**SUBJECT: CHEMISTRY**

**TOPIC: WATER**

**CLASS: SS 1**

**ABILITY: MIXED**

**OBJECTIVE: At the end of the topic the students should be able to:**

1. Identify some types of water;
2. Draw the water cycle;
3. Describe the process of treating town water supply;
4. Define hardness in water;
5. Write equations for removal of hardness in water;
6. Define water pollution;
7. Identify sources of water pollution;
8. Define solutions and solvents;
9. Differentiate between true and false solutions.

## DEVELOPMENT

## WATER

OCCURRENCE: Water occurs in vast quantities all over the world in water bodies. It does not occur in its pure form in nature.

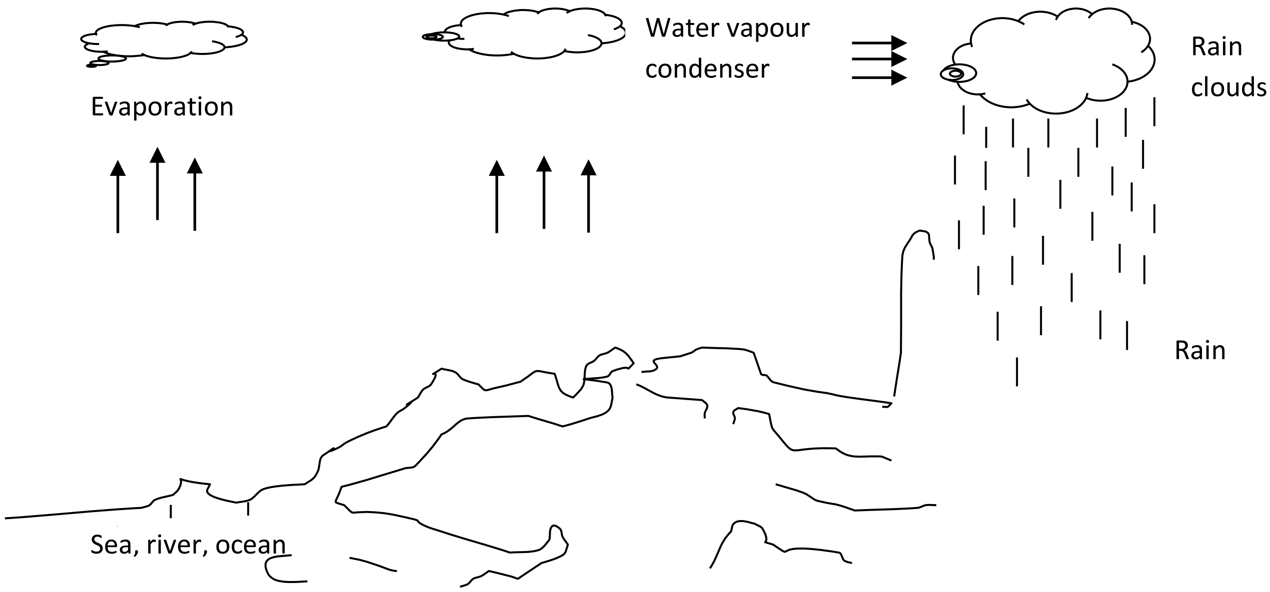
## TPYES OF WATER

There are two major types of water: Natural and treated

1. RAIN WATER: Purest form of water. It is formed as a result of the condensation of water vapour in the atmosphere.
2. SPRING WATER: This is rain water which sinks through the porous soil layers but collects above an impervious layer. It is a good source of drinking water; with mineral salt.
3. WELL WATER: This is stagnant water. It contains a lot of clay, mineral salts and dead organisms.
4. RIVER WATER: Formed when spring or other running water come together.
5. LAKES, SEA, OCEAN: These form reservoirs for rivers and other running waters. They contain all sorts of substances including bacteria, mineral salts, air etc.

## WATER CYCLE

All the different types of natural water are in constant circulation forming a gigantic water cycle. The largest collections of water are in the lakes, rivers, seas which are exposed to the atmosphere. Evaporation takes place continuously from them, and the water vapour formed condenses to water droplets in the atmosphere, form clouds and fall as rain.




## TREATED WATER

Treated water is usually prepared for special purposes: Example: distilled water and pipe-borne water for townships.

DISTILLED WATER: This is the purest form of water. It is prepared by condensing water vapour or stream. The apparatus used for the purpose is Liebig condenser.

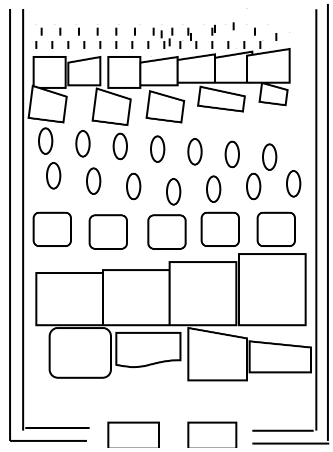
## TREATMENT OF WATER SUPPLY

Water from the dams, lakes or rivers may contain high level of bacteria and undesirable micro-organisms. Hence there is the need for treatment to reduce these organisms. Also the water may contain clayed materials, mineral salt and other particles.

## PROCEDURE

The procedure for treatment include:

1. Sedimentation/Flocculation/ Coagulation: By allowing the water to settle down or by use of flucculators to gather the particles or by addition of alum to coagulate the particles.
2. The water is then filtered using a filter bed
3. Aeration: Exposure to sunlight for dissolution of atmospheric oxygen which prevents anaerobic conditions that may produce foul odour. Sunlight also kills bacteria.
4. Addition of Chlorine: This acts as a germicide to kill bacteria. Others: $Ca(OH)_2$ may be added to adjust the pH; fluoride may be added to prevent tooth decay and iodine may be added to prevent goiter. Water is now ready to be supplied to citizens.



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## HARDNESS OF WATER

Water is said to be hard when it does not lather easily with soap.

