ELEMENTS   1 TO 30 SYMBOLS, ATOMIC NUMBER, ATOMIC WIEGHTS, AND VALENCIES:

ATOMIC NUMBER	ELEMENT	SYMBOL	ATOMIC MASS (U)	ELECTRONIC CONFIGURATION	Valence Electrons	VALENCY
1	HYDROGEN	H	1.008	$1s^1$	1	1
2	HELIUM	He	4.00	$1s^2$	2	0
3	LITHIUM	Li	6.94	$1s^2\,2s^1$	1	1
4	BERYLLIUM	Be	9.01	$1s^2\,2s^2$	2	2
5	BORON	B	10.81	$1s^2\,2s^2\,2p^1$	3	3
6	CARBON	C	12.01	$1s^2\,2s^2\,2p^2$	4	4
7	NITROGEN	N	14.01	$1s^2\,2s^2\,2p^3$	5	3
8	OXYGEN	O	16.00	$1s^2\,2s^2\,2p^4$	6	2
9	FLOURINE	F	19.00	$1s^2\,2s^2\,2p^5$	7	1
10	NEON	Ne	20.18	$1s^2\,2s^2\,2p^6$	8	0
11	SODIUM	Na	22.99	$1s^2\,2s^2\,2p^6\,3s^1$	1	1
12	MAGNESIUM	Mg	24.31	$1s^2\,2s^2\,2p^6\,3s^2$	2	2
13	ALUMINIUM	Al	26.98	$1s^2\,2s^2\,2p^6\,3s^2\,3p^1$	3	3
14	SILICON	Si	28.09	$1s^2\,2s^2\,2p^6\,3s^2\,3p^2$	4	4
15	PHOSPHORUS	P	30.97	$1s^2\,2s^2\,2p^6\,3s^2\,3p^3$	5	3
16	SULPHUR	S	32.07	$1s^2\,2s^2\,2p^6\,3s^2\,3p^4$	6	2
17	CHLORINE	Cl	35.45	$1s^2\,2s^2\,2p^6\,3s^2\,3p^5$	7	1
18	ARGON	Ar	39.95	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6$	8	0
19	POTASSIUM	K	39.10	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^1$	1	1
20	CALCIUM	Ca	40.08	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2$	2	2
21	SCANDIUM	Sc	44.96	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^1$	3	3
22	TITANIUM	Ti	47.88	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^2$	4	4
23	VANADIUM	V	50.94	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^3$	5	5,4
24	CHROMIUM	Cr	52.00	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^4$	6	2
25	MANGANESE	Mn	54.94	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^5$	7	7,4,2
26	IRON	Fe	55.85	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^6$	8	2,3
27	COBALT	Co	58.93	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^7$	9	3,2
28	NICKEL	Ni	58.69	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^8$	10	2
29	COPPER	Cu	65.55	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^9$	2	2,1
30	ZINC	Zn	65.39	$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2 3d^{10}$	2	2

UNIT - I: Water and its treatment: [8]

1.1 Hardness of water

Introduction

Causes of hardness, expression of hardness

Types of hardness

Estimation of hardness of water by complexometric method

Numerical problems.

1.2 Potable water

Potable water and its specifications

Steps involved in the treatment of potable water

Disinfection of potable water by chlorination and break - point chlorination. Defluoridation

Determination of F^- ion by ion- selective electrode method.

1.3 Boiler troubles (Sludges, Scales and Caustic embrittlement)

I. Internal treatment of Boiler feed water
(a) Calgon conditioning

(b) Phosphate conditioning

(c) Colloidal conditioning,

II. External treatment of Boiler feed water

   (a) Softening of water by ion-Exchange processes.

1.4 Desalination of water -Reverse osmosis.

CHAPTER-1

WATER AND ITS TREATMENT

INTRODUCTION

The nature's most abundant supply i.e., water is essential for the survival of all the living beings on earth i.e., man, animals and plants. Water is not only essential for the survival of life, but it is also used for the operation in a large number of industries as coolant, solvent, for steam generation, for air conditioning, fire-fighting etc. Water is also used for all domestic purposes like bathing, drinking, washing, sanitary, irrigation etc.

1Q :why water act as universal solvent ?

Ans: Water is called a 'universal solvent' because water can dissolve much more substances than any other liquid found in nature.

2Q;Why is water polar?

water molecule has two poles - a positive charge on the hydrogen pole (side) and a negative charge on the oxygen pole (side). We say that the water molecule is electrically polar.
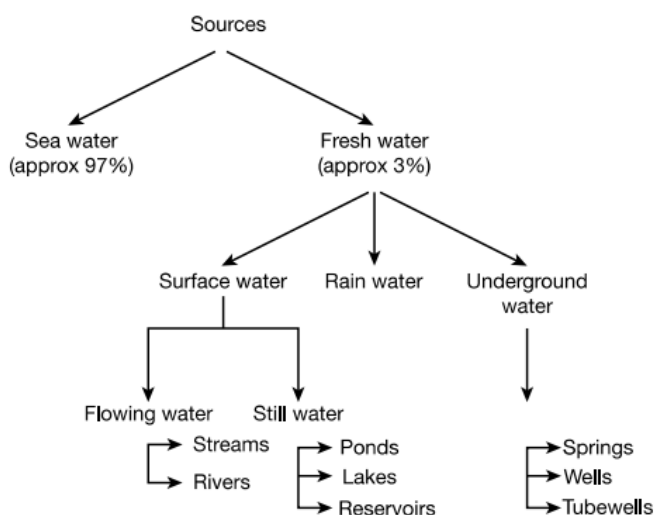
SOURCES OF WATER

Figure 1.1 Flow diagram of sources of water

Impurities of water:

Water may contain various impurities due to

  (i) The ground or soil with which it comes in contact (e.g. garbage, soil particles, etc.)
 (ii) Its contact with sewage or industrial wastes
(iii) The decomposition of dead plants and animals
(iv) The growth of bacteria, algae, viruses, etc.

Types of Impurities present in water:
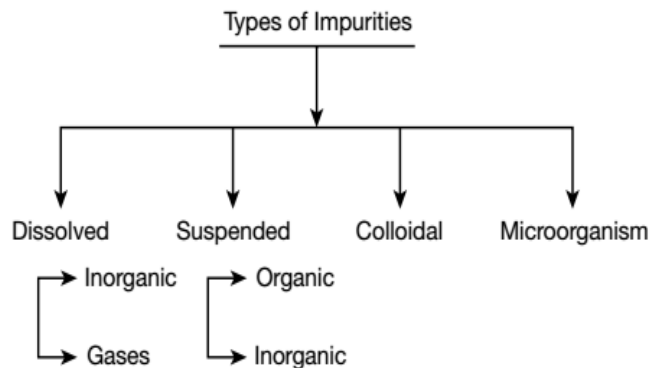The natural water is usually contaminated by different types of impurities. They are mainly three types.

Figure 1.2 Types of impurities

(i) Dissolved impurities

(a) Dissolved gases – NO_2, CO_2, SO_2, etc., which are soluble in water and make it impure.
(b) Dissolved inorganic salts or ions

(1) Cations: Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+}, Al^{3+}, Zn^{2+}, etc.

(2)Anions: CO_3^{2-}, SO_2^4 , HCO_3 , Cl , etc

(ii) Suspended impurities

   (a) Inorganic – sand, clay, lime, etc.
   (b) Organic – Plant and animal materials like discarded vegetables, dry leaves, dead materials, etc.

(iii)Colloidal impurities
Finely divided silica, clay, organic products, colouring matter, etc.

(iv)Microorganism
Various pathogenic microorganisms such as bacteria, fungi, virus, etc.

3Q: what are impacts of impurities present in water?

The various types of impurities present in the water impact certain properties in water.
(a) Presence of different chemicals impart colour, odour and taste to the water.
(b) Presence of dissolved salt makes the water hard.
(c) Excess quantities of metals and dissolved gases make the water corrosive in nature.
(d) Presence of pathogenic bacteria in water makes it unfit for drinking or domestic purposes.
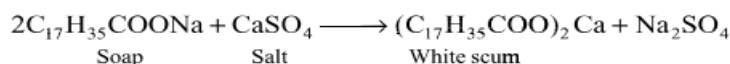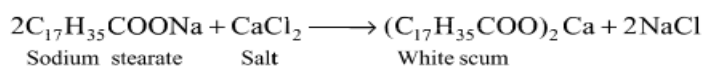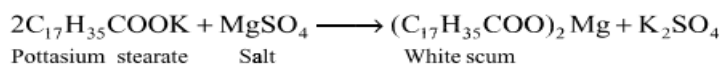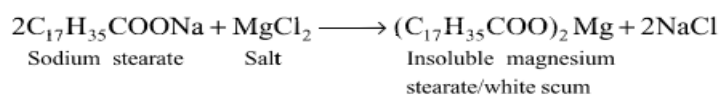(e) Suspended matter create turbidity to the water.

