FIRST TERM E-LEARNING NOTES

SUBJECT: CHEMISTRY CLASS: SS 2

SCHEME OF WORK

WEEK TOPIC

THEME: THE CHEMICAL WORLD

1. **Periodic Table:** Periodic law, Electronic configuration of first thirty elements, Blocks of elements – metals, non-metals, metalloids and transition metals, families of elements

2. **Periodic Table (cont'd):** Atomic properties and the periodic table, Diagonal Relationship between elements in the periodic table.

3. **Chemical Reactions:** Basic concept (Activation energy) and Introduction to collision theory, Factors affecting rate of chemical reactions, Types of chemical reactions.

4. **Chemical Reactions (cont'd):** Chemical equilibrium: characteristics of a chemical system at equilibrium, Introduction of chemical equilibrium using simple equations, Factors affecting equilibrium of chemical reaction and Equilibrium constant, Kc

5. **Mass - Volume Relationships:** S.I unit of quantities and Basic concepts (mole, molar quantities, molality, standard temperature and pressure (S.T.P), Calculations involving mass and volume.

6. **Acid-Base Reactions:** Common indicators and their pH ranges, standard solution and Simple acid-base

titration, , Heat of Neutralization.

7. **Mid –Term Break and Revision**

THEME: CHEMISTRY AND ENVIRONMENT

8. **Water:** Structure of water and Solubility (basic concepts: solute, solvent, solution), Factors affecting solubility and uses of solubility curve, Hardness of water and removal sof hardness, Municipal water supply.
9. **Air:** Constituents of air, Percentage composition, Properties of air, Flame, noble gases and their uses
10. **Revision.**
11. **Examination.**

WEEK 1:

SUBJECT: CHEMISTRY

CLASS: SS2

TOPIC: PERIODIC TABLE

CONTENT:

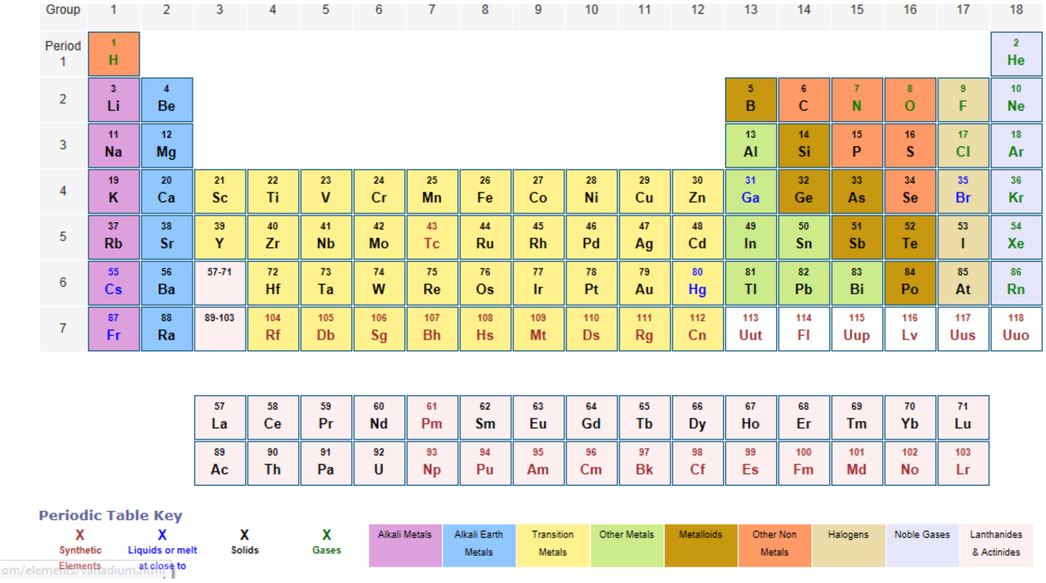
1. Periodic law

2. Electronic configuration of the first thirty elements

3. Blocks of elements – metals, non-metals, metalloids and transition metals

4. Families; S-P-D-F (according to group I-VIII to group IA- Alkalis metals, group IIA- Alkali earth and other family names)

PERIOD 1 AND 2 : PERIODIC LAW



Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period 1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Periodic Table Key

X Synthetic Elements	X Liquids or melt at close to	X Solids	X Gases	Alkali Metals	Alkali Earth Metals	Transition Metals	Other Metals	Metalloids	Other Non Metals	Halogens	Noble Gases	Lanthanides & Actinides

Periodic Table: This shows the arrangement or grouping of elements in order of increasing atomic number.

