Topic 2 – Water Chemistry

Syllabus: - Natural sources of water, Impurities in natural water. Water quality parameters Hardness- Definition, Causes, Types, expressing hardness, units to measure hardness, Numerical problems on hardness calculation, ill effects of hard water in steam generation, Alkalinity, Dissolved oxygen(DO), Biological Oxygen Demand (BOD)and Chemical Oxygen Demand (COD) its significance. Ion exchange method of water softening.

2.1 Introduction: Water is one of the most essential commodity in the universe, 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 essential for the daily industrial, for all domestic purposes and agriculture, irrigation etc.

Water is one of the most abundantly found chemical compound in the universe, justified from fact that almost 70% of earth's surface is covered by water i.e. seas and oceans. It is chemically known as di hydrogen monoxide and chemically represented as H_2O. The importance of water with respect to its use in several utilisations is Day by day availability of water towards such needs is decreasing day by day.

Say all water from universe is considered 100% then out of these today only 0.1% of it is actually available for us from following justification.

1. 93% water is sea water and not suitable for any use as it is highly saline, containing about 3.5% dissolved salts of which about 2.6% is sodium chloride.
2. 3.5% water is present as polar ice which cannot be available for use as it is expensive to bring water from poles of earth to actual site of work.
3. About 3.4% water is present in such form that it cannot be used i.e. atmospheric moisture, very deep underground water, water held by living things (Animals, plants etc.) Chemically bonded water etc.

So we have to fulfil all our needs with just 0.1% of water. Day by day the extent of useful water is decreasing continuously. Thus while using water towards any kind of use it should be used with care avoiding wastage and after use it will be disposed by giving suitable treatment to avoid contamination of water source where it will be disposed.

2.2 Sources of Water:

1. **Rainwater** - It is the purest form of natural water. It dissolves the gases like CO_2, SO_2, NO_2, O_2 etc. and other solids like fine dust and clay particles, which pollute the atmosphere. Rain water can only be used in various purposes only on storage. Even it cannot be used it serves as source of water to rivers, lakes, ponds, streams, well water etc. Thus rain is primary water source.
2. **Sea water** - It is the most impure form of natural water containing about 3.5% dissolved salts of which about 2.6% is sodium chloride. Other salts present include sulphates, bicarbonates, bromides of sodium, potassium, magnesium etc. Other impurities are carried to sea through rivers as its salinity is high it cannot be used in any kind of utilisation.

   Presence of seas and oceans play main role in water cycle.
3. **River water** - The sources of river water are the springs and the rainwater. River water while flowing through the land collects lots of organic matters from falling trees and nearby habitats and also other soluble and suspended matters from the lands, soils etc. The

dissolved matters include the salts like sulphates, bicarbonates and bromides of sodium, potassium and magnesium.

4. **Lake water** - It is much purer than river water, dissolved impurities are less but contains lots of organic matter.

5. **Underground water** - The rainwater and other surface water percolate down through the soil and rocks and get filtered and finally collected on rocky surface or again come out as spring. Though it contains less suspended matter but the dissolved mineral content is quite high and is of high organic purity. Thus we can say that the surface water collects lots of suspended materials, micro-organisms and other pollutants from the habitats and become unsuitable for direct human consumption and other usage.

Natural source	Purity	Impurities	Type of source	Significance
Rain Water	Purest form	Dissolved gases like CO_2, SO_2, NO_2, Clay and dust particles	Primary source	Primary source of water provide water to other sources
Seas/Oceans	Most impure form	High extent of dissolved salts NaCl, KCl etc.	Secondary source	Important/ key component in water cycle
Rivers/Streams	Moderately Pure	Floating matter, vegetative waste, Sand, Gravel, Clay along with dissolved salts and minerals	Secondary source	Used for all kind of needs after suitable treatment.
Lakes/Ponds	Moderately Pure		Secondary source	
Underground	Moderately Pure		Secondary source	

2.3 Impurities in Natural Water:

The water from different sources consist various kind of impurities depending on type of water source as shown above. There are two main types of impurities viz. Dissolved impurities and Suspended impurities.

Dissolved impurities contain mainly salts and minerals and its presence in water leads to impart particular characteristics to water like Acidity, Alkalinity, Salinity, Hardness etc. Dissolved impurities mostly cannot be detected by eyes. Suspended impurities consist insoluble matter and these can be easily detected by eyes.