4Q: Differences between hard water and soft water

Table 2.3 Difference between hard and soft water

S.No	Hard water	Soft water
1	Water that does not form lather with soap but forms white precipitate	Water that produces lather or foam easily with soap is called 'soft water'
2	It contains soluble salts of calcium magnesium and other heavy metal ions like Al^{3+}, Fe^{3+}, and Mn^{2+} dissolved in it	It does not contain dissolved salts of calcium and magnesium
3	In hard water, the cleaning properties of soap is depressed and lot of soap is wasted in bathing and washing	The cleaning quality of soap is not depressed hence it is good for washing and cleaning
4	Owing to dissolved hardness, boiling point of water is elevated, therefore more fuel and time is required for cooking	Less fuel and time is required for cooking

HARDNESS OF WATER

Depending on salts presents in water and reaction with soap, water is categorized into hard water and soft water. Hardness is the characteristic of water by which water does not produce lather with soap. It is due to presence of chlorides, sulphates and bicarbonates salts of magnesium, calcium and other heavy metals [$CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$, $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, etc]. When hard water is treated with soap, it does not produce lather, rather it forms a white scum. Soap is the sodium or potassium salt of higher fatty acids like stearic acid [$C_{17}H_{35}$ COONa – sodium stearate].

$$2C_{17}H_{35}COONa + MgCl_2 \longrightarrow (C_{17}H_{35}COO)_2\,Mg + 2NaCl$$
Sodium stearate   Salt   Insoluble magnesium stearate/white scum

$$2C_{17}H_{35}COOK + MgSO_4 \longrightarrow (C_{17}H_{35}COO)_2\,Mg + K_2SO_4$$
Pottasium stearate   Salt   White scum

$$2C_{17}H_{35}COONa + CaCl_2 \longrightarrow (C_{17}H_{35}COO)_2\,Ca + 2NaCl$$
Sodium stearate   Salt   White scum

$$2C_{17}H_{35}COONa + CaSO_4 \longrightarrow (C_{17}H_{35}COO)_2\,Ca + Na_2SO_4$$
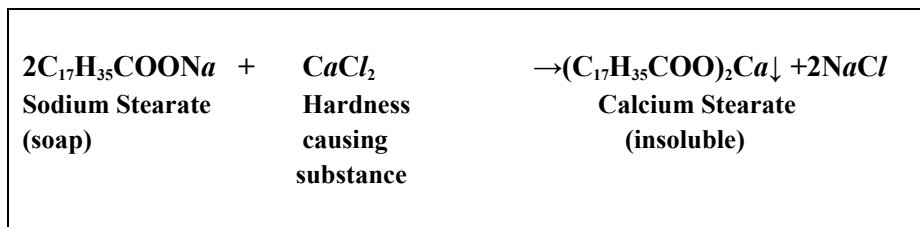Soap   Salt   White scum

Water which can produces lather with soap easily is called soft water.

"Hardness of water is the characteristic of preventing lather formation of water with soap". Generally salts like chlorides, bicarbonates and sulphates of Ca2+, Mg2+ and Fe2+ make water hard. This hard water on treatment with soap which is stearic or palmitic acid salts of

sodium or potassium causes white precipitate formation of calcium or magnesium stearate or palmitate.

Thus the cause of hardness is the precipitation of the soap and hence prevents lathering at first. When the hardness causing ions are removed as insoluble soaps, water becomes soft and forms lather.

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

2C$_{17}$H$_{35}$COONa +	**CaCl$_2$**	**→(C$_{17}$H$_{35}$COO)$_2$Ca↓ +2NaCl**
Sodium Stearate	**Hardness**	**Calcium Stearate**
(soap)	**causing**	**(insoluble)**
	substance	

TYPES OF HARDNESS

Hardness of water is mainly two types:

 1. Temporary Hardness

2. Permanent Hardness

 (1) *Temporary Hardness* is due to the bicarbonates of Ca^{2+} and Mg^{2+} and carbonate of Fe2+. Since bicarbonates readily get precipitated on boiling the water, the temporary hardness can be easily removed, viz.

$$Ca(HCO_3)_2 \xrightarrow[\triangle]{\textbf{heat}} CaCO_3 + H_2O + CO2\uparrow$$

(2) *Permanent Hardness* is due to the presence of chlorides and sulphates of Ca, Mg, Fe, etc. Permanent Hardness cannot be removed on boiling.

$$CaCl_2 + Na_2CO_3 \quad \rightarrow CaCO_3 \downarrow + 2NaCl$$
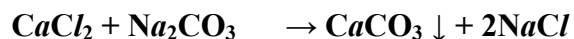
(Soda)

Table 2.4   Comparison between temporary and permanent hardness

S.No	Temporary hardness	Permanent hardness
1	Also called carbonate hardness or alkaline hardness	Also called non-carbonate or non-alkaline hardness
2	It is due to the presence of bicarbonates, carbonates of calcium and magnesium	It is due to the presence of dissolved chlorides, sulphates and nitrates of calcium, magnesium, iron and other heavy metals
3	It can be removed by boiling $Ca(HCO_3)_2 \xrightarrow{boil} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$ $Mg(HCO_3)_2 \xrightarrow{boil} Mg(OH)_2 \downarrow + H_2O + 2CO_2 \uparrow$	Cannot be removed by simple boiling but can be removed by specific chemical methods, like lime–soda process, zeolite method, etc.

EXPRESSION AND UNITS OF HARDNESS

The expression of hardness producing salts usually expressed in terms of an equivalent amount of CaCO3. Calcium Carbonate is chosen as a standard because:

  i.   Its molecular weight (100) and equivalent weight (50) is a whole number, so the calculations in water analysis can be simplified

  ii.   It is the most insoluble salt that can be precipitated in water treatment. The conversion of the hardness causing salts into CaCO3 equivalents can be achieved by using the following formula:

$$\frac{CaCO_3 \text{ equivalent}}{\text{of hardness}} = \frac{\text{Equivalent weight of } CaCO_3 (50)}{\text{Equivalent weight of hardness producing substance}} \times \frac{\text{Weight of hardness producing}}{\text{substance in mg/L}}$$

$$= \frac{W \times 50}{E}$$

W = Mass of hardness-producing substance in mg/L
E = Equivalent weight of hardness-producing substance

For bivalent hardness causing salts present in water using the following formula

$$\text{Hardness} (CaCO_3 \text{ equivalent}) = \frac{\text{Mol. wt. of } CaCO_3 (100)}{\text{Mol. wt. of the substance}} \times \frac{\text{Wt. of hardness producing}}{\text{substance in mg/L}}$$

$$= \frac{W \times 100}{M}$$

Units of Hardness:

1. Parts per Million (ppm): The number of parts of calcium carbonate equivalent hardness presents in 10^6 parts of water.

1ppm = 1 part of CaCO3 eq hardness in 10^6 parts of water.

2. Milligrams per litre (mg/l): The number of milligrams of calcium carbonate equivalent hardness presents in litre of water.

1 mg/L = 1 mg of CaCO3 eq hardness in 1 litre of water. But one litre of water weights =1 kg

=1000g = 1000 x 1000 mg = 10^6 mg = 1 ppm.

3. Clark's degree (°Cl): The number of parts of calcium carbonate equivalent hardness presents in 70,000 or (7×10^4) parts of water.

1° Clarke = 1 part of CaCO3 eq hardness per 70,000 parts of water.

4. Degree French (°Fr): The number of parts of calcium carbonate equivalent hardness presents in 10^5 parts of water.

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

Relationship between various units of hardness:

1 ppm = 1 mg/L = 0.1° Fr = 0.07° Cl

1 mg/L = 1 ppm = 0.1° Fr = 0.07° Cl

1 ° Cl = 1.433° Fr = 14.3 ppm = 14.3 mg/L

1 ° Fr = 10 ppm = 10 mg/L = 0.7° Cl

Problem-1: A sample of water is found to contains following dissolving salts in milligrams per litre $Mg(HCO_3)_2$ = 73, $CaCl_2$ = 111, $Ca(HCO_3)_2$ = 81, $MgSO_4$ = 40 and $MgCl_2$ = 95. Calculate temporary and permanent hardness and total hardness.

Solution:

Name of the hardness causing salts	Amount of the hardness causing salts(mg/Lit)	Molecular weight of hardness causing salts	Amounts equivalent to $CaCO_3$ (mg/Lit)
$Mg(HCO_3)_2$	73	146	73×100/146 = 50
$CaCl_2$	111	111	111×100/111 = 100
$Ca(HCO_3)_2$	81	162	81×100/162 = 50
$MgSO_4$	40	120	40×100/120 = 33.3
$MgCl_2$	95	95	95×100/95 = 100

Temporary hardness = $Mg(HCO_3)_2$ + $Ca(HCO_3)_2$
                    = 50 + 50 = 100mgs/Lit.
Permanent hardness = $CaCl_2$ + $MgSO_4$ + $MgCl_2$
                    = 100 + 33.3 + 100 = 233.3mgs/Lit.
Total hardness = Temporary hardness + Permanent hardness
                    = 100 + 233.3 = 333.3mgs/Lit.

Problem 1: If a sample of water contains 50 mgs of $Ca2+$ ions per liter, calculate its hardness in terms of $CaCO_3$ equivalent?

