CY 104_Applied Chemistry

by

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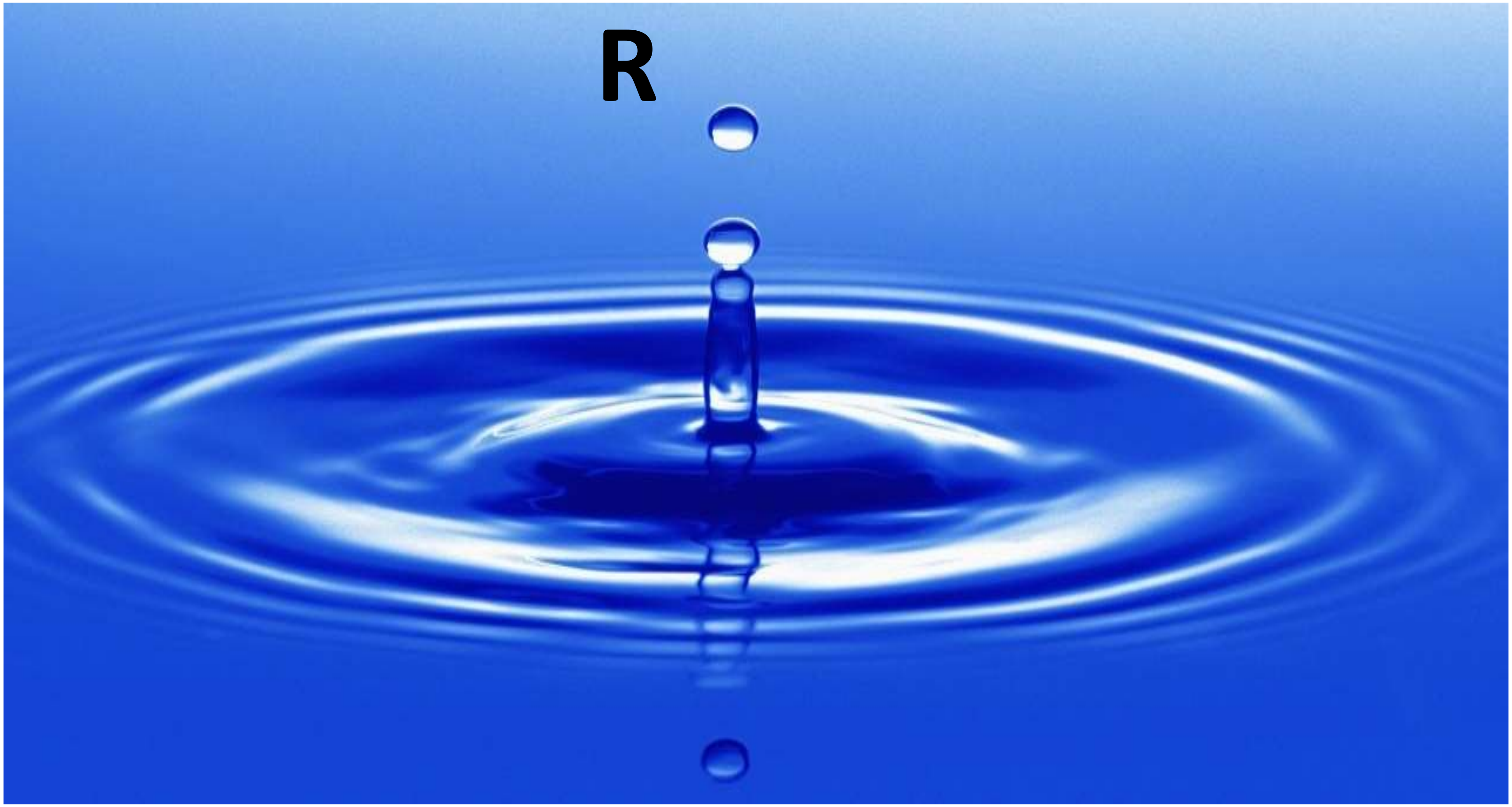
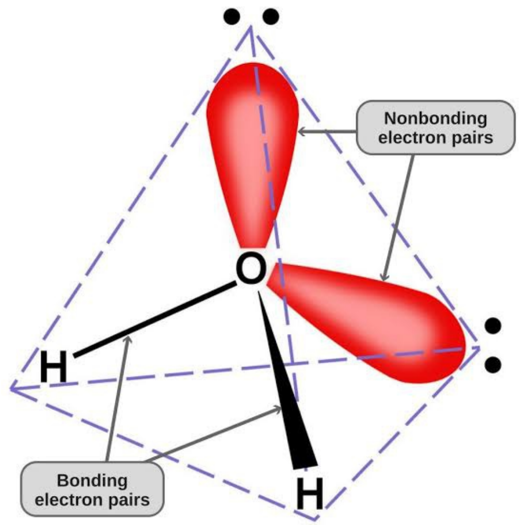
WATER

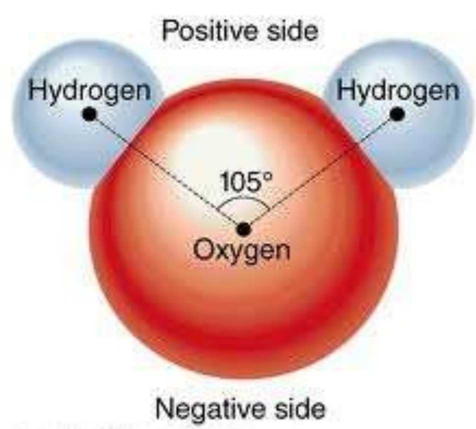


- Water is essential for life. It covers 2/3 of the earth's surface and every living thing is depend upon it.
- The human body is comprised of over 70% water, and it is a major component of many body fluids including blood,urine,and saliva.