The water is tested for different parameters before its use in industries. Hardness is prime parameter with respect to industrial use of water. The impurities are classified as under.

Impurities in Natural water	
Dissolved Impurities	**Suspended Impurities**
i)**Acidic solids** – Increase H^+ ion conc. Make water acidic – measured as **Acidity** of water	Floating matter – Floats on surface of water. Includes Dry leafs, wooden pieces, plastic etc. Eliminated by screening of water.
ii)**Alkaline solids** – Increase concentration of OH^-, CO_3^{--}, HCO_3^- ions making water alkaline – Measured as **Alkalinity**.	Heavy Suspended matter – Held by rapid flowing water. Includes Coarser sand and gravel. Eliminated by Sedimentation
iii) **Neutral salts** – Water dissolves many salts from soil. The neutral salts like NaCl,	Fine Suspended matter – Held by slow flowing water. Includes fine sand and clay. Eliminated by Sedimentation

KCl makes water saline – Measured as **Salinity.**	
iv)**Calcium and Magnesium salts** – Water dissolves different Ca and Mg salts/ minerals from soil. Such salts make water hard – measured as hardness of water.	**Colloidal Matter** – Held even by steady water. Include colloidal particles i.e. finely divided silica. Eliminated by coagulation
v)**Transition metals** – Water also dissolves minerals containing transition metals. They generally impart colour to water	**Biological Matter** – Include harmful disease spreading microorganisms. Eliminated by Sterilisation of water.
vi)**Toxic Metals** – If water dissolves certain metal compound beyond certain limit then such water may be responsible for some sort of health hazards Presence of Hg, Mn, Pb, As, Mo etc	
Dissolved gases –Water dissolve gases like CO_2, SO_2, H_2S, O_2 etc. **Dissolved oxygen** in water is major quality parameter of water.	

2.4 Hardness of Water:

Hardness of water -Resistance offered by water towards formation of foam/lather with soap is hardness

Cause- It is caused by dissolved salts of Ca and Mg.

Justification -Soap on treatment with water release free foaming agent which is caustic alkali. Soap is Na or K salt of fatty acid. This is salt of weak acid and strong base undergoing reverse reaction when come in contact with water forming acid and base. The base is foaming agent. If water contains dissolved Ca and Mg then these ions interfere reverse reaction forming Ca or Mg salt of fatty acid as curdy ppt. and corresponding Na or K salt Thus resisting foam formation

$C_{17}H_{35}COONa + H_2O \rightarrow C_{17}H_{35}COOH + NaOH$ - Foaming agent

$C_{17}H_{35}COONa + H_2O + CaCl_2$ (from hard water) $\rightarrow (C_{17}H_{35}COO)_2Ca\downarrow + 2\ NaCl$

Scum No Foaming agent

Degree of Hardness – Extent of Resistance offered by water towards formation of foam/lather with soap.

Hard water – Kind of water which difficultly produce foam or lather with soap.

Soft water - Kind of water which easily/readily produce foam or lather with soap.

2.4.1. Types of Hardness:

Hardness of water is classified on the basis of its removal. Some of Ca and Mg salts are not thermally stable and these can be eliminated by mere heating the water at 70 -80 °C. While other salts cannot be eliminated. Thus based on this hardness is of two types

i) **Temporary / Carbonate hardness** – It is hardness of water which can be removed on mere boiling of water. It is caused by Ca and Mg Bicarbonates. Bicarbonates of Ca and Mg decompose to insoluble $CaCO_3$ and $Mg(OH)_2$ on heating water and gets removed as shown.

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

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

ii) **Permanent / Non carbonate hardness** - It is hardness of water which cannot be removed on mere boiling of water. It is caused by Ca and Mg salts other than Bicarbonates.

iii) **Temporary hard water** – Kind of water which lose its hardness on mere boiling.
iv) **Permanent hard water** - Kind of water which retain its hardness even on boiling.

2.4.2Expressing Hardness of water:

Hardness is due to several Ca and Mg salts therefore it cannot be represented as single value as amount of different chemical substances cannot be directly added. To overcome this difficulty, it is expressed as $CaCO_3$ equivalents. Amount of all salts causing hardness is converted in equivalents of $CaCO_3$ and then added to each other for getting single quantity. This is applicable to all water quality parameters.

