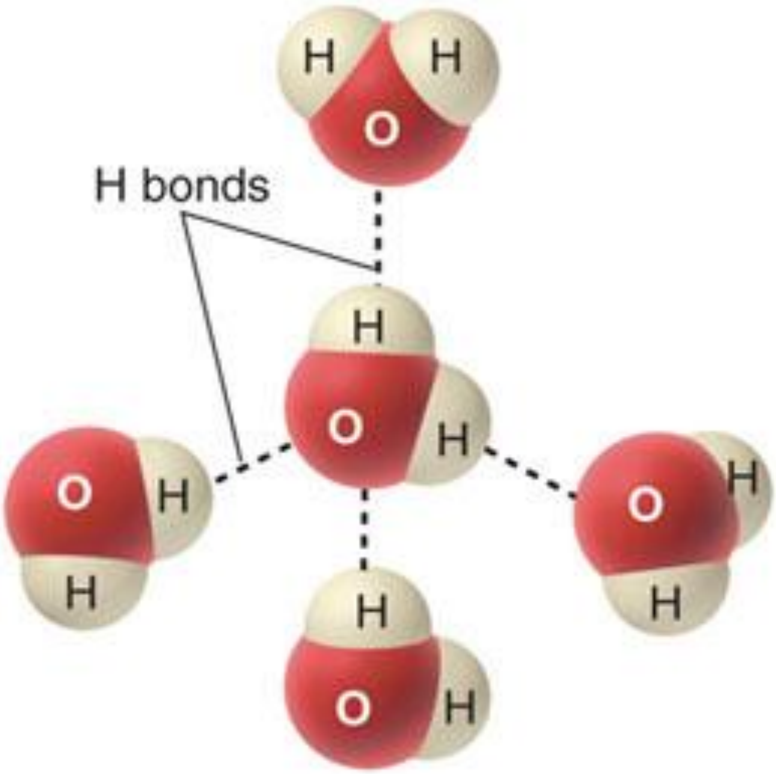
Chemistry in daily life

- Soaps
- Fuels
- Batteries
- Plastics
- Food
- Cloths
- Medicines
- Environmental protection (green chemistry)
- Paper industries
- Textiles
- Constructions

Water Technology

Chemistry of Water

- **Universal Solvent**
- **Polar Molecule**
- **High Dielectric constant**
- **High Specific Heat**
- **High Heat of Vaporization**
- **Hydrogen bonding**
- **High Surface Tension**
- **Capillary Action**
- **Adhesion**
- **Cohesion**



WHO Specifications for Drinking Water

Parameter	Values (ppm) except pH
pH	6.5 - 8.5
Hardness	300
Chloride	250
DO	5
Nitrate	50
Turbidity	5
Fluoride	1.5
TDS	500

https://www.youtube.com/watch?v=LDLjKlBroUA

Impurities in water

- **Suspended Impurities**
- **Dissolved Impurities**
- **Colloidal Impurities**
- **Biological Impurities**

Water Analysis

- **Hardness**
- **Alkalinity**
- **Chlorides and sulphates**
- **Dissolved oxygen**

Hardness of Water

- **Soap consuming capacity of water sample**
- **Due to dissolved salts of Ca & Mg**
- **Expressed in terms of ppm of $CaCO_3$**

$$2C_{17}H_{35}COONa + CaCl_2 \longrightarrow (C_{17}H_{35}COO)_2Ca\downarrow + 2NaCl$$

Sodium stearate — **Curd like ppt**

Temporary Hardness

- Also known as Carbonate or alkaline hardness
- Due to presence of $Ca(HCO_3)_2$ & $Mg(HCO_3)_2$
- Hardness can be removed by boiling hard water

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

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

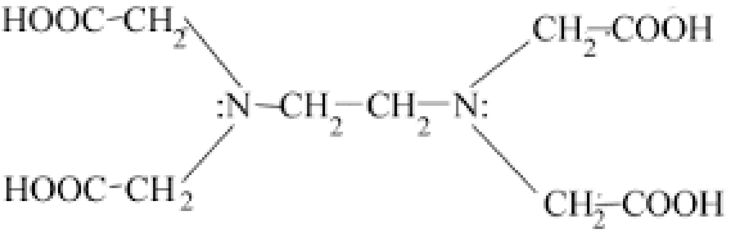
Permanent Hardness

- **Also known as non carbonate or non alkaline hardness**
- **Due to Chlorides, Nitrates & sulphates of Ca & Mg**
- **Can not be removed by boiling**

Total hardness = Temporary Hardness + Permanent Hardness

Determination of Hardness by EDTA Method

- **EDTA - EthyleneDiamineTetraAcetic Acid**
- **Chelating agent**
- **Hexadentate ligand**
- **Na_2EDTA is preferred as it is more soluble in water**



structure of EDTA

Determination of Hardness by EDTA Method

- **Complexometric titration**
- **EBT is used as indicator**
- **pH 10 is maintained by Buffer (NH_4Cl + NH_4OH)**

Hardness = B.R x Molarity of EDTA x100 x 1000 / V

- **V is volume of sample used for titration**

Procedure

Part-A: Standardization of Na_2EDTA by $ZnSO_4$

Part-B: Determination of total hardness using Std. Na_2EDTA

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Reactions involved in Hardness

$$M^{2+} + EBT \rightarrow M\text{-}EBT + 2H^{+}$$

Wine red

$$M\text{-}EBT + EDTA \rightarrow M\text{-}EDTA + EBT$$

(Blue)

Numerical on Hardness

1. 20 ml standard hard water contain 14 gm $CaCO_3$ per lit. 20 ml of this required 22 ml EDTA for the end point. 100 ml of water sample required 15 ml EDTA solution. The same sample after boiling required 10 ml of EDTA solution Calculate carbonate and noncarbonate hardness of water.