Periodic Law: Is the basic assumption behind the modern periodic table; it states that the properties of the elements are the periodic function of their atomic number.

ELECTRONIC CONFIGURATION OF THE FIRST THIRTY ELEMENTS

The lectronic configuration of an atom is the representation of the arrangement of the electrons distributed among the orbital shells and subshells. Commonly, the electronic configuration is used to describe the orbitals of an atom in its ground state

MEANING OF ATOMIC ORBITAL

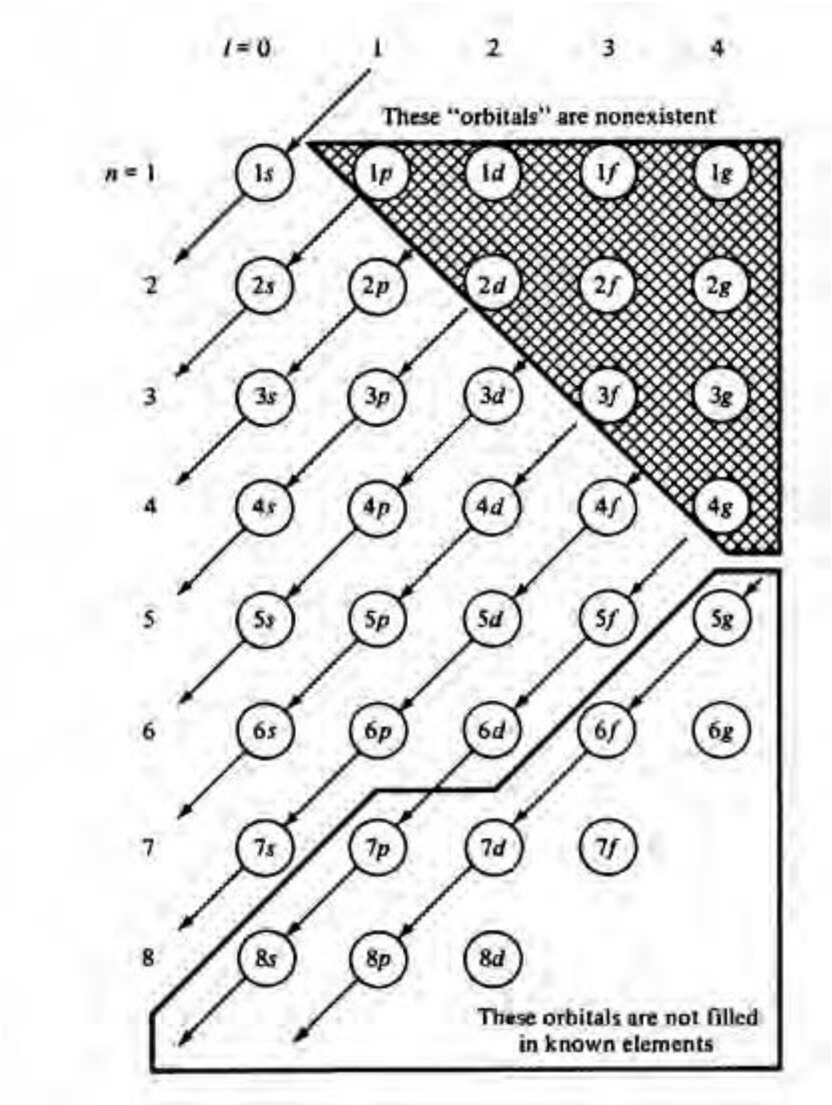
Orbital is the region of space around the nucleus where there is a high probability of finding electron. The four different types of orbitals are s, p, d, and f. These orbitals have different shapes and one orbital can hold a maximum of two electrons. The p-orbital has three degenerate orbitals, with a maximum of six electrons, d has five sub orbitals with a maximum of ten electrons and the f-orbital has seven sub-orbitals with maximum of fourteen electrons.