Problem 2: A water sample contains 204 mgs of $CaSO4$ and 73 mgs of $mg(HCO3)2$ per liter. What is the total hardness in terms of $CaCO3$ equivalent?

Problem 3: Calculate the carbonate and non-carbonate hardness of a sample of water containing the dissolved salt s as given below in mgs/lit . M $g(HCO3)2$ = 7.3; $Ca(HCO3)2$ = 40.5; $CaSO4$ = 13.6; $MgCl_2$ = 21.75 and $NaCl$ = 50.

Problem 4: A sample of water is found to contains following dissolving salts in milligrams per liter $Mg(HCO_3)_2$ = 73, $CaCl_2$ = 111, $Ca(HCO_3)_2$ = 81, $MgSO_4$ = 40 and $MgCl_2$ = 95. Calculate temporary and permanent hardness and total hardness.

Problem 5: A sample of water is found to contains following dissolving salts in milligrams per liter $Mg(HCO_3)_2$ = 16.8, $MgCl_2$ = 12.0, $MgSO_4$ = 29.6 and NaCl = 5.0. Calculate temporary and permanent hardness of water.

Problem6: A sample of water is found to contains following analytical data in milligrams per liter $Mg(HCO_3)_2$ = 14.6, $MgCl_2$ = 9.5, $MgSO_4$ = 6.0 and $Ca(HCO_3)_2$ = 16.2. Calculate temporary and permanent hardness of water in parts per million, Degree Clarke's and Degree French.
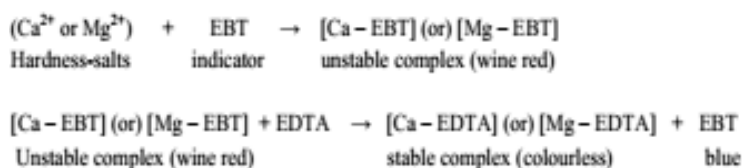
Problem 7: Calculate the amount of temporary and permanent hardness of a water sample in Degree Clarke's, Degree French and Milligrams per Litre which contains following impurities. $Ca(HCO3)_2$ = 121.5 ppm, $Mg(HCO_3)_2$= 116.8 ppm, $MgCl_2$ = 79.6 ppm and $CaSO_4$ = 102 ppm.
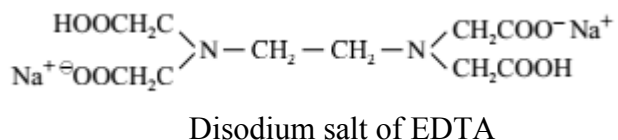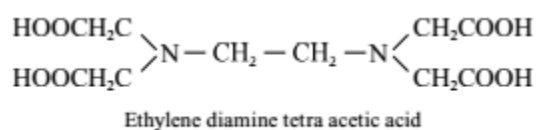
DETERMINATION OF HARDNESS

EDTA Method: It is the most important and more accurate method to determine the hardness of water.
EDTA has limited solubility in water, Hence, disodium salt of EDTA is used which is soluble in water.
***Principle***: EDTA can from complex with salts (Ca^{2+} and Mg^{2+}) which are present in hard water. Hence, it is known as complexometric titration. Calcium or magnesium ions present in the water sample with ammonical buer solution form an unstable wine red colour complex with Eriochrome BlackT (EBT) indicator. When it is titrated with EDTA solution the metal ions present in water give a stable deep blue colour (M-EDTA) complex and releases the free indicator.

$$(Ca^{2+} \text{ or } Mg^{2+}) + EBT \rightarrow [Ca-EBT] (or) [Mg-EBT]$$
$$\text{Hardness-salts} \quad\quad \text{indicator} \quad\quad \text{unstable complex (wine red)}$$

$$[Ca-EBT] (or) [Mg-EBT] + EDTA \rightarrow [Ca-EDTA] (or) [Mg-EDTA] + EBT$$
$$\text{Unstable complex (wine red)} \quad\quad \text{stable complex (colourless)} \quad\quad \text{blue}$$

The structure of EDTA is written as

Ethylene diamine tetra acetic acid

Disodium salt of EDTA

It is a hexadentate ligand, and it forms complexes with bivalent cations (Mg^{2+}, Ca^{2+}, etc.), and these complexes are stable in alkaline medium (pH 9-10).
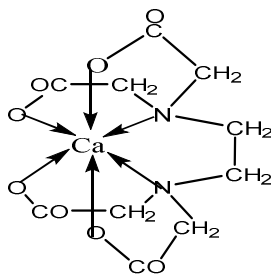
Ca-EDTA Complex

Procedure:

a) Preparation of standard hard water(0.01M): Dissolve 1g of pure, dry $CaCO_3$ in minimum quantity of dil.HCl and then evaporate the solution to dryness on a water bath. Dissolve the residue in distilled water to make 1 Litre solution. Each ml of this solution thus contains 1mg of $CaCO_3$ equalent hardness.

b) Standardization of EDTA solution: Pipette out 10ml of standard hard water into a conical flask, add 3ml of buffer and few drops of EBT indicator, the solution obtain wine red colour. Titrate the contents of the conical flask against EDTA solution. Stop the addition of solution from the burette, when the color of the solution in the conical flask changes from wine red to blue. Note down the burette reading**(Xml)** and repeat titration to get concurrent values.

M1 V1 = M2 V2

Where,

M1 = Molarity of Standard Hard water (0.01M),

V1 = Volume of Standard Hard water (20 ml),

M2 = Molarity of EDTA,

V2 = Volume of EDTA **(Xml)** from burrette

$M_2 = M_1V_1 /V_2$

Concentration of EDTA = M_2 = _____M

b) Determination of total hardness: Pipette out 10ml of test sample of water in the conical flask, add 3ml of buffer and few drops of EBT indicator, the solution obtain wine red colour. Titrate the contents of the conical flask against EDTA solution till the colour changes from wine red to blue. Note down the burette reading and repeat the titration to get concurrent values.

M2 V2 = M3 V3

Where, M2 = Molarity of EDTA,

V2 = Volume of EDTA **(Yml)** from burrette.

M3 = Molarity of sample water,

V3 = Volume of Sample water (20 ml).

Total Hardness = M3 × Molecular weight of CaCO3 (100) × One Litre (1000ml)

$$= M3 \times 10^5 \text{ ppm.}$$

c) Determination of Permanent Hardness

Take 100 ml of sample water in 250 ml beaker. Boil it to remove temporary hardness to about half of its volume and cool to room temperature, filter through filter paper to remove insoluble salts. Make up the volume to the original 100ml by adding distilled water. Now Pipette out 20 ml of this solution (V4) in a conical flask. Add 4 ml of buffer solution and 2 drops indicator. Titrate with EDTA solution till wine-red colour changes to clear blue. Let volume used by **'Z' ml**.

M2 V2 = M4 V4

Where,

 M2 = Molarity of EDTA,

V2= Volume of EDTA (**Z ml)** from burrette.

M4 = Molarity of Permanent hard water,

V4 = Volume of Permanent hard water (20 ml)

Permanent Hardness = M4 × Molecular weight of CaCO3 (100) × One Litre (1000ml)

$$= M4 \times 10^5 \text{ ppm}$$

Determination of Temporary Hardness:

Temporary Hardness = Total Hardness - Permanent Hardness

Problem-1: 50 ml of standard hard water containing 1 gram of pure $CaCO_3$ per liter consumed 20 ml of EDTA. 50 ml of hard water consumed 25 ml of same EDTA solution EBT indicator. Calculate the total hardness of water sample in ppm.

Problem-2: 0.28 grams of $CaCO_3$ were dissolved in HCl and the solution was made upto one litre with distilled water. 100 ml of the above solution required 28 ml of EDTA solution on titration. 100 ml of hard water sample consumed 33 ml of same EDTA solution EBT indicator. 100 ml of this water after boiling cooling and filtering required 10 ml of EDTA solution in titration. Calculate the permanent and temporary hardness of water sample in ppm.

## POTABLE WATER AND ITS SPECIFICATIONS

Water free from contaminants or water that is safe for human consumption is called potable water.