Hardness of water

2.Calculate temporary Hardness total hardness and Permanent hardness in terms of $CaCO_3$ for sample with composition

a) $Ca(HCO_3)_2$ = 6.4

b) $Mg(HCO3)_2$ = 8.2

c) $MgSO_4$ = 5.6

d) $MgCl_2$ = 4.2

e) $CaSO_4$ = 12.3

f) Na_2SO_4 = 6.5

Alkalinity

- **Acid Neutralizing Capacity of Water Sample**
- **Significance of alkalinity determination**
- **Determined By an acid-base Titration**
- **Phenolphthalein And Methyl Orange Are Used As Indicators**

Alkalinity Types

- Only HO^-
- Only CO_3^{2-}
- Only HCO_3^-
- OH^- & CO_3^{2-} together
- CO_3^{2-} & HCO_3^- together

Reactions Involved

P

$OH^- + H^+ \rightarrow H_2O$

$CO_3^{2-} + H^+ \rightarrow HCO_3^-$

M

$HCO_3^- + H^+ \rightarrow H_2O + CO_2\uparrow$

Alkalinity Procedure

100 ml water sample

→ Add 2-3 drops of phenolphthalein

→ Titrate against HCl till color changes from pink to colorless (V_1)

→ Add 2 drops of Methyl orange

→ Titrate with HCl till color changes from yellow to orange (V2)

Computing Alkalinity

- **Phenolphthalein alkalinity (P)**

  P $= (V_1 \times Z \times 50 \times 1000) / V$ ppm of $CaCO_3$ equivalents.

- **Methyl orange alkalinity (M) OR Total alkalinity**

  M $= (V_2 \times Z \times 50 \times 1000) / V$ ppm of $CaCO_3$ equivalents

Alkalinity Interpretation

Relation between P & M	OH^-	CO_3^{2-}	HCO_3^-
P = 0	0	0	M
P = M	P/M	0	0
P=1/2 M	0	2P	0
P>1/2M	2P-M	2(M-P)	0
P<1/2M	0	2P	M-2P

Numericals

- 50 ml water sample requires 4.5 ml of N/50 H_2SO_4 upto phenolphthalein end point and another 6 ml upto methyl orange end point, compute alkalinity result.
- water sample is not alkaline to phenolphthalein .100ml of sample on titration with N/50 HCl required 17.5 ml to get methyl orange end point. compute alkalinity result.

Mohr's Method

- **Chloride ion concentration is determined by titration of water sample with $AgNO_3$ in neutral or alkaline media**
- **Highly alkaline pH leads to formation of Silver Hydroxide (AgOH)**
- **At Low pH Chromate may transformed into dichromate leading to inaccurate result ($CrO_4^{2-} \Rightarrow Cr_2O_7^{2-}$)**
- **Desired pH can be achieved by adding $CaCO_3$**

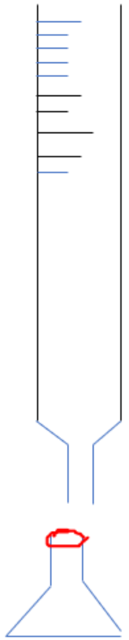
Mohr's Method

- **At the start chloride ions react with silver ions forming white ppt of Silver Chloride**

$$Ag^{+} + Cl^{-} \longrightarrow AgCl\downarrow$$

- **After all chloride are used up Ag^{+} reacts with chromate forming brick red precipitate**

$$Ag^{+} + CrO_4^{2-} \longrightarrow Ag_2CrO_4\downarrow$$



Chloride ions Concentration Calculation

1 mole of $AgNO_3$ = 1 mole of Cl^-

1000 ml $1NAgNO_3$ = 35.5 gm Cl^-

amount of chloride = N1 x V1/ V2 x 35.5

gm/lit.

N1 = Normality of $AgNO_3$

V1 = Volume of $AgNO_3$

V2 = Volume of water sample

- Chloride ion concentration above 250 ppm is not acceptable

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Dissolved Oxygen

- **Measurement gives idea about status of water system (Aerobic /Anaerobic)**
- **Indicator of water pollution**
- **DO level can give idea about survival of aquatic life**
- **DO is important factor causing corrosion of boiler material**
- **Possibility of aerobic biological processes for transforming biodegradable organic contaminants**

https://www.youtube.com/watch?v=oVW5LAzd7Ec

Steps in Winkler's Method

- O_2 Fixation

$$MnSO_4 + 2KOH \Rightarrow Mn(OH)_2 \downarrow + K_2SO_4 \quad (\text{ White })$$