## ORIGIN OF HARD WATER

Water acquires hardness when it dissolves gypsum $CaSO_4 . 2H_2O$ or limestone from the soil over which it passes. Gypsum is sparingly soluble in water but limestone is not. However, the water which contains some Carbon(iv) oxide can dissolve $CaCO_3$ according to the equation:

$$CaCO_3 + CO_2 + H_2O \longrightarrow \underset{\text{Soluble}}{Ca(HCO_3)_2}$$

## HARD WATER AND SOAP

Soap is the sodium or potassium salt of an organic acid. e.g. $C_1nH_{35+}$ COONa (Sodium Octedecanoate). When soap is added to hard water the dissolved salt in the water will react with soap to give the insoluble calcium or magnesium salts called 'scum' which stick to clothes and is difficult to rinse away.

$$2C_{17}H_{35}COONa + Ca^{2+} \longrightarrow \underset{\text{Scum}}{(C_{17}H_{35}COO)_2 Ca} + 2Na^+$$

## TYPES OF HARDNESS

There are two types of hardness in water

(1) Temporary hardness (2) Permanent hardness

## TEMPORARY HARDNESS

Temporary hardness is caused by the presence in water of calcium hydrogen trioxocarbonate(iv) $Ca(HCO_3)_2$ and magnesium hydrogen trioxocarbonate(iv) $Mg(HCO_3)_2$

## REMOVAL OF TEMPORARY HARDNESS (SOFTENING)

(1) By Boiling – deposition of $CaCO_3$

$$Ca(HCO_3)_2 \xrightarrow[boil]{} \underset{deposit}{CaCO_3} + H_2O + CO_2$$

$$Mg(HCO_3)_2 \longrightarrow MgCO_3 + H_2O + CO_2$$

(2) By adding calculated amounts of slaked lime $Ca(OH)_2$

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow \underset{insoluble}{2CaCO_3} + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3 + CaCO_3 + 2H_2O$$

(Note that if excess $Ca(OH)_2$ is used, this will cause hardness in water).

## EFFECT OF TEMPORARY HARDNESS

i. Furring of kettles and boilers

When a kettle or boiler has been used to boil temporarily hard water for sometime there will be deposits of $CaCO_3$ which are fur-like.

ii. Formation of stalagmites and stalactites

These are pillars of limestone ($CaCO_3$) growing from the roof and floor of hot caves in area of temporary hardness. Temporary hard water flowing through the rooftop of the cave gets hot and decomposes the $Ca(HCO_3)$ in the water. A Calcium trioxocarbonate(iv) deposit which grows downwards from the rooftop is called a stalactite while the one growing upwards from the floor is called a stalagmite.

## PERMANENT HARDNESS

This is caused by the presence in water of Calcium and magnesium ions in the form of soluble teraoxosulphate(vi), Chlorides – $CaSO_4$, $MgSO_4$, $CaCl_2$ etc.

## REMOVAL OF PERMANENT HARDNESS

- Not easily removed by boiling.

**1.** Addition of washing Soda (Sodium trioxocarbonate(iv)

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2SO_4$$

Or $MgSO_4 + Na_2CO_3 \longrightarrow MgCO_3 + Na_2SO_4$

Also removes temporary hardness

$$Ca(HCO_3)_2 + Na_2CO_3 \longrightarrow 2NaHCO_3 + CaCO_3$$

$Mg(HCO_3)_2 + Na_2CO_3 \longrightarrow 2NaHCO_3 + MgCO_3$

2. **Addition Of Caustic Soda**

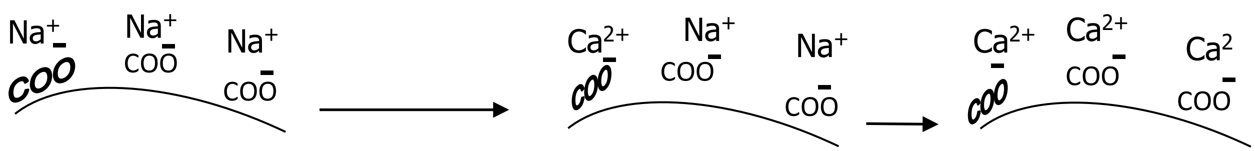
$CaSO_4 + 2NaOH \longrightarrow Ca(OH)_2 + Na_2SO_4$

$MgSO_4 + 2NaOH \longrightarrow Mg(OH)_2 + Na_2SO_4$

3. **Distillation**

4. **Permutit or Zeolite or Ion-Exchange Method (resin)**

An ion-exchange resin is an insoluble compound which has sodium ions($Na^+$) attached to its surface. The most common types are sodium aluminium trioxosilicate(iv) (sodium zeolite) solid under the name of permutit. The resin in the form of beads is packed into a cylinder. When hard water is passed through the cylinder, calcium ions from the water takes the place of sodium ions on the resin. The water flows out without $Ca^{2+}$.




Refresh resin

Reaction is:

$CaSO_4$+Sodium $\longrightarrow$ Calcium + $Na_2SO_4$.

Zeolite Zeolite

After sometime the resin is spent to regenerate it, Conc NaCl is poured through the resin. The $Na_+$ replaces the $Ca_{2+}$ and the resin can be reused.

## ADVANTAGES OF HARD WATER

1. Tastes better due to dissolved minerals in it
2. The calcium salts in hard water help animals to build strong bone and teeth
3. Helps animals like crabs or snails to make their shells
4. Does not dissolve lead from lead pipes
5. It is better for some manufacturing processes like the brewery industry.

## DISADVANTAGES OF HARD WATER

i. It wastes soap
ii.
iii. It causes furring of kettles and boilers and wastes energy during heating (far act, as insulators)
iv. It is not suitable for dyeing and tanning as the salts interfere with the dyeing process.

## WATER POLLUTION

Water pollution is the contamination of water bodies (rivers, ocean, lakes etc) as a result of human activities.

## WATER POLLUTANTS

The sources of water pollution include:

a. Sewage and garbage – human wastes, sewers, garbage;
b. Industrial waste from industries;
c. Agricultural waste – fertilizers, pesticides, herbicides (weed growth);
d. Oil spillage – oil producing areas;
e. Thermal sources – breweries, iron and steel industries increase temperature and remove oxygen from river.