The following are the **specifications of water drinking purpose.**

 1. The water should be clear (colorless), odorless and pleasant taste.

 2. The optimum *hardness* of water must be 125ppm.

3. The *pH* of potable water should be 7.0 to 8.5.

 4. The recommended maximum concentration of *total dissolved solids (TDS)* in potable water must not exceed 500 ppm.

5. The *turbidity* in drinking water should not exceed 25 ppm.

6. The water must be free from *heavy metals* like Lead, Arsenic, Chromium and Manganese.

7. The water must be *free from pathogenic bacteria*

8. The water must be *free from dissolved gases* like H_2S, CO_2 and NH_3.

STEPS INVOLVED IN THE TREATMENT OF POTABLE WATER

Treatment of water for drinking purposes mainly includes the removal of suspended impurities, colloidal impurities and harmful pathogenic bacteria. The following stages are involved in purification.
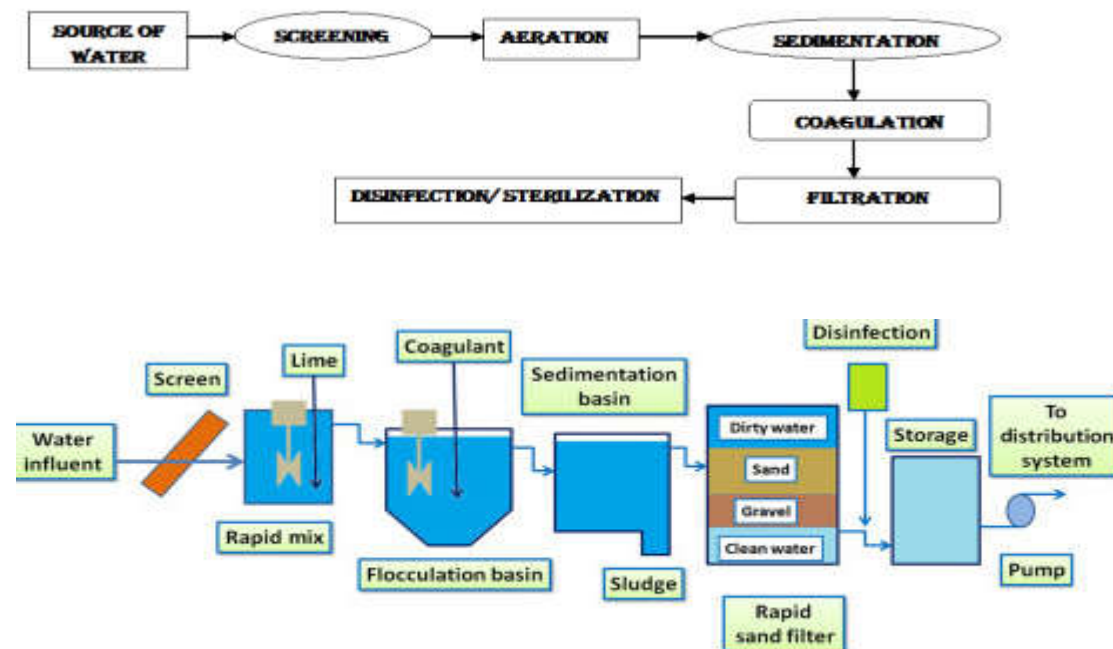
Purification of water for potable use involves mainly the following steps:
(i) Screening: Removes the floating materials like leaves.

(ii) Aeration: Removes the dissolved gases like CO_2 and NH_3.........etc
(ii) Sedimentation: Removes suspended impurities like sand, clay, etc.
(iii) Coagulation: Removes finely divided suspended particles.
(iv) Filteration: Removes colloidal impurities and large organisms.
(v) Disinfection: Kills the bacteria.

1. Screening:

The water is passed through screens having larger number of holes; it retains floating impurities like wood pieces, leaves, heaver objectives etc…

2. Aeration: The water is then subjected to aeration(reacting with air) which helps in exchange of gases between water and air, increases the oxygen content and removes the impurities like iron, manganese and dissolved gases like H_2S, CO_2 and NH_3.

3.Sedimentation: Sedimentation is a process for retention of water for certain period in a deep tank
(~5 meter) or to fl ow quietly at low velocities. Most of the suspended particles settle down due to the force of gravity. This process takes two to eight hours. This process removes 70%–75% of suspended impurities.

4. Coagulation: Coagulation is the process by which the fine, suspended, and colloidal impurities
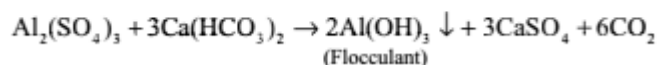are removed from the water by the addition of suitable chemicals (coagulants). The fi nely divided
suspended inorganic matters do not settle down so easily, so these smaller particles are converted into larger ones, which have higher settling velocities.
The commonly used coagulants are the salts of iron and aluminium, e.g., alum (K_2SO_4 $Al_2(SO_4)_3$. $24H_2O$), ferrous sulphate ($FeSO_4$.$7H_2O$), sodium aluminate ($NaAlO_2$), etc. These coagulants react with alkaline salts and form a t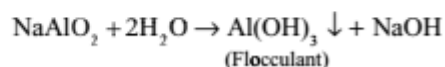hick gelatinous precipitate known as Flock. Flock has the property to attract finely suspended particles and form big fl ock, which settles down rapidly. This process is called flocculation.
A few commonly used coagulants and their reactions are as follows:

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

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 \downarrow + 3CaSO_4 + 6CO_2$$
(Flocculant)

(b) Sodium aluminate ($NaAlO_2$)

$$NaAlO_2 + 2H_2O \rightarrow Al(OH)_3 \downarrow + NaOH$$
(Flocculant)

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

$$FeSO_4 + Mg(HCO_3)_2 \rightarrow Fe(OH)_2 \downarrow + MgSO_4 + H_2O + CO_2$$

5. Filtration: Filtration helps in removal of the colloidal and suspended impurities not removed by sedimentation. Usually sand filters are employed. In this filtration fine sand layer on the top supported by coarse sand layer, which is supported by gravel.

The colloidal impurities are retained by the fine sand layer resulting the very slow filtration of water. Periodically the top layers of the fine sand layer is scraped off, washed, dried and introduced into the filter bed for reuse.

6. Disinfection of water by sterilization:

The process of destroying the harmful bacteria's is known as sterilization or disinfection. Sterilization of water means complete destruction of all living microorganisms (bacteria, virus, etc.) present in water. We know that water after passing through different processes such as sedimentation, coagulation, and filtration processes still contains a small percentage of pathogenic bacteria. Therefore, it is necessary to remove these bacteria and microorganisms from water. The chemicals used for sterilization are known as sterilizers or disinfectants. Some of them are given below:
(a) Boiling method
(b) Chlorination method
(c) Ozonolysis method
(d) UV-rays method
(e) Membrane technology method

*Boiling method***:**

Water for domestic purposes on a smaller scale may be sterilized by simple boiling method. In this method, water is boiled for about 20–30 min.

This method kills the harmful disease-causing bacteria and germs. But this method is useful only for household purposes because this process is very much expensive for municipal supply of water, and in addition, a large quantity of fuel is required to boil water on a large scale. It does not provide any protection for further contamination of water.

1. By Ozonization: Ozone is a powerful disinfectant and is readily absorbed by water. Ozone is highly unstable and breaks down to give nascent oxygen.

$O_3 \rightarrow O_2 + [O]$ nascent oxygen
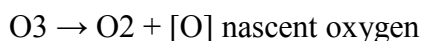
The nascent oxygen is a powerful oxidizing agent and kills the bacteria.

Advantages

(1) It removes color and odor from water.

(2) It improves the taste of water.

(3) The excess dose of ozone is not harmful, because it releases O2 on decomposition.

Disadvantages: This process is costly and cannot be used in large scale, due to unstable of ozone cannot be stored for long time.

*UV-rays method***:** When water is exposed to UV-rays from electric mercury lamp that is immersed in water, most of the pathogenic bacteria are destroyed. This method is widely used for the disinfection of swimming pool water.

Advantages

(1) It does not require any chemicals.

(2) It has not any bad effect during treatment.

(3) It does not produce any odour in water

2. By Chlorination: The process of adding chlorine to water is called chlorination. Chlorination can be done by the following methods.

It is the most important method for sterilization of water. Chlorination

is done by the following methods:

(1) By using chlorine gas or concentrated aqueous solution.

(2) By using bleaching powder.

(3) By using chloramine.

a. By adding Chlorine gas: Chlorine gas is a very good disinfectant, which can be bubbled in the water. In this process calculated amount of chlorine gas is passed in order to destroy the pathogenic bacteria is called chlorination. Chlorine is also reacts with water and generates hypochlorous acid and nascent oxygen, which acts a powerful oxidizing agent and kills the bacteria.

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$
$$\text{Hypochlorous acid}$$
$$HOCl \rightarrow HCl + [O]$$
$$\text{(nascent oxygen)}$$
$$Germs + [O] \rightarrow \text{Germs are oxidised}$$
$$HOCl + bacteria \rightarrow \text{Deactivated bacterias}$$
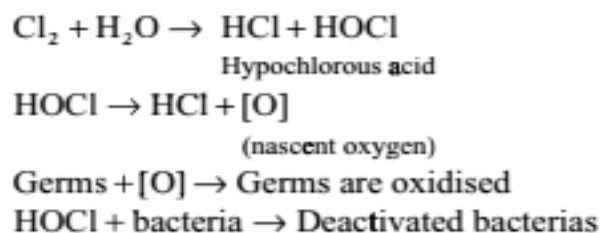
Advantages
(i) It is cheap and is an easily available disinfectant.
(ii) At a low concentration, it is very effective bactericide.
(iii) It can be used at high and low temperatures.
(iv) It is stable and does not deteriorate on keeping.
(v) Chlorine residue can be maintained in treated water, which provides additional
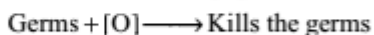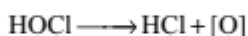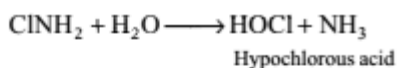safety for preventing regrowth of bacteria.
Disadvantages
(i) Excess of chlorine produces an unpleasant taste and odour in water.
(ii) It is less effective at higher pH value but more effective at lower pH value (below
pH 6.5)

b. By adding Chloramine: When chlorine and ammonia are mixed in the ratio 2:1 a compound
chloramine is formed.

$$Cl_2 + NH_3 \rightarrow ClNH2 + HCl$$
Chloramine
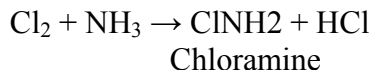
Whenever water is treated with chloramine, hypochlorous acid is formed and with release of

hypochlorous acid it provides greater safeguard from recontamination.

