑ Mostly can be due to presence of small quantities of sulphides.
- ❑ Presence of inorganic and organic compounds of Nitrogen, Sulphur and Phosphorous can impart odour to water.
- ❑ Also industrial effluents like alcohols, aldehydes, phenols, esters, ketones lead to odour.

Chemical Impurities

1. Inorganic and Organic Chemicals

- ❖ Dyes
- ❖ Paints
- ❖ Varnishes
- ❖ Drugs
- ❖ Insecticides
- ❖ Pesticides
- ❖ Detergents
- ❖ Pulp and Textiles industries

2. Acids discharged in water by following:

- ❖ Battery Industries
- ❖ Explosives
- ❖ DDT

Gases

- ❖ All natural water contains **dissolved CO₂** from Air
- ❖ Solubility is dependent on the temperature, pressure and dissolved mineral content of water.
- ❖ One more source is biological oxidation of dissolved organic matter.

- ❖ **Dissolved O₂** is also dependent on the temperature, pressure and salts content of water.
- ❖ Essential for aquatic life.
- ❖ Should be avoided as it can lead to corrosion.

- ❖ **Dissolved NH₃**
- ❖ From decomposition of nitrogenous organic matter.
- ❖ nitrogenous organic compounds like urea

Minerals

Could be present in water coming from rocks and industrial origin.

Mineral Acids,

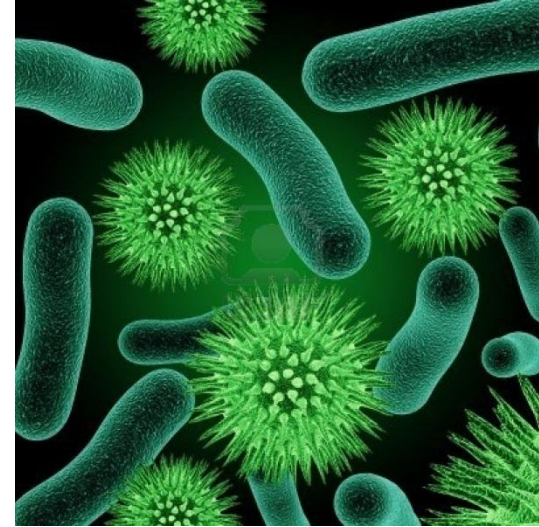
❖ Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Fe^{2+} , Mn^{2+} ,

❖ CO_3^{2-} , HCO_3^- , SO_4^{2-} , NO_3^- , F^- ,

Biological Impurities



Algae



Bacteria's, Viruses



fungi

Hardness of water

What is hard water?

❖ Prevents lathering of soap.

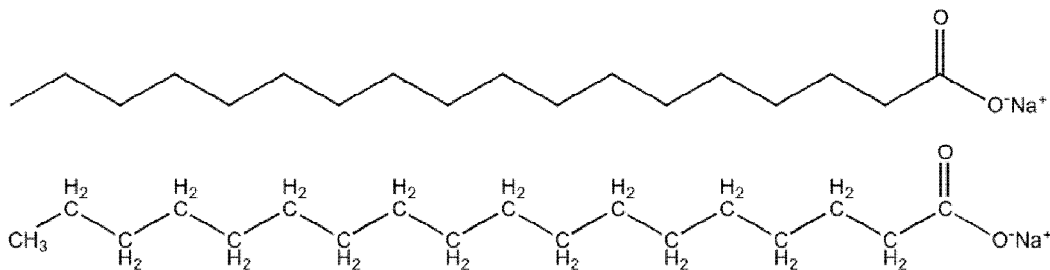
Why?



What is soap?

Salt of fatty acid

e.g. Stearate

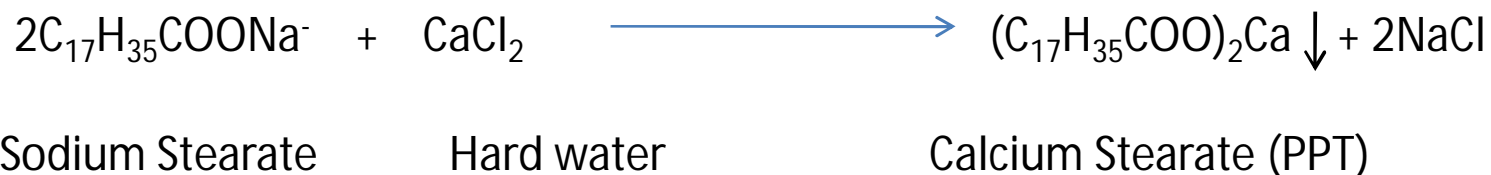


Hard water contents

- Salts of calcium
- Salts of Magnesium
- Other heavy metals

What happens when we use soap with hard water?

Instead of forming lather/foam it forms white scum or precipitate!



Water which does not produce lather with soap solution readily but instead forms a white scum or precipitate is called hard water.

Types of hardness

Temporary or Carbonate Hardness

Is due to presence of dissolved bicarbonates of calcium, Magnesium and other heavy metals and the carbonates of Fe.

Can be removed by boiling water.

Permanent or Non -Carbonate Hardness

Is due to presence of chlorides and sulphates of calcium, Magnesium and other heavy metals. Can not be removed by boiling.

Temporary Hardness

1. Due to bicarbonates and some soluble carbonates of heavy metals.
2. e.g. $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$, MgCO_3 , FeCO_3
3. Can be removed by boiling
4. $\text{Ca}(\text{HCO}_3)_2 \xrightarrow{\Delta} \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2$

Permanent Hardness

1. Due to heavy metal salts other than bicarbonates
2. e.g. CaCl_2 , MgCl_2 , CaSO_4 , MgSO_4 , $\text{Ca}(\text{NO}_3)_2$, $\text{Mg}(\text{NO}_3)_2$
3. Can not be removed by boiling
4. Removed by chemical treatment

Substances which do not contribute towards hardness (*i.e.*, KCl, NaCl, SiO₂, Na₂SO₄, Fe₂O₃, K₂SO₄, etc.) should be ignored

How hardness is expressed?

Usually expressed in terms of
Equivalents of CaCO_3

- ❖ The molecular weight of CaCO_3 is 100 (eq. wt = 50)
- ❖ Most insoluble salt that can be precipitated in water.

The equivalent of CaCO_3

$$\begin{aligned} & \left[\begin{array}{c} \text{Mass of hardness} \\ \text{producing substance} \end{array} \right] \times \left[\begin{array}{c} \text{Chemical equivalent} \\ \text{Of } \text{CaCO}_3 \end{array} \right] \\ = & \frac{\text{Chemical equivalent of hardness producing substance}}{\text{Mass of hardness producing substance} \times 50} \\ = & \frac{\text{Mass of hardness producing substance} \times 50}{\text{Chemical equivalent of hardness producing substance}} \end{aligned}$$

Conversion to CaCO_3 equivalent

$$= \frac{\text{Mass of hardness producing substance} \times 50}{\text{Equivalent wt of hardness producing substance}}$$

$$= \frac{\text{Mass of hardness producing substance} \times 100}{2 \times \text{Equivalent wt of hardness producing substance}}$$

	Molar Mass	Equivalent weight	Multiplication factor for CaCO ₃
Ca(HCO ₃) ₂	162	81	100/162
Mg(HCO ₃) ₂	146	73	100/146
CaSO ₄	136	68	100/136
CaCl ₂	111	55.5	100/111
MgSO ₄	120	60	100/120
MgCl ₂	95	47.5	100/95
CaCO ₃	100	50	100/100
MgCO ₃	84	42	100/84
CO ₂	44	22	100/44
Ca(NO ₃) ₂	164	82	100/164
Mg(NO ₃) ₂	148	74	100/148
HCO ₃ ⁻	61	61	100/122
OH ⁻	17	17	100/34
CO ₃ ²⁻	60	30	100/60
NaAlO ₂	82	82	100/164
Al ₂ (SO ₄) ₃	342	57	100/114
HCl	36.5	36.5	100/73

The equivalent of CaCO_3

Salt	Molar Mass	Chemical Equivalent	Multiplication factor for CaCO_3 equivalent
$\text{Ca}(\text{HCO}_3)_2$	162	81	100/162
$\text{Mg}(\text{HCO}_3)_2$	146	73	100/146
CaSO_4	136	68	100/136
CaCl_2	111	55.5	100/111
MgSO_4	120	60	100/120
MgCl_2	95	47.5	100/95
CaCO_3	100	50	100/100

Units of hardness

1. Parts per million (ppm)

Is the parts of calcium carbonate equivalent hardness of 10^6 parts of water.

1 ppm = 1 part of CaCO_3 equivalent hardness

2. Milligrams per liter (mg/L)

Is the number of milligrams of CaCO_3 equivalent hardness present per liter of water

1 mg/L = 1 mg of CaCO_3 eq hardness of 1 Liter of water

But 1 L of water = 1 kg = 1000 g \times 1000 mg = 10^6 mg

\therefore 1 mg/L = 1 mg CaCO_3 eq per 10^6 mg of water

= 1 part of CaCO_3 eq per 10^6 parts of water = 1 ppm

3. Clarke's Degree (°Cl)

Is number of grains (1/7000*lb*) of CaCO_3 equivalent hardness per gallon (10 *lb*) of water.

Or parts of CaCO_3 equivalent hardness per 70,000 parts of water.

1 **clarke** = 1 grain of CaCO_3 (64.8 mg) eq hardness per Imperial gallon (4.55 litres) of water, equivalent to 14.254 ppm.

4. Degree French (°Fr)

Is the parts of CaCO_3 equivalent hardness per 10^5 parts of water.

1°Fr = 1 part of CaCO_3 hardness per 10^5 parts of water

5. Milliequivalent per liter (meq/L)

Is the number of milli equivalents of hardness per liter of water.

$$\begin{aligned} 1 \text{ meq/L} &= 1 \text{ meq of CaCO}_3 \text{ per liter of water} \\ &= 10^{-3} \times 50 \text{ g of CaCO}_3 \text{ eq per liter} \\ &= 50 \text{ mg of CaCO}_3 \text{ eq per liter} \\ &= 50 \text{ mg/L pf CaCO}_3 = 50 \text{ ppm} \end{aligned}$$

$$1 \text{ ppm} = 1 \text{ mg/L} = 0.1 \text{ }^\circ\text{Fr} = 0.07 \text{ }^\circ\text{Cl} = 0.02 \text{ meq/L}$$

Disadvantages of hard water

Water used for domestic purpose

Washing : No lather formation, but white sticky ppt of calcium and Magnesium forms.

This formation of ppt continues till all the Ca and Mg salts are precipitated and then the soap starts to form lather.

Bathing: Sticky ppt on body thus cleansing quality of soap is disturbed. Waste of water.

Drinking: Affects digestive system. Could lead to formation of calcium oxalate crystals in urinary track.