- Conversion Mn (II) to Mn(IV) State forming Brown ppt of Basic Manganic oxide

$$2Mn(OH)_2 + O_2 \Rightarrow 2MnO(OH)_2 \downarrow \quad (\text{Brown})$$

- Conversion of Mn (IV) to Mn(II) on Acidification

$$MnO(OH)_2 + H_2SO_4 \Rightarrow MnSO_4 + 2H_2O + (O)$$

Winkler's Method

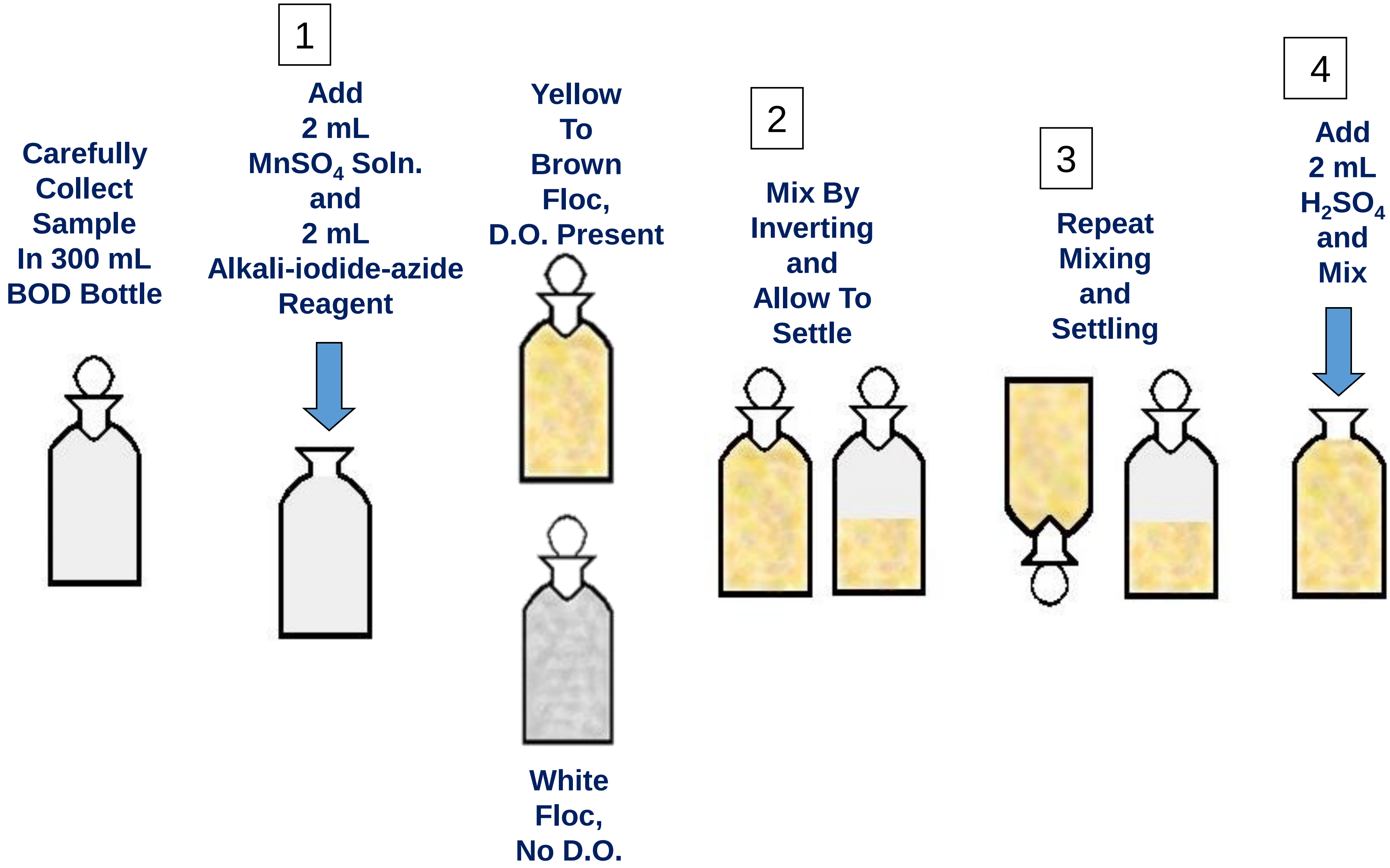
Oxidation of KI into I_2 by Nascent oxygen

$$2KI + H_2SO4 + O \longrightarrow K_2SO_4 + H_2O + I_2$$

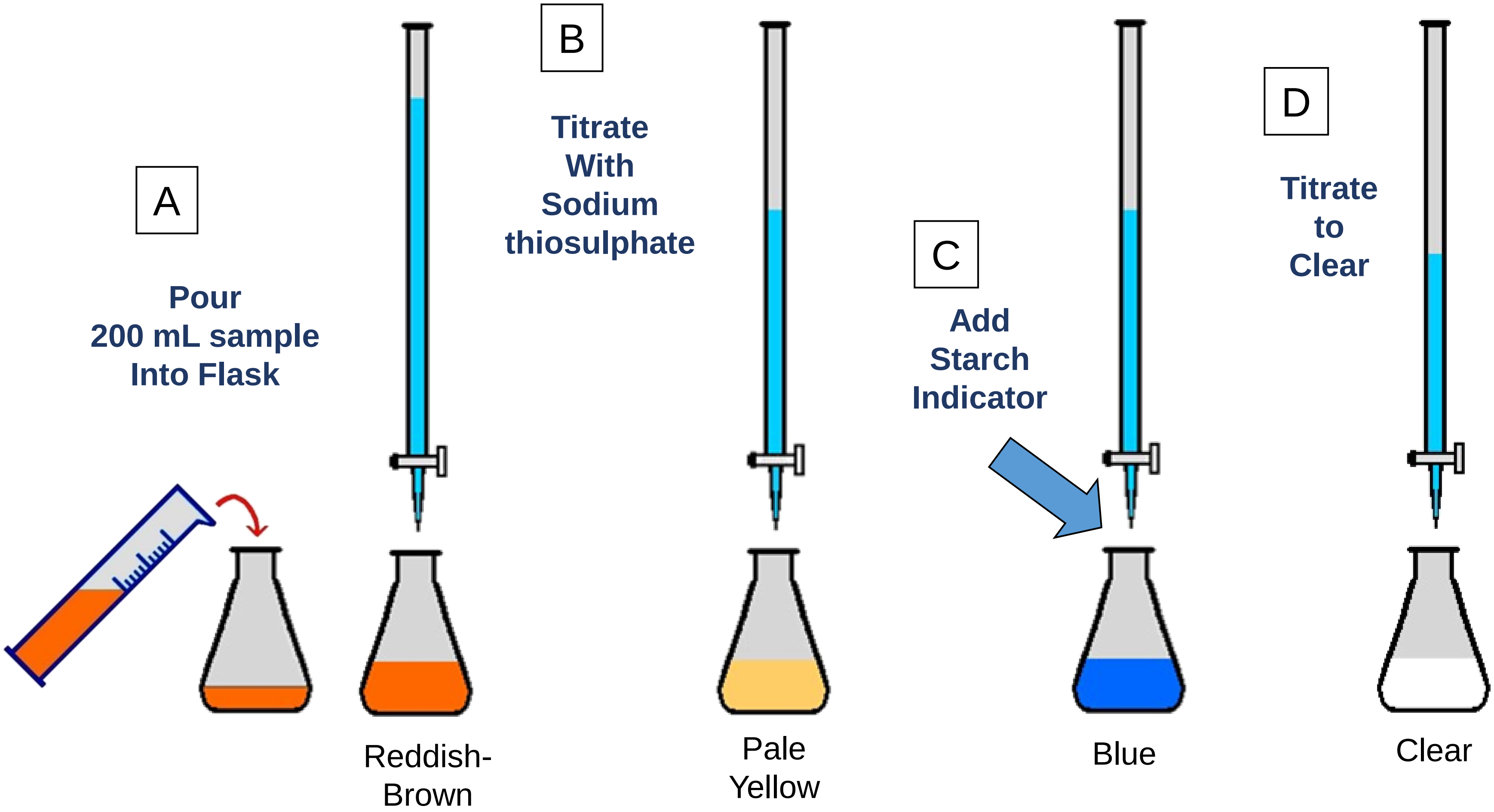
Titration of liberated iodine with sodium thiosulphate using starch indicator