Chloramine compounds decompose slowly to give nascent oxygen which will be act as good
disinfectant than the Chlorine. Chloramine gives good taste to the treated water.

$$ClNH_2 + H_2O \longrightarrow HOCl + NH_3$$
Hypochlorous acid

$$HOCl \longrightarrow HCl + [O]$$
$$Germs + [O] \longrightarrow Kills\ the\ germs$$
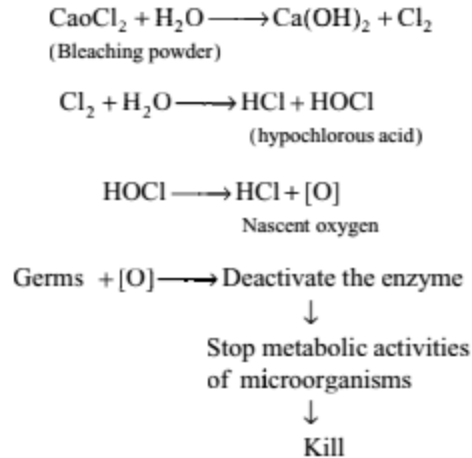
So, HOCl + germs → germs are killed.

Advantages
(i) Excess dose of $ClNH_2$ does not create bad odour and taste in water.
(ii) It provides a greater lasting effect than chlorine.

c) *By using bleaching powder* ($CaOCl_2$)
Bleaching powder is a strong oxidizing agent and is having 30 per cent available chlorine.
When water is treated with bleaching powder, hypochlorous acid is formed. It releases
nascent oxygen and the nascent oxygen thus released deactivates the enzymes of
microorganisms; due to this, metabolic activities will stop and the microorganisms get killed

$$CaoCl_2 + H_2O \longrightarrow Ca(OH)_2 + Cl_2$$
(Bleaching powder)

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$
(hypochlorous acid)

$$HOCl \longrightarrow HCl + [O]$$
Nascent oxygen

$$Germs + [O] \longrightarrow Deactivate\ the\ enzyme$$
$$\downarrow$$
Stop metabolic activities
of microorganisms
$$\downarrow$$
Kill

Disadvantages

(i) Excess of bleaching powder creates bad taste and odour to water.

(ii) It introduces calcium hardness in water due to the formation of Ca(OH)2.

(iii) It is unstable, so its storage is difficult.

Break-point chlorination: Chlorination of water is done carefully in a controlled manner with the dip or break is called breakpoint chlorination. Added chlorine consumed for different reactions such as

(i) Oxidation of reducing substance

(ii) Chlorination of organic substance

(iii)Oxidation of ammonia and disinfection of bacteria

With this method not only living organisms but also organic impurities and free NH_3 present in water are destroyed.

 The point at which free residual chlorine begins to appear is called break-point chlorination. It is also known as free residual chlorination..

The water sample is treated with chlorine and estimated for the residual chlorine in water and ploted a graph as shown below which gives the break-point chlorination.

From graph it is clear that:
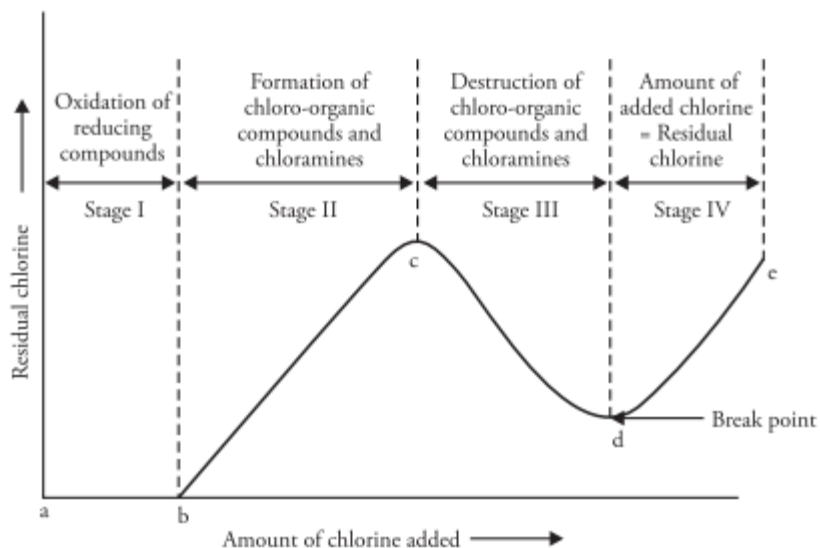
'a' gms of chlorine added oxidizes reducing impurities of water.

'b' gms of chlorine added forms chloramines and other chloro compounds.

'c' gms of chlorine added causes distruction of bacteria.

'd' gms of chlorine is residual chlorine.

'c' gms is the break point for addition of chlorine to water. This is called **break- point chlorination**.

Advantages of break-point chlorination:

It removes bad taste, colour, oxidizes completely organic compounds, ammonia and other reducing impurities

It destroys completely (100%) all disease producing bacteria.

It prevents growth of any weeds in water.

**Defluoridation (Nalgonda technique)**

Developed by Nawlak at NEERI-National Environmental engineering research institute Nagpur in 1974.

Deflouridation is the removal of excess fluoride from water. Nalgonda technique is simple and economical. Reverse osmosis, activated alumina and distillation methods are used to remove fluorine.

In Nalgonda technique, where fluoride is precipitated using 500 mg/L of alum and 30 mg/L of lime with small amount of bleaching powder (3 mg/L) for disinfection.
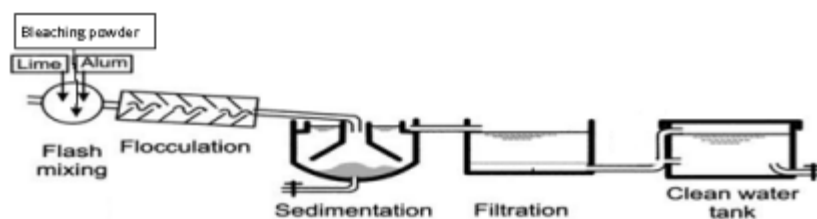
Steps involved in Nalgonda technique: Nalgonda Technique involves rapid mixing (with that chemical interaction is very effective), flocculating, sedimentation, filtration and disinfection. Alum (coagulant) is used to flocculate fluoride ions.
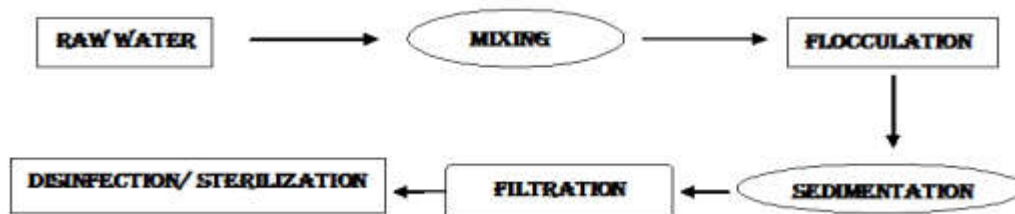
The process is best carried out under alkaline conditions, therefore, lime is added. For disinfecting, bleaching powder is added. After stirring, the chemical elements coagulate into flocks and settle down in the bottom.

Advantages: i. Nalgonda Technique is adoptable to domestic use because low price.

ii. Ease of Handling. Bleaching powder

Disadvantages: i. It is not suitable if the pH of untreated water is alkaline.

ii. It is not suitable when the fluoride concentration is very high.

Sailent features of Nalgonda Technique:

Nalgonda Technique is adoptable to domestic use.

Simultaneous removal of colour, odour, turbidity, bacteria and organic contaminants possible.

Sludge generated is convertible to alum for reuse.

No handling of caustic acids and alkalis, Local skills/capability readily employable.

Needs minimum mechanical and electrical equipment and no energy except muscle power for domestic equipment.

Highly efficient removal of fluoride from 1.5 to 20 mg/L to desirable levels.

DETERMINATION OF FLUORIDE ION BY ION- SELECTIVE ELECTRODE METHOD.

An ion-selective electrode (ISE) is defined as an electro analytical sensor with a membrane whose potential indicates the activity of the fluoride ion to be determined in a solution.

Ion-sensitive membrane may be glass, a crystalline inorganic material, or an organic ion - exchanger.

The membrane interacts with the ion of choice, here fluoride, allowing electrical potential of the half cell which is controlled by the fluorine concentration.

The potential of the ISE is measured against a suitable reference electrode using a pH meter.