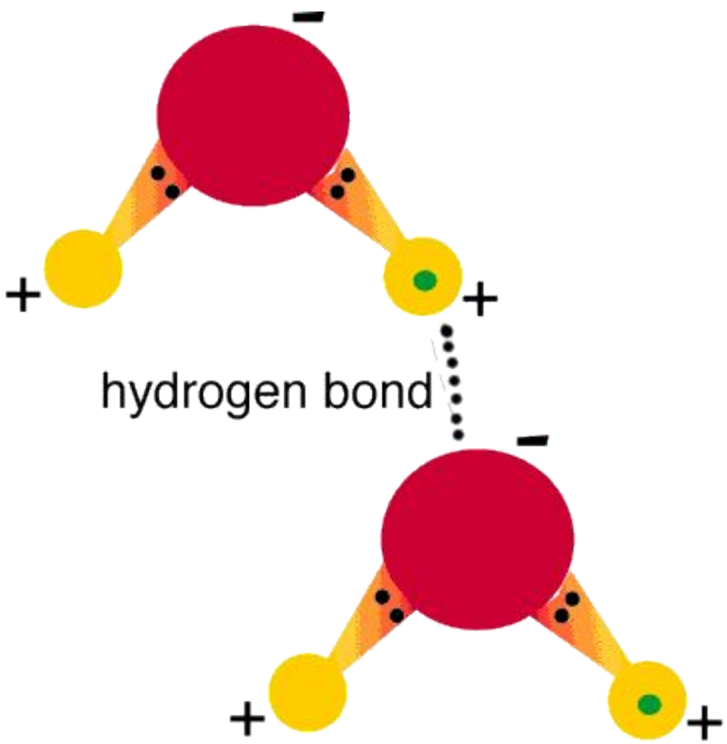
- Water is formed when two hydrogen atoms bond to one oxygen atom.
- With a total atomic weight of 18 daltons
- The structure of the electrons surrounding water is tetrahydral, resembling a pyramid.
- The angle between H-O-H bond is 104.45 degree.

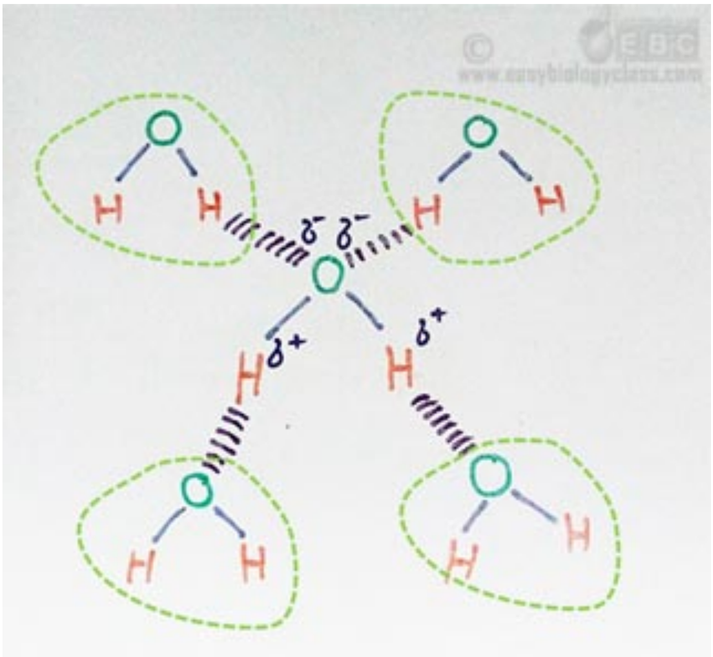


- There is a great concentration of electrons around the nucleus of the oxygen than around the hydrogen.
- Therefore, the hydrogen end is slightly positive and the oxygen end is slightly negative.

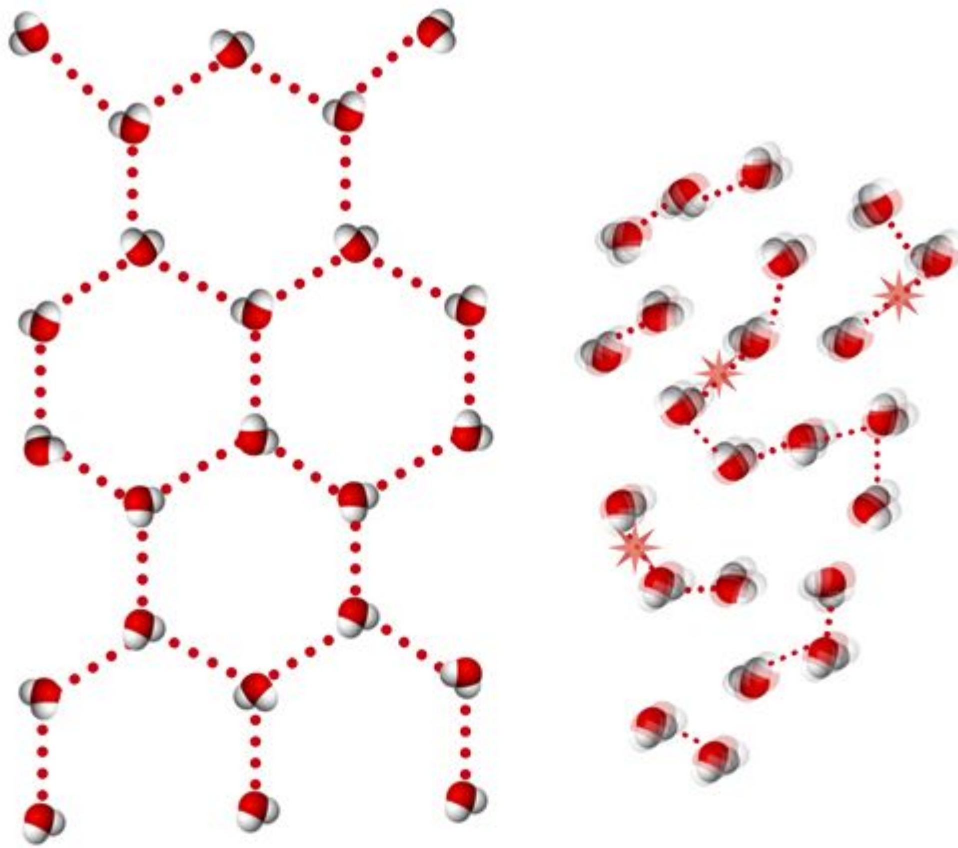


- **Hydrogen bond exists between a highly Electronegative atom (like oxygen in another water) of a polar molecule and a hydrogen**
- **Weak bond, but strong in great numbers.**