Orbitals	Number of sub-ortals	Max.no. electrons	Shape
S	-	2	Spherical
P	3	6	Dumb-bell
D	5	10	Double dumb-bell
F	7	14	Complex

RULES AND PRINCIPLES FOR FILLING IN ELECTRONS

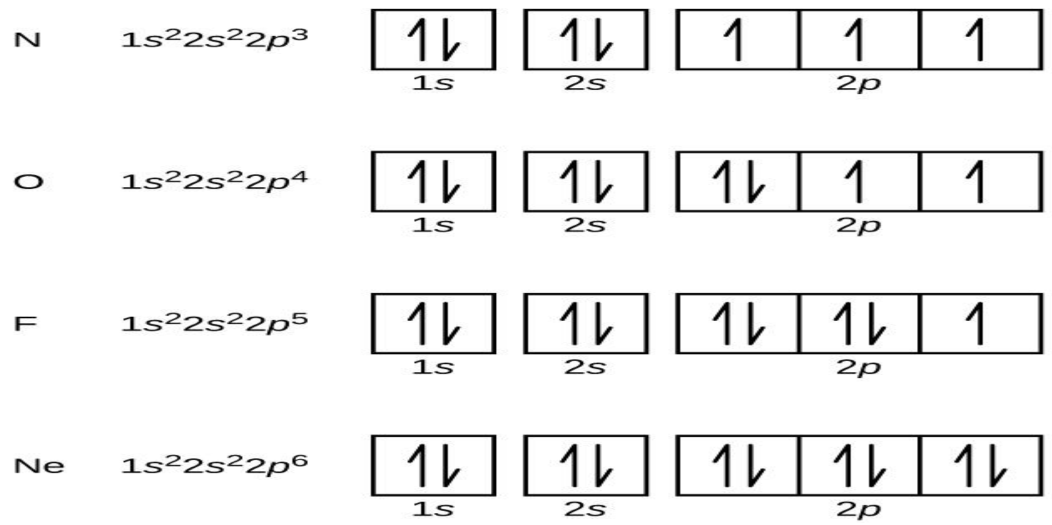
1. Aufbau Principle: states that electrons are filled in their orbital in order of increasing energy level. The order is as follows:

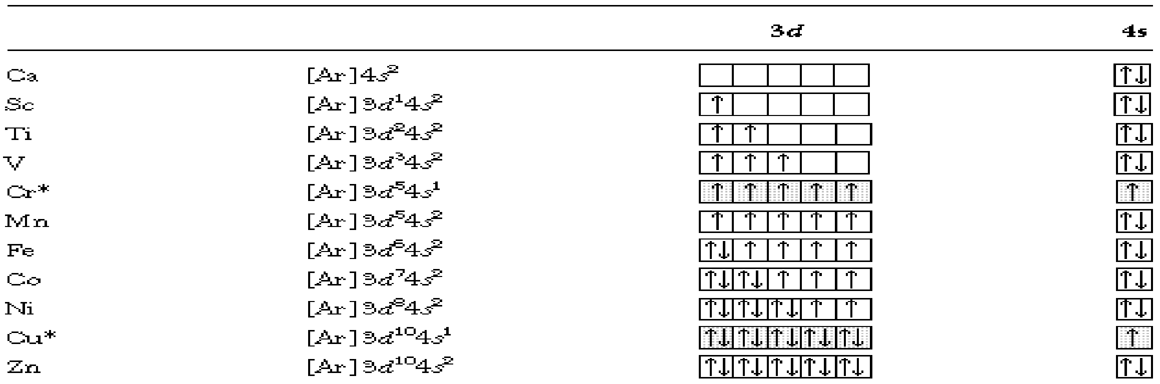
1s < 2s < 2p< 3s < 3p <4s < 3d <4p etc.



2. **Pauli's Exclusion Principle:** states that two electrons in the same orbital of an atom cannot have same values for all quantum numbers. Usually the first electron in an orbital is assumed to enter with up-spin (clockwise),↑ while the second electron enters the same orbital but with a down-spin (anti-clockwise), ↓.

3. **Hund's Rule of maximum Multiplicity:** This rule states that electrons occupy each orbital singly first before pairing takes place in a degenerate orbital. Hence, no pairing in degenerate orbital until each orbital is singly occupied with parallel spin.