## BIODEGRADABLE SUBSTANCES

Pollutants that cannot be broken down into harmless substances are called non-biodegradables, detergents, plastics, some organic substances.

## PREVENTION OF WATER POLLUTION

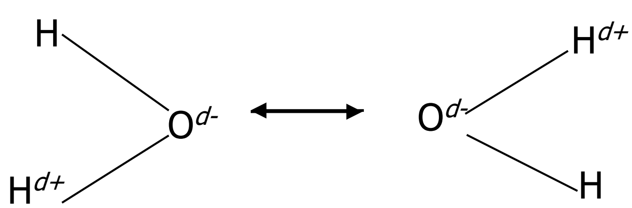
i. Refuse should be burned or burnt in incinerators;
ii. Sewage should be processed and converted to useful organic fertilizers;
iii. Chemicals should be converted first to harmless substances before discharge to water;
iv. Care should be taken to avoid oil spillage;
v. Educate the citizenry on dangers and effects of water pollution;
vi. Environmental protection agencies should carryout inspection of industries and ensure safety rules.

## COMPOSITION OF WATER

Priestly (1781) observed that hydrogen and oxygen explode to form water vapour. Cavendish established ratio of H to O to be 2:1

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)}$$

Water is a polar solvent and can dissolve many substances.




## PHYSICAL PROPERTIES

a. Pure water is colourless, odourless and tasteless.
b. It boils at $100^{oc}$ at atmospheric pressure of 760mmHg.
c. It freezes at $O^{oc.}$
d. It has its maximum density of $1.0gcm^3$ at $4^{oc.}$
e. It is neutral to litmus.

## CHEMICAL PROPERTIES

**1. Reaction With Metal**

Na and K react rigorously with cold water to give hydrogen gas

Ca reacts slowly with cold water.
Mg and Zn react only with steam
Al and Iron need to be red hot to react with steam
Cu, Hg, Ag and Au do not react with water under any condition.

**Mnemonic For Reaction**

Professor, S, C — liberate $H_2$ with cold water, liberate $H_2$ slowly    $2Na+2H_2O \longrightarrow 2NaOH+H_2$

M, A — liberate $H_2$ with steam

Z, I, L — liberate $H_2$ at red hot and steam

Has, Conquered, Mercury, Stale, Government — do not liberate $H_2$ under any condition

**2. With Non Metals**

$C+H_2O \longrightarrow CO+H_2$
White hot    water gas.
$Cl_2+H_2O \longrightarrow HOCl+HCl$.

**3. With Metallic Oxides**

$Na_2O + H_2O \longrightarrow 2NaOH$
Alkaline

**4. With Non-Metallic Oxides**

$SO_2 + H_2O \longrightarrow H_2SO_3$
Acids

$CO_2 + H_2O \longrightarrow H_2CO_3$
Acids

**TEST FOR WATER**

$CuSO_4 + 5H_2O \longrightarrow CuSO_4.5H_2O$

Anhydrous white    blue

$CoCl_2 + 6H_2O \longrightarrow CoCl_2.6H_2O$
Blue    pink

## SOLUTIONS

A solution is a uniform or homogenous mixture of two or more substances.

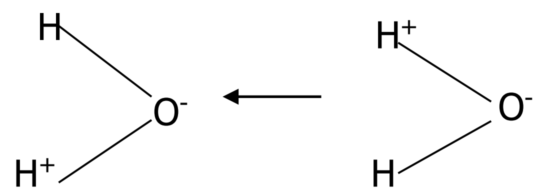
The substance that dissolves the other is called the solvent – usually water. The dissolved substance is called the solute. Solvent + Solute $\longrightarrow$ Solution.

## TYPES OF SOLUTIONS

a. Solutions of solid in liquid e.g. NaCl in water.
b. Solutions of liquid in liquid of ethanol and water – miscible liquids.
c. Gas in liquid of $CO_2$ in water.
d. Solutions of solid in solid of copper zinc to brass or copper and tin to form bronze.

## SOLVENTS

The most common solvent is water. It is said to be polar because of its molecular structure. It is usually referred to as a universal solvent




When a solid substance dissolves in water the solution is said to be **aqueous**.

## SUITABLE SOLVENTS FOR SOME SOLUTES

| Solute | Solvent |
|---|---|
| Sodium Chloride | Water |
| Sugar | Water |
| Grease | Petrol |
| Sulphur | Carbon(iv) Sulphide |
| Rubber | Benzene |
| Paint | Turpentine. |

Suspension:- A heterogeneous mixture of undissolved particles in a given medium.

## USES OF SOLVENTS

1. In laundries, some stains that cannot be removed by ordinary water could be subjected to other solvents like carbon tetrachloride, kerosene, borax (coffee)
2. In manufacture of perfumes (ethanol)
3. In dispensaries – iodine in ethanol
4. In laboratory work – water and benzene
5. Vulcanisers solution for mending patches/punctures (rubber in $C_6H_6$).

## SUSPENSION

If chalk dust is added to water in a beaker, it will float for some time and settle at the bottom later. The particles will form sediments. The mixture is called a **Suspension**.

A suspension is a heterogeneous mixture of two substances.

In a suspension the solute particles are insoluble in the water e.g. harmatan dust, (2) fog – dust particles and water droplets, smoke etc.

Particles of suspension can be seen with the naked eyes and can be filtered.

## COLLOIDS

Colloids are false solutions in which the individual solute particles are larger than the particles of the true solution but not large enough to be seen by the naked eyes.

## TYPES OF COLLOIDS

In discussing colloids, the liquid solvent is known as the dispensing medium while the solid particles constitute the dispersed substances.

| EXAMPLES OF COLLOIDS | SOLVENT OR DISPERSION MEDIUM | SOLUTE OR DISPERSED SUBSTANCES |
|---|---|---|
| Fog } Aerosol<br>Smokey | Air (gas)<br>Air (gas) | Water particles (liquid) or solid<br>Carbon particles (solid) |
| Foam or lather | Water (liquid) | Air bubbles (gas) |
| Emulation | Water (liquid) | Oil globules (liquid) – milk, hair cream, butter, paint |
| Sols/gels$^{-conc}$ | Water (liquid) | Starch (solid), honey |

## TRUE AND FALSE SOLUTIONS

**True Solution:-** Solute particles dissolve and get in between the solvent particles – homogenous e.g. NaCl in water.
**False Solution:-** Solute particles are larger than the solvent particles e.g. starch in water.