Single water molecule can form FOUR hydrogen bonds at a time in Liquid water



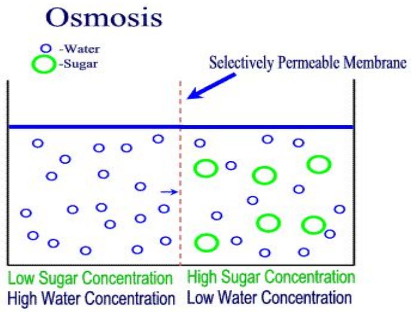
a) Solid water (ice) b) Liquid water

Properties of water

Physical Properties

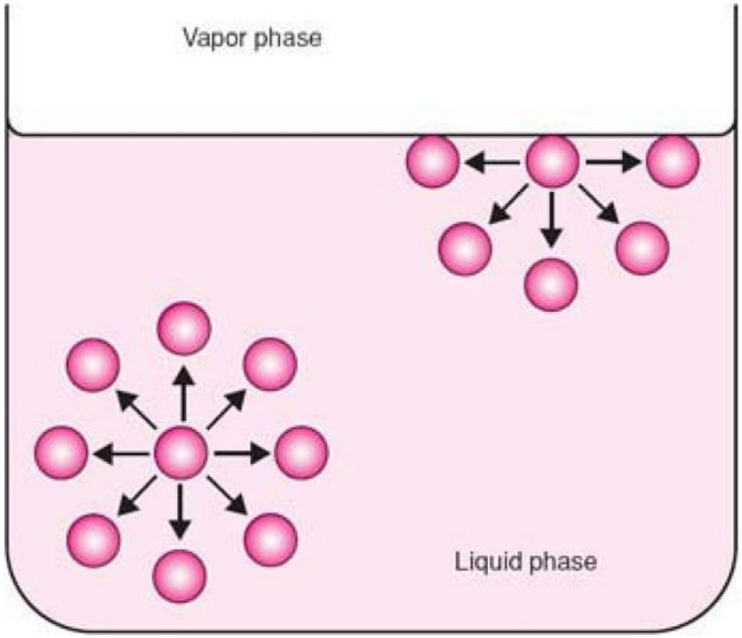
- Polar molecule: Water is a polar molecule because of the way the atoms bind in the molecule with more positive(+) charges on one side of the molecule and more negative(-) charges on the other side of the molecule. In other words the hydrogen atoms group on one side of the molecule making that more positive, such that there are more electrons from the oxygen atom on the other side of the molecule.
- Solubility: Water dissolves salts such as NaCl by hydrating and stabilizing the Na and Cl ions, weakening the electrostatic interactions between them. The same factors apply to charged biomolecules, Water readily dissolves such compounds by replacing solute-solute hydrogen bonds with solute-water hydrogen bonds, thus screening the electrostatic interactions between solute molecules.

- Osmosis: Osmosis is the passage of water from a region of high water concentration through a semi-permeable membrane to a region of low water concentration. Osmosis, transfer of a liquid solvent through a semipermeable membrane that does not allow dissolved solids (solutes) to pass.



- Surface tension : Molecules at the surface (i.e., at the liquid–air interface) can only develop attractive cohesive forces with other liquid molecules that are situated below and adjacent to them. They can develop adhesive forces of attraction with the molecules constituting the other phase involved in the interface, although, in the case of the liquid–gas interface, this adhesive force of attraction is small. The net effect is that the molecules at the surface of the liquid experience an inward force toward the bulk. Such a force pulls the molecules of the interface together and, as a result, contracts the surface, resulting in a surface tension.

72 dynes/cm



✔ Viscosity: When a shearing force is applied to a liquid, it flows. However, the forces of friction between the layers offer resistance to this flow.

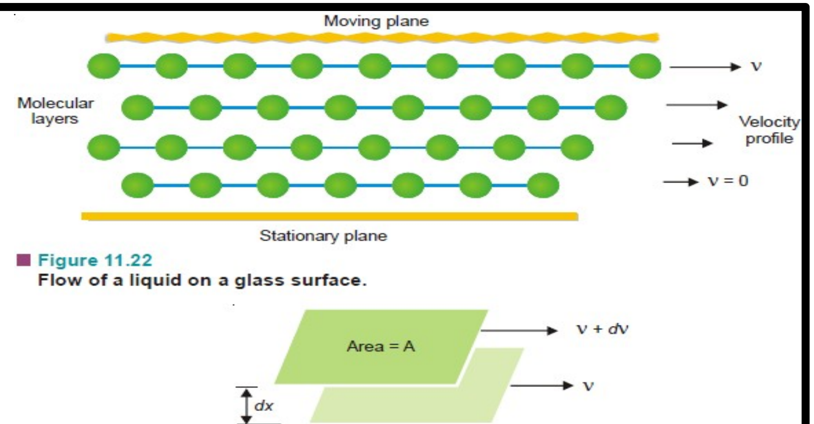


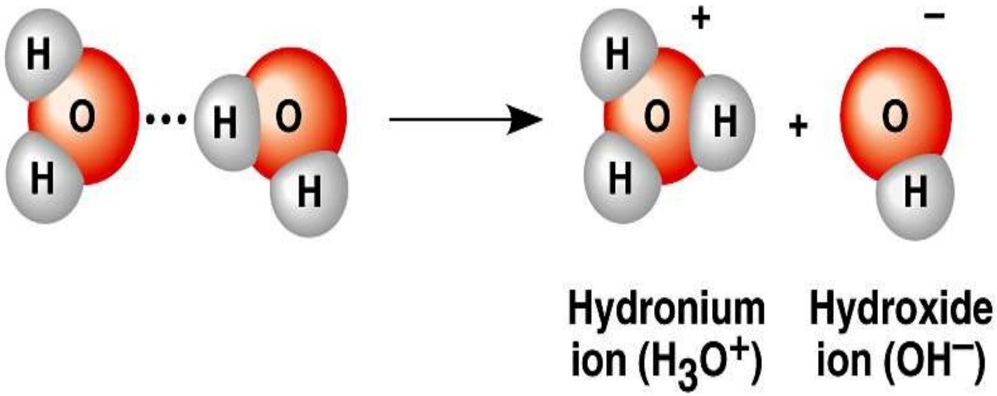
Figure 11.22
Flow of a liquid on a glass surface.