$$I_2 + Na_2S_2O_3 \longrightarrow Na_2S_4O_6 \downarrow \quad + 2NaI$$

Outline Of Winkler Dissolved Oxygen Procedure



Titration of Iodine Solution



Winkler's Method

- Nitrate ion interference may be avoided by adding sodium azide

DO = (X x N1 x 8)/200 (water sample taken) x 1000

= ………………..mg/lit.

N1 = Normality of Sodium thiosulphate

X = Burette Reading

Ill effects of Hard Water In Boiler

A) Priming & foaming (carryover)

B) Caustic embrittlement

C) Boiler Corrosion

D) Scales & Sludges

Priming

Wet Steam formation inside boiler

Causes

- **Very high level of boiler feed water**
- **Presence of excessive foam**
- **High speed of steam generation**
- **Faulty boiler design.**

Prevention of Priming

- **Avoiding rapid changes in steaming rate**
- **Maintaining low level of water**
- **Better Boiler Design**
- **Removing impurities from water**

Foaming

Formation of continuous foam or bubbles on the surface of water

Causes:

- **High conc. of dissolved salts in boiler feed water**
- **Presence of oil droplets and alkalies**
- **Presence of Finely dispersed suspended material**
- **Violent agitation of boiler feed water**

Prevention of Foaming

- **Use of antifoaming agents**
- **Removal of oil and greases using sodium aluminates**
- **Removal of silica using ferrous sulphate**
- **By using soft water**

Disadvantages of priming and foaming

- **Actual height of water column cannot be judged well due to foaming**
- **Because of priming, the salts present in the droplets enter in the part of machineries.**
- **The dissolved salts in droplet of wet steam get deposited on evaporation of water**
- **Foaming causes wet steam formation**

Caustic Embrittlement

Boiler material gets brittle due to exposure to caustic solution at high pressure and high temperature condition

$$Na_2CO_3 + H_2O \Rightarrow 2NaOH + CO_2 \uparrow$$

Galvanic cell formation or Concentration cell

$$2Fe + 2NaOH + O_2 \Rightarrow 2NaFeO_2 + H_2 \uparrow$$

Prevention

- Use of Sodium phosphate instead of Na_2CO_3
- Addition of Tannin or Lignin
- Adjustment of pH between 8-9
- Adding Na_2SO_4

Boiler Corrosion

1.Dissolved oxygen

- $2Fe + 2H_2O + O_2 \longrightarrow 2Fe(OH)_2\downarrow$
- $2Fe(OH)_2 + 1/2O_2 \longrightarrow Fe_2O_3.2H_2O$ (Rust)

Removal of oxygen

- $Na_2SO_3 + 1/2O_2 \longrightarrow Na_2SO_4$
- $N_2H_4 + O_2 \longrightarrow N_2\uparrow + 2H_2O$

2.Dissolved CO_2

$CO_2 + H_2O \longrightarrow H_2CO_3$

Corrosion in Boiler

Hydrolysis of salts

- $MgCl_2 + 2H_2O \longrightarrow 2Mg(OH)_2 + 2HCl$
- $Fe + 2HCl \longrightarrow FeCl2 + H2$
- $FeCl_2 + 2H_2O \longrightarrow Fe(OH)_2 + 2HCl$

Disadvantages

- **Reducing the life of boiler**
- **Leakage of joints and rivets**
- **Increased cost of repairs & maintenance**

Scales & Sludges formation

- **Scales :Hard adherent deposit formed after saturation point inside boiler**
- **Due to presence of $CaSO_4$, $MgCl_2$,silicates of Ca & Mg**