		3d					4s
Ca	[Ar]$4s^2$						↑↓
Sc	[Ar]$3d^14s^2$	↑					↑↓
Ti	[Ar]$3d^24s^2$	↑	↑				↑↓
V	[Ar]$3d^34s^2$	↑	↑	↑			↑↓
Cr*	[Ar]$3d^54s^1$	↑	↑	↑	↑	↑	↑
Mn	[Ar]$3d^54s^2$	↑	↑	↑	↑	↑	↑↓
Fe	[Ar]$3d^64s^2$	↑↓	↑	↑	↑	↑	↑↓
Co	[Ar]$3d^74s^2$	↑↓	↑↓	↑	↑	↑	↑↓
Ni	[Ar]$3d^84s^2$	↑↓	↑↓	↑↓	↑	↑	↑↓
Cu*	[Ar]$3d^{10}4s^1$	↑↓	↑↓	↑↓	↑↓	↑↓	↑
Zn	[Ar]$3d^{10}4s^2$	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓

EVALUATION:

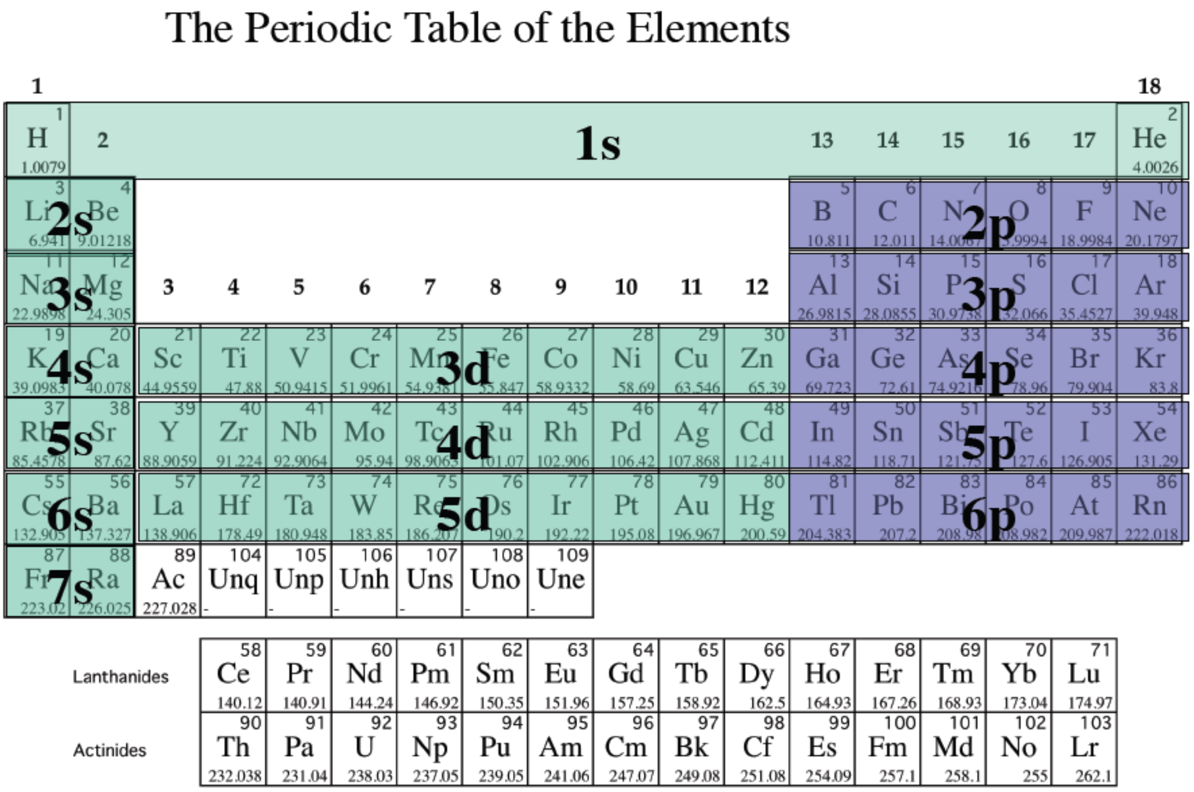
1. Draw a periodic table showing the 1st 20 elements

2. Define periodic law

3. Define periodic table.

4. Write the electronic configuration of the following elements: Cu, Na, Al, and Cl

PERIOD 3: BLOCKS OF ELEMENTS



The Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.01218											5 B 10.811	6 C 12.011	7 N 14.0067	8 O 5.9994	9 F 18.9984	10 Ne 20.1797
11 Na 22.9898	12 Mg 24.305											13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9381	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.8
37 Rb 85.4578	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc 98.9063	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.6	53 I 126.905	54 Xe 131.29
55 Cs 132.905	56 Ba 137.327	57 La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.98	84 Po 08.982	85 At 209.987	86 Rn 222.018
87 Fr 223.02	88 Ra 226.025	89 Ac 227.028	104 Unq -	105 Unp -	106 Unh -	107 Uns -	108 Uno -	109 Une -									

Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 146.92	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinides	90 Th 232.038	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 239.05	95 Am 241.06	96 Cm 247.07	97 Bk 249.08	98 Cf 251.08	99 Es 254.09	100 Fm 257.1	101 Md 258.1	102 No 255	103 Lr 262.1

From the position of the various elements on the periodic table and the electrons arrangements or configuration seem to stand out. Elements that have one and two electron(s) in their last s- orbital i.e. group 1 and 2 elements are **called s-block elements**. P-block elements have their last electron (s) in the p-orbital are **called P block elements**.