Figure 11.23
Two parallel layers moving in a liquid.

Water has a **viscosity** of 0.0091 poise at 25 °C

Chemical properties

- Occasionally, a hydrogen atom shared by two water molecules shifts from one molecule to the other.
  - The hydrogen atom leaves its electron behind and is transferred as a single proton - a **hydrogen ion** (H^+).
  - The water molecule that lost a proton is now a **hydroxide ion** (OH^-).
  - The water molecule with the extra proton is a hydronium ion (H_3O^+).



Water reacts with a lot of substances to form different compounds. Some significant reactions are as follows:

- **Amphoteric nature:**

Water can act as both acid and base, which means that it is amphoteric in nature.
Example:

***Acidic Behaviour*:** $H_2O(l)+NH_3(aq) \rightleftharpoons HO^-(aq)+NH_4^+(aq)$

Basic Behavior: $H_2O(l)+H_2S(aq) \rightleftharpoons H_3O+(aq)+HS^-(aq)$

- **Redox reactions:**

Electropositive elements reduce water to hydrogen molecule. Thus, water is a great source of hydrogen. Let us see an example in this case:

$2H_2O(l)+2Na(s) \rightarrow 2NaOH(aq)+H_2(g)$

During the process of photosynthesis, water is oxidized to O_2. As water can be oxidized and reduced, it is very useful in redox reactions.

- **Hydrolysis reaction**

Water has a very strong hydrating tendency due to its dielectric constant. It dissolves many ionic compounds. Some covalent and ionic compounds can be hydrolyzed in water.

Sources of Water:

The Main Sources Of Water Are:

1) Rain water
2) River water
3) Spring or well water
4) Sea water

1). **Rain water:** Rain water is the purest form of natural water. However, it dissolves considerable amount of gases (CO_2, SO_2, NO, NO_2 etc) and suspended solid particles from atmosphere, during its journey through it and becomes polluted.

2). **River water:** River are formed by rain and spring waters. During its flow over the surface of land, it dissolves minerals of the soil such as chlorides, sulfates, bicarbonates of sodium, calcium, magnesium ions etc..

3) **Spring or well water or Lake water:** it contains cosnstant chemical composition. The minerals present in the lake water in the form dissolved form and high quantity of organic matter.

4) **Sea water:** It is the most impure form of natural water. It contains larger percentage of the dissolved salts (above 3.5%) out of which about 2.6% is NaCl. The NaCl which is present in the dissolved form in sea water will come out as NaCl crystals due to evaporation of sea water. The other salts present in the sea water are sulphates of sodium, bicarbonates of potassium, magnesium, calcium, bromides of potassium, magnesium etc.

5) **Underground water:** Spring & well waters are the underground water sources. They are in general clearer in appearance due to the filtering action of the soil. They contain more of the dissolved salts generally, underground water is of high organic purity.

Types of water

1. **Raw water:**
   - Untreated, unfiltered water
   - Unsafe for human consumption
   - Without treatment raw water can be used for farming, construction or cleaning purposes.
2. **Cooling water:**
   - Cooling water system are widely used in industry to reject waste heat.
   - Cooling water should be free from solid impurities which could damage pumps and cause blockages.
3. **Boiler water:**
   - Water within a boiler, associated with piping, pumps and other equipments, that is intended for evaporation into steam.
4. **Nuclear water:**
   - Water is used in processing (mining, milling, fuel fabrication) of fuel (Uranium).
   - Nuclear cooling systems are designed so that if pipes begin to leak, local water rans into the plant rather than radioactive water leaking out.
   - After being removed from the reactor the nuclear fuel is still very hot and requires storage both to cool down and to control risks of radiation poisoning.

Types of impurities in water:

The impurities present in water are classified as:

1). Dissolved impurities: Dissolved impurities may organic or inorganic. Inorganic impurities: the carbonates, bicarbonates, sulphates, chlorides of calcium, magnesium, iron potassium and aluminium.

Organic impurities: Organic water products, amino acids, proteins, etc.

Gases: O_2 , CO_2 , Oxides of nitrogen and sulphur, H_2S etc.

2) Suspended impurities: It is of two types:

1. Inorganic - sand & clay;
2. Organic – vegetable and animal matter.

3) Biological Impurities: Micro-Organisms like Pathogenic bacteria, fungi, algae etc

HARDNESS OF WATER

Hard Water : Those water which does not produce lather (or) very little lather with soap is called Hard Water

Soft Water : Soft water readily produce a lot of lather when mixed with little soap.

The Hardness of water is caused by the presence of dissolved salts such as Bicarbonates, Sulphates, Chlorides and Nitrates of bivalent metal ions like Ca^{+2} & Mg^{+2}

Soap is sodium/potassium salt of higher fatty acids like stearic, oleic and palmetic acids.

When soap is mixed with soft water lather is produced due to stearic acid and sodium stearate

 Na – Stearate + H_2O NaOH + Stearic Acid [$C_{17}H_{35}COOH$]

 Stearic Acid + Na-Stearate Formatioin of lather.