Scale formation

Causes -

i) **Decomposition of bicarbonates**

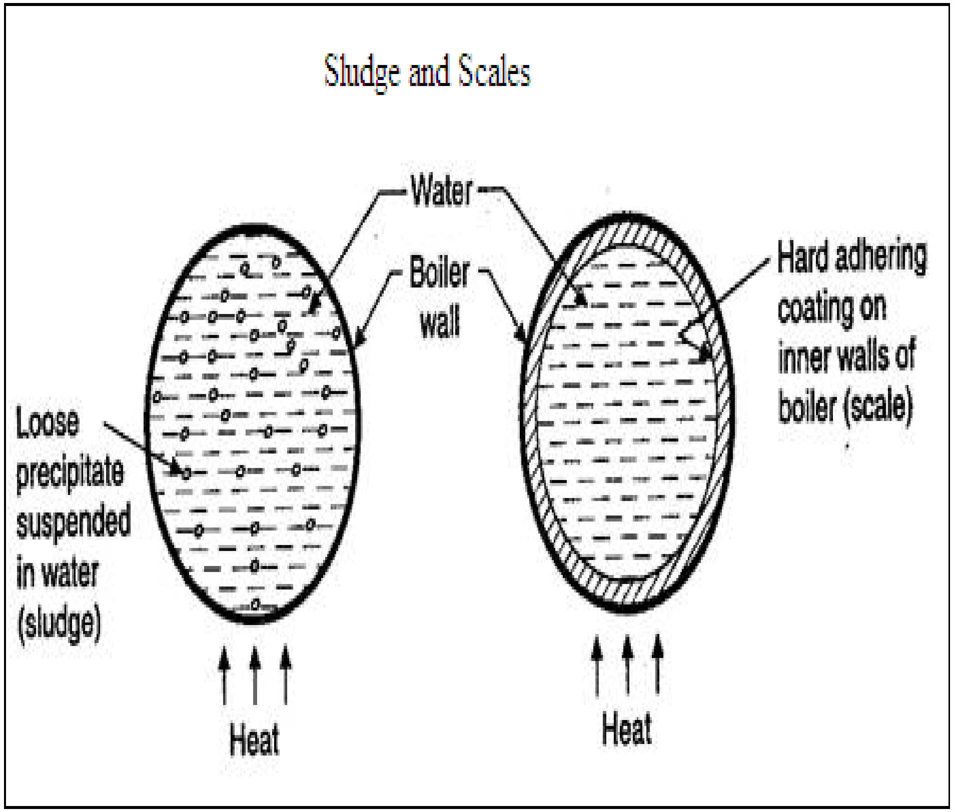
ii) **Hydrolysis of magnesium salts**

iii) **Presence of silica**

iv) **Decreased solubilities of $CaSO_4$ at high temperature**

Disadvantages of Scale Formation

- **Wastage of Fuel**
- **Over heating of boiler**
- **Boiler safety**
- **Danger of explosion**



Sludge

Disadvantages

- **Bad conductor of heat (Wastage of Fuel)**
- **Reduces boiler efficiency**
- **Reduces the flow rate of water in boiler.**

Prevention

- **Use of water containing very low quantity of total dissolved solids.**
- **Frequently making blow down operation.**

Prevention of Scale formation

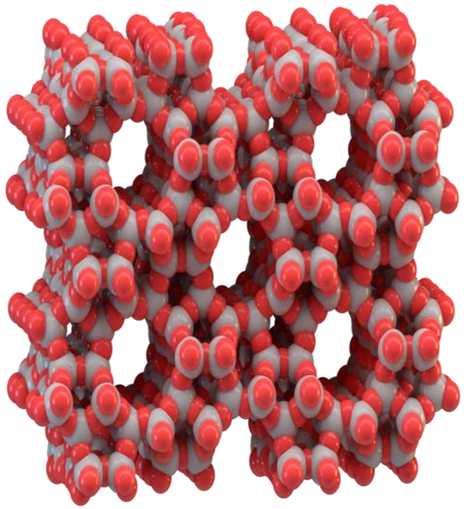
- **Use of softened water**
- **Phosphate conditioning**
- **Adding sodium aluminates**
- **Adding organic chemicals like tannin.**