## DIFFERENCE BETWEEN FALSE AND TRUE SOLUTIONS

| S/N | TRUE SOLUTION | FALSE SOLUTION |
|---|---|---|
| 1 | Solutes can pass through a filter paper | Solutes cannot pass through a filter paper |
| 2 | Solutes can diffuse through a medium | Solutes cannot diffuse through a medium |
| 3 | The solutes can exert an osmotic pressure | The solutes does not exert any observable osmotic pressure |
| 4 | The solutes can be dialysed. Solutes can pass through a semi permeable membrane | The solutes cannot be dialysed. The solutes cannot pass through a semi permeable membrane |
| 5 | The solutes do not scatter light – Do not exhibit tyndal effect | The solutes scatter light. They exhibit tyndal effect. |

**DEFINITION**

A suspension is a heterogeneous mixture of undissolved substances/particles in a given medium. In a given suspension the solute particles are insoluble in a given solvent e.g. muddy water, fog, dust particles and water droplets harmattan dust. Particles of suspension can be seen with the naked eyes and can be filtered.

**COLLOIDS**

Colloids are false solutions in which the individual solute particles are larger than the particles of the true solution, but not large enough to be seen with the naked eyes.

**TYPES OF COLLOIDS**

In discussing colloids, the liquid solvent is known as the dispensing medium while the solid solute particles constitute the dispersed substances.

| **Examples of colloids** | **Solvent or dispersing medium** | **Solute or disperses substance** |
|---|---|---|
| Fog (aerosol | Air (gas) | Water particles (liquid) or solid |
| Smoke | Air (gas) | Carbon particles (solid) |
| Foam or lather | Water )liquid) | Air bubbles (gas) |
| Emulsion | Water (liquid | Oil globules (liquid), milk, hair cream, butter, paint |
| Solid/gels | Water (liquid) | starch (solid), honey |

**TRUE AND FALSE SOLUTIONS**

**TRUE SOLUTION:** Solute particles dissolve and get in between the solvent particles – homogenous mixture e.g. NaCl in water.

**FALSE SOLUTION:** Solute particles are larger than the solvent particles. Examples, starch in water.

**DIFFERENCES BETWEEN TRUE AND FALSE SOLUTIONS**

| | **TRUE SOLUTION** | **FALSE SOLUTION** |
|---|---|---|
| 1. | Solutes can pass through a filter paper | Solutes cannot pass through a filter paper |
| 2. | Solutes can diffuse through a medium | Solutes cannot diffuse through a medium |
| 3. | The solution can exert osmotic pressure | The solution does not exert any observable osmotic pressure |
| 4. | The solutes can be dialysed – solutes can pass through a semi – permeable membrane | The solution cannot be dialysed the solutes cannot pass through a semi-permeable membrane. |

| | | |
|---|---|---|
| 5. | The solutes do not scatter light – do not exhibit Tyndale effect | The solutes scatter light – they exhibit tyndal effect. |

**TOPIC: SOLUBILITY**

**CLASS: SS 2**

**ABILITY: MIXED**

**OBJECTIVE**: At the end of the topic the students should be able to:

1. Define saturated and unsaturated solutions.
2. Define a supersaturated solution
3. Define solubility
4. Describe experiments to demonstrate solubility
5. Give some applications of solubility.
6. Perform some calculations involving solubility.

Previous knowledge: The students are conversant with water as a solvent and also solutes of various types.

**SATURATED SOLUTION**

Saturated solution of a solute at a particular temperature is one which contains as much solute as it can dissolve at that temperature in the presence of excess undissolved solute particles. The composition of a saturated solution is not affected by the presence of excess solute.

**UNSATURATED SOLUTION**

An unsaturated solution is one that has a lower concentration of solute than a saturated solution and can dissolve more solutes if added until it becomes saturated.

**CONDITION**

The concentration of a saturated solution varies with the (a) solute (b) solvent (c) temperature.

Generally solubility increases with increase in temperature. When a saturated solution is cooled, excess solute crystallize out at the lower temperature since solubility decreases with decrease in temperature.

Examples: Some substances whose saturated solution could be cooled without the solute particles crystallizing out include:

1. $Na_2SO_4 . 10H_2O$. Sodium tetraoxosulphate (VI) decahydrate
2. $Na_2S_2O_3 . 5H_2O$. Sodium trioxothiosulphate (II) Pentahydrate

Super saturated solutions are instable and excess solute will separate out if the solution is disturbed slightly or if a tiny crystal of the solute or even dust particle is dropped into it.

**SOLUBILITY**

The solubility of a solute in a solvent at a particular temperature is the maximum amount of solute that will saturate or dissolve in $1dm^3$ of solvent at that temperature. Unit is $moldm^{-3}$.

Or the maximum mass of solute in grams that will saturate or dissolve in 1 $dm^3$ of solvent unit is $gdm^{-3}$.

**TO DETERMINE THE SOLUBILITY OF A GIVEN SOLUTE**

The process involves two stages:

(a) The preparation of a saturated solution at the temperature.

(b) Heating a known mass of the saturated solution to dryness to determine the mass of the solvent and the mass of the solute in the saturated solution.

**TO MEASURE THE SOLUBILITY OF POTASSIUM TRIOXONITRATES (V) AT ROOM TEMPERATURE ($KNO_3$).**

Half fill a $50cm^3$ beaker with distilled water. Add an excess of potassium trioxonitrate (V) to the water. Weigh a dry evaporating dish and pour in some of the saturated solution. Weigh the dish and the content. Heat the solution to dryness on a water bath. Cool the salt and dry in a desiccators. Weigh the content of the evaporating dish and hence calculate the amount of solute that dissolved and the mass of the solvent evaporated.