$CaCO_3$ is considered as it is most insoluble in water, it is removed on large scale from water during water treatment and its molecular weight is exactly 100.

$$CaCO_3 \text{ equivalent} = \frac{\text{Amount of Hardness causing Substance} \times \text{Equivalent wt. of } CaCO_3}{\text{Equivalent wt. of Hardness causing Substance}}$$

OR

$$CaCO_3 \text{ equivalent} = \frac{\text{Amount of Hardness causing Substance} \times \text{Molecular wt. of } CaCO_3}{\text{Molecular wt. of Hardness causing Substance}}$$

If $CaCl_2$ is causing hardness, then $CaCO_3$ equivalent = $\frac{\text{'X'} \times 100}{111}$

Where 'X' is amount of $CaCl_2$/Lit, 100 is molecular weight of $CaCO_3$ and 111 molecular wt. of $CaCl_2$

2.4.3Units to measure hardness:

Hardness of water is measured with several units as per standard adopted by various countries. The common units accepted globally are as explained below

Sr.No	Unit	Meaning
1	Parts per million -ppm	One part by weight of an impurity present in one million parts by weight of water.
2	Degree French - °F	One part by weight of an impurity present in one lakh parts by weight of water.
3	Degree Clark - °Cl	One part by weight of an impurity present in 70000 parts by weight of water.
4	Milligram per /Litre mg/lit	One part by weight of an impurity present in one litre of water.
Hardness can be converted from one unit to other by using relation **1 ppm = 0.1 °F = 0.07 °Cl = 1 mg/lit**		

2.4.4 Numerical Problems –

1. A water sample was found to contain following impurities in mg/lit

i) $Ca(HCO_3)_2$ = 64.8 Mol. Wt. =162
ii) $Mg(HCO_3)_2$ = 73.0 Mol. Wt. =146
iii) $CaSO_4$ = 68.0 Mol. Wt. =136
iv) $MgCl_2$ = 47.5 Mol. Wt. =095

Calculate temporary, permanent and total hardness in ppm.

Name of impurity	Amount of impurity mg/L	$CaCO_3$ equivalents mg/L	Temporary Hardness in ppm	Permanent Hardness in ppm	Total Hardness in ppm
$Ca(HCO_3)_2$	64.8	64.8 x 100 /162 = 40	40	--	Temporary + Permanent 90 +100 = 190 ppm
$Mg(HCO_3)_2$	73.0	73 x 100 /146 = 50	50	---	
$CaSO_4$	68.0	68 x 100 /136 = 50	--	50	
$MgCl_2$	47.5	47.5 x 100 /95 = 50	---	50	
		Sum	90 ppm	100 ppm	190ppm

OR

Solution

			CaCO3 equivalents
i) $Ca(HCO_3)_2$	= 64.8	Mol. Wt. =162	64.8 x 100 /162 = 40
ii) $Mg(HCO_3)_2$	= 73.0	Mol. Wt. =146	73 x 100 /146 = 50
iii) $CaSO_4$	=68.0	Mol. Wt. =136	68 x 100 /136 = 50
iv) $MgCl_2$	= 47.5	Mol. Wt. =095	47.5 x 100 /95 = 50

Temporary = 40 + 50 = 90 ppm, Permanent = 50 + 50 = 100 ppm, Total = 90 + 100 = 190ppm

2. A water sample was found to contain following impurities in mg/lit

i) $Ca(HCO_3)_2$	= 64.8	Mol. Wt. =162
ii) $Mg(HCO_3)_2$	= 87.6	Mol. Wt. =146
iii) Na_2CO_3	= 68.0	Mol. Wt. =106
iv) $NaHCO_3$	= 47.5	Mol. Wt. =84

Calculate total hardness of sample after boiling in degree Clark.

Solution -As water is boiled hardness is only due to non bicarbonates which is not present hence harness after boiling is zero.

3 A water sample was found to contain following impurities in mg/lit

i) $Ca(HCO_3)_2$	= 48.6	Mol. Wt. =162	**Solution** – i) 100 x48.6/162 =30 Temp =90
ii) $Mg(HCO_3)_2$	= 87.6	Mol. Wt. =146	ii) 100 x 87.6/146 =60 Perm= 60
iii) $CaSO_4$	=54.4	Mol. Wt. =136	iii) 100 x 54.4/100 =40 Tot = 150
iv) $MgCl_2$	= 19	Mol. Wt. =095	iv) 100 x 19/95 =20

Calculate temporary, permanent and total hardness in ppm

4. A water sample was found to contain following impurities in mg/l

$Ca(HCO_3)_2$ = 10, $Mg(HCO_3)_2$ = 8.5, $CaSO_4$ = 12, Na_2CO_3 = 14. Calculate temporary, permanent & total hardness in mg/l.