Water treatments

- **Zeolite process**
- **Ion exchange method**

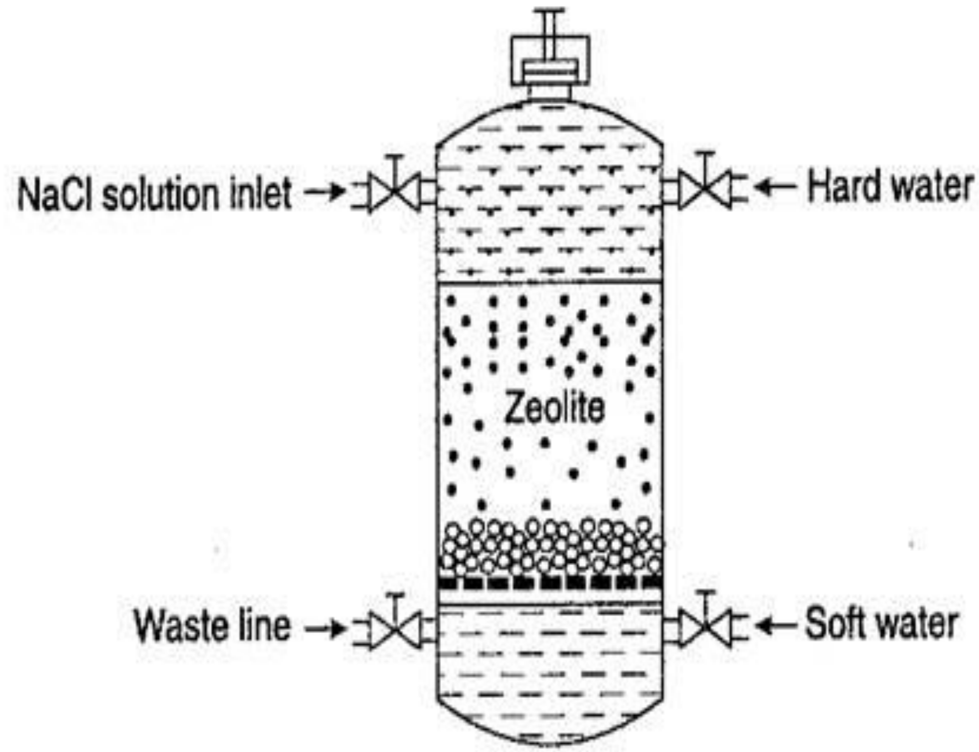
Zeolite

- **Naturally occurring hydrated aluminosilicates**
- **Also known as Permutit**
- **Porous Material**
- **Insoluble in water**
- **Works on Ion exchange Process**



Zeolite

- **Zeolite can trap Ca^{2+} , Mg^{2+} from hard water and releases Na^{+} ions into water**



Zeolite process

Process

- Zeolite capture cations and releases equivalent Na^{+} ions into water

$$Na_2Ze + Ca^{2+} \rightarrow CaZe + 2Na^{+}$$

Regeneration

- Brine solution is used

$$CaZe + 2\,NaCl \rightarrow Na_2Ze + CaCl_2$$

Limitations of Zeolite

- **The effective concentration of sodium salt increases**
- **Mineral acid may disintegrate Zeolite bed**
- **Highly turbid water can not be treated**
- **Boiler feed Water with Fe^{+2} and Mn^{+2} can not be treated properly**
- **Capable of removing only Cations**
- **Hot water dissolves Zeolite**

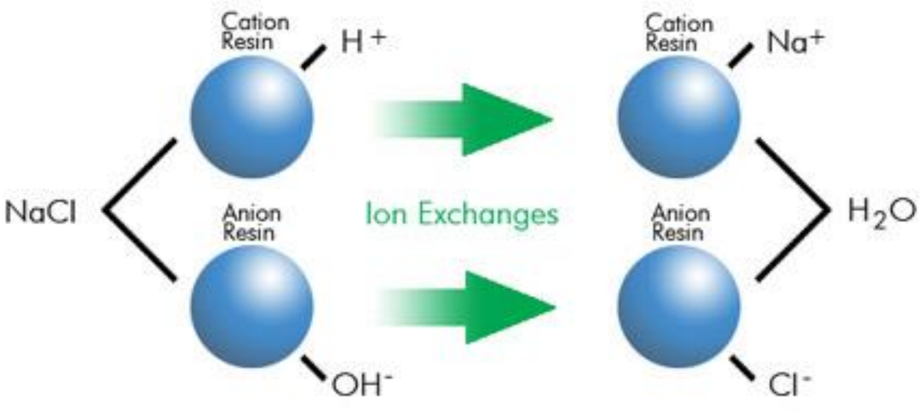
Numericals

1. **A zeolite bed was exhausted on softening of 4000 litre of water requires 10 litres of 15 % NaCl solution for regeneration. Calculate hardness of water sample.**

2. **A Zeolite softner was completely exhausted and was regenerated by passing 100 litre of NaCl containing 120 gm/litre of NaCl. How many litre of sample of water having hardness 500 ppm can be soften by this softner ?**

Ion Exchange Method

- **Resin** are used for water softening
- Resin have either **acidic or Basic Functional group** with loosely bound ions
- **Cation Exchange** and anion exchange resins are used



Cation Exchange Resin (RCOOH)

$$RCOOH + Ca^{2+} \rightarrow n\,[(RCOO)_2Ca^{2+}] + 2H^{+}$$

Key Points – Ion Exchange Method

- Cation exchange resin allow only cation exchange
- Anion exchange resin allow only anion exchange
- Net result is demineralised water
- Cation Exchange resin are regenerated by dilute HCl
- Anion exchange resin are regenerated by dilute NaOH

Anion Exchange Resin

$n\,[R - N^{+}(CH_3)_3\,OH^{-}] + Cl^{-} \Rightarrow n[R - N^{+}(CH_3)_3\,]Cl^{-} + OH^{-}$

Regeneration of resin

- **Process of regeneration is reversal of reaction for ion exchange process**
- **Regeneration of <u>cation Exchange resin</u>**