The electrode potential is related to the logarithm of the concentration of the fluoride ion by the Nernst equation.

$$E = E\,0 + 2303\,RT.\log[M]\,/nF$$

n = ion charge, the equation is valid for very dilute solutions where the ionic strength is constant.
    In this experiment we will use fluoride-sensitive electrode, either a saturated calomel electrode or Ag/AgCl external reference electrode to measure the fluoride ion concentration.
    Flouride ISEs only respond to free ionized F- in solution and can be used to measure this ion in the presence of other fluorine compounds.
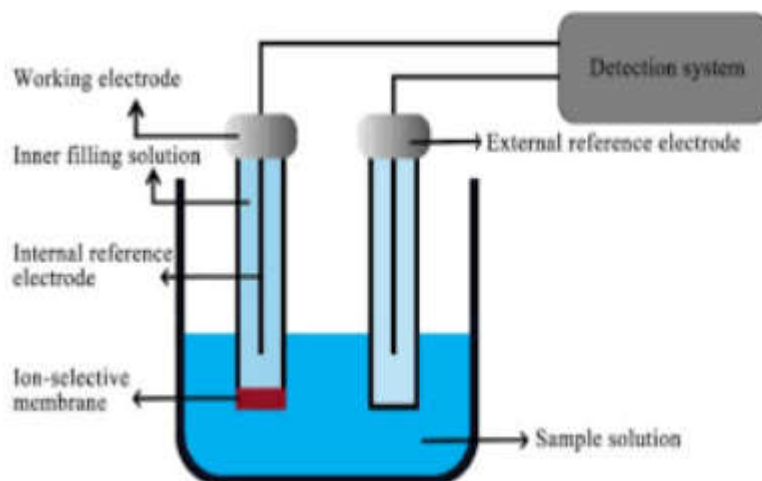
Reagents required:
    NaF(dried at 100°C for 1 hour)
    KCl
    Liquid NaF unknown
    Flouride ISE and Ag/AgCl reference electrode
    pH meter capable of displaying mV potentials
Procedure:
    Dry the NaF solid for 1 hour at 100°C
    NaF(10-1): Weigh 0.42 g of NaF, dissolve in deionized water, and dilute to 100 ml in a volumetric flask. This solution is about 10-1 F in NaF.
    Transfer 10 ml of above solution to 100 ml volumetric flask and dilute with deionized water.

This solution is about 10-2 F in NaF.

KCl (1 M): Weigh 7.55 g of KCl on a top loading balance and dissolve in 100 ml deionised water.

Prepare four 100 ml volumetric standard flasks as follows:

NaF(10^{-2} M) ml	KCl (1 M) ml	
(a) 1.00	10	
(b) 2.00	10	Dilute each flask with deionised water
(c) 5.00	10	
(d)10.00	10	

Analysis:

Take unknown solution into a 100 ml volumetric flask and dilute upto the mark.

Add 1 ml of prepared unknown solution and add 10 ml of KCl and dilute it to 100 ml with deionised water.

Measure the potential in MV of the fluoride ISE Vs reference electrode for each of the four standard and for unknown solution.

Pour about 30 ml of each standard solution (or) unknown into clean 100 ml beaker and immerse the electrode in the solution in the depth of 2 cm and then measure the electrode potential.

After completion of the experiment rinse the electrodes with deionised water and keep the reference electrode in the appropriate solution.

The F-ISE should be stored dry and loosely capped.

Calculations:

Calculate the molarity of NaF accurately.

Plot a graph of the concentration of NaF Vs potential. Find the best line passing through four standard solution points. Calculate the slope of the calibration curve slope = dE/dlog[NaF]

By using calibration curve determine the concentration of NaF in your prepared unknown solution. Report this as percent fluoride (% w/v) in the prepared unknown.
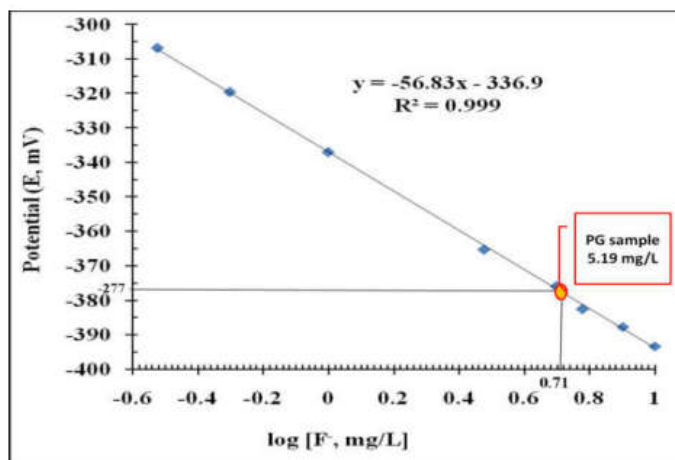
Boiler feed water and Boiler Troubles

For the generation of steam a huge quantity of water is used in boilers and is known as boiler feed water. If water used for boilers is hard, it may create number of problems like caustic embrittlement, corrosion, scale and sludge formation, priming and foaming, etc. This is very dangerous because at high pressure the same causes explosions. Hence water which is used in boilers should be softened and should be pure before feeding into the boilers.
Boiler-feed water should satisfy the following requirements:
(a) Hardness < 0.5 ppm
(b) Caustic alkalinity $= 0.15 - 0.45$ ppm
(c) Soda alkalinity < 1 ppm
(d) Excess soda ash < 0.55 ppm

(e) It's should be free from dissolved gases like O2, CO2, in order to prevent boiler corrosion.

Excess of impurities in the boiler feed water generally cause the following problems:

1. Sludge's and Scale formation   2. Caustic embrittlement

Boilers are employed for the steam generation in power plants, where water as continuously heated to produce steam. As more and more water is removed from water in the form of steam, the boiler water gets concentrated with dissolved salts progressively reaches the saturation point. At this point the dissolved salts are precipitated out and slowly settle on the inner walls of the boiler plate. The precipitation takes place in two ways

Scale and Sludge formation
In the boilers, when water is vaporized to steam gradually the concentration of dissolved salts increases. When the concentration of salts reaches their saturation, they are thrown out in the form of precipitates. Sludge is the soft, slimy and non-adherent layer of precipitate inside the boiler and also called mud. Hard adhering coating of precipitate inside the boiler walls is called scale. Scale and sludge are shown in Figure 1.8.

(a) Sludge in boiler   (b) Scale in boiler
Sludges and scales in boiler
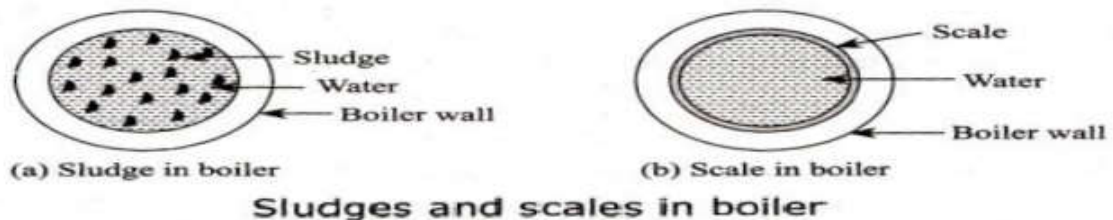
Sludges

Sludge is a soft, loosy and slimy non adherent precipitate formed within the boiler. It is formed at comparatively colder portions of the boiler and collects in the area where flow rate is slow.

Ex: MgCO3, MgCl2, CaCl2, MgSO4.

Reasons for formation of sludges:

The dissolved salts whose solubility is more in hot water and less in cold water produce sludges

Disadvantages
(1) Sludges are poor conductor of heat, so they tend to waste a portion of heat generated.
(2) Sludges decrease the efficiency of the boiler.
(3) Since sludges settle in areas of poor water circulation such as joints, bends, etc., therefore choking of pipes takes place.

Prevention of sludge formation:
a. By using soft water which is free from dissolved salts like MgCO3, MgCl2, CaCl2 and MgSO4 can be prevent sludge formation.
b. By blow down operation carried out frequently can prevent sludge formation.

Scales

Scales are hard, adhering precipitates formed on the inner walls of the boilers. Scales are stick very firmly on to the inner walls of the boiler. It is removed with chisel and hammer. Scales are formed by decomposition of calcium bicarbonate in low pressure boilers.
Reasons for formation of scales:
a. Decomposition of calcium bicarbonate: The calcium bicarbonate at high temperature decomposes to calcium carbonate which is insoluble salt, forms scale in low pressure boilers.

b.Hydrolysis of Magnesium salts: Magnesium salts gets hydrolyzed at high temperature forming Mg(OH)2 precipitation which forms salt type scale.

c.Decomposition of calcium sulphate: The solubility of CaSO4 in water decreases with the increase in temperature and forms precipitation on the surface of the boiler further which forms hard scale. This type of scales is formed in high-pressure boilers.
d. Presence of silica: Sio_2 present even in small quantities, deposits as Calcium silicates (CaSiO3) or Magnesium silicates (MgSiO3). The deposits form hard scale and are very difficult to remove.

Disadvantages of Scales:
1. Wastage of heat and fuels: Scales poor thermal conductivity so that rate of heat transformation is reduced.
2. Lowering of boiler safety is due to overheating of the boiler material becomes softer and weaker, which causes distortion of boiler.