**SPECIMEN RESULT**

Mass of evaporating dish – Xg

Mass of dish saturated solution – yg

Mass of saturated solution – (y – x)g

Mass of dish + dry residue – zg

Mass of dry residue – (z-x)g

∴ Mass of water used – (y – z)g

Hence amount of salt that dissolved in $1000cm^3$ ($1dm^3$) of solvent = $\frac{(z-x)}{(y-z)}$ x $\frac{100}{1}$

i.e. (z – x)g dissolved in (y – z)g of solvent

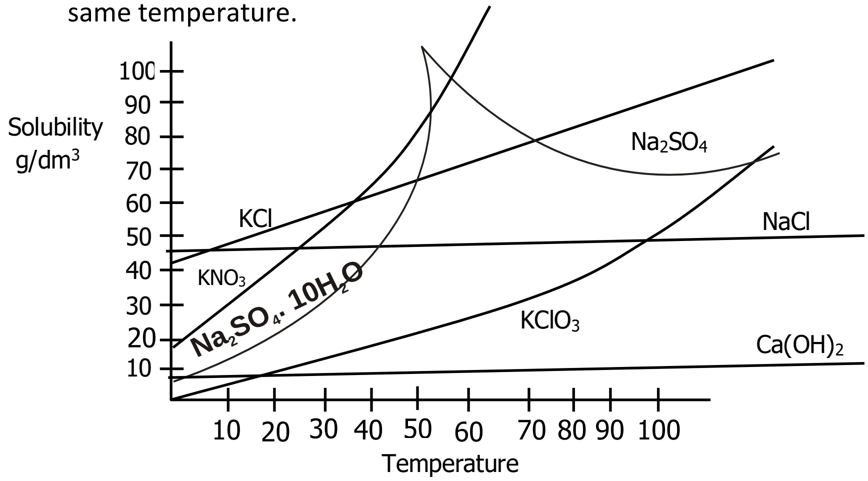
The value of mass of salt could be converted into moles/$dm^3$ by using the relationship

Amount = $\frac{mass\ of\ substance}{molar\ mass}$

Assignment: Determine how you would determine the solubility of $KNO_3$ at $60^{0C}$

## SOLUBILITY CURVES

If the solubilities of a solute in a given solvent are plotted against their respective temperatures, a graph, called solubility curve/graph is obtained. It is possible to plot the solubilities of different solutes at the same temperature.




**DEDUCTIONS FROM THE GRAPH**

For the temperature range of $0^{0c}$ to $100^{0c}$

1. The solubilities of $KClO_3$ and $KNO_3$, KCl increase very rapidly with increase in temperature
2. The solubilities of NaCl and $Ca(OH)_2$ are fairly independent of temperature.
3. $Na_2SO_4$. $10H_2O$ show a solubility curve with a sharp break at about $36^{0c}$. Above $36^{0c}$ it gives up its water of crystallization and becomes anhydrous. The solubility decreases.
4. $Ca(OH)_2$ has the lowest solubility of the compounds.

**APPLICATION OF SOLUBILITY**

- Solubility enables drug manufacturers to determine the amount of solid drugs that must be dissolved together in a given quantity of solvent to give a prescribed drug mixture.
- Enables chemists to determine the most suitable solvent to be used at various temperatures for the extraction of essential chemicals from various natural sources
- Could help in separation of solutes or purified fractional crystallization, when saturated solutions are cooled. The fractions with low solubilities will be the first to crystallize out of solution.
- Enables us to determine the mass of solute that will crystallize out when a saturated solution at a higher temperature is cooled to a lower temperature.
- It enables us to predict the order at which solutes will separate when a mixed solution is cooled.
- It enables us to read solubilities any required temperatures covered by the graph.

**CALCULATIONS OF SOLUBILITY**

Calculate the solubility of the following in (a) $g/dm^3$ (b) $mole/dm^3$ salts from the following

| | SUBSTANCE | MASS IN GRAMS | VOLUME OF WATER |
|---|---|---|---|
| (a) | NaCl | 2.93 | $250cm^3$ |
| (b) | $KNO_3$ | 12.64 | $500cm^3$ |
| (c) | NaOH | 2.5 | $25cm^3$ |
| (d) | $NaNO_3$ | 8.5 | $100cm^3$ |
| (e) | KCl | 3.74 | $200cm^3$ |

[Na=23; K=39; O=16; N=16; Cl=35.5; H=1]

1. 2.93g of NaCl dissolved or saturated $250cm^3$ of $H_2O$

Xg of NaCl will dissolved or saturated $1000cm^3$ of $H_2O$

250 x $x$ = 1000 x 2.93

$x$(mass) = $\frac{1000\ x\ 2.93}{250}$ = $11.72g/dm^3$

In $moles/dm^3$

Convert 2.93g of NaCl to moles = $^{2.93}/_{58.5}$ = 0.0050 moles.

$250cm^3$ of water dissolved 0.0050 moles.

∴ $1000cm^3$ of water will dissolve $\frac{0.0050}{250}$ x 1000

= $0.20\ mol/dm^3$

Or convert $11.72g/dm^3$ to $moledm^{-3}$ = $\frac{11.72}{58.5}$ = $0.20\ mol/dm^3$

2. $300cm^3$ of a saturated solution of potassium chloride contains 5.85g dissolved at room temperature. What is the solubility of the KCl at this temperature (K=39; Cl=35.5). Molar mass of KCl equal to $74.5gmol^{-1}$

Amount of KCl in 5.85g = $^{5.85}/_{74.5}$ = 0.079 mole.

$300cm^3$ of solution dissolved 0.079 moles.

∴ $1000cm^3$ of solution will dissolve $\frac{0.079}{300}$ x 1000 = $0.26\ moldm^{-3}$.

3. Water was added to 80g of a salt $MCl_2$ to produce $30cm^3$ of a saturated solution at $25^0C$. The solubility of the salt at $25^{0c}$ is $8.0\ moldm^{-3}$. If the Atomic Mass of M = 29, calculate the mass of the undissolved salt.