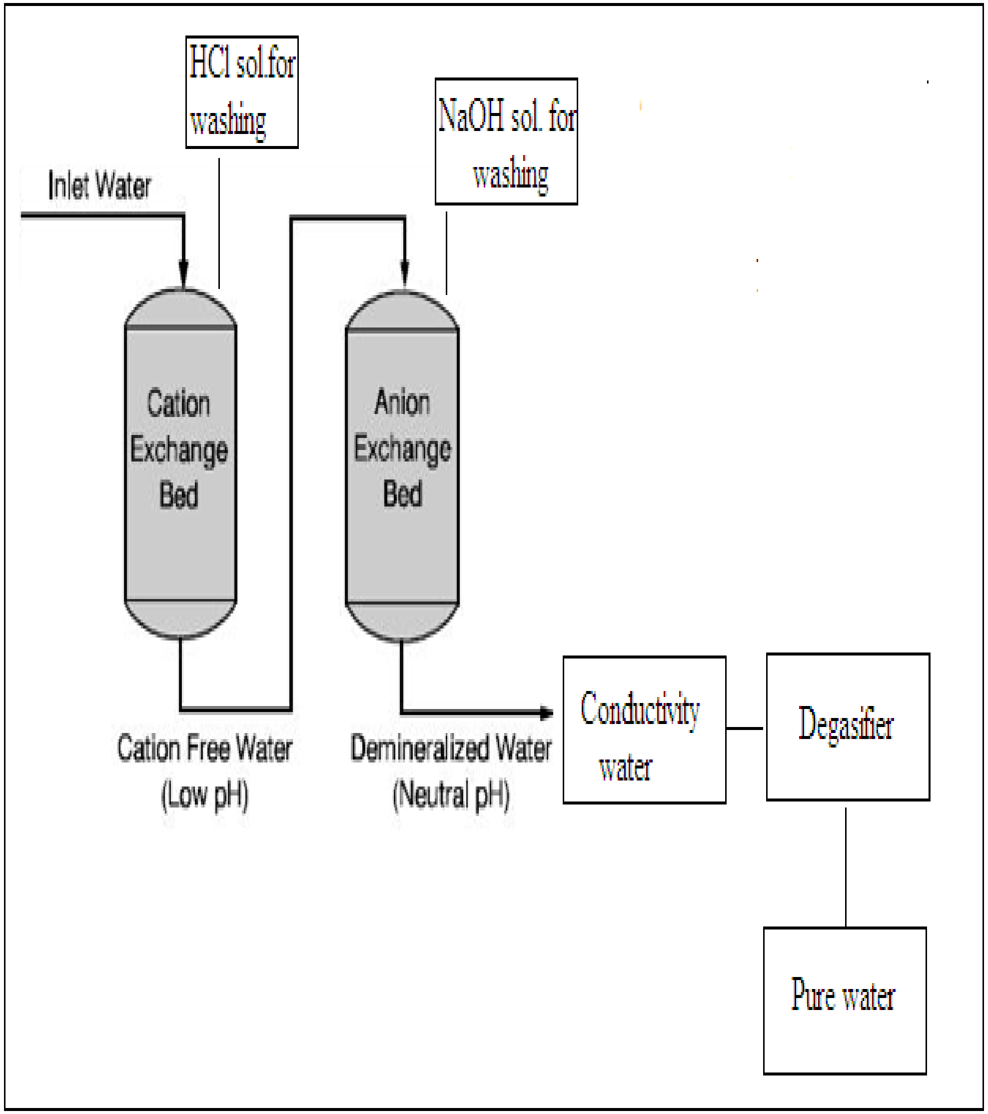
$$(RCOO)_2M^{2+} \;+\; 2H^+ \longrightarrow RCOOH \;+\; M^{2+}$$

- **Regeneration of <u>anion Exchange resin</u>**

$$[RN^+(CH_3)_3]\,Cl^- \;+\; OH^- \longrightarrow [\,RN^+(CH_3)_3]OH^- \;+\; Cl^-$$

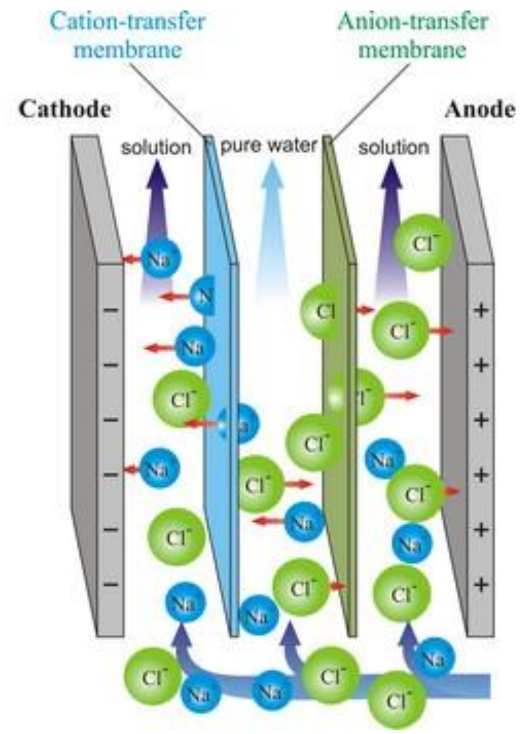
Ion Exchange Process

- Works well for variation of hardness of water
- Apparatus occupies small space
- Process is easy to operate
- Highly acidic or highly alkaline water can be treated effectively