3.Decrease in efficiency of the boiler due to scales deposited in the values and condensers of the boiler cause choking.

4. Danger of explosion which happens the formation of the scales, the boiler plate faces higher temperature outside and lesser temperature inside due to uneven expansion. The water comes suddenly contact with overheated portion and larger amount steam is formed immediately, this results in development of sudden high pressure which may cause explosion of the boiler.

Prevention of scales:

a. If the scale formation is soft it can be removed by a scrapper, wire brush.

b. By giving thermal shocks, by sudden heating and sudden cooling which makes scale brittle and removed by scrubbing with wire brush.

c. If scale is very hard that is formed by CaCO3 can be removed by washing with 5-10% HCl and $CaSO_4$ can be removed with EDTA solution.

Caustic Embrittlement

Caustic embrittlement is the special type of boiler corrosion caused by the use of highly alkaline water. With this phenomena boiler material becomes brittle with the accumulation of caustic substances.

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

The main reason for this is the presence of alkali-metal carbonates and bicarbonates in feed water. In lime-soda process, it is likely that, some residual Na_2CO_3 is still present in the softened water. This Na_2CO_3 decomposes to give NaOH and CO2, due to which the boiler water becomes "Caustic Soda".

$$Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2$$
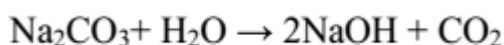
The concentration of NaOH is increased by evaporation of water, and attacks the boiler material by giving sodium ferroate (Na_2FeO_2), which decomposes and forms rust.

$$Na_2FeO_2 + 4H_2O \longrightarrow 6NaOH + Fe_3O_4 + H_2 \uparrow$$
Sodium ferroate   Rust
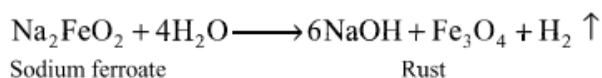
This is an electrochemical phenomenon and can be explained on the basis that a concentration cell is formed due to concentration difference of sodium hydroxide in the boilers particularly at highly stressed parts like joints, rivets, etc. The dilute NaOH region in the boiler acts as a cathode and the concentrated NaOH region acts as an anode and undergoes corrosion.

(+)Iron at joint rivets, bends, etc.	Concentrated NaOH region	Dilute NaOH region	(−)Iron at plane surfaces

Caustic embrittlement can be prevented:

a. By maintaining the pH value of water and neutralization of alkali.

b. By using Sodium Phosphate as softening reagents, in the external treatment of boilers.

c. Caustic embrittlement can also be prevented by adding Tannin or Lignin or Sodium sulphate which prevents the infiltration of caustic-soda solution blocking the hair-cracks.
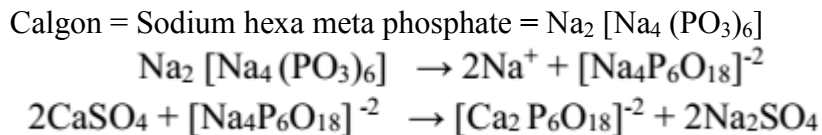
SOFTENING OF WATER

In water, there is a formation of scale-like impurities in the boiler. This scale formation may be minimized by the following treatments:

   (i) Internal treatment
  (ii) External treatment

Internal treatment of Water

Suitable chemicals are added to the boiler water either to precipitate or to convert the scale into compounds is called **internal treatment** of the boiler feed water. Internal treatment can be done following types.

1. Calgon conditioning: Involves in adding calgon to boiler water. It prevents the scale and sludge formation by forming soluble complex compound with CaSO4.

$$Calgon = Sodium\ hexa\ meta\ phosphate = Na_2\ [Na_4\ (PO_3)_6]$$
$$Na_2\ [Na_4\ (PO_3)_6]\ \rightarrow 2Na^+ + [Na_4P_6O_{18}]^{-2}$$
$$2CaSO_4 + [Na_4P_6O_{18}]^{-2}\ \rightarrow [Ca_2\ P_6O_{18}]^{-2} + 2Na_2SO_4$$

2. Phosphate conditioning: The addition of sodium phosphate in hard water reacts with the hardness causing agents and gives calcium and magnesium phosphates which are soft and non-adhere and can be removed easily by blow-down operation.

$$3CaCl_2 + 2\ Na_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6NaCl$$
$$3MgSO_4 + 2\ Na_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3Na_2SO_4$$
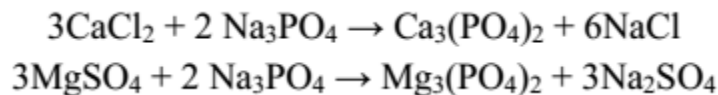
Genarally three types of Phosphates are employed.

i.   Tri sodium Phosphate (Na_3PO_4): is too alkaline used for treat to too acidic water.
ii.   Di sodium Phosphate ($Na_2\ HPO_4$): is weakly alkaline used for treat to weakly acidic water.
iii.   Sodium dihydrogen Phosphate (Na H_2PO4): is too acidic used for treat to too alkaline water.

3. Colloidal conditioning: The addition of organic substances such as Kerosene, tannin, Gel. These substances gets coated over the scale forming precipitates and gives a loose and non-sticky precipitates which can be removed by using blow-down operation.

External treatment: Hard water causes a number of harmful effects when used for domestic, industrial, and boiler purposes. So we have to remove or reduce hardness-causing impurities present in water before using it for any purpose.

The most common methods for softening of water are given below:

(a) Lime soda process
(b) Zeolite process/permutit process/base exchange process
(c) Demineralization/ion-exchange process/de-ionization

SOFTENING OF WATER BY ION EXCHANGE PROCESS

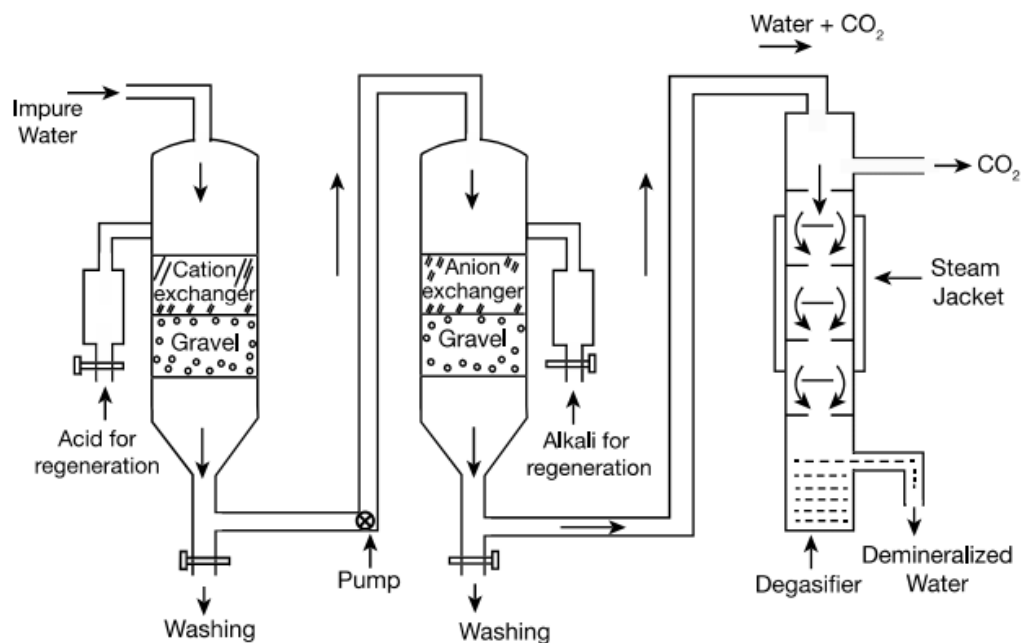Ion exchange process is also known as demineralization process.

Figure 1.13 Demineralization by ion exchangers

Ion- Exchange resins are insoluble.

Cross linked long chain organic polymers with a micro porous structure, and the "functional Groups" attached to the chains are responsible for the ion-exchanging properties.

Resins with acidic functional group are capable of exchanging $H+$ ions with other cations.

Resins with basic functional groups are capable of exchanging OH ions with other anions.