Solution:

Name of impurity	Amount of impurity mg/L	$CaCO_3$ equivalents mg/L	Temporary Hardness in ppm	Permanent Hardness in ppm	Total Hardness in ppm
$Ca(HCO_3)_2$	10	(10 X 100)/162 = 6.17	6.17	--	Temporary + Permanent 11.99 +8.82 = 20.81 ppm
$Mg(HCO_3)_2$	8.5	(8.5 X 100)/146 = 5.82	5.82	---	
$CaSO_4$	12	(12 X 100)/136 = 8.82	--	8.82	
Na_2CO_3	10.6	Not hardness causing salt	---	--	
		Sum	11.99 ppm	8.82 ppm	20.81ppm

Impurities	Amt (mg/l)	$CaCO_3$ equivalent	Temp. Hardness	Perm.t Hardness	Total Hardness
$Ca(HCO_3)_2$	10	(10 X 100)/162 = 6.17	6.17 + 5.82 = 11.99 mg/l	8.82 = 8.82 mg/l	11.99 +8.82 = 20.81 mg/l
$Mg(HCO_3)_2$	8.5	(8.5 X 100)/146 = 5.82			
$CaSO_4$	12	(12 X 100)/136 = 8.82			
Na_2CO_3	10.6	Non hardness salt			

2.5 Disadvantages of hard water / Ill effects of hard water

Hard water when used in domestic and industrial applications, then it produces several ill effects. The disadvantages of hard water

For domestic use are as given

1) Wastage of large quantity of soap. It produces curdy white ppt. the scum.
2) Scum damages texture of fabric and also produce skin disorders when chokes skin pores.

3) It causes digestive disorders and kindly disorders when regularly consumed as drinking water.
4) Damages kitchenware like cookers by scaling and waste more fuel.
5) Damages water heating appliances like geysers.
6) Causes water line corrosion to metallic store tanks.
7) In pharmaceutical industry produce undesirable products.

The disadvantages in industrial use are as under.

1. Scale and Sludge formation in boilers:

Water is used in most of industries towards steam generation. Steam under pressure is source of energy which is used in various industrial needs. Steam is generated through water boiler. Boiler is filled with water and the same is taken out as steam on built up of adequate pressure.

If water available for steam generation is hard water then all salt present in water are left in boiler vessel. Some of these salts adhere to boiler walls called as scale and some deposits at bottom called as sludge. Presence of dissolved impurities like$MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$ in boiler water forms loose slimy mass called sludge & dissolved impurities like $Ca(HCO_3)_2$, $CaSO_4$, $MgCl_2$, SiO_2 forms hard deposits on inner wall of boiler called as Scale.

Scale and sludge formation is disadvantageous because

i) It reduces water carrying capacity of boiler –When hard water is continuously used for steam generation then sufficient sludge is collected at bottom and it tends to occupy some volume thereby reducing water carrying capacity. This rises level of water as boiler is filled with its capacity by water. Raised water level reduces space for collection of steam leading to show quick built up of pressure. When steam is withdrawn pressure suddenly fall. Net effect is non continuous supply of steam causing frequent disturbances in industrial operations.

ii) It reduces efficiency of boiler – Due to excessive sludge a thermal insulator water do not pick heat released from fuel quickly and required extent of steam is not formed within expected interval of time. Thus efficiency of boiler is decreasing continuously.

iii) Wastage/ more consumption of fuel – Both scale and sludge are insulating heat transfer from fuel to water gets affected and more time is taken for generation of adequate amount of steam, thereby burning some more fuel.

iv) Corrosion of boiler metal – Cracks formed in scale layer due to cooling and heating allow water to enter through these cracks, this separates boiler metal at these locations from scale layer via thin film of water. It generates potential difference and boiler metal will behave as anode resulting in its oxidation (Corrosion). It reduces life span of boiler.

v) Increased risk of an accident - Sludge may choke various pipes fitting of boiler as it gets stirred vigorously inside boiler vessel due to strongly boiling water and increases chance of an accident or explosion.