Elements that have their last electrons in the d orbital are **called d blocks elements** while f block elements have their last electrons in the f- orbital.

Moving across a particular period on the periodic table, two elements are present in the S block, six elements in the P block, ten elements in the d- block and fourteen elements in the f- block. This corresponds with the maximum number of electrons in the s, p, d, and f orbitals respectively. Also, S block elements are metals, P block elements are mostly non-metals d- block elements are transition metals while f-block elements are lanthanides (rare earth metals) and actinides (heavy rare earth metals).

There is therefore a diagonal division of the elements into metals and non-metals as shown below. Metals are found on the left side of the thick boundary line and the non-metals on the right with metalloids occurring along the boundary line.

CHARACTERISTICS PROPERTIES OF TRANSITION ELEMENTS

1. **Paramagnetism:** Transition elements exhibit paramagnetism because of the presence of unpair elecrons in the d-orbital. Paramagnetism is the ability of an element to align to the poles of a magent.

2. **Variable oxidation states:** Transition elements exhibit variable oxidation states because they can lose electrons from both 4s and 3d orbitals for bond formation e.g we have Fe^{2+} and Fe^{3+}

3. **Complex ion formation:** Transition elements form complex ions due to the presence of vacant or empty d- orbitals in their ions.

4. **Catalytic ability:** The catalytic ability of transition metals is due to the fact that they exist in different oxidations states, hence they are used as catalyst. The partially filled d-orbital allows the exchange of electrons to and from molecules which enable them to act as catalyst.

EVALUATION:

1. State the blocks of the following elements: H, F, Na, Ca, Fe and Mn

2. State three properties of transition elements and explain any two of the properties.

PERIOD 4: FAMILIES OF ELEMENTS.

Elements are arranged into groups or families and periods. Each group has been given a name to allow proper understanding during discussions on the periodic table.

Names of the different group (1-8) on the periodic table are shown below.

Group (i) i.e. Li, Na, K etc. -------- alkaline metals

Group (ii) i.e. Be, Mg, Ca, etc. ------ Alkaline earth metals

Group (iii) i.e. B, Al, Ga, etc. ------- Boron family

Group (iv) i.e. C, Si, Ge, etc. --------- Carbon family

Group (v) i.e. N, P, As, etc. ---------- Nitrogen family

Group (vi) i.e. O, S, Se, etc. --------- Oxygen family or Chalcogens

Group (vii) i.e. Fl, Cl, Br, etc. ------ Halogens

Group (viii) or group O i.e. He, Ne, Ar, etc. ------ Rare, inert, noble gases.

Transition Elements: These are between groups 2 and 3 on periods 4 and 5.

Lanthanides (Rare- earth elements): these are fifteen elements La- Lu.

Actinides: These are found on the seventh period AC –Lr.

Artificial Elements: These are elements with atomic numbers 93 to 103. They are products formed during chemical reactions. They are unstable and disintegrate in a short time e.g. Plutonium (Pu) and curium (Cm)

EVALUATION:

1. Four elements P, Q, R and S, have 1, 2, 3 and 7 electrons in their outermost shell respectively. What is the element that is unlikely to be a metal?

2. The elements listed below belong to the same group in the periodic table; ${}_{9}F$, ${}_{17}Cl$, ${}_{35}Br$, ${}_{53}I$

   (i) What is the electronic structure of the first-member?
   (ii) What is the family name of the elements?

(iii) Which of the elements has the strongest oxidizing ability?

GENERAL EVALUATION

OBJECTIVE TEST;

1. The period table is an arrangement of elements in order of their. (a) Relative molecular mass (b) mass numbers (c) molecular masses (d) atomic numbers.