Disadvantages of hard water

Water used for Industrial purpose

The following industries are affected

- ❖ Pharmaceutical Industry
- ❖ Textile Industry
- ❖ Paper Industry
- ❖ Dye Industry
- ❖ Sugar Factories
- ❖ Construction works

Scales and Sludge Formation



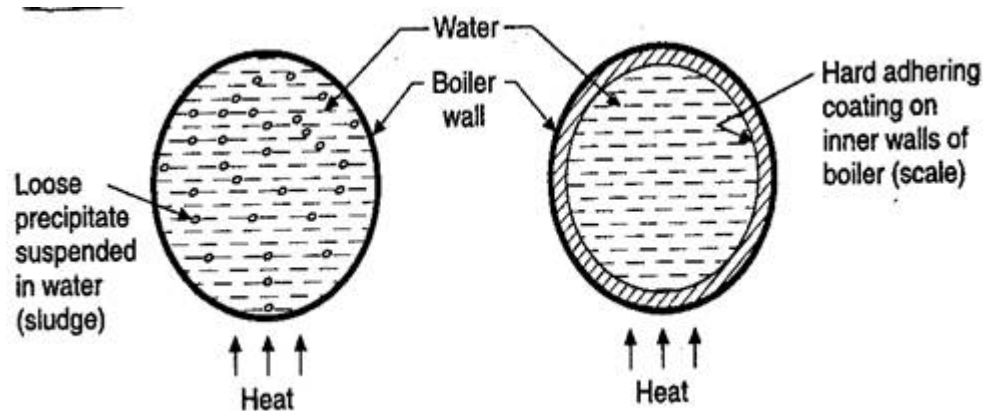
Prerequisites for boiler feed water

- ❖ Hardness : below 0.2 ppm
- ❖ Caustic alkalinity : 0.15-0.45
- ❖ Soda alkalinity : 0.45 to 1.00 ppm
- ❖ Excess soda ash: 0.3-0.5 ppm

A boiler is water containing vessel which transfers heat from a fuel source (oil, gas, coal) into steam which is piped to a point where it can be used to run production equipment, to sterilize, provide heat, to steam-clean, etc.

Scales and Sludge Formation

- ❖ Inside a boiler water is continuously evaporating and due to this the concentration of different salts present in water increases rapidly.
- ❖ Once these salts reach a critical concentration they are thrown out of water in the form of precipitates!
- ❖ Usually they are present in the inner walls of boiler.
- ❖ Loose and slimy precipitate is called as Sludge
- ❖ Hard, adherent precipitates are called as Scales.



Sludge

Definition

Sludge is a soft, loose and slimy precipitate formed within the boiler.

Formed in comparatively colder region of the boiler.

Made up of substance which have greater solubility in hot water rather than cold water!

e.g., CaCl_2 , MgSO_4 , MgCO_3 , MgCl_2 ,



Disadvantages

- ❖ Loss of heat generated
- ❖ If formed along with scales, sludge can be trapped in scales and finally get deposited as scales.
- ❖ Disturbs the functioning of boiler.
- ❖ Settles down in regions of poor water circulation and could cause chocking of pipes.

Prevention:

1. Use softened water
2. By blow down operation.

Scales

Definition

Scales are hard deposits which sticky firmly to the inner surfaces of the boiler.

Main sources of boiler problems. Are difficult to remove even with hammer chisel.

Scales can be formed due to following reasons

1. Decomposition of $\text{Ca}(\text{HCO}_3)_2$



2. Deposition of CaSO_4 (low solubility in hot water)

3. Hydrolysis of Magnesium Salts

4. Presence of Silica (SiO_2)

Could lead to formation of $\text{MgSiO}_3/\text{CaSiO}_3$



Scales

Disadvantages

- ❖ Waste of Fuel used in boiler operation. Low thermal conductivity. Thickens of the scales layer drastically wastes the fuel used.
- ❖ Low safety due to overheating
- ❖ Explosion hazards due to excess pressure!
- ❖ Low efficiency

Thickness (mm)	0.32	0.62	1.25	2.5	12
Wastage of Fuel (%)	10	15	50	80	150

Removal of Scales:

1. Use of Scraper or wire brush
2. By thermal shocks
3. Use chemicals to dissolve them(HCl, EDTA)
4. Blow down operations

Prevention:

1. Use externally softened water
2. Use internal treatment to avoid scales formation.

How do we prevent scale formation?

External methods: Using water which has been softened externally.

Internal Methods (Sequestering) : Treating the water inside the boiler.

In this the substance causing hardness is complexed or converted into a more water soluble salt.

How it is achieved?

By adding a suitable chemical to boiler water

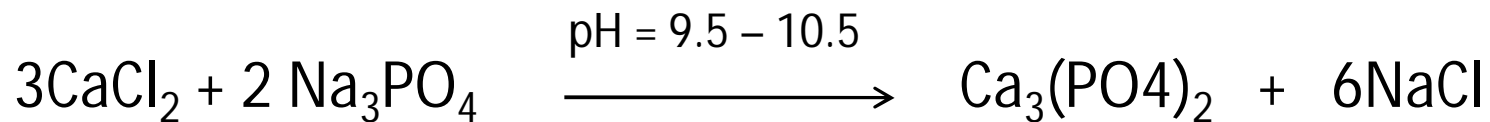
- ❖ It precipitates the scale forming impurities in the form of sludge and then can be removed by proper blow down operation.
- ❖ Convert the impurities in suitable compounds which remain dissolved in water and thus do not cause any problems.

Colloidal Conditioning

- ❖ Used in low pressure boilers.
- ❖ Formation of scales can be avoided by adding organic substances to water.
- ❖ e.g. Tannin, kerosene, Agar-agar gel.
- ❖ These substances get coated on the scale forming precipitates forming loose and non sticky deposits.
- ❖ These can be easily removed by blow down operations.

Phosphate Conditioning

- ❖ Used in high pressure boilers.
- ❖ Formation of scales can be avoided by adding Sodium Phosphate.
- ❖ Calcium and magnesium phosphates are formed and can be removed by blow down operations.



NaH_2PO_4 : Sodium dihydrogen phosphates (acidic) (**high alkalinity**)

Na_2HPO_4 : Disodium hydrogen phosphate (weakly alkaline) (**moderate alkalinity**)

Na_3PO_4 : Trisodium Phosphate (alkaline) (**low alkalinity**)

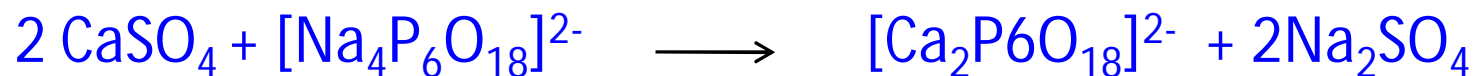
Calogen Conditioning

Calogen: Sodium hexa meta phosphate
(NaPO_3)₆ or $\text{Na}_2[\text{Na}_4\text{P}_6\text{O}_{18}]$

❖ Prevents scale formation from salts like CaSO_4

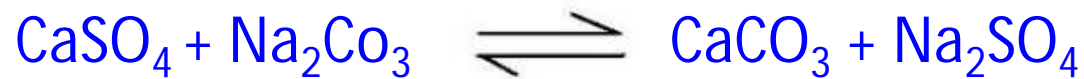
How?

- ❖ Sodium hexa meta phosphate can form highly soluble coordination complexes with metal ions such as Ca^{2+} , Mg^{2+} or Fe^{2+}
- ❖ It can also attack the scales formed by dissolving it.



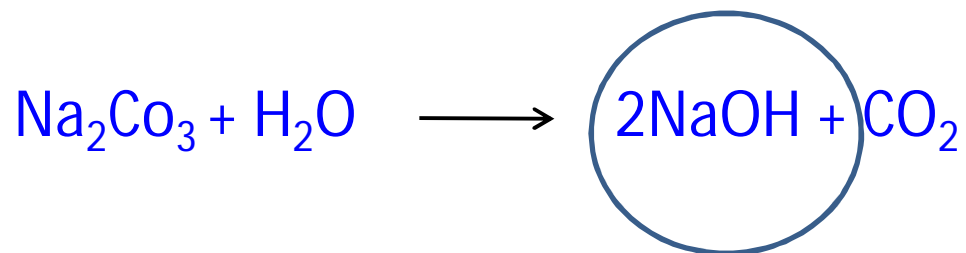
Carbonate Conditioning

- ❖ Used in low pressure boilers.
- ❖ Formation of scales due to presence of CaSO_4 in water can be avoided by adding Sodium Carbonate.
- ❖ Calcium sulphate is converted in calcium carbonate in the form of loose sludge.



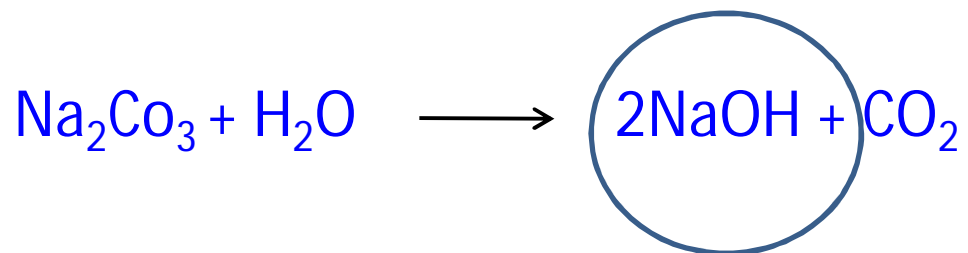
Caustic Embrittlement

- ❖ Type of Boiler corrosion
- ❖ Caused due to highly alkaline water.
- ❖ Where from it becomes alkaline?
- ❖ During softening process by soda lime process, free Na_2CO_3 present in small amount.
- ❖ This Na_2CO_3 can react with water giving sodium hydroxide and carbon dioxide.



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❖ NaOH present in excess amounts in water, could react with the boiler material Fe forming sodium ferroate.

❖ This leads to embrittlement of the boiler parts such as bends, joints and rivets etc causing boiler failure.

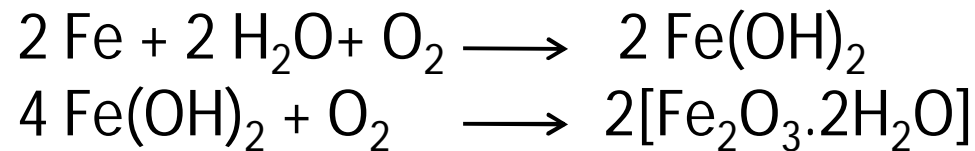
How it can be avoided

1. By using sodium phosphate
2. By adding tannin, lignin to boiler water.
3. By adding sodium sulphate.

Boiler Corrosion

Dissolved Oxygen. : (8 ppm) at room temperature.