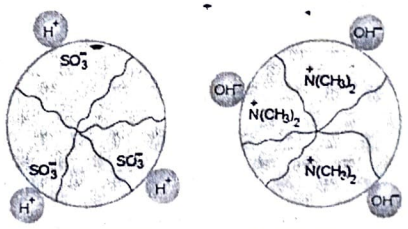
1) Use of hard water causes corrosion of metallic parts, spares, components, equipment, machinery etc.
2) Produce disorders in working of heat exchangers using water as coolant.
3) Textile industry- Hard water causes wastage of soap, damages texture of fabric and does not give expected shade or colour to fabric.
4) Sugar Industry- Hard water is used cause opacity to crystals, reduces, crystal size. Sugar becomes deliquescent.
5) Food Industry- Hard water spoils taste of food product.
6) Paper Industry- Hard water affects paper quality like texture and finish.
7) Chemical and Pharmaceutical Industry- Hard water when used in such industries then it tends to reduce purity of final product. Also reactors are affected by scale formation, corrosion etc.

2.6 Ion exchange process of water softening:

Softening of hard water is nothing but removing dissolved Ca and Mg salts from it. This can be done by several ways like a) Distillation – removes almost all dissolved solids b) Precipitation – Unwanted ions can be removed as precipitate c) Ion exchange – Exchanging unwanted ions for other d) Reverse osmosis etc. Among these Ion exchange process is best alternative for water softening as it removes all dissociable solids and add H^+ and OH^- ions which forms water molecule.

Ion exchange method removes hardness by exchanging impurity cations & anions for H^+ & OH^- ions from ion exchange resins. Ion exchange resins are organic high polymers with ability to exchange ions. The resins with functional group like SO_3H or COOH will exchange H^+ with Ca & Mg from water & are called as cation exchange resins. The resins with $Me_2(OH)$ functional group will exchange anions for OH^- and are called anion exchange resins.

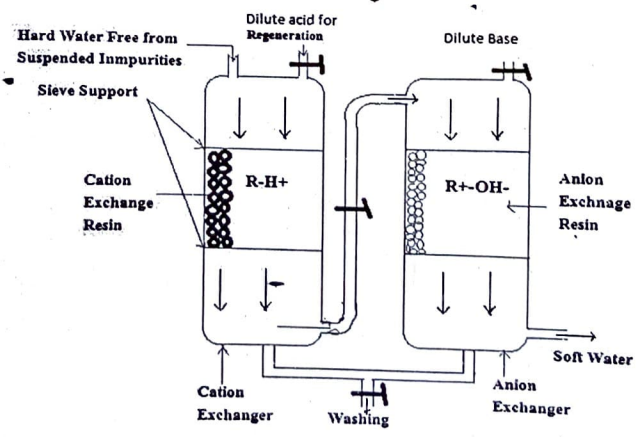
Many synthetic resins have been made which function as ion-exchangers. In effect, the resin has one ion adsorbed on it. The resin releases this ion and adsorb another like ion. The process is called **ion-exchange adsorption**. When cations are exchanged, the resin is known as **cation exchanger**. When anions are exchanged, it is referred to as **anion exchanger.**



Cation exchange resin Anion exchange resin

The cationic exchangers are high polymers containing acidic groups such as sulphonic acid group, $-SO_3^-$, H^+. The resulting macro-anion has adsorbed H^+ ions. When solution of another cation (Na^+) is allowed to flow over it, H^+ ions are exchanged for Na^+ ions. This process in fact, consist of desorption of H^+ ions and adsorption of Na^+ ions by the resin.

The equipment used is simple and is shown in figure. It is known as ion exchange water softener or water deioniser or water demineraliser.



ION EXCHANGE WATER SOFTNER

Construction- It consist of two cylindrical vessels, one containing bed of cation exchange resins and other a bed of anion exchange resins. The vessels are equipped with pipe fittings required like hard water inlet, washing outlet, soft water outlet etc.

Working- Water to be softened is passed at regulated flow rate adjusted with rate of percolation through cation exchanger. When water percolates through resin bed it comes in contact with resins and during this impurity cations are exchanged for H^+ ions. The water then passes to anion exchanger and here impurity anions are exchanged for OH^- ions. The drain is soft water collected through soft water outlet.