2. Four elements T, X, Y, Z have 1, 2, 3 and 6 electrons in their outmost shells respectively. The element that is likely to be a non-metal is. (a) X (b)T (c) Z (d) Y

3. An atom with the electronic configuration: Is^2, $2s^2$, $2p^6$, $3S^2$, $3d^1$, $4s^2$ is that of:

(a) an alkali metal (b) an alkali earth metal (c) a transition metal (d) a halogen

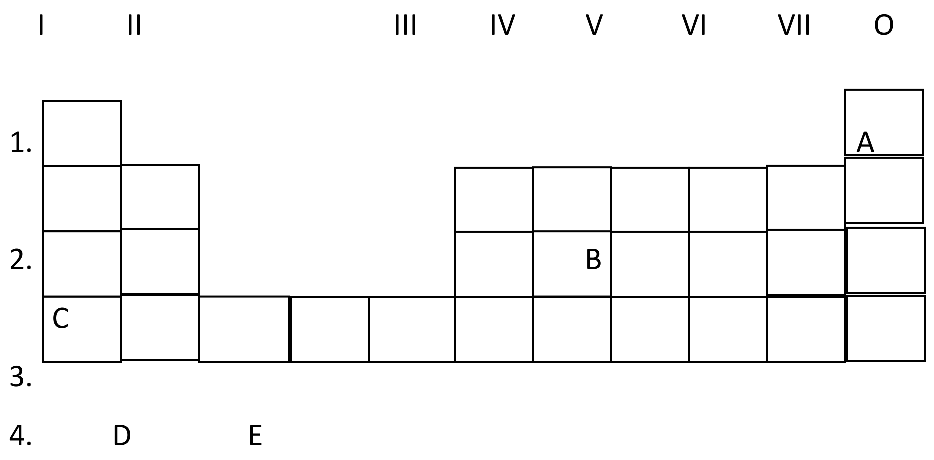
4. An element whose atomic number is 19 is

(a) a noble gas (b) an alkali earth metal (c) An alkali metal (d) a transition metal

5. Group 0 or 8 elements are called. (a) Active elements (b) lanthanides (c) noble gas (d) alkali earth metals.

ESSAY QUESTIONS

1. A shortened form of the periodic table is shown below. Use it to answer questions a and b.



(a) Which of the elements represented as A to E in the table above is

(i) A transition metal; (ii) an alkaline earth metal

(iii) The least reactive (iv) the most electronegative

2. State the four properties of transition elements (d-block)

3. Name one element in each case which

   (a) forms an amphoteric oxide;

   (b) Liberates hydrogen from cold water;

   (c) Exists as a liquid at room

4. Give the names of the members of the alkaline earth metal family.

WEEK 2

TOPIC: PERIODIC TABLE

CONTENT:

1. Periodic properties

2. Periodic gradation of the element in the third period

3. Diagonal relationships

PERIOD 1 AND 2 : PERIODIC PROPERTIES. Some properties of the atom change along a group or across a period on the periodic table. Atomic radius which is measured of the size is one of such properties. The orbiting electrons in an atom are best represented by an electron cloud which has no distinct limit as the size of an action cannot be defined easily.

1. **Atomic radius:** This has been defined as the distance of closest approach to another identical atom in a given bonding situation. There are two types of atomic radii. Covalent radius and Van der Waals radius. Covalent radius is half the distance between two identical atoms which are not chemically bonded. For the two types of atomic radius two variations are noticeable:

(i) The atom radius increases down a group
(ii) The atomic radius decreases along a period.

This is because going down any group on the periodic table the number of valence electrons remains constant while the shells increase in size (radius) despite increase in nuclear charge. The atomic radius of potassium is greater than that of Sodium. The atomic radius of caesium is greater than that of rubidium.

Across a period, electrons are added to orbitals in the same shell, all the valence electrons are therefore at the same energy level. As atomic number increase the positive charge of the nucleus increases giving rise to greater attraction between the positive nucleus and negative electrons. This is turn result in contraction of the electrons cloud resulting in a smaller atom. Atomic radii therefore decrease across a given period on the periodic table.

2. Ionic Radius: Ions are formed by a loss or gain of electrons by an atom. A positive ion (cation) is smaller than the original metal atom because electrons are pulled in due to increase in effective nuclear charge.

A negative ion (anion) is bigger than the corresponding non- metal atom because the effective nuclear charge is reduced.

As we move across the second short period, the cationic radii decrease from sodium to aluminium while the anionic radii increase from phosphorous to chlorine.

3. **Ionization energy**: Ionization occurs when gaseous atom loses electrons from its outer most shell to become positively charged

K ——— e^- K^+———

The energy required to do this is called ionization energy or ionization potential.