Molar mass of MCl = 29 + 71 = 100 gmol-1
i.e. 1 mole of $MCl_2$ = 100g
Solubility of $MCl_2$ = $8.0moldm^{-3}$
Hence 800g of Salt Saturated 1000 $Cm^3$ of water
∴ $30cm^3$ of water will saturate Xg

$800\ x\ 30g = X\ x\ 1000$

Xg = $\frac{800}{1000}$ x 30 = 24g

∴ Mass of undissolved Salt = mass added – mass in 30cm$^3$

80 – 24 = 56g

4. If the solubility of anhydrous sodium trioxocarbonate (IV) is 2.5 moles/dm$^3$. Calculate the mass of Salt that dissolved in 10cm$^3$ of water. [Na = 23, C = 12, O = 16].

   1000cm$^3$ of water dissolved 2.5 mole of salt

   ∴ 10cm$^3$ of water will dissolve $\frac{2.5}{1000}$ x 10 = 0.025mole

   $NaCO_3$= 106g = 1 mole

   ∴ 0.025 mole = 0.025 x 106 = 2.65g

5. At a given temperature, 730Cm$^3$ water were saturated with 6.355 moles of $Zn(NO_3)_2$. Calculate the solubility of the solute at that temperature in (a) moles dm$^{-3}$ (b) gdm$^{-3}$ [Zn = 65, N = 14, O = 16].

   Solution: 730cm$^3$ of Solution was Saturated by 6.35 moles.

   ∴ 1000 Cm$^3$ of Solution will re-saturated by $\frac{6.35}{730}$ x 1000

   = 8.69 moles

   Molar mass of Zn $(NO_3)_2$ = 65 + (14 x 3) + (16 x 6) = 189g mole

   Amount = $\frac{mass}{molarmass}$. 8.69 = $\frac{m}{189}$

   Mass = 8.69 x 189 = 1642g/dm$^3$.

6. The Solubility of $CuSO_4$ is 60g at 85$^{0C}$ and 20g at 15$^{0C}$. Calculate the mass of $CuSO_4$ that will be deposited when 100g of the solution are cooled from

| 85$^{0c}$ to 15$^{0C}$ | Solvent + | Solute | Solution |
|---|---|---|---|
| Masses involved at 85$^{0C}$ | 100 | 60 | 160 |
| Masses involved at 15$^{0C}$ | 100 | $\underline{20}$ | 120 |
| Solute deposited at | | 40 | |

   On cooling 160g of Saturated Solution 40g of Solute was deposited

   ∴ 100g of saturated solution will deposited $\frac{40}{160}$ x 100 = 25g

7. The solubility of $XCl_2$ is 1.5 moldm$^3$ at 60$^{0C}$ and 0.95 moldm$^{-3}$ at 10$^{0C}$. Calculate how much of $XCl_2$ in (a) moles (b) grams that will be deposited when 1.5moldm$^{-3}$ solution is cooled from 60$^{0C}$ to 10$^{0C}$

   [X = 40, Cl = 35.5]

| | Solvent | Solute | Solution |
|---|---|---|---|
| At 60$^{0C}$ | 1 dm$^3$ | 1.5 | 1 dm$^3$ of 1.50moldm$^{-3}$ |
| At 10$^{0C}$ | 1 dm$^3$ | $\underline{0.95}$ | 1 dm$^3$ of 0.95 moldm$^{-3}$ |
| | | 0.55mol | |

   If 1 dm$^3$ of 1.5moldm$^{-3}$ deposit 0.55 mil of solute

   ∴ 2 dm$^3$ of 1.5 moldm$^{-3}$ Solution deposit 0.55 x 2 mol of solute = 1.1 moldm$^{-3}$

   Molar mass of $XCl_2$ = 111g

   ∴ 1.1 mol = 1.1 x 111g = 1221g.

# TOPIC: TYPES OF CHEMICAL REACTIONS

**CLASS: SS2**

**ABILITY: MIXED**

**OBJECTIVES:** At the end of the topic, the students should be able to:

i. State different types of chemical reactions;

ii. Write chemical equations to illustrate different types of chemical reactions;

iii. Write the signs for reversible reactions.

## TYPES OF CHEMICAL REACTIONS

Chemical reactions are changes in which some new chemical substances are formed. The substances which undergo the chemical changes are known as reactants, while the new substances formed are called products.

### CLASSIFICATION

Chemical reactions can be classified into several different groups. Some of the common types are:

1. Combination (2) Displacement (3) Decomposition (4) Double decomposition (5) catalytic reactions (6) Thermal desiccation (7) Redox reaction (8) reversible reactions.

1. **Combination:** This occurs when two or more substances combine to form a single compound. Eg.

$Fe + S \longrightarrow FeS$

$PbO_2 + SO_2 \longrightarrow PbSO_4$

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

2. Decomposition: Here a single compound splits up into two or more simpler substances. Very often hear is needed for the reaction.

$2Pb(NO_3)_2 \longrightarrow 2PbO + 4NO_2 + O_2$

$2KClO_3 \longrightarrow 2KCl + 3O_2$

3. Displacement: This occurs when one element has replaced another in a compound.

$A + By \longrightarrow Ay + B$.

The ability of an element or radical to displace another is determined by their relative positions in the electrochemical series. A more electropositive metal will displace a less electropositive one from a solution of its salt.

$$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$$

$$Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$$

4. Double Decomposition: Here the two reactants are both decomposed to form two new substances by radical exchange.

$$AB + CD \longrightarrow AD + BC$$

$$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$$

$$2NaCl + H_2SO_4 \longrightarrow Na_2SO_4 + 2HCl$$

They are normally used to prepare insoluble salts or volatile compounds.

5. THERMAL DISSOCIATION: Here each molecule of a substance dissociates into two or more simpler molecules or atoms on application of heat. They are often reversible unlike thermal decomposition.

$$NH_3Cl \underset{\text{Cool}}{\overset{\text{heat}}{\rightleftharpoons}} NH_3 + HCl$$

$$N_2O_4 \underset{\text{Cool}}{\overset{\text{heat}}{\rightleftharpoons}} 2NO_2$$

6. Redox Reaction: This involves two opposing yet complimentary processes Oxidaion and reduction

$$H_2S + Cl_2 \longrightarrow 2HCl + S$$

RA OA

$$CuO + H_2 \longrightarrow Cu + H_2O$$

OA RA

$H_2S$ is oxidized to sulphur and $Cl_2$ is reduced to HCl.
The oxidized substance is the reducing agent and the reduced.
Substance is the oxidizing agent.