At high temperatures. The dissolved oxygen can attack the boiler material:



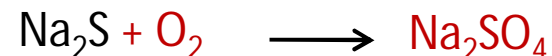
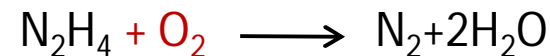
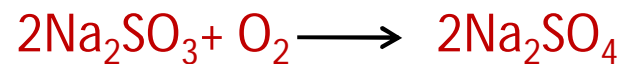
Ferrous Hydroxide

Rust

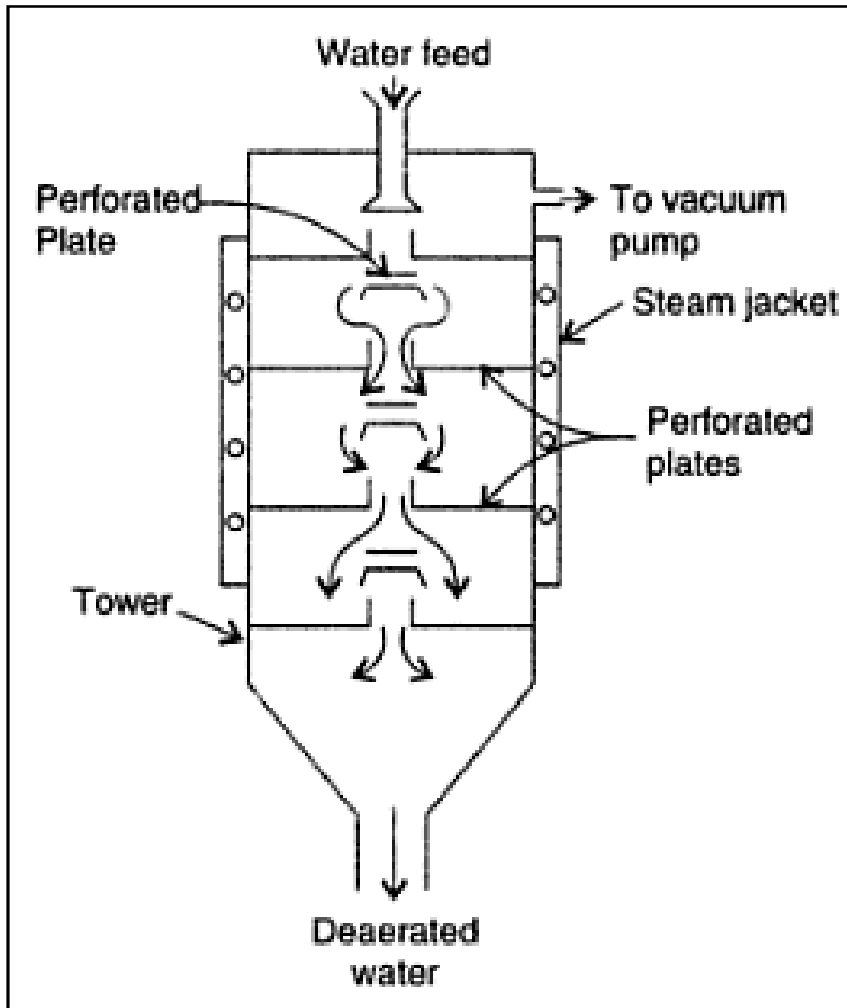
Removal of dissolved oxygen :

By adding

- ❖ sodium sulphite
- ❖ hydrazine
- ❖ Sodium Sulphide



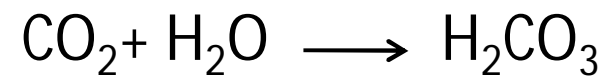
By mechanical deaeration



- ❖ Water is sprayed in a tower fitted with perforated plates.
- ❖ Heated from sides and is connected to a vacuum pump.
- ❖ **The high temperature, low pressure and large exposed surface** reduces the dissolved oxygen.

Dissolved carbon dioxide (CO₂)

Carbon dioxide dissolved in water forms Carbonic acid.

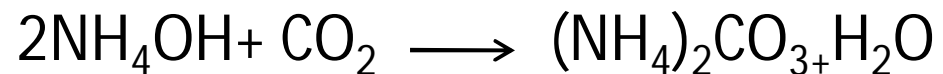


It also shows a corrosive effect on the boiler material.

Water used for steam generation containing bicarbonates can release carbon dioxide at high temperatures

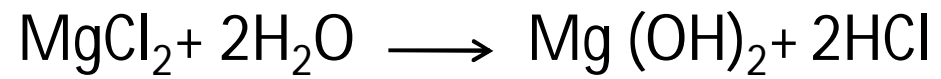
Removal of CO₂: By adding

- ❖ Calculated quantity of ammonia
- ❖ By mechanical deaeration method.

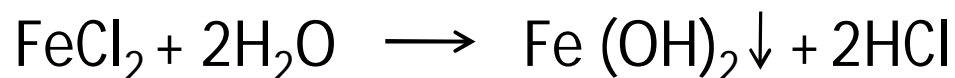
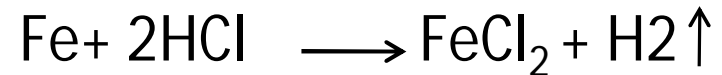


Acids generated from dissolved salts

Water containing dissolved salts of Mg liberate acids on hydrolysis.

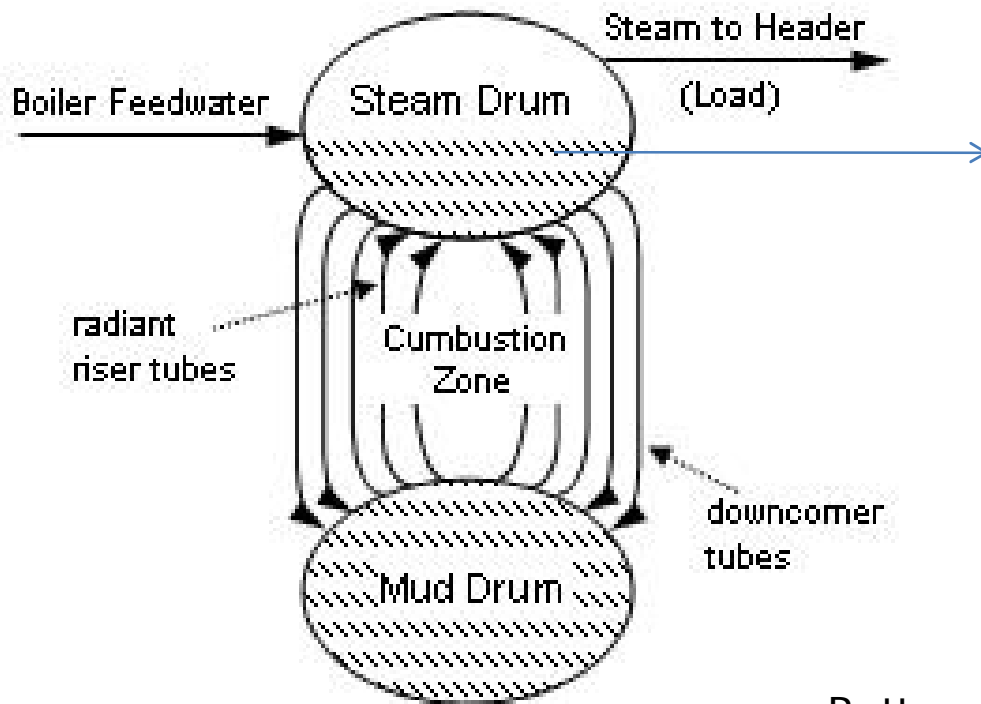


This liberated acids attacks Fe (boiler material) and again produces HCl and this process goes on in a continuous manner.



Therefore small amounts of Magnesium chloride will have a significant effect on boiler corrosion!

Surface blow down



Region where steam leaves the boiler. Water in this region contains the highest level dissolved impurities. The water from this region is continuously sent back to the reservoir so that the boiler is free of dissolved impurities.

Bottom blow down

Bottom blowdown involves periodically opening valves in the mud drum to allow boiler pressure to force accumulated sludge out of the boiler.

Priming and Foaming

Due to rapid production of steam in boilers , some water droplets are carried along with the steam. This process of wet steam formation is called as Priming.

Causes of Priming

- Boiler design faults
- High steam velocities
- High levels of boiler feed water
- High speed of steam generation
- Sudden drop in steam pressure due to high demand for steam

Foaming

The formation of persistent foam or bubbles on water surface, which do not break easily is called as foaming.

Causes of Foraming

- High concentration of dissolved salts in boiler feed water.
- Presence of alkali in boiler water.
- Presence of oil droplets.
- Presence of finely dispersed suspended material.
- Voilant agitation of boiler feed water.

Disadvantages of Priming and Foaming

- It is difficult to determine the actual height of water level in the boiler. Thus maintenance of the boiler is affected.
- Priming leads to deposition of salts in different parts of the machinery leading to decreased lifetime.
- Deposition of salts in different parts of the machines also reduces the efficiency of the machines. It may also lead to corrosion of those parts.

Prevention of Priming and Foaming

Priming

- ☐ By fitting mechanical steam purifiers.
- ☐ By avoiding rapid change in steaming rate.
- ☐ By use of well softened and filtered water.
- ☐ By maintaining low water levels in boilers.

Foaming

- ☐ By adding antifoaming chemicals like cater oils.
- ☐ By removing oils from boiler water by using chemicals such as sodium aluminate.

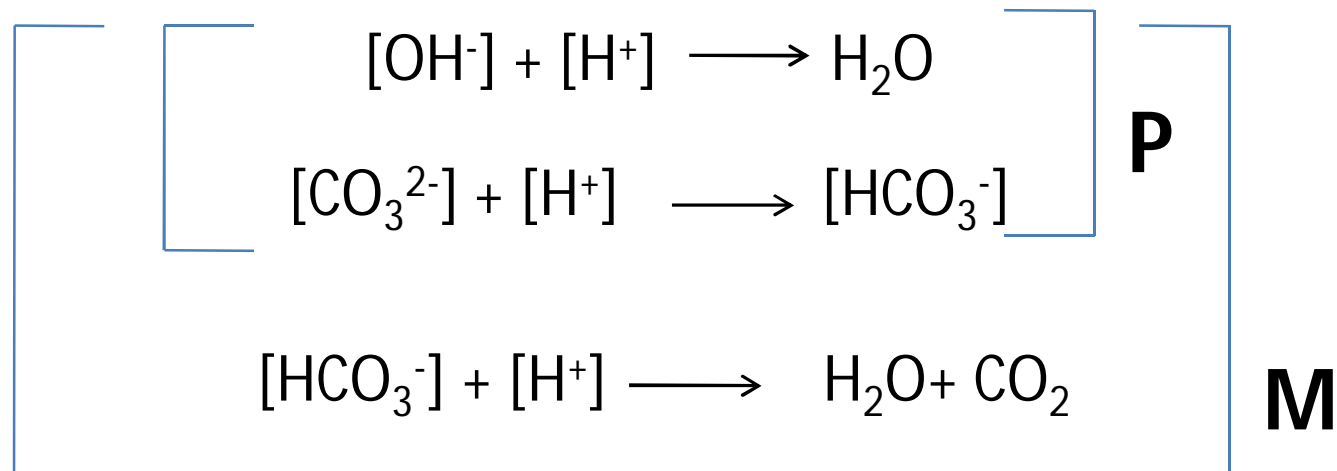
Alkalinity of water

The alkalinity of water is due to the presence of following.

1. Hydroxyl Ions (OH^-)
2. Carbonate Ions (CO_3^{2-})
3. Bicarbonate Ions (HCO_3^-)

How it is determined?

Standard acid base titration using phenolphthalein and methyl orange indicator.



Possible combinations

- ❖ OH^- only
- ❖ CO_3^{2-} only
- ❖ HCO_3^- only
- ❖ OH^- and CO_3^{2-} together
- ❖ CO_3^{2-} and HCO_3^- together.