First ionization energy of an element is the energy needed to remove one mole of electron(s) from one mole of atoms in the gaseous state. It is expressed in kilo- joules per mole of atoms ionized.

First ionization energy increase across the period with noble gases having the highest. As we go down he the group, the value of first ionization energy decreases.

FIRST IONIZATION ENERGIES OF ALKALI METALS

Element	LI	Na	K	Rb	Cs
First ionization energy KJMOL^{-1}	520	500	420	400	380

FIRST IONIZATION ENERGIES OF THE ELEMENTS IN THE THIRD PERIOD OF THE PERIODIC TABLE

Element	Na	Mg	Al	Si	P	S	Cl	Ar
First ionization energy KJMOL^{-1}	496	737	577	786	1012	999	1255	1521

Three factors that affect the ionization potential of an atom

Ionization potential of an atom is affected by.

(i) Distance of the outer most electrons from the nucleus.

(ii) Size of the positive or effective nuclear change.

(iii) Screening effect of the inner electrons.

Moving from left to right across a period, there is a general rise in the first ionization energy. This is due to the fact that the nuclear charge is increasing across the period. This in turn causes a decrease in atomic radius that is a decrease in the distance of the outermost electrons from the nucleus. The screening effect is almost the same across the period. Down a group of the periodic table, ionization energy decreases because the nuclear charge on the outermost electron is reduced. The outermost electron are properly shielded from the effect of nuclear charge

4. **Electron Affinity:** is the energy released when an electron is added to gaseous atom in its lowest energy state. Its unit is kJmol^{-1} or electron volts (ev). Electron affinity increase across a period from left to right and decrease down the group on the periodic table.

Group 1 elements, alkali metals have the least tendency to add electrons to their neutral atoms.

Elements in groups VI and VII have greatest tendency to accept electron. Noble gases (group 8 or 0) have stable electronic configuration

5. **Electronegativity:** Electronegativity is the ability or power of that atom in a molecule to attract shared pair of electrons. It is more pronounced in heteronuclear molecules where two dissimilar atoms share one or more pairs of electrons.

Electronegativity increases across the period, i.e. going from left to right of the Periodic Table but decreases down the group i.e. going down the Periodic Table. The steady increase as one goes across the period is due to a steady increase in nuclear charge and decrease in atomic size. Consequently, the halogen atom, Fluorine, has the highest electronegativity in the period, due to the strong affinity for electrons. But down the group, the increase in atomic size due to screening effect of the inner shells of electrons decreases the nuclear attraction for shared electrons. The noble gases of group O are not assigned electronegativity values since they have completed shells of electrons.

EVALUATION

1. List three periodic properties of elements that generally increase the across the period of the Periodic Table.
2. Explain the term electron affinity and discuss how it varies across the period and down the group of the Periodic Table.

PERIOD 3: PERIODIC GRADATION OF THE ELEMENTS IN THE THIRD PERIOD (Na-Ar)

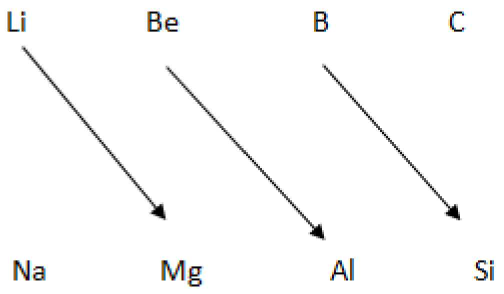
Gradation in properties is not confined only to the elements, but it is also found in their compounds with increasing atomic number.

The extent of hydrolysis of the chlorides changes across the third period. Sodium chloride is not hydrolyzed at all in aqueous solution. The same applies to magnesium chloride although hydrated crystals undergo hydrolysis when heated given off HCl and leaving a basic salt. An aqueous solution of aluminium chloride shows appreciable hydrolysis and turns blue litmus red. The chlorides of silicon, phosphorus and Sulphur hydrolyze completely in water.

The general conclusion from the above is therefore as follows: From left hand side to right hand side across any period of representative elements, the metallic character, i.e. tendency to lose electron(s) decreases, and the non-metallic character, i.e. tendency to gain electron(s) increases. Also, as one goes across the period, ionic property decreases while covalent property increases.