When soap comes in contact with <u>HARD WATER,</u>

Sodium stearate will react with dissolved calcium and magnesium salts and produce calcium stearate or magnesium stearate which is white precipitate

- $\mathbf{2Na - Stearate + Ca^{+2} \rightarrow Ca - Stearate \downarrow + 2Na^{+}}$

- $\mathbf{[2C_{17}H_{35}COONa] + Ca^{+2} \rightarrow [(C_{17}H_{35}COO)_2\,Ca] \downarrow + 2Na^{+}}$

  (Soap) (Soluble) (Insoluble) (Soluble)

- $\mathbf{[2C_{17}H_{35}COONa] + Mg^{+2} \rightarrow [(C_{17}H_{35}COO)_2\,Mg] \downarrow + 2Na^{+}}$

  (Soluble) (Soluble) (Insoluble) (Soluble)

DISADVANTAGES OF HARDWATER / CAUSES OF HARDNESS:

The following are the disadvantages when hard water is used for various purpose:

(i) DOMESTIC USE:

(a) Washing and Bathing : Hard water does not form lather easily with soap is wasted

(b) Drinking : Hard water causes bad effects on our digestive system. Sometimes, stone formation takes place in kidneys

(c) Cooking : The boiling point of water is increased due to the presence of salts. Hence, more fuel and time are required for cooking.

(ii) INDUSTRIAL USE:

(a) Textile Industry : Hard water causes wastage of soap. Precipitates of calcium and magnesium soap adhere to the fabrics and cause problem

(b) Paper Industry : Calcium and Magnesium salts in water may effect the quality of paper.

(c) Sugar Industry : Water containing sulphates, carbonates, nitrates affects the crystallisation of sugar.

(d) Pharmaceutical Industry : Hard water may form some undesirable products while preparation of pharmaceutical products.

(iii) STEAM GENERATION IN BOILERS: For steam generation, boilers are employed. If hard water is used in boilers, It may lead to the following troubles

(a) Boiler Corrosion

(b) Scale and Sludge formation.

(c) Priming and Foaming

(d) Caustic embrittlement

TYPES OF HARDNESS

The hardness of water is of two types

(1) **Temporary hardness (or) Carbonate hardness**
(2) **Permanent hardness (or) Non-Carbonate hardness**

(3) **Temporary Hardness: Temporary hardness is caused by two dissolved bicarbonate salts $Ca(HCO_3)$ and $Mg(HCO_3)$. The hardness is called "Temporary Hardness" Because it can be removed easily by means of boiling.**

$$Ca(HCO_3)_2 \xrightarrow{Heating} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

$$Mg(HCO_3)_2 \xrightarrow{Heating} Mg(OH)_2 \downarrow + 2CO_2 \uparrow$$

(2) PERMANENT HARDNESS:

Permanent hardness of water is due to the dissolved chlorides, sulphates and nitrates of calcium and magnesium.

These salts are $CaCl_2$, $CaSO_4$, $Ca(NO_3)_2$, $MgCl_2$, $MgSO_4$, $Mg(NO_3)_2$

These Hardness cannot be removed easily by boiling. Hence it is called "Permanent Hardness". Only chemical treatment can remove this hardness.

Total Hardness Of Water = Temporary Hardness + Permanent Hardness

DEGREE OF HARDNESS:

- **The Concentration of hardness as well as non-hardness constituting ions are, usually expressed in the term of "Equivalent amount of $CaCO_3$"**

- **Since this mode permits the multiplication and division concentration, when required. The choice of CaCO3 in particular is due to its molecular weight (m.wt) is "100" (Equivalent wt = 50), and moreover, It is insoluble salt that can be precipitated in water treatment.**

- **Therefore 100 parts by weight of $CaCO_3$ hardness must be equivalent to**

1	162 parts by weight of $Ca(HCo_3)_2$ hardness
2	146 parts by weight of $Mg(HCo_3)_2$ hardness
3	136 parts by weight of $CaSo_4$ hardness
4	111 parts by weight of $CaCl_2$ hardness
5	164 parts by weight of $Ca(No_3)_2$ hardness
6	120 parts by weight of $MgSo_4$ hardness
7	146 parts by weight of $MgCl_2$ hardness
8	136 parts by weight of $Mg(No_3)_2$ hardness

The method of calculating degree of hardness will be clear from the following formula

•Hardness causing in salt in terms of $CaCO_3$ =

$$\frac{\text{Amount of the hardness causing salt x 100}}{\text{Molecular weight of hardness causing salt}}$$

$$Equivalents\ of\ CaCO_3 = \frac{\begin{pmatrix}\text{Mass of hardness}\\ \text{producing substance}\end{pmatrix} X \begin{pmatrix}Chemical\ equivalent\\ of\ CaCO_3\end{pmatrix}}{\begin{pmatrix}Chemical\ equivalent\ of\\ hardness\ producing\ substance\end{pmatrix}}$$

UNITS OF HARDNESS:

These are 4 different units in which the hardness of water is expressed as given below

(1) Parts per million (PPM): PPM is the number of parts of $CaCO_3$ equivalent hardness per 10^6 parts of water.

i.e., 1 PPM = 1 part of $CaCO_3$ equivalent hardness in 10^6 parts of water.

(2) Milli grams Per Litre (mg/litre): mg/L is the number of milligrams of

$CaCO_3$ equivalent hardness present per litre of water.

i.e., 1 mg/L = 1 mg of $CaCo_3$ equivalent hardness of 1 L of water.

But 1 L water weights = 1 kg of water

1 kg = 1000 gms

= 1000 x 1000 mg

= 10^6 mg

∴ 1 mg/L = 1 mg of $CaCo_3$ equivalent per 10^6 mg of water

= 1 part of $CaCo_3$ equivalent per 10^6 parts of water

$$\boxed{\therefore 1 \text{ mg/L} = 1 \text{ ppm}}$$

Degree Of Clark (°Cl)
:

It is defined as the number of parts of $CaCo_3$ equivalent hardness per 70,000 parts of water.

$\therefore$ 1°Cl = 1 grain of $CaCO_3$ eq. hardness per gallon of water. (or)

1°Cl = 1 part of $CaCo_3$ eq. hardness per 70,000 parts of water

$$\boxed{\therefore 1\ ppm = 0.07°Cl}$$

<u>Degree of French</u> (ºFr) :

ºFr is the number of parts of $CaCo_3$ equivalent hardness per 10^5 parts of water.