7. CATALYTIC REACTIONS. Any chemical reaction which can be made to employ a catalyst is called catalytic reaction.

$KClO_3 \xrightarrow{MnO_2} KCl + 3O_2$ ($MnO_2$ is catalyst )

8. Reversible Reaction: This is a reaction which can be made to go in both directions by a change in the

$$A+B \underset{\text{Backwards}}{\overset{\text{forward}}{\rightleftharpoons}} C + D$$

Reversible reactions are identified by the sign

$\rightleftharpoons$ Written between the reactants and products .e.g.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

$$3Fe + 4H_2O \rightleftharpoons Fe3O4 + 4H_2$$

# TOPIC: REDUCTION – OXIDATION

**CLASS: SS2**

**ABILITY: MIXED**

**Objectives:** at the end of the topic the students should be able to:

(a) Define oxidation and reduction in terms of:

i. Oxygen and hydrogen;

ii. Election loss or gain;

iii. Oxidation number.

b. Write equations to illustrate oxidation and reduction;

c. Write and balance redox equations;

d. Define oxidizing and reducing agents;

e. Give names of oxidizing and reducing agents.

## REDUCTION- OXIDATION REACTION (REDOX REACTION)

Oxidation-reduction reactions are two opposing yet complementary reactions. Every oxidation must be accompanied by a reduction and vice-versa.

## DEFINITIONS

### (A) IN TERMS OF OXYGEN AND HYDROGEN.

Oxidation is the addition of oxygen to a substance while reduction is the removal of oxygen from a substance.

Oxidation is the removal of Hydrogen from a substance while reduction is the addition of hydrogen to a substance.

| | |
|---|---|
| Eg. $2Mg + O_2 \longrightarrow 2MgO$ | mg is oxidized to MgO |
| $S + O_2 \longrightarrow SO2$ | S is oxidized |
| $CuO + H_2 \longrightarrow Cu + H2O$ | CuO is reduced to Cu |
| | $H_2$ is oxidized to $H_2O$ |
| $C + 2ZnO \longrightarrow CO_2 + Zn$ | C is oxidized to $CO_2$. |

| | | |
|---|---|---|
| H2 s + $Cl_2$ | HCl + S | H2S is oxidized (removal of $H_2$) |
| H2 + Cl2 | 2HCl | Cl2 is reduced too HCl |
| 4HCl + $MnO_2 \rightarrow MnCl_2+2H_2O+Cl_2$ | | HCl is oxidized to $Cl_2$ (removal of $H_2$) |
| Also $Fe_2O_3+3CO \rightarrow 2Fe +3CO_2$ | | $Fe_2O_3$ is reduced to Fe |

## OXIDIZING AND REDUCING AGENT

An oxidizing agent is the substance that donates the oxygen to another substance or that receives the hydrogen from another substance.

A reducing agent is a substance that removes the oxygen from a substance or supplies the hydrogen to another substance.

Eg $CuO + H_2 \longrightarrow Cu+H_2O$
O.A. R.A.

$C + ZnO \longrightarrow Zn + CO_2$
RA O.A.

$H_2S + Cl_2 \longrightarrow 2HCl + S$
R.A. O.A.

$Fe2O3+3CO \longrightarrow 2Fe + 3CO_2$
O. A. R.A.

## IN-TERMS OF ELECTRONS

Oxidation is the loss of electrons while reduction is the gain of electrons..E.g.2Na +Cl2 $\longrightarrow$ 2NaCl

or $Na \longrightarrow Na+ \ +e-$ Cl + e $Cl^-$

Na is oxidized to $Na^+$ and Cl is reduced to $Cl^-$

$Mg + O_2 \longrightarrow 2MgO$

$Mg \longrightarrow Mg2+ +2e^-$ $2O + 2e^- \longrightarrow O^{2-}$

## OXIDIZING AND REDUCING AGENT

The oxidizing agent is the substance that gains electrons, while the reducing agent is the substance that loses electron.

e.g Na is the reducing agent while $Cl_2$ is the oxidizing agent.

Mg is the reducing agent while O2 is the oxidizing agent.

## IN-TERMS OF OXIDATION NUMBER

Oxidation is increase in oxidation number.

Reduction is decrease in oxidation number.

reduction

Eg. Zn + CuSO4 $\longrightarrow$ ZnSo4 + Cu

O +2 +2 O

RA OA oxidation

Zn is oxidized to $ZnSO4$ – increase in oxidation number.

$Fe + AgNO_3 \rightarrow Fe(NO_3)_2 + Ag$.

$Cu\ SO_4$ is reduced to Cu.___ decrease oxidation number

$2FeCl_2 + Cl_2 \rightarrow 2FeCl_3$

+2 RA O +3

$FeCl_2$ is oxidized to $FeCl_3$ ___ increase in oxidation number

**REDUCING AND OXIDIZING AGENT**

The reducing agent is the substance whose oxidation number increases.
The oxidizing agent is the substance whose oxidation number decrease.

Note: The oxidizing agent is always oxidized.
The reducing agent is always oxidized.

Eg. $H_2S+Cl_2 \rightarrow 2HCl + S$

-2 O -1 O

RA O.A Oxidized

## BALANCING REDOX EQUATION ____ RULES

1. Assign oxidation number per atom of every element that changes.
2. Separate the change into half reactions.
3. Balance each half by (a) adding appropriate coefficients to balance various atoms (b) adding appropriate number of electrons to the side hearing more posture charges or less negative charges.
4. Multiply each half reaction by the appropriate coefficients to balance electron loss or gain.
5. Add the two half reactions

   e.g. $Fa^+ + Ag^+ \rightarrow Fe^{2+} + Ag$

   O +1 +2 O

   $Fe \rightarrow Fe^{2+}$ (ox) 2e….. (i) Ag+ +e- Ag (redx2 (2)

   $2Ag^+ + 2e^-$ 2Ag…….(2b)

   $Fe + 2Ag^+ \rightarrow 2Ag + Fe^{2+}$.