❖ OH^- and HCO_3^- can not exist together. It combines to form CO_3^{2-} ions.

❖ Since OH^- and HCO_3^- can not exist together., all the three OH^- and HCO_3^- and CO_3^{2-} ions can not exist together.

- ❖ OH^- only then $P = M$
- ❖ CO_3^{2-} only then $2P$
- ❖ HCO_3^- only then M
- ❖ OH^- and CO_3^{2-} together
- ❖ CO_3^{2-} and HCO_3^- together.

OH^- and CO_3^{2-} together

Since $M - P = \frac{1}{2} \text{CO}_3^{2-}$

$$\therefore 2 (M - P) = \text{CO}_3^{2-}$$

$$\therefore \text{OH}^- = M - 2(M - P)$$

$$= M - 2M + 2P$$

$$= -M + 2P$$

$$\text{OH}^- = 2P - M$$

CO_3^{2-} and HCO_3^- together

$$\text{Only } \text{CO}_3^{2-} = 2P$$

$$\therefore \text{HCO}_3^- = M - 2P$$

Alkalinity of water

Alkalinity	OH^-	CO_3^{2-}	HCO_3^-
$P = 0$	0	0	M
$P = \frac{1}{2} M$	0	2P	0
$P < \frac{1}{2} M$	0	2P	(M-2P)
$P > \frac{1}{2} M$	(2P-M)	2(M-P)	0
$P = M$	P = M	0	0

Alkalinity determination

- ❖ First step involves neutralization of all the OH^- ions and half neutralization of all the CO_3^{2-} to HCO_3^-
- ❖ Water is titrated against a strong acid using Phenolphthalein indicator.
- ❖ The end point is pink to colorless. (V_1 ml)
- ❖ The titration is continued further by adding a few drops of methyl orange indicator. During this the bicarbonates (half neutralised from carbonate and the ones already present in water) are completely neutralised. The completion is marked by colour change from colourless to rosy red. (V_2 ml)

Alkalinity is expressed in terms of CaCO_3 equivalent.

$$P = \text{Phenolphthalein alkalinity} = \frac{V1 \times Z \times 50 \times 1000}{V}$$

Where,

Z = Normality of acid solution

V1 = Reading at Phenolphthalein end point

V = volume of water sample taken

50 = Equivalent wt of CaCO_3

$$M = \text{Methyl Orange alkalinity} = \frac{V_2 \times Z \times 50 \times 1000}{V}$$

Where,

Z = Normality of acid solution

V₂ = Reading at methyl orange end point

V = volume of water sample taken

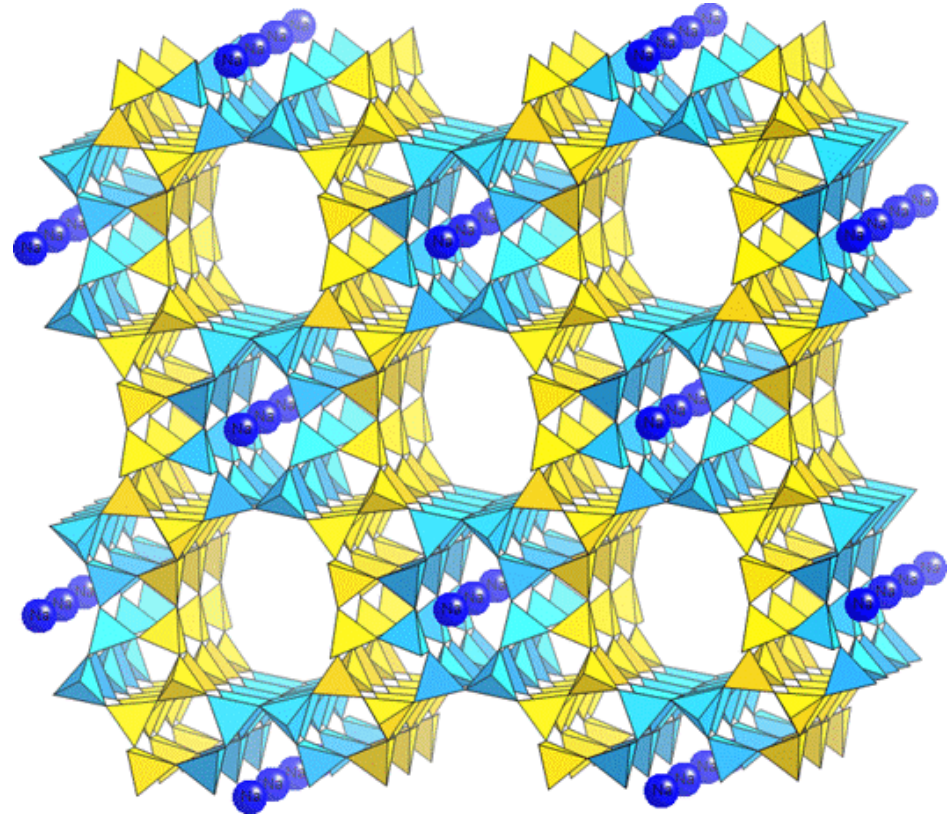
50 = Equivalent wt of CaCO₃

Zeolite or permutit process

Natural: Natrolite, $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$



Synthetic



Complex mixture of metal
Alumino Silicate



Representation as $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$

Where $x = 2-10$ and $y = 2-6$

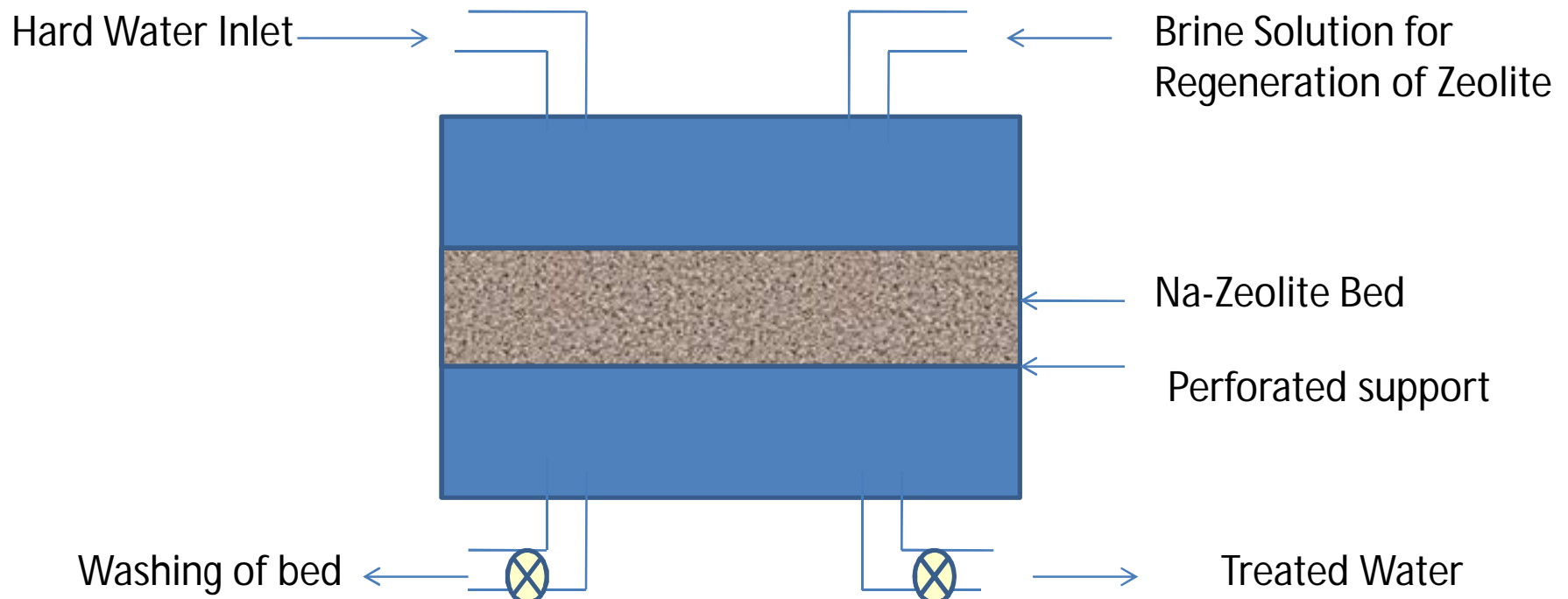
Sodium zeolite is hydrated sodium aluminosilicate

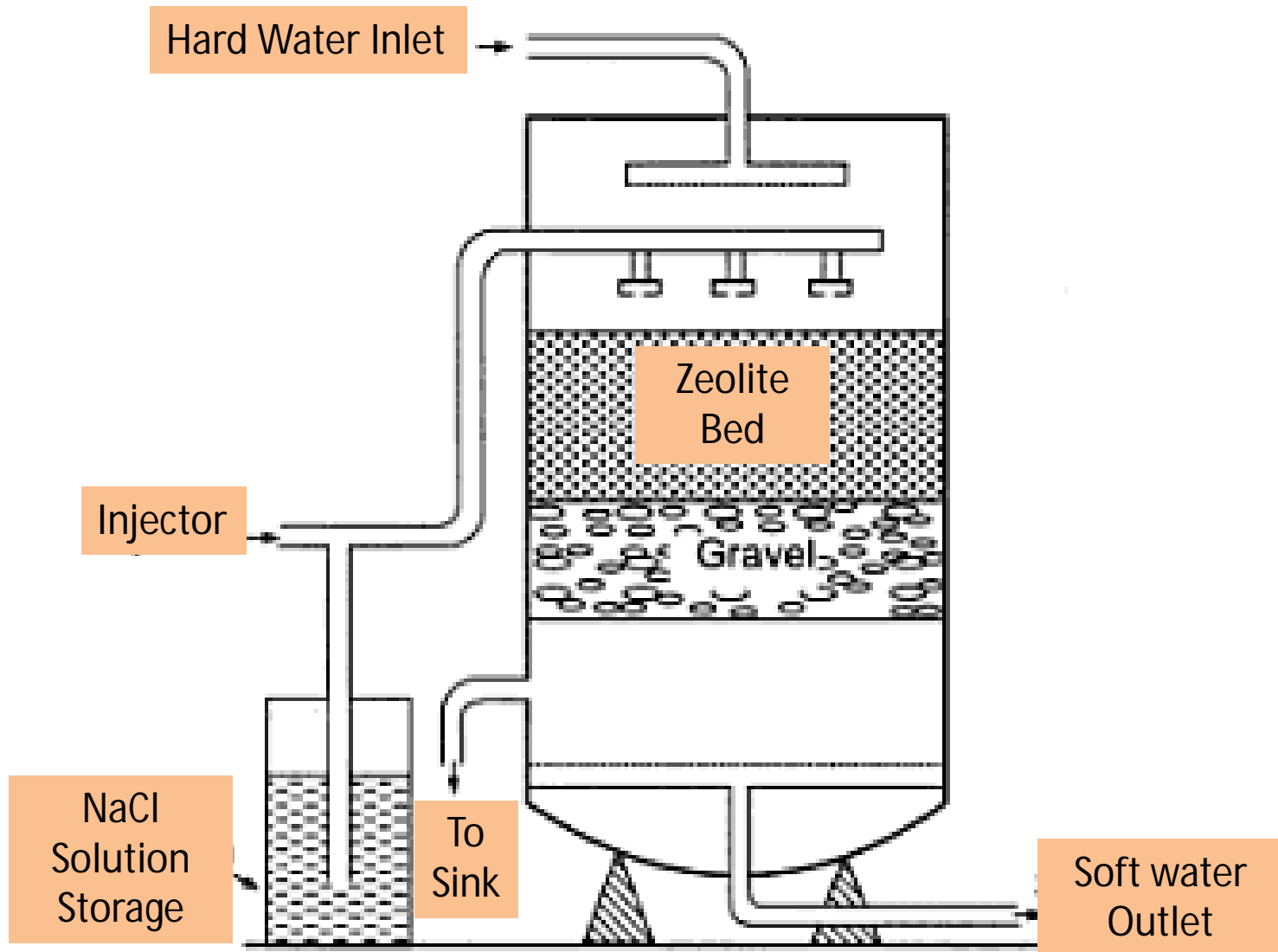
Can be prepared from fusion of SiO_2 , Al_2O_3 and Soda (Na_2CO_3)

Principle

Na-Zeolite has the property of capturing heavy metal ions from water and in exchange it releases the Na^+ ions.