Resins are classified as:

i. Cation Exchange Resins ii. Anion Exchange Resins.
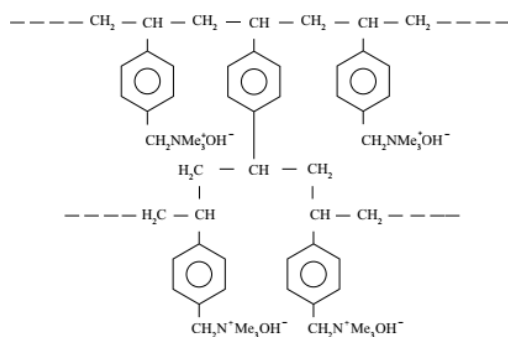
i. Cation Exchange Resins:

These are styrene-divinylbenzene copolymers. These resins have acidic functional groups such as -COOH, -SO3H, etc., which are capable of exchanging the cation by their hydrogen ions. Hence, they are also called cation exchangers.
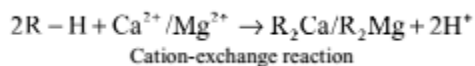
They can be represented as R-H, where R is the insoluble polymeric heavy part.
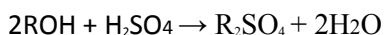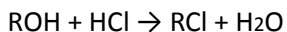
Sulphonation form of cation-exchange resin
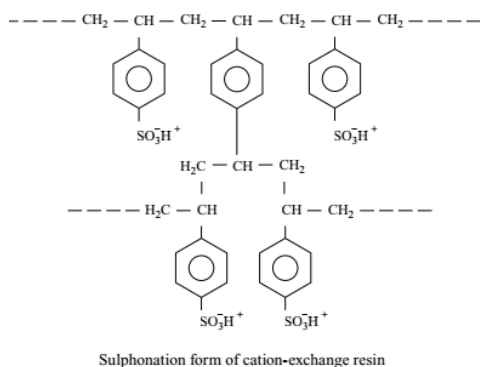
Anion-exchange resins: These are copolymers of styrene and divinylbenzene containing basic functional groups such as amine, substituted amine, quaternary ammonium groups, etc. They can be represented as R′-OH.

Process: Both cation exchanger and anion exchanger are inter-connected with a pipe as shown in the Figure 1.13. The hard water is fi rst passed through cation-exchange resin chamber, which removes all the cations (e.g., Ca^{2+} and Mg_{2+}) from it, and equal amount of H^+ ions are released from its column to water.

$$2R - H + Ca^{2+}/Mg^{2+} \rightarrow R_2Ca/R_2Mg + 2H^+$$

Cation-exchange reaction

$2RH + Ca(HCO)_2 \rightarrow R_2Ca + H_2CO_3$
$2RH + Mg(HCO)_2 \rightarrow R_2Mg + H_2CO_3$
$2RH + CaCl_2 \rightarrow R_2Ca + 2HCl$
$2RH + MgCl_2 \rightarrow R_2Mg + 2HCl$
$2RH + MgSO_4 \rightarrow R_2Mg + H_2SO_4$
$2RH + CaSO_4 \rightarrow R_2Ca + H_2SO_4$ (RH = Cation exchange resin)

After passing through cation-exchange chamber, the hard water is now pumped to 'anion-exchange resin' chamber where all anions like Cl^-, $SO_2 4^-$, etc., are removed, and equal amount of OH^- ions are released from this resin bed to water.

$ROH + HCl \rightarrow RCl + H_2O$
$2ROH + H_2SO_4 \rightarrow R_2SO_4 + 2H_2O$
$ROH + H_2CO_3 \rightarrow RHCO_3 + H_2O$ (ROH = anion exchange resin)

In ion-exchange process, hard water is allowed to pass through cation exchange resins, which remove Ca^{+2} and Mg^{+2} ions and exchange equivalent amount of H+ ions. Anions exchange resins remove bicarbonates, chlorides and sulphates from water exchange equivalent amount of OH ions. Thus by passing hard water through cation hardness is observed by the following reactions.

H+ and OH ions, thus released in water from respective cation and anion exchange columns, get combined to produce water molecules.
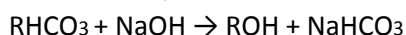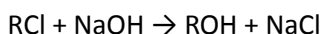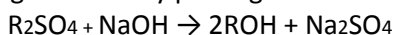
$$H^+ + OH^- \rightarrow H_2O$$

The water coming out from the exchanger is ion free from anions and cations. Thus water of zero hardness is obtained.

When cation exchanger losses capacity of producing H^+ ions and exchanger losses capacity of producing OH ions, they are said to be exhausted.

The exhausted cation exchanger is regenerated by passing it through dilute sulphuric acid.

$$R_2Ca + 2HCl \rightarrow 2RH + CaCl_2$$
$$R_2Mg + 2H_2SO_4 \rightarrow 2RH + MgSO_4$$
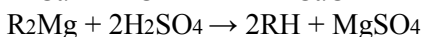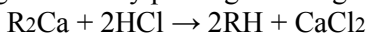
The exhausted anion exchanger is regenerated by passing a dilute solution of NaOH.

$$R_2SO_4 + NaOH \rightarrow 2ROH + Na_2SO_4$$
$$RCl + NaOH \rightarrow ROH + NaCl$$
$$RHCO_3 + NaOH \rightarrow ROH + NaHCO_3$$

Merits of Ion-exchange process:
   The process can be used to soften highly acidic or alkaline water.
   It produces water of very low hardness (2ppm)
   So it is very good for treating water for use in high-pressure boil.

Demerits of Ion-exchange process:
   The equipment is costly and more expensive chemicals are needed.
   If water contains turbidity, the output of the process is reduced. The turbidity must be below 10ppm; else it has to be removed by coagulation and filtration.

DESALINATION OF WATER -REVERSE OSMOSIS(RO)

The process of removing common salt (Sodium Chloride) from the water is known as **desalination.**

The water containing dissolved salts with a salty or brackish taste is called **brackish water**. Sea water and brackish water can be made available as drinking water through desalination process. Desalination is carried out either by reverse osmosis or electro dialysis.

Reverse Osmosis:

Reverse osmosis cell
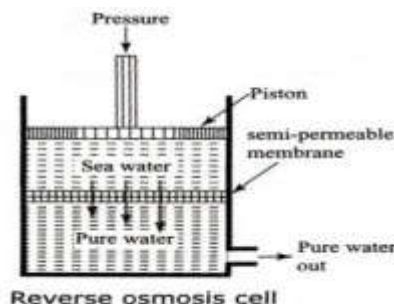
Reverse Osmosis is a process in which pressure greater than the osmotic pressure is applied on the high concentration side of the membrane, the flow of solvent move from concentrated side to dilute side across the membrane. Osmosis is the phenomenon by virtue of which flow of solvent takes place from a region of low concentration to high concentration when two solutions of different concentrations are separated by a semi-permeable membrane. In this process pure water is separated from salt water. 15-40 kg/cm^2 pressure is applied for separating the water from its contaminants. The membranes used are cellulose acetate, polymethyl acrylate and polyamide polymers. The process is also known as **super or hyperfiltration**.

Advantages:

It is simple and reliable process & Capital and operating expenses are low.

The life of the semi-permeable membrane is about two years and it can be easily replaced within a few minutes, thereby nearly uninterrupted water supply can be provided.

Descriptive question (long answer questions)

1. How temporary hardness differs from permanent hardness?
2. Define hardness and estimate hardness of water by using EDTA solution?
3. Explain Caustic embrittlement, Scale & Sludge.
                    (Or)
Write a note of boiler problems?
4. Explain determination of fluoride ions (F-) by ion selective electrode method.
5. Explain softening of water using Ion exchange process.
6. What is desalination? Explain reverse osmosis process.
7. what are the types of hardness and give their units with interrelation.
8. What is Potable water and what are its specifications.
9. Explain Steps involved in the treatment of potable water.
10. What is boiler feed water? Explain internal water treatment method?

11. 0.28 grams of $CaCO_3$ were dissolved in HCl and the solution was made upto one litre with distilled water. 100 ml of the above solution required 28 ml of EDTA solution on titration. 100 ml of hard water sample consumed 33 ml of same EDTA solution EBT indicator. 100 ml of this water after boiling cooling and filtering required 10 ml of EDTA solution in titration. Calculate the permanent and temporary hardness of water sample in ppm.
12. Explain the following? a. Calgon conditioning and Phosphate conditioning of boiler feed water. b. What is defluoridation and explain Nalgonda technique.

13. What is Hardness and calculate a sample of water is found to contains following analytical data in milligrams per litre $Mg(HCO_3)_2$ = 14.6, $MgCl_2$ = 9.5, $MgSO_4$ = 6.0 and $Ca(HCO_3)_2$ = 16.2. Calculate temporary and permanent hardness of water in parts per million, Degree Clarke's and Degree French.
14. calculate the temporary and permanent hardness of 100 litres of water containing the following impurities per litre $MgCl_2$ = 19mg, , $MgSO_4$ = 60mg, $CaCl_2$=111mg, $Ca(HCO_3)_2$ = 32.4mg, $Mg(HCO_3)_2$ = 7.3mg in degree French.

One Mark Questions

1. Write two balanced equations to describe when temporary hard water is heated
2. What are the constituents that cause hardness in water?
3. Explain the terms Carbonate hardness and Non-Carbonate hardness.
4. What is the inter relation of units of hardness?
5. Write the principle involved in complexometric method for the determination of hardness of water.
6. What is the need for an alkaline buffer in the determination of hardness of water by EDTA titration?
7. Write the specifications of potable water.

8. Explain disinfection by chlorination.
9. What is Break-point of chlorination?
10. What is meant by deflouridation.
11. How is deflouridation carried out
12. Write differences between scales and sludges.
13. What is Caustic embrittlement?
14. Calgon treatment prevents scale formation in boilers. Give reasons.
15. What is Phosphate conditioning?
16. Write the principle of Ion exchange process of softening water.
17. What are advantages of Ion exchange process?
18. What is ment by Reverse osmosis?
19. What are advantages of Reverse osmosis?
20. How Reverse osmosis applied in the desalination of water?