When all H^+ and OH^- from resin are exchanged. then these resins become exhausted which are regenerated with dilute acid and base solution and washing thus formed are rejected.

Resin Reactions:

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

Cation Ex Resin. Exhausted Resin

$$2ROH + 2Cl^- \rightarrow 2RCl + 2OH^-$$

Anion Ex Resin

Resin Regeneration:

$$R_2Ca + 2HCl \rightarrow 2RH + CaCl_2$$

(Washing)

$$2RCl + 2NaOH \rightarrow 2ROH + 2NaCl$$

(Washing)

Advantages: 1) Very low residual hardness O-2 ppm 2) Compact and portable equipment 3) No sludge formation 4) No need of skilled labour 5) Resin are used for longer time 6) Almost all dissolved solids are removed 7) Treats acidic or alkaline water 8) Treated water is suitable for steam generation in boiler.

Disadvantages: 1) Resin are costly 2) Water must be free from suspended matter.

2.7 Dissolved Oxygen(DO), BOD and COD-

Dissolved Oxygen in water (DO) play very important role in deciding water quality for domestic & industrial use. Water when comes in direct contact with air then it dissolves oxygen from air. Oxygen is sparingly soluble & water can dissolves maximum 15 ppm of oxygen.

Maximum extent of DO in natural water ensure freshness. If DO is very less then this water is not fresh & not safe for drinking & other uses. Decreases in DO is due to any or all following reasons.

1. Direct contact of air & water is not possible: This is due to presence of great extent of floating matter or presence of oil & greasy impurities which spreads on surface of water.

2. Contamination of water by Organic matter: If water consist large extent of organic matter then it consumes DO towards its decomposition. The residual DO level will then leave organic matter partially decomposed, which produces foul odour & accelerates growth of pathogens.

3. Presence of oxidisable matter: If water contain greater extent of oxidisable waste then it consumes DO & reduces DO level in water.

Thus, water with less DO is not suitable for domestic use & DO level must be maximum.

In industrial use water is used after de-oxygenation when it is used for boiler & in contact with metals at high temperature. This is because if DO is maximum, at high temperature it is removed & causes corrosion.

a) BOD – BOD is used to designate the term Biological oxygen demand. BOD is very important parameter to determine extent of water pollution. It is defined as 'amount of oxygen

consumed by bacteria towards decomposition/ oxidation of organic matter present in known quantity of water at 25°C within 120 hours'. It is expressed in ppm.

Determination – 250 cc water is taken in BOD bottle. Some of sample is analysed for initial DO content. The bottle is then kept in an incubator at 25°C for 120 hours. Then the final DO level is measured. The difference in initial and final DO level is BOD of water.

BOD is important as 1) High BOD indicates presence of large extent of organic matter and bacteria in water 2) Such water is unsuitable for domestic use as it consist harmful microorganisms and possess offensive odour. 3) Nil BOD indicates absence of organic matter as well as bacteria feeding on it.

BOD of natural water increases due to introduction of high amounts of decomposable waste through disposal of domestic and industrial waste water. This organic matter is not completely decomposed due to deficiency of oxygen and this shoots up BOD.

b) COD – (Chemical oxygen demand) – It is defined as amount of oxygen consumed towards oxidation of oxidisable waste present in known quantity of water by adding known excess of strong oxidizing agent.

COD is parameter generally associated with effluent (Industrial waste water). COD of water is high if it contains non decomposable oxidisable substances. Such constituents can be only oxidized by providing oxygen.

Determination – Known volume of water is taken in reflux flask. To this known excess of $K_2Cr_2O_7$ is added as oxidizing agent. The mixture is strongly refluxed for one and half hours. The un utilized $K_2Cr_2O_7$ is determined by titrating known volume of refluxed solution with std. solution of ferrous ammonium sulphate.

COD is important polluting parameter as 1) High COD indicates presence of high amounts of non-decomposable waste which is harmful. 2) High COD reduces DO level 3) If an effluent with high COD is disposed directly to natural source then it affects aquatic life.