1ºFr = 1 part of $CaCo_3$ equivalent hardness per 10^5 parts of water

$$\boxed{\therefore\ 0.1^{o}\ Fr = 1\ ppm}$$

<u>Note</u>: The hardness of water can be converted into all the four units by making use of the following interconversion formula

1 ppm = 1mg/L = 0.07ºCl = 0.1ºFr
1ºCl = 1.43ºFr = 14.3 ppm = 14.3 mg/L

PROBLEM:

(1) A sample of water gives an analysis 13.6 mg/L of $CaSO_4$. 7.3 mg/L of $Mg(HCO_3)_2$. Calculate the total hardness and permanent hardness.

Sol:

Salt	Quantity Present (mg/L)	M.Wt	Eq. of $CaCo_3$
$CaSO_4$	13.6	136	$\frac{13.6 \times 100}{136} = 10$
$Mg(HCo_3)_2$	7.3	146	$\frac{7.3 \times 100}{146} = 5$

The Total hardness of H_2O = Temporary hardness + Permanent Hardness

= 5 + 10 = 15 mg/L

Permanent hardness = 10 ppm (or) 10 mg/L

PROBLEM

(2) Calculate the total hardness of 1000 litre of a sample of water containing the following impurities 16.2 mg/L of $Ca(HCO_3)$, 11.1 mg/L of $CaCl_2$, 60 mg/L of $MgSo_4$ and $Ca(HCO_3)_2$, 11.1 mg/L of $CaCl_2$, 60 mg/L of $MgSo_4$ and 19 mg/L if $MgCl_2$.

Sol:

Salt	Quantity Present (mg/L)	M.Wt	Eq. of $CaCo_3$
$Ca(HCO_3)_2$	16.2	162	$\frac{16.2 \times 100}{162} = 10$
$CaCl_2$	11.1	111	$\frac{11.1 \times 100}{111} = 10$
$MgSO_4$	60	120	$\frac{60 \times 100}{120} = 50$
$MgCl_2$	19	95	$\frac{19 \times 100}{95} = 20$

Total hardness of H_2O = Temporary hardness + Permanent Hardness

= 10 + 10 + 50 + 20 = 90 mg/L

Total hardness for 1000 litres

= 90 x 1000 = 90,000 mg/L

PROBLEM

(3) A Sample of hard water contains the following dissolved salts per litre. $CaCl_2$ = 111 mgs, $CaSO_4$ = 1.36 mgs, $Ca(HCO_3)_2$ = 16.2 mgs, $Mg(HCO_3)_2$ = 14.6 mgs, Silica = 40 gms, Turbidity = 10 mgs.

Calculate the temporary, permanent and total hardness of water in ppm, ^{O}cl & ^{O}Fr

Sol:

Salt	Quantity Present (mg/L)	M.Wt	Eq. of $CaCo_3$
$CaCl_2$	111 mg/L	111	$\frac{111 \times 100}{111} = 100$
$CaSO_4$	1.36 mg/L	136	$\frac{1.36 \times 100}{136} = 1$
$Ca(HCO_3)_2$	16.2 mg/L	162	$\frac{16.2 \times 100}{162} = 10$
$Mg(HCO_3)_2$	14.6 mg/L	146	$\frac{14.6 \times 100}{146} = 10$

Note: Si & Turbidity must not be considered because they do not cause hardness to water.

Total hardness of H_2O = Hardness of $Ca(HCO_3)_2$+ $Mg(HCO_3)_2$ interms of $CaCO_3$ equivalents

= 10 + 10 = 20 mg/L

Permanent hardness = Hardness of $CaCl_2$+ $CaSO_4$ interms of $CaCO_3$ equivalents

= 100 + 1 = 101 mg/L

<u>Conversion of hardness</u>:

1 ppm = 1mg/L = 0.07°cl = 0.1° Fr

Total hardness of the sample of water = 121 ppm = 121 mg/L
= 121 x 0.07 = 8.47°cl and
= 121 x 0.1 = 12.1° F

Permanent hardness = 101 mg/L, 101 ppm, 7.07°cl, 10.1° Fr

Total hardness = 20 mg/L, 20 ppm, 1.4°cl and 2° Fr

PROBLEM

(04) 1 litre of water from an underground reservoir in Tirupati town in A.P showed the following analysis for contents:
$Mg(HCO_3)_2$ = 42 mg; $Ca(HCO_3)_2$ = 146 mg; $CaCl_2$ = 71 mg;
NaOH = 40 mg; $MgSO_4$ = 48 mg; Organic impurities = 100 mg;

Calculate temporary and permanent and total hardness of the sample of 10,000 lit. of water

Note: NaOH & Organic impurities donot causes any hardness.
The Bicarbonate salt cause temp hardness,

While other are responsible for Permanent hardness.

$Mg(HCO_3)_2$ = 42 mg in 10,000 (or) 42/10,000 ppm
Its $CaCO_3$ eq's are = [42/10000] x [100/146]

Similarly for $Ca(HCO_3)_2$ it is [146/10000] x [100/162]
For $CaCl_2$ it is [71/10000] x [100/111]
For $MgSO_4$ it is [48/10000] x [100/120]

Temporary Hardness = [42/10000] x [100/146] + [146/10000] x [100x162]

Permanent Hardness = [71/10000] x [100/111] + [48/10000] x [100x120]

Total Hardness = Temporary Hardness + Permanent Hardness

= .... + ………

= …….... ppm

PROBLEM

(5) Calculate the temporary & permanent hardness of water in ^{o}cl, containing the following dissolved salts. $CaCO_3$=50 mg/L, $MgCl_2$=9.5 Mg/L, $CaCl_2$=2.2 mg/L and $MgSO_4$=12 mg/L

Note: $CaCO_3$ is an insoluble salt. It does not cause hardness. If $CaCO_3$ is given as H.C.S, It must be considered as $Ca(HCO_3)_2$ whose hardness is expressed in the term of $CaCO_3$ equivalent

Sol:

Salt	Quantity Present (mg/L)	M.Wt	Eq. of CaCo3
$CaCO_3$	50 mg/L	100	50 mg/L
$MgCl_2$	9.5 mg/L	95	$\frac{9.5x100}{95} = 10$
$MgSO_4$	12 mg/L	120	$\frac{12x100}{12} = 10$
$CaCl_2$	22.2 mg/L	111	$\frac{22.2x100}{111} = 20$

Temporary Hardness Of Water = [Hardness Of $CaCO_3$]

$= 50$ ppm/50 mg/L

$= 50 \times 0.7 = 3.5\ ^{o}cl$

Permanent Hardness Of Water = Hardness of $MgCl_2 + MgSO_4 + CaCl_2$

$= 10 + 10 + 20$

$= 40$ mg/L

$= 40 \times 0.7$

$= 2.8^{o}$ cl

Problem: 100 mL of water sample has a hardness equivalent of 12.5 mL of 0.08 N $MgSO_4$. What is its hardness in ppm. (Mol.Wt. of $MgSO_4$=120)

Hardness = Hardness

12.5 mL of 0.08 N $MgSO_4$ = 100 mL water

$$0.08 = \frac{g}{60} = 4.8\,g \text{ in } 1000\,mL$$

4.8 g in 1000 mL

~~4.8 mL~~ so in 12.5 — $\frac{4.8}{1000} \times 12.5$

= 0.06 g.

(60 mg)

0.06 g. in 100 mL

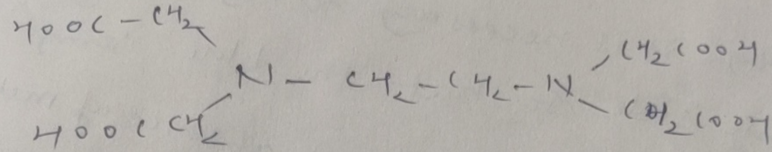
so in 1000 — $\frac{60}{100} \times 1000 =$ 600 mg.

Hardness in $CaCO_3$ equivalent $= 600 \times \frac{100}{120} =$ 500 ppm or mg/L

Estimation of water Hardness — EDTA method / soap titration method.

① **EDTA method :-**
Analysis is done by complexometric titration using standard EDTA [Ethylene diammine tetra acetic acid] as titrant and EBT (Eriochrom Black T) as indicator

EDTA :- Tetra protic acid => H_4Y
limited solubility so Na_2H_2Y salt as is used [372.24]
as can be used as Primary standard



with Ca^{2+} and Mg^{2+}

binds in 1:1

$$M^{2+} + H_2Y^{2-} \rightleftharpoons MY^{2-} + 2H^+$$

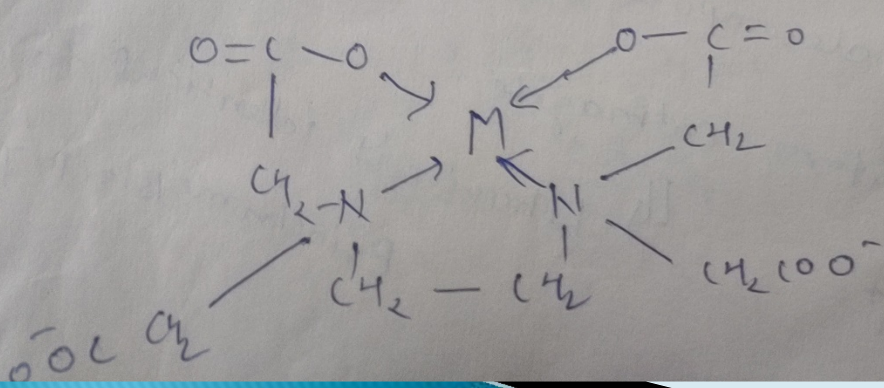
$$M^{3+} + H_2Y^{2-} \rightleftharpoons MY^{-} + 2H^+$$

$$M^{4+} + H_2Y^{2-} \rightleftharpoons MY + 2H^+$$

$\Downarrow$

This equilibrium is markedly affected by pH of the solution

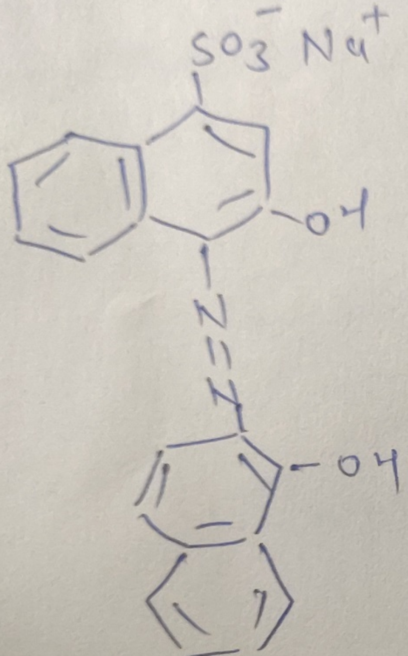
complexes are stable in basic or slightly acidic solution only.



$^-OOC\ CH_2$ $CH_2 - CH_2$

Eriochrome Black T (EBT)

↳ chemical name



H_2In^- (Red)

HIn^{2-} (Blue)

sodium 1-(1-hydroxy-2 naphthylazo]-6-nitro-2-naphthol-4-sulphonate

weak acid

$$H_2O + H_2In^- \rightleftharpoons HIn^{2-} + H_3O^+$$

red   blue

$$H_2O + HIn^{2-} \rightleftharpoons In^{3-} + H_3O^+$$

blue   orange

behaves as acid/ base indicator as well as metal-ion indicator.

For metal ion detection it is necessary to adjust the pH on the basic side so that the blue form of species, HIn^{2-} Bedominates in the absence of metal ion.