The Removal of heavy metal ions (Ca^{2+} , Mg^{2+} etc) converts the hard water in to soft.





Reactions during water flow through the bed



Advantages of Zeolite process

- Low operating cost
- Easy operating procedure
- No precipitation of impurities so no sludge formation.
- Almost complete removal of hardness is achieved and water with 10 ppm hardness is obtained.
- Testing of Zeolite bed can be done simply with soap solution
- It requires less time for softening.

Disadvantages of Zeolite process

- The treated water contains more sodium salts.
- Only Ca^{2+} and Mg^{2+} are replaced leaving behind carbonates and bi carbonates.
- Highly turbid water can not treated.
- If too much of Fe and Mn are present they can react forming Mn and Fe zeolites..

The exhausted Zeolite is regenerated by using 10% NaCl solution. It is also called as brine solution

Reactions during Regeneration of the bed



Numerical: A zeolite bed gets exhausted on softening 1200 liters of hard water. The exhausted bed requires 5.85 liters of 10% NaCl Solution for regeneration. Find the hardness of water.

Given: Volume of water sample softened = **1200 Liters**

Amount of 10% NaCl = **5.85 liters**

10 % NaCl = 10 gm NaCl in 100 ml water = **100 gm/lite**

∴ Total amount of NaCl (in mg) present in

$$\begin{aligned} 5.85 \text{ liters water will be} &= \text{Concentration in grams /lit} \times 1000 \times \text{volume} \\ &= 100 \times 1000 \times 5.85 \\ &= \mathbf{5.85 \times 10^5 \text{ mg}} \end{aligned}$$

Lets express this amount of NaCl (in mg) in terms of CaCO_3 equivalent

$$\begin{aligned} &= \text{Mass of NaCl (in mg)} \times 50(\text{ eq. wt of } \text{CaCO}_3) / 58.5 (\text{eq. wt of NaCl}) \\ &= 5.85 \times 10^5 \times 50 / 58.5 \\ &= \mathbf{5 \times 10^5 \text{ mg } \text{CaCO}_3 \text{ equivalent}} \end{aligned}$$

Formula:

Hardness of Water \times Volume of water = Amount of NaCl in CaCO_3 equivalent

$$\begin{aligned} \text{Hardness of water} &= \text{Amount of NaCl in } \text{CaCO}_3 \text{ equivalent} / \text{Volume of water} \\ &= \mathbf{5 \times 10^5 \text{ mg } \text{CaCO}_3 \text{ equivalent} / 1200 \text{ liters}} \\ &= \mathbf{416.6 \text{ ppm}} \end{aligned}$$

Numerical: A zeolite bed was regenerated by passing 50 lit of 250 g/lit NaCl. Hardness of water was 400 ppm CaCO_3 equivalent. Calculate the amount of hard water softened.

Given: Volume of water sample softened = **to be found**

Amount of 250 gm/ lit NaCl = **50 liters**

Hardness of water = 400 ppm

\therefore Total amount of NaCl (in mg) present in

$$\begin{aligned} 50 \text{ liters water will be} &= \text{Concentration in grams /lit} \times 1000 \times \text{volume} \\ &= 250 \times 1000 \times 50 \\ &= \mathbf{1.25 \times 10^7 \text{ mg}} \end{aligned}$$

Lets express this amount of NaCl (in mg) in terms of CaCO_3 equivalent

$$\begin{aligned} &= \text{Mass of NaCl (in mg)} \times 50(\text{ eq. wt of } \text{CaCO}_3) / 58.5 (\text{eq. wt of NaCl}) \\ &= \mathbf{1.25 \times 10^7 \times 50 / 58.5} \\ &= \mathbf{1.068 \times 10^7 \text{ mg } \text{CaCO}_3 \text{ equivalent}} \end{aligned}$$

Formula:

Hardness of Water \times Volume of water = Amount of NaCl in CaCO_3 equivalent

$$\begin{aligned} \therefore \text{Volume of water softened} &= \text{Amount of NaCl in } \text{CaCO}_3 \text{ equivalent} / \text{Hardness of Water} \\ &= \mathbf{1.068 \times 10^7 \text{ mg } \text{CaCO}_3 \text{ equivalent} / 400} \\ &= \mathbf{26709 \text{ liters}} \end{aligned}$$

The hardness of 50,000 liters of water sample was removed by passing through a Zeolite softener. The softener required 200 liters of NaCl solution containing 125g/litre of NaCl for regeneration. Calculate the hardness of water.

Ion Exchange Resins

Also known as **deionization** or **de-mineralization** process

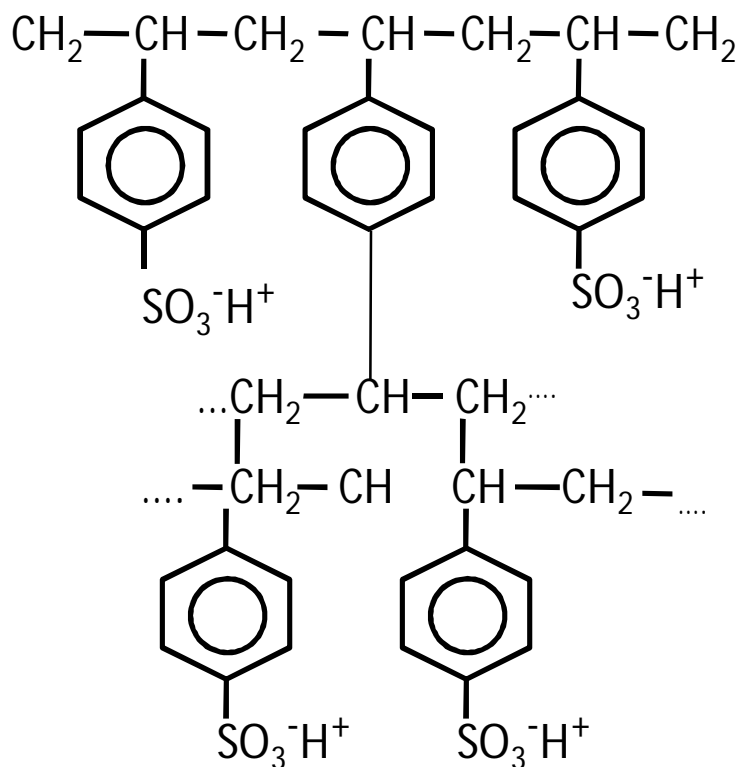
In this process a reversible exchange of ions takes place between the stationary exchange phase and the external liquid mobile phase.

Ion exchange resins are

Insoluble, Cross linked, Long chain polymers having microporous structure. The Functional groups attached to them are responsible for ion exchanging properties.

Type of Ion exchanger	Functional Groups
Strongly acidic cation exchangers	$-\text{SO}_3\text{H}$
Moderately strong cation exchangers	$-\text{PO}(\text{OH})_2$
weakly acidic cation exchangers	$-\text{COOH}$ or $-\text{OH}$
Strongly basic anion exchangers	$-\text{NR}_3^+$, $\equiv \text{P}-\text{CH}_3$, etc
weakly basic anion exchangers	$-\text{NH}_2$, $(\text{C}_2\text{H}_4)_x(\text{NH})_y^-$

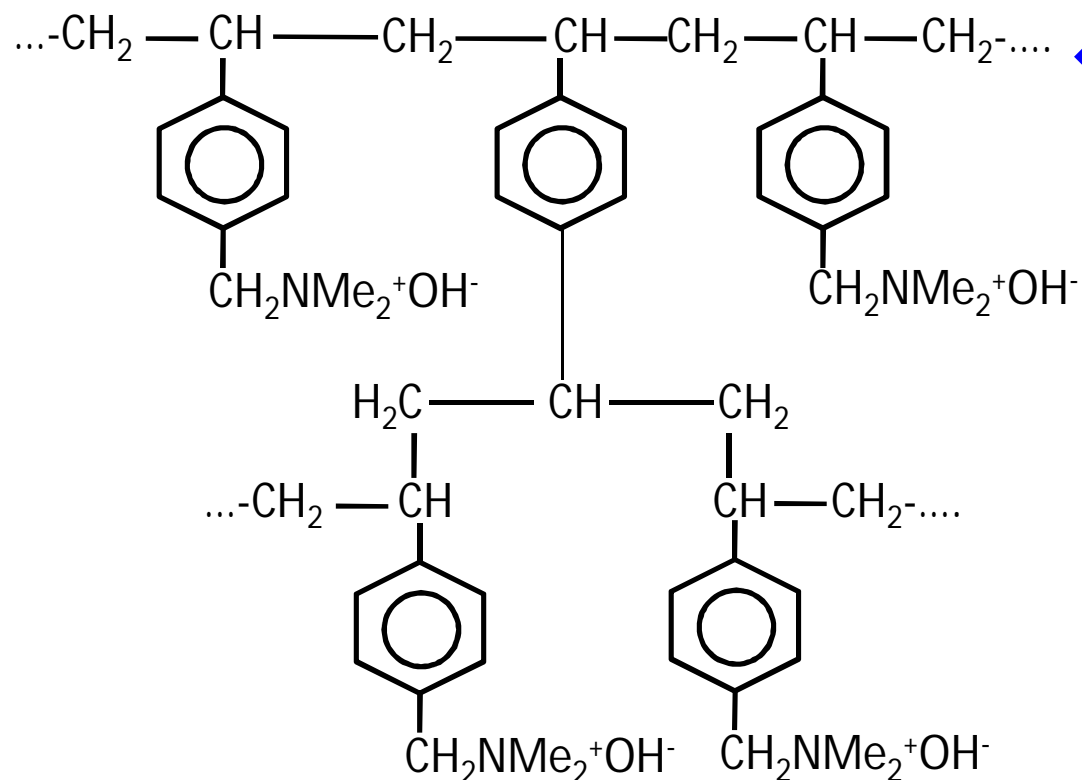
Cation Exchange Resin (Sulphonate form)



Styrene –divinyl benzene copolymers:
Which on sulphonation or carboxylation
exchange their hydrogen ions with the
cations on water.