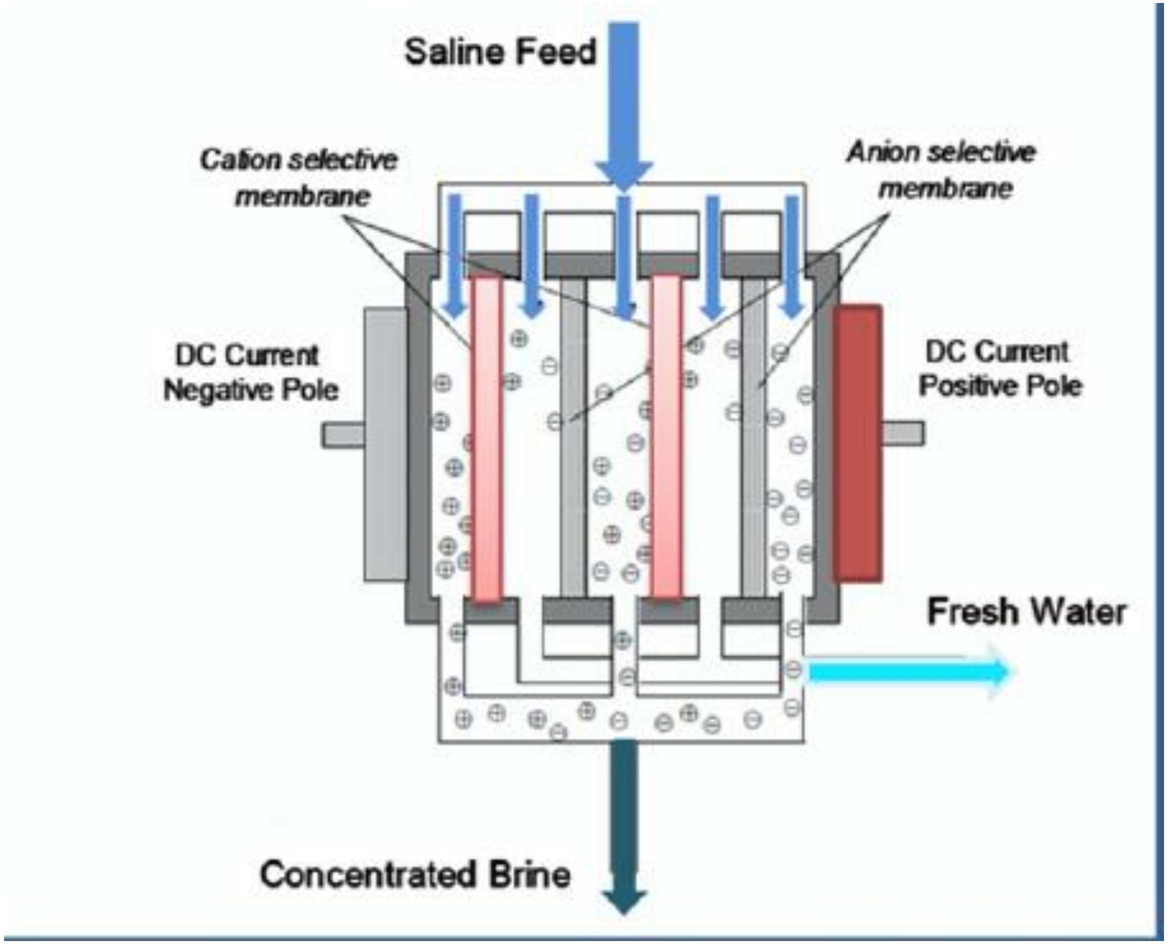
Electrodialysis

- **The process of removing ionic pollutants from water using membranes and electric field is known as Electro dialysis.**
- Ion selective membranes **are used**
- **Cation selective membrane allow passage of cations only**
- **Anion Selective Membrane allow passage of anions only**



Electrodialysis

- Under influence of electric field ions migrate towards Electrode with opposite sign
- Concentrated and dilute solution are created in alternate compartment

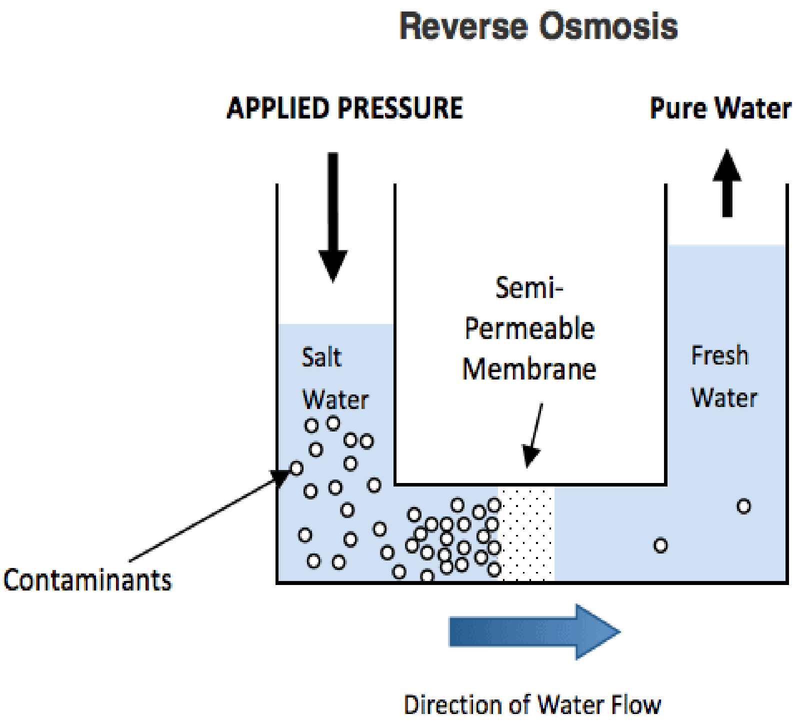


Applications of Electrodialysis

- Removal of ionic pollutants from treated industrial waste.
- Removal of salt from water
- Removal of limited quantity of salts from sea water.

Reverse Osmosis

- In RO process Solvent molecules travelled from high region of solute concentration to low Solute concentration through SPM
- External pressure is applied through high solute concentration compartment



https://www.youtube.com/watch?v=aVdWqbpbv_Y

Reverse Osmosis

- **External applied pressure is greater than osmotic pressure**
- **Semi permeable membrane made up from polymeric materials like acrylics, polyamides, aramids**
- **Membrane allow only passage of water molecules (Selective Porosity) by which other impurities are rejected**
- **water gets separated from contaminants**

Advantages of RO Process

- **Ionic, colloidal, non-ionic impurities removed from water.**
- **Pure water for high pressure boiler can be obtained.**
- **Used to obtain drinking mineral water.**
- **Simple to operate.**
- **Low cost process.**