EBT (Blue dye) + sample [Hard water] $\xrightarrow{pH-10}$ wine-red

Buffered pH = 10
[$NH_4OH - NH_4Cl$]

$NH_4OH + HCl \rightarrow H_2O + NH_4Cl$
$NH_4Cl + NaOH \rightarrow NH_4OH + NaCl$

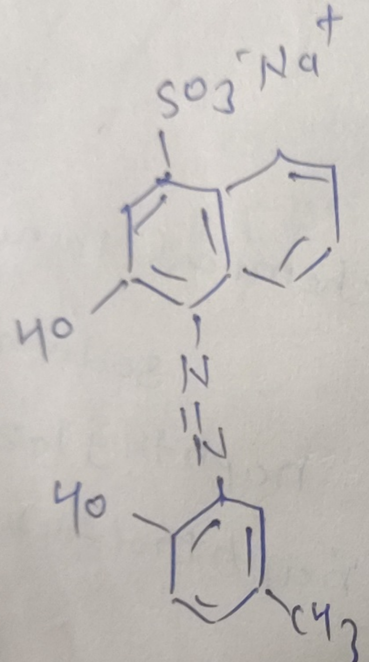
M-EBT-complex + EDTA $\xrightarrow{\text{Titration}}$ [M-EDTA] complex + EBT
Red Blue.

$CH_3COONa - CH_3COOH$
$CH_3COONa + HCl \rightarrow CH_3COOH + NaCl$
$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

limitation of Eriochrome BLACK T

that its solutions are not stable slowly decompose on standing slowly de...

Another indicator calmagite its behavior is identical to Eriochrome Black T



procedure :-

① standarization of EDTA solution :-

EDTA ⇓ in burette

50 mL of standard hard water (conical)

Prepared such a way that it contains ~~1mg~~ 1 mL − 1 mg of $CaCO_3$

into a 250 mL conical flask

+

Add 10 mL of buffer solution

+

2 - 3 drops of indicator,

↓

At the end wine-red color changes to blue

Standard water = 1 mg. of $CaCO_3$ in 1 mL

or.

$\frac{0.001 g.}{100}$ or 80 1g − 1000 mL sol.

molarity of standard water,

$\frac{1}{100} = 0.01 M$

Step. (i) standarization.

$\boxed{M_{std \cdot H_2O} V_{std \cdot H_2O} = M_{EDTA} \times V_1}$

$\underbrace{M_1 V_1}_{\text{std. water}} = \underbrace{M_2 V_2}_{\text{EDTA}}$

$50 mL \times 0.01 M = M_2 \times V_1$

$M_{EDTA} = \frac{0.5}{V_1} M$ $\quad M_1 = M_{EDTA}$

② Determination of total Hardness [let the volume of EDTA ⇒ V_1 mL]

50 mL of unknown water sample against EDTA

and suppose V_2 volume of EDTA consumed

$\boxed{V_{unknown \cdot H_2O} M_{unknown \cdot H_2O} = M_{EDTA} \times V_2}$

$V_{unknown H_2O} \times M_{unknown H_2O} = \underbrace{M_2 V_2}_{EDTA}$

$50 \times M_{unknown H_2O} =$

$M_{unknown H_2O} = V_2 \times \frac{0.5}{V_1} \times \frac{1}{50} = 0.01 \times \frac{V_2}{V_1} M$

$$M = \frac{0.01 \frac{V_2}{V_1} \cdot g}{\cancel{10}\,100}$$

$M = \frac{g}{\cancel{tot}}$ M.wt

$M = \frac{g}{100}$

$0.01 \frac{V_2}{V_1} \times 100\, g \longrightarrow$ in 1000mL

$0.01 \frac{V_2}{V_1} \times 100 \times 1000$ mg / L

$\cancel{so}$ $\frac{V_2}{V_1} 1000$ mg / L

or

$= \frac{V_2}{V_1} 1000$ PPM

(iii) Determination of Permanent Hardness :-

$M_{unknown-H_2O} V_{unknown-H_2O} = M_{EDTA} \times V_3$

Take 250mL of water in 500mL of beaker $\xrightarrow{\text{Boil}}$ Reduced to 50mL

↓

filtered

↓

Make-up volume 250mL with distilled water.

↓

Titrate 50mL of this water, against EDTA let the volume used V_3 mL

Permanent Hardness of water.

$= 1000 \frac{V_3}{V_1}$ PPM

(iv) Determination of temporary Hardness

Total Hardness - Permanent Hardness.

$1000 \times \frac{V_2}{V_1} - 1000 \frac{V_3}{V_1}$

or $\frac{1000 (V_2 - V_3)}{V_1}$ PPM

* Advantages of EDTA method :-

Determination of Hardness with greater accuracy, convenience and more rapid Procedure.

Example :-

A standard hard water contains 15 g of $CaCO_3$ per litre, 20 mL of this required 25 mL of EDTA solution, 100 mL of sample required 18 mL of EDTA solution. The sample after boiling required 12 mL EDTA solution. Calculate temporary hardness of the given sample of water in terms of ppm.

step (i) Standardization of EDTA

$\frac{153}{1000}$ $\frac{180}{}$ $\frac{153}{\cancel{180}100}$ = ~~0.83 M~~ 0.15 M

$M_{std-H_2O} V_{std-H_2O} = M_{EDTA} V_1$

~~0.83~~ 0.15 M × 20 = 25 × M_{EDTA}

M_{EDTA} = ~~0.664 M~~ 0.12 M

~~0.664 =~~ g

(ii) Total hardness :-

$M_{H_2O} V_{H_2O} = M_{EDTA} V_2$

$M_{H_2O} = \frac{\cancel{0.664} 0.12 \times 18}{100}$ = 0.0216 M

= ~~0.1195 M~~

~~0.1195 = $\frac{g}{100}$~~

~~= 11.952 g. in 1000 ml~~

~~11952 mg in 1000 ml~~

$0.0216 = \frac{g}{100}$ g = 2.16

~~g~~ 2160 ppm

(iii) Permanent Hardness

Temporary

2160 − 1440 = 720 ppm

$M_{H_2O} V_{H_2O} = M_{EDTA} \times V_3$

$M_{H_2O} \times 100$ = ~~0.664~~ 0.12 × 12

$M_{H_2O} = \frac{0.12 \times 12}{100}$ = 0.0144

= 1440

$0.0144 = \frac{g}{}$