Cation Exchange Resin is represented as
(RH^+)

Anion Exchange Resins



❖ Styrene-divinyl benzene or amine formaldehyde copolymers which contain amino or quaternary ammonium groups.

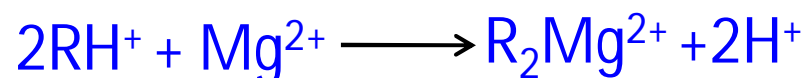
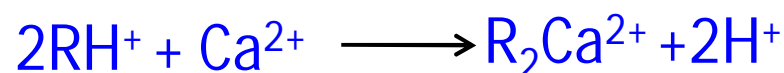
❖ These polymers on treatment with dilute NaOH become capable to exchange OH⁻ anions with anions in water.

Represented as (R'OH⁻)

Reactions

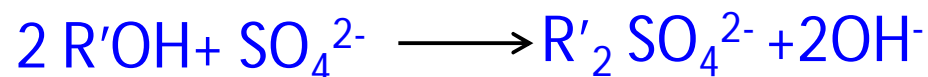
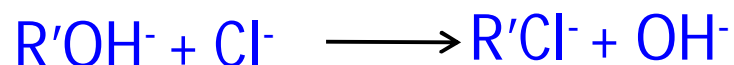
Step I : Water is passed through the cation exchange column.

In this process cations such as Ca^{2+} , Mg^{2+} etc are removed from it and equivalent amount of H^+ ions are released in water.



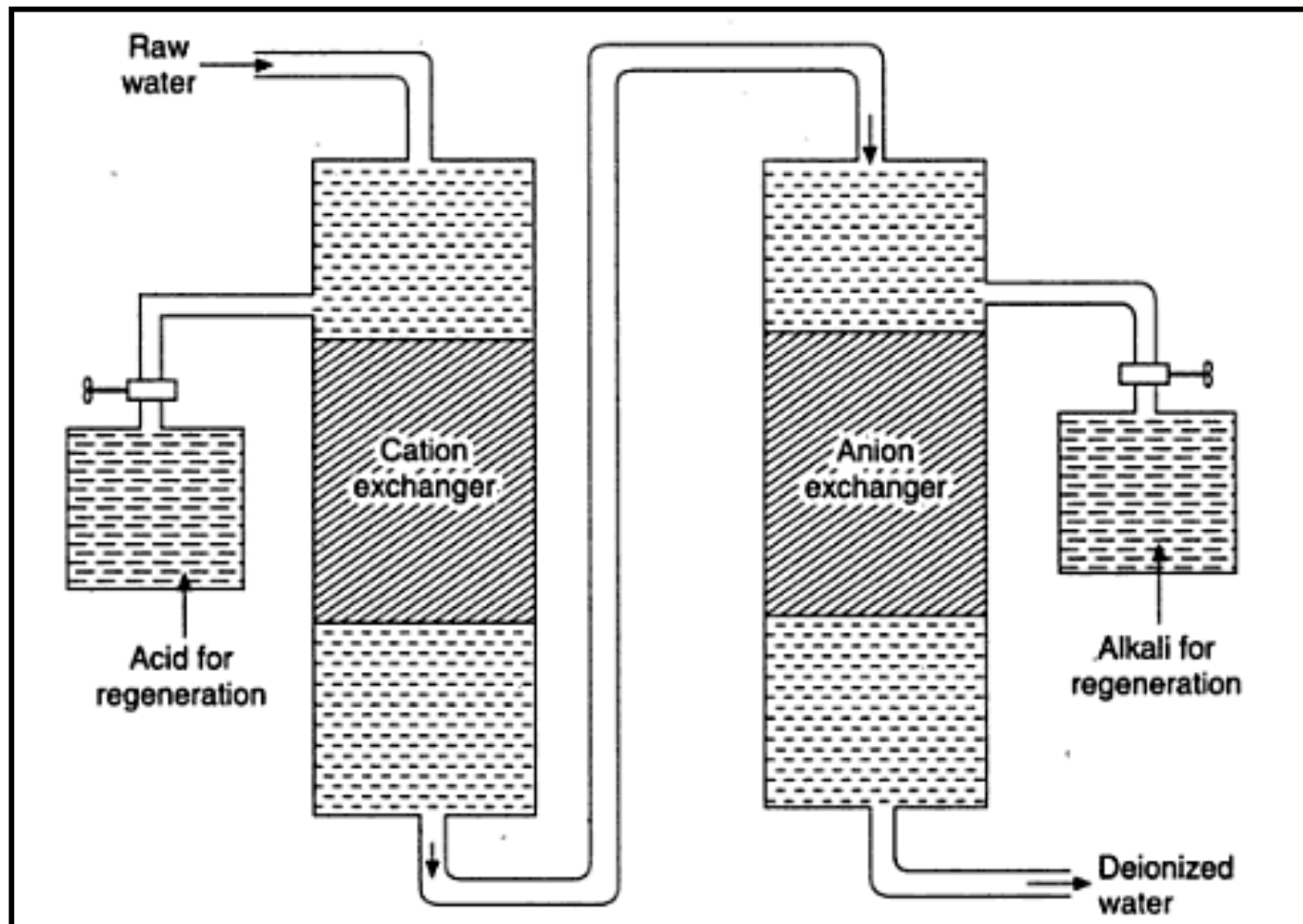
Step II : Water is then passed through the anion exchange column.

In this process anions such as SO_4^{2-} , Cl^- etc are removed from it and equivalent amount of OH^- ions are released in water.



H^+ and OH^- ions combine to form water.

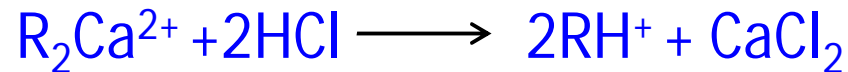
Ion exchange process



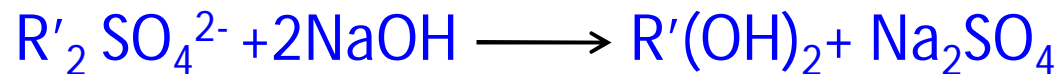
Regeneration of exhausted resin bed/column

When the cation and anion exchange resin loses its capacity to exchange H^+ and OH^- ions the resin is said to be exhausted.

Cation exchange resin is regenerated by passing /washing with dilute HCl.



Anion exchange resin is regenerated by passing /washing with dilute NaOH.



1. Lime Soda Process

Lime [Ca(OH)_2] and Soda [Na_2CO_3]

Calcium and Magnesium salts are converted into insoluble compounds like CaCO_3 and Mg(OH)_2 and are filtered.