**BALANCING COMPLEX IONIC EQUATION (ION ELECTRON METHOD) ACIDIC MEDIUM - RULES**

1. Assign oxidation number par atom of every element that changes.
2. Separate the changes into half reactions.
3. Add appropriate coefficients to balance all atoms
4. Add appropriate number of water molecules ($H_2O$) to the side deficient of oxygen atoms.
5. Add $H^+$ to balance H atoms.

6. Add enough electrons to side with more positive charges.
7. Multiply the half reactions by appropriate coefficient to balance electron loss or gain.
8. Add the two half reactions and subtract any duplication on both side.

# TOPIC: REDUCTION – OXIDATION

**CLASS: SS2**

**ABILITY: MIXED**

**Objectives:** at the end of the topic the students should be able to:

(a) Define oxidation and reduction in terms of:

i. Oxygen and hydrogen;

ii. Election loss or gain;

iii. Oxidation number.

b. Write equations to illustrate oxidation and reduction;

c. Write and balance redox equations;

d. Define oxidizing and reducing agents;

e. Give names of oxidizing and reducing agents.

## REDUCTION- OXIDATION REACTION
## (REDOX REACTION)

Oxidation-reduction reactions are two opposing yet complementary reactions. Every oxidation must be accompanied by a reduction and vice-versa.

## DEFINITIONS

### (B) IN TERMS OF OXYGEN AND HYDROGEN.

Oxidation is the addition of oxygen to a substance while reduction is the removal of oxygen from a substance.

Oxidation is the removal of Hydrogen from a substance while reduction is the addition of hydrogen to a substance.

Eg. $2Mg + O_2 \longrightarrow 2MgO$ mg is oxidized to MgO

$S + O_2 \longrightarrow SO_2$ S is oxidized

$CuO + H_2 \longrightarrow Cu + H_2O$ CuO is reduced to Cu

$C + 2ZnO \longrightarrow CO_2 + Zn$

$H_2$ is oxidized to $H_2O$
C is oxidized to $CO_2$.

$H2\ s + Cl_2 \longrightarrow HCl + S$ — $H_2S$ is oxidized (removal of $H_2$)
$H2 + Cl_2 \quad 2HCl$ — $Cl_2$ is reduced too HCl
$4HCl + MnO_2 \rightarrow MnCl_2 + 2H_2O + Cl_2$ — HCl is oxidized to $Cl_2$ (removal of $H_2$)

Also $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ — $Fe_2O_3$ is reduced to Fe

**OXIDIZING AND REDUCING AGENT**

An oxidizing agent is the substance that donates the oxygen to another substance or that receives the hydrogen from another substance.

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Eg $CuO + H_2 \longrightarrow Cu + H_2O$
O.A. R.A.

$C + ZnO \longrightarrow Zn + CO_2$
RA O.A.

$H_2S + Cl_2 \longrightarrow 2HCl + S$
R.A. O.A.
$Fe2O3 + 3CO \longrightarrow 2Fe + 3CO_2$
O. A. R.A.

**IN-TERMS OF ELECTRONS**

Oxidation is the loss of electrons while reduction is the gain of electrons..E.g.$2Na + Cl2 \longrightarrow 2NaCl$
or $Na \longrightarrow Na+ \ +e-$ $\quad Cl + e \quad Cl^-$
Na is oxidized to $Na^+$ and Cl is reduced to $Cl^-$
$Mg + O_2 \longrightarrow 2MgO$
$Mg \longrightarrow Mg2+ + 2e^-$ $\quad 2O + 2e^- \longrightarrow O^{2-}$

**OXIDIZING AND REDUCING AGENT**

The oxidizing agent is the substance that gains electrons, while the reducing agent is the substance that loses electron.
e.g Na is the reducing agent while $Cl_2$ is the oxidizing agent.
Mg is the reducing agent while O2 is the oxidizing agent.

**IN-TERMS OF OXIDATION NUMBER**

Oxidation is increase in oxidation number.
Reduction is decrease in oxidation number.

reduction

Eg. $Zn + CuSO_4 \longrightarrow ZnSo_4 + Cu$

O +2 +2 O

RA OA oxidation

$Zn$ is oxidized to $ZnSO_4$ – increase in oxidation number.

$Fe + AgNO_3 \longrightarrow Fe(NO_3)_2 + Ag$.

$Cu\ SO_4$ is reduced to Cu.___ decrease oxidation number

$2FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$

+2 RA O +3

$FeCl_2$ is oxidized to $FeCl_3$ ___ increase in oxidation number

**REDUCING AND OXIDIZING AGENT**

The reducing agent is the substance whose oxidation number increases.
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Eg. $H_2S+Cl_2 \longrightarrow 2HCl + S$

-2 O -1 O

RA O.A Oxidized

## BALANCING REDOX EQUATION ____ RULES

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5. Add the two half reactions

   e.g. $Fa^{+} + Ag^{+} \longrightarrow Fe^{2+} + Ag$

   O +1 +2 O

   $Fe \longrightarrow Fe^{2+}$ (ox) 2e….. (i) Ag+ +e- Ag (redx2 (2)

   $2Ag^{+}+2e-$ 2Ag…….(2b)

   $Fe + 2Ag^{+} \longrightarrow 2Ag + Fe^{2+}$.

**BALANCING COMPLEX IONIC EQUATION (ION ELECTRON METHOD)**

**ACIDIC MEDIUM - RULES**

1. Assign oxidation number par atom of every element that changes.

2. Separate the changes into half reactions.
3. Add appropriate coefficients to balance all atoms
4. Add appropriate number of water molecules ($H_2O$) to the side deficient of oxygen atoms.
5. Add $H^+$ to balance H atoms.
6. Add enough electrons to side with more positive charges.
7. Multiply the half reactions by appropriate coefficient to balance electron loss or gain.
8. Add the two half reactions and subtract any duplication on both side.