BOD	COD
1. It is amount of oxygen required for oxidation of decomposable organic matter	1. It is amount of oxygen required for oxidation of non-decomposable impurities
2. It is amount of O_2 consumed towards bio-chemical reaction.	2. It is amount of O_2 consumed towards direct chemical reaction.
3. High BOD indicates presence of large extent organic matter and bacteria in water.	3. High COD indicates presence of large extent of oxidisable waste in water.
4.Determination requires period of 120 Hrs.	4. Determined within 2 hours.
5. BOD is high for domestic waste water (Sewage)	5. High for industrial waste water (Effluent)
6. BOD is reduced by aerobic/anaerobic methods	6. COD is reduced by aeration

Questions –

Answer the following

1. Discuss importance of water with respect to industrial use.
2. Compare different natural sources of water with respect to purity, type of impurities, primary/ secondary source and significance.
3. Discuss various impurities associated with natural sources of water.
4. What is hardness of water? Justify that hardness of water is due to dissolved salts of

Calcium and Magnesium.

5. How hardness of water is classified?
6. How hardness of water is expressed?
7. Give an account and comparison different units used to measure hardness of water.
8. Discuss disadvantages of hard water when used towards industrial purpose.
9. Discuss ill effects of scale and sludge formation during steam generation through boiler.
10. With neat diagram discuss construction, working of Ion exchange water softener.
11. Explain significance of Dissolved oxygen as water quality parameter.
12. Write brief account of BOD & COD of water.
13. What are ion exchange resins? How these are classified and anion exchange resin? Discuss in brief mechanism of exchange of ions by resin.
14. List disadvantages of scale and sludge formed in boiler due to use of hard water.

Define following terms

Hardness, Hard water, Soft water, Degree of hardness, Temporary hardness, Permanent hardness, Temporary hard water, Permanent hard water, Scum, Scale, Sludge, Ion exchange resin, Cation exchange resin, Anion exchange resin, BOD, COD.

Give reason.

1. Rain water is purest form of natural water.
2. Rain water is primary source of water
3. Salinity of sea water is continuously increasing.
4. Temporary hardness of water vanish on mere boiling of water.
5. Permanent hardness of water retain even on boiling of water.
6. Hard water difficultly produces foam and lather with soap.
7. Scales formed in boiler reduce life span of boiler.
8. Water treated by ion exchange method is free from any type of ion.
9. Water treated by ion exchange method is suitable for steam generation through boiler.
10. Hardness of water is expressed by $CaCO_3$ equivalence.
11. Potable water should not possess any BOD.

Numerical on Hardness calculation.

1. A water sample was found to contain following impurities in mg/L
$Ca(HCO_3)_2$: 4.05 (162), $NaHCO_3$: 8.4 (84), $CaSO_4$: 3.4 (136), $MgSO_4$: 3.0 (120), $CaCl_2$: 11.1 (111), $MgCl_2$: 4.75 (95), Na_2SO_4: 14.2 (142) (Figures in bracket indicates Molecular weights of respective impurities.)

a) Calculate Temporary, Permanent and Total Hardness in terms of Degree Clark / French

b) Calculate Carbonate & Non carbonate Hardness in terms of ppm.

c) Calculate hardness of water before and after boiling in mg/L

d) Calculate Temporary, Permanent and Total Hardness in terms of Equivalence of $CaCl_2$.

e) Assuming all above impurities are in mg/L and as an equivalence of $CaCO_3$, Calculate

Temporary, Permanent and Total Hardness of water in ppm.

2. A water sample was found to contain following impurities in mg/L
$Ca(HCO_3)_2$: 4.05 (162), $NaHCO_3$: 8.4 (84), $CaSO_4$: 3.4 (136), $MgSO_4$: 3.0 (120), $CaCl_2$: 11.1 (111), $MgCl_2$: 4.75 (95), Na_2SO_4: 14.2 (142) as CaCO3 equivalence.(Figures in bracket indicates Molecular weights of respective impurities.)
Calculate Temporary, Permanent and Total Hardness in terms of mg/L.

3. How much $MgSO_4$ is required to dissolve in distilled water to get 500cc of solution with hardness of 125 ppm.(Mol. Wt. 120)

4. A standard hard water was prepared by dissolving 0.5 g pure $CaCO_3$ in minimum HNO_3 and then distilled water to get 400cc solution. To this 5cc Na_2CO_3 solution was added. Calculate Hardness of standard hard water after adding Na_2CO_3 solution. (Given Mol.Wt.- Na_2CO_3 - 106, $CaCO_3$ - 100, CaO - 56)