Chemical Reactions involved in lime soda process

1. Removal of dissolved CO₂ and H₂S



2 . Neutralization of free mineral acids HCl, H₂SO₄



3 . Removal of temporary hardness



4 . Removal of permanent Magnesium hardness



5. Removal of dissolved Iron and Aluminium Salts

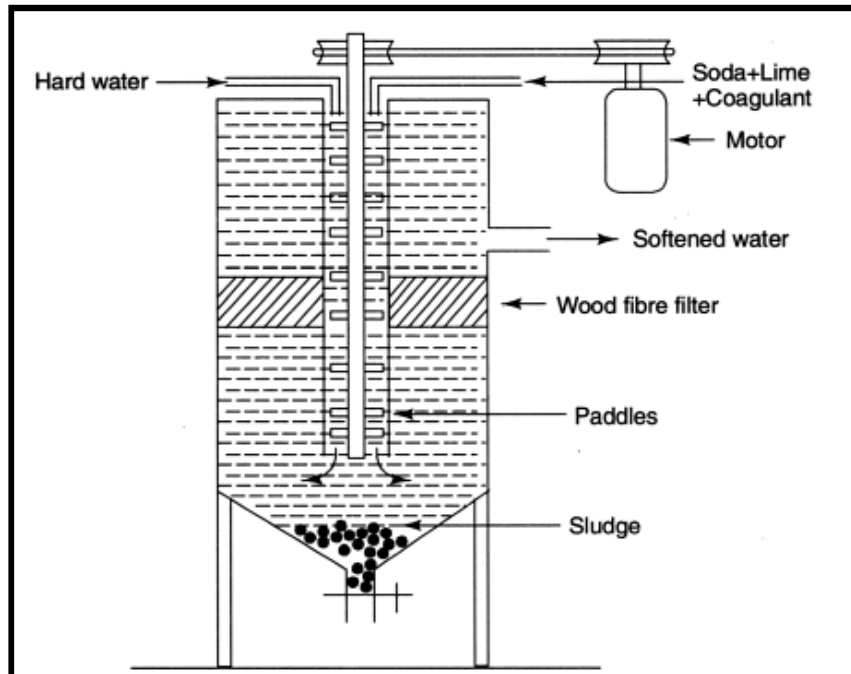


5. Reactions of soda remove all the Calcium permanent hardness



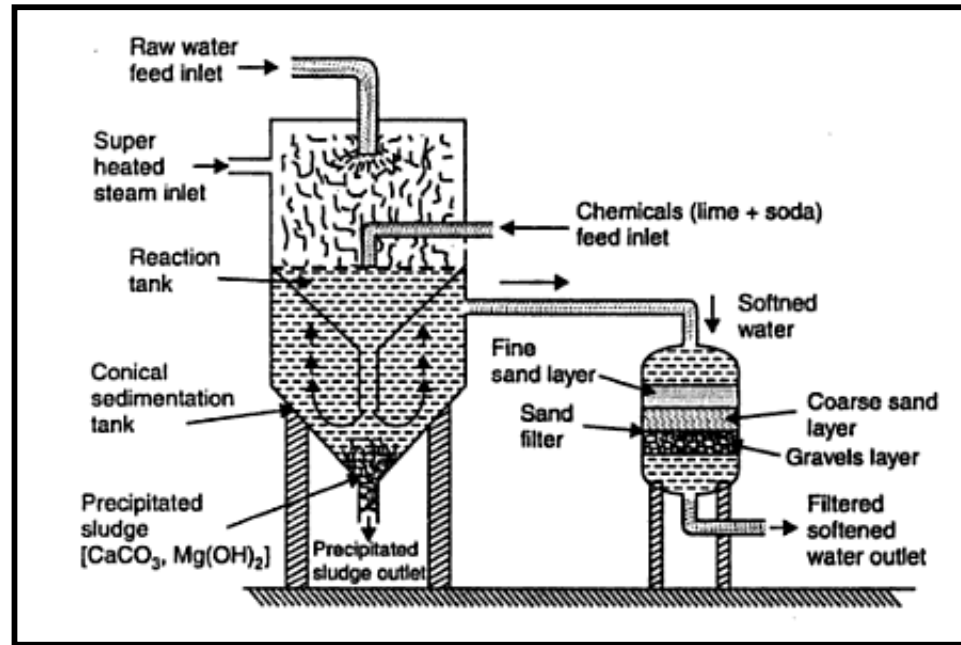
Constituent	Reaction	Need
Ca^{2+} (Perm Ca)	$\text{Ca}^{2+} + \text{Na}_2\text{CO}_3 \longrightarrow \text{CaCO}_3 + 2 \text{Na}^+$	S
Mg^{2+} (Perm. Mg)	$\text{Mg}^{2+} + \text{Ca}(\text{OH})_2 \longrightarrow \text{Mg}(\text{OH})_2 + \text{Ca}^{2+}$	L+S
HCO_3^-	$\text{Ca}^{2+} + \text{Na}_2\text{CO}_3 \longrightarrow \text{CaCO}_3 + 2 \text{Na}^+$	
	$2\text{HCO}_3^- + \text{Ca}(\text{OH})_2 \longrightarrow \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_3^{2-}$	
$\text{Ca}(\text{HCO}_3)_2$	$\text{Ca}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 \longrightarrow 2\text{CaCO}_3 + \text{H}_2\text{O}$	L
$\text{Mg}(\text{HCO}_3)_2$	$\text{Mg}(\text{HCO}_3)_2 + 2\text{Ca}(\text{OH})_2 \longrightarrow \text{Mg}(\text{OH})_2 + 2\text{CaCO}_3 + 2 \text{H}_2\text{O}$	2L
CO_2	$\text{CO}_2 + \text{Ca}(\text{OH})_2 \longrightarrow \text{CaCO}_3 + \text{H}_2\text{O}$	L
H^+ (from free acids like HCl, H_2SO_4 etc	$2\text{H}^+ + \text{Ca}(\text{OH})_2 \longrightarrow \text{Ca}^{2+} + 2\text{H}_2\text{O}$	L+S
	$\text{Ca}^{2+} + \text{Na}_2\text{CO}_3 \longrightarrow \text{CaCO}_3 + 2 \text{Na}^+$	
Coagulants		
$\text{Al}_2(\text{SO}_4)_3$	$2 \text{Al}^{3+} + 3 \text{Ca}(\text{OH})_2 \longrightarrow 2 \text{Al}(\text{OH})_3 + 3 \text{Ca}^{2+}$	L+S
	$3 \text{Ca}^{2+} + 2 \text{Na}_2\text{CO}_3 \longrightarrow 3 \text{CaCO}_3 + 6 \text{Na}^+$	
NaAlO_2	$\text{NaAlO}_2 + \text{H}_2\text{O} \longrightarrow \text{Al}(\text{OH})_3 + \text{NaOH}$ (eq. to $\text{Ca}(\text{OH})_2$	-L

Cold lime-soda process



- ❖ Calculated quantities of chemical (Lime and Soda) are mixed with water at RT.
- ❖ At RT the precipitates formed are very fine so they do not settle down easily .
- ❖ Small amounts of coagulants (like alum, Sodium Aluminate, Aluminum sulphate) are added.
- ❖ These hydrolyze to form precipitate of aluminum hydroxide which can entrap the fine precipitates.
- ❖ It also helps in removal of silica and oils present in water.

Hot lime-soda process



- ❖ Water is treated with the water softening chemicals at temperature of 80-150 degree Celsius.
- ❖ Since the process is operated close to boiling point of water, it is faster.
- ❖ The softening capacity is enhanced many fold.
- ❖ The formed ppt settles down rapidly and no coagulants are required. It can also drive out the dissolved gases like CO and air.

Advantages of Lime soda process

- ✓ Economical
- ✓ The process in combination with sedimentation with coagulation then less quantities of coagulants are needed.
- ✓ The process leads to increase in the pH of the treated water. Thus the corrosion of the distribution pipes is reduced.
- ✓ Due to the same reason the amount of pathogenic bacteria's present in water is also reduced.
- ✓ The process also helps in removal of iron and manganese from water.

Disadvantages of Lime soda process

- For high efficiency, a careful operation and skilled supervision is required.
- Sludge disposal is a problem.
- Can remove hardness up to 15 ppm which is still not desirable for use in boilers.

Lime and soda requirement of softening

Lime

$$= \frac{74}{100} \left[\begin{array}{l} \text{Temporary Calcium hardness} + (2 \times \text{Temporary} \\ \text{magnesium hardness}) + \text{Permanent Mg hardness} + \text{CO}_2 + \\ \text{HCl} + \text{H}_2\text{SO}_4 + \text{HCO}_3^- + \text{Salts of Fe}^{2+}, \text{Al}^{3+} \text{ etc, -NaAlO}_2, \text{ all} \\ \text{expressed in terms of their CaCO}_3 \text{ equivalents} \end{array} \right] \times \text{Vol. of water}$$

Soda

$$= \frac{106}{100} \left[\begin{array}{l} \text{Permanent Calcium hardness} + \text{Permanent Mg hardness} \\ + \text{Salts of Fe}^{2+}, \text{Al}^{3+} \text{ etc, HCl} + \text{H}_2\text{SO}_4 - \text{HCO}_3^- \text{ all expressed} \\ \text{in terms of their CaCO}_3 \text{ equivalents} \end{array} \right] \times \text{Vol. of water}$$

Calculate the amount of **lime required** for softening 50,000 liters of hard water containing the following.

SALT	Conc. (ppm)
CaCO_3	25
MgCO_3	144
MgCl_2	95
Na_2SO_4	15
Fe_2O_3	25
CaCl_2	111

Step 1. First Convert the salt into CaCO_3 equivalents

SALT (eq.wt)	Type of hardness	Multiplication factor	CaCO_3 equivalent
CaCO_3 (50)	T	100/100	$25 \times 100/100 = 25 \text{ mg/L}$
MgCO_3 (42)	T	100/84	$144 \times 100/84 = 171.43 \text{ mg/L}$
CaCl_2 (55.5)	P	100/111	$111 \times 100/111 = 100 \text{ mg/L}$
MgCl_2 (47.5)	P	100/95	$95 \times 100/95 = 100 \text{ mg/L}$
Fe_2O_3	NA	NA	Not Considered
Na_2SO_4	NA	NA	Not Considered

Formula

$$\text{Lime required for softening} = \frac{74}{100} \times \left\{ \begin{array}{l} \text{Temporary calcium hardness} + (2 \times \text{Temporary magnesium hardness}) + \text{Perm. Mg hardness} + \text{CO}_2 + \text{HCl} + \text{H}_2\text{SO}_4 \\ + \text{HCO}_3^- + \text{salts of Fe}^{2+}, \text{Al}^{3+} \text{ etc., -Na AlO}_2; \text{ all expressed} \\ \text{in terms of their CaCO}_3 \text{ equivalents.} \end{array} \right\} \times \text{Vol. of water}$$

Lime required for softening 50000 liters of water will be

$$= 74/100 [\text{CaCO}_3 + (2 \times \text{MgCO}_3) + \text{MgCl}_2 \text{ as CaCO}_3 \text{ Equivalent) } \times \text{volume of water}$$

$$= 74 /100 [25.0+2 \times \mathbf{171.43} + \mathbf{100}] \text{ mg /L} \times \mathbf{50,000 \text{ L}}$$

$$= 74/100 [467.86 \text{ mg/L}] \times \mathbf{50,000 \text{ L}}$$

$$= 17310820 \text{ mg}$$

$$= (1,73,10,280 / 10^6) \text{ Kg} = \mathbf{17.311 \text{ Kg}}$$

Calculate the amount of **lime and Soda required** for softening 50,000 liters of hard water containing the following.

SALT	Conc. (ppm)
$\text{Ca}(\text{HCO}_3)_2$	8.1
$\text{Mg}(\text{HCO}_3)_2$	7.5
CaSO_4	13.6
MgSO_4	12
MgCl_2	2

Step 1. First Convert the salt into CaCO_3 equivalents

SALT (eq.wt)	Type of hardness	Multiplication factor	CaCO_3 equivalent
$\text{Ca}(\text{HCO}_3)_2$ (81)	T	100/162	$8.1 \times 100/162 = 5.0 \text{ mg/L}$
$\text{Mg}(\text{HCO}_3)_2$ (73)	T	100/146	$7.5 \times 100/146 = 5.14 \text{ mg/L}$
CaSO_4 (68)	P	100/136	$13.6 \times 100/136 = 5 \text{ mg/L}$
MgSO_4 (60)	P	100/120	$12 \times 100/120 = 10.0 \text{ mg/L}$
MgCl_2 (47.5)	P	100/95	$2.0 \times 100/95 = 2.11 \text{ mg/L}$

$$\text{Lime required for softening} = \frac{74}{100} \times \left\{ \begin{array}{l} \text{Temporary calcium hardness} + (2 \times \text{Temporary magnesium hardness}) + \text{Perm. Mg hardness} + \text{CO}_2 + \text{HCl} + \text{H}_2\text{SO}_4 \\ + \text{HCO}_3^- + \text{salts of Fe}^{2+}, \text{Al}^{3+} \text{ etc., -Na AlO}_2; \text{ all expressed} \\ \text{in terms of their CaCO}_3 \text{ equivalents.} \end{array} \right\} \times \text{Vol. of water}$$

Lime required for softening 50000 liters of water will be

$$= 74/100 [\text{Ca(HCO}_3)_2 + (2 \times \text{Mg(HCO}_3)_2 + \text{MgSO}_4 + \text{MgCl}_2 \text{ as CaCO}_3 \text{ Equivalent)} \times \text{volume of water}$$

$$= 74 /100 [5.0 +2 \times 5.14 + 10. 0 + 2.11] \text{ mg /L} \times 50, 000 \text{ L}$$

$$= 74/100 [27.39 \text{ mg/L}] \times 50, 000 \text{ L}$$

$$= 1013430 \text{ mg}$$

$$= (1013430 / 10^6) \text{ Kg} = 1.0134 \text{ Kg}$$

$$\text{Soda required for softening} = \frac{106}{100} \times \left\{ \begin{array}{l} \text{Permanent calcium hardness + permanent Mg hardness +} \\ \text{Salts of Fe}^{2+}, \text{Al}^{3+}, \text{etc., + HCl + H}_2\text{SO}_4 - \text{HCO}_3^- \\ \text{-Na AlO}_2; \text{ all expressed in terms of their CaCO}_3 \text{ equiv.} \end{array} \right\} \times \text{Vol. of water}$$

Soda required for softening 50000 liters of water will be

$$= 106/100 [\text{CaSO}_4 + \text{MgSO}_4 + \text{MgCl}_2 \text{ as CaCO}_3 \text{ Equivalent}] \times \text{volume of water}$$

$$= 106 / 100 [5.0 + 10.0 + 2.11] \text{ mg /L} \times 50,000 \text{ L}$$

$$= 106 / 100 [17.11 \text{ mg/L}] \times 50,000 \text{ L}$$

$$= 906830 \text{ mg}$$

$$= (906830 / 10^6) \text{ Kg} = 0.9068 \text{ Kg}$$

Purification of water for domestic Use.

Characteristics of Potable water.

- ❖ clear and odourless
- ❖ moderate temperatures.
- ❖ Turbidity should not be more than 10 ppm
- ❖ Dissolved solids should be less than 500 ppm
- ❖ Should be free of dissolved gases like H_2S
- ❖ Should be free of Pb, As. Cr and other hazardous materials.
- ❖ IT should be reasonably soft.
- ❖ pH should be about 8
- ❖ Should be free of micro-organisms which can lead to some diseases.

1. Removal of Suspended impurities in water.

A. Screening: water is passed through screens having large no. of pores. The floating matter is retained .

B. Sedimentation: Removal of suspended solids by settling them down due to gravity



In case of fine clay particles or colloidal matter, sedimentation along with coagulation is required

Chemical Coagulants:

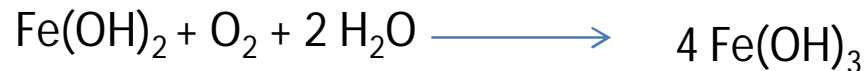
Alum : $[K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O]$



Sodium Aluminate ($NaAlO_2$)

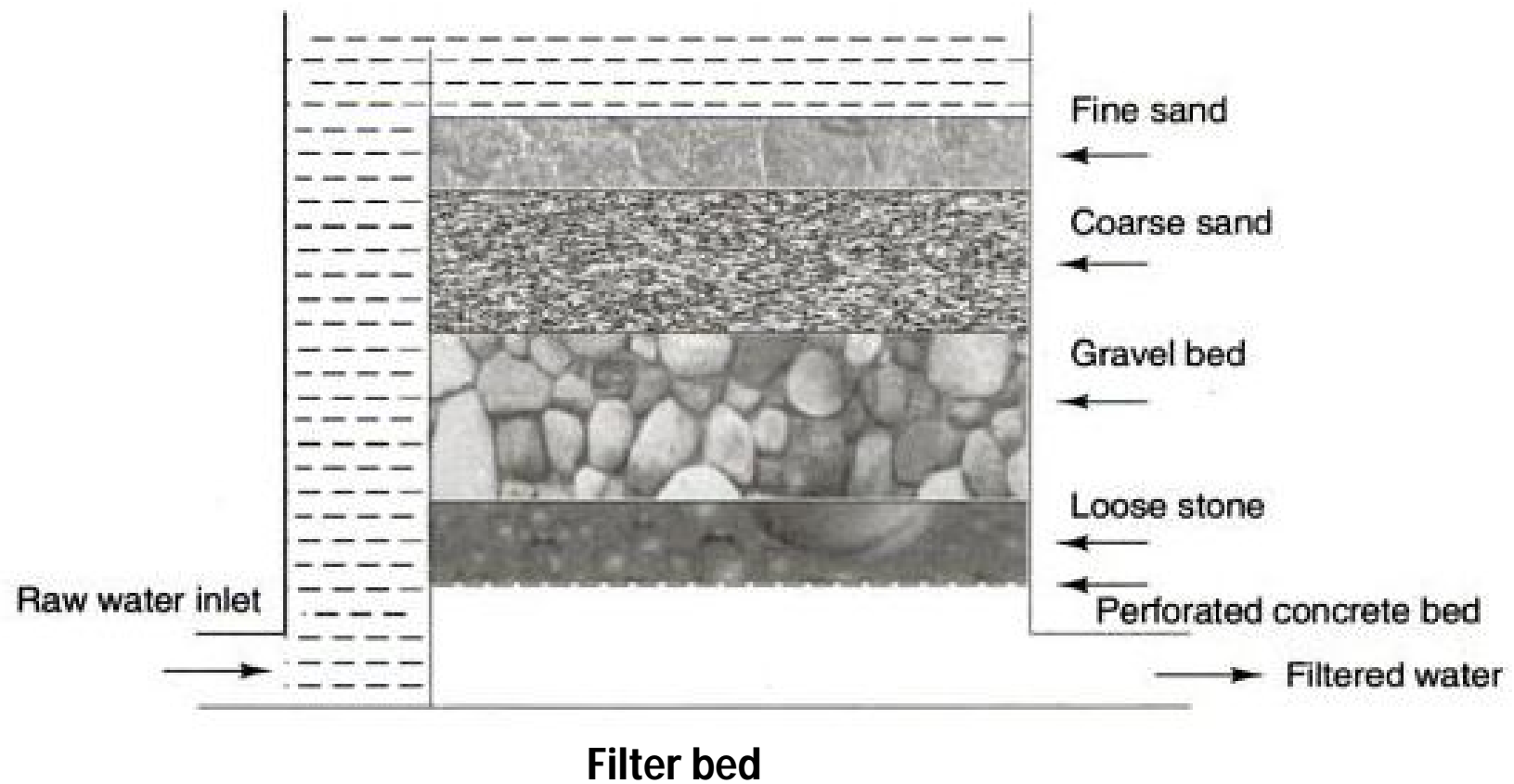


Ferrous Sulphate ($FeSO_4$)



Filtration

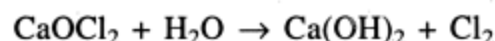
Filtration: This is the process of removing colloidal matter and most bacteria, and microorganisms by passing water through a bed of fine sand.



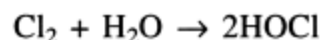
Chlorination

For disinfecting water in large quantities, municipalities use bleaching powder and chlorine commonly. Chloramine-T, hyperchlorite and UV radiation is also used for disinfecting water. In chlorination, chlorine, bleaching powder, chloramine-T or chlorine dioxide is added to water in measured quantities

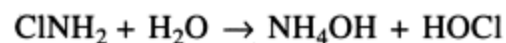
Bleaching powder liberates chlorine gas when it reacts with water.



Chlorine further reacts with water to liberate hypochlorous acid.

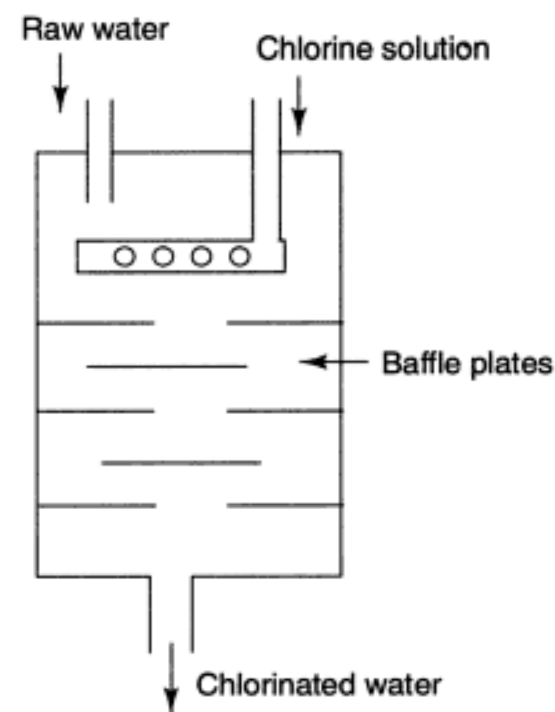


Chlorination by adding bleaching powder is cheap and quick and bleaching powder being a solid, it is easier to handle than chlorine that has to be stored in cylinders. However, chlorine is lost from bleaching powder if bleaching powder is not stored properly and comes in contact with moisture. Adding of bleaching powder to water increases its hardness as Ca^{+2} ions are introduced in water. Further, bleaching powder causes disagreeable taste and smell of chlorine in water. The disinfecting action of *chloramines* (ClNH_2) is similar to that of chlorine.



In comparison to bleaching powder, however, chloramine is a stable compound and is a better though costlier disinfectant.

$\text{HOCl} + \text{germs} \rightarrow \text{germs are killed}$

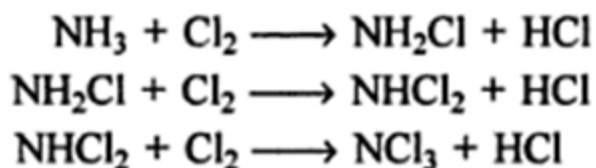


Chlorinator

Break point chlorination

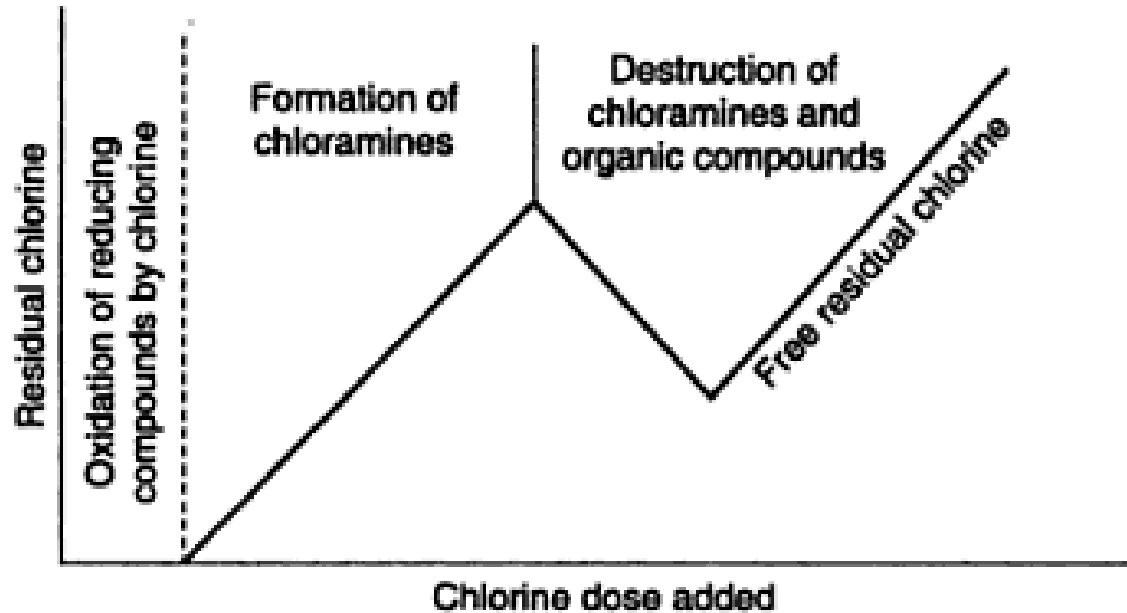
Break point chlorination is also known as free residual chlorination. It involves the addition of sufficient amount of chlorine to oxidise (a) Organic matter (b) Reducing substances (Fe^{2+} , H_2S etc.) (c) Free ammonia in water; leaving behind mainly free chlorine, which has disinfecting action against disease causing bacteria.

When chlorine is added to water, initially it reacts with ammonia and there will be formation of chloramines:



Thus the amount of combined residual chlorine (chloramines) increases with increasing dosage. Then the oxidation of chloramines and other impurities start and there is a fall in combined chlorine content. Thus combined residual chlorine decreases to a minimum at which oxidation of chloramines and other organic compounds complete. This minimum is the break point.

Further chlorination increases the free residual chlorine (Cl_2 , HOCl , OCl^-). Hence, to use chlorine as a good disinfectant, the chlorine dosage has to be given more than the break point.



Break point chlorination

Advantages:

- (i) All the organic compounds, pathogenic (disease causing) bacteria and impurities present in water are oxidised completely with break point chlorination.
- (ii) The colour, taste and odour present in water due to the microorganisms can be removed by this process.
- (iii) It also prevents the growth of algae and other organic matter.