PERIOD 4: DIAGONAL RELATIONSHIP

Because metallic character increases down a group and decreases from left to right along a period, there exists a diagonal relationship between the chemical properties of the first member of a group and that of the second member of the next group as in the cases of lithium and magnesium on one hand, and beryllium and aluminium on the other (see the periodic table)



EVALUATION

1. The atoms of four elements are represented as $_{20}Q$, $_{16}R$, $_{10}S$ and $_{8}T$. Which of the elements would be unreactive?
2. Explain the meaning of the diagonal relationship the periods 2 and 3 of elements in the Periodic Table.

GENERAL EVALUATION

OBJECTIVE TEST:

1. An element which has atomic number 11, is likely to have similar chemical properties with another element having atomic number. (a) 7 (b) 9 (c) 18 (d) 19

2. If the electronic configuration of an element X is $1s^2$, $2S^2$, $2P^5$, which of the following statements about X is false? It (a) Have five electrons in its valence shell. (b) Has atomic number 9 (c) Is a halogen (d) Is a non-metal

3. The electronic configuration of an element X is $1s^2$, $2s^2$, $2p^6$, $3s^2$,$3P^4$. It can be deduced that X (a) Belongs to group 6 of the periodic table.(b) Belongs to period IV of the periodic table.(c) Has 3 unpaid electrons in its atom. (d) belongs to group 4

4. Which of the properties of the atom increases across the period and down the group in the periodic table? (a) Atomic radius (b) electronegativity (c) electropositivity (d) Ionic radius

5. Which of the following group 1 elements has the highest Ionization energy? (a) LI (b) Na (c) K (d) Rb

ESSAY QUESTIONS

1. (a) What are isoelectronic ions? (b) Give two examples, one each of a cation and an anion, which are isoelectronic with neon.

2. (a) Which of the following elements: calcium fluorine, iodine, neon, magnesium and helium are: (a) Halogens (b) noble gas (c) alkaline earth metal

3. List three periodic properties of elements that generally increase across the periodic table.

4. Arrange the following elements in order of decreasing electro negativity.

$_{16}S$, $_{13}Al$, $_{11}Na$, $_{15}P$

5. State the periodic law.

WEEK 3

TOPIC: CHEMICAL REACTIONS

CONTENTS:

1. Basic concept (Activation energy) and
2. Introduction to collision theory.
3. Factors affecting rate of chemical reactions.
4. Types of chemical reactions – Endothermic and Exothermic.

PERIOD 1: BASIC CONCEPTS: REACTANTS AND PRODUCTS

Chemical reactions can be represented simply on paper by chemical equations involving only formula and symbols e.g.

$$4NH_{3(g)} + O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(g)}$$

Reactants Products

Reaction time: The total time taken for a particular reaction to take place.

Reaction rate: is the number of moles of reactions converted or product formed per unit time. **Unit is $moldm^{-3}s^{-1}$**

In all chemical reactions, existing bonds in the reactants particles must be broken first before new bonds can be formed to form products. The breakings of bonds require energy. An initial energy input is required to activate the reactant particles. This energy is the activation energy of the reaction. The activation energy of a reaction is equivalent to that energy barrier that must be overcome before bonds are broken to enable the reaction to occur. Hence, **activation energy** can be defined as the minimum amount of energy required for a reaction can occur. When this activation is acquired by the reactant particles, they form complex particles of high energy content. This complex particle is known as the **activated complex**. **Therefore activated complex is an unstable molecule with high energy contents which gives the product** It is unstable because of its high energy content and so will readily decompose to give the products or the reactants, depending on the nature if the reaction.

EVALUATION

Define activation energy.

PERIOD 2: INTRODUCTION TO COLLISION THEORY

The collision theory was developed from the kinetic theory of gases to account for the kinetic theory of gases to account for the influence of concentration and temperature on reaction rates. The theory is based on the following postulates:

i. Reactions occur as a result of the collision of reactant particles.

ii. A reaction results only if collision attains certain minimum energy. This minimum energy is called activation energy.

iii. Collision will not give rise to a reaction unless the colliding particles are correctly oriented to one another.

iv. The rate of reaction is proportional to the number of effective collisions. A collision is said to be effective if the energy of the colliding molecules is greater than or equal to the activation and the molecules are correctly oriented to one another.

The collision theory assumes that for a chemical reaction to occur there must be collisions between reactant particles.

EVALUATION

Explain the collision theory.

PERIOD 3: FACTORS AFFECTING THE RATE OF CHEMICAL REACTION

The rate at which reaction takes place will be affected by the following factors:

1. Nature of reactant: The chemical nature of the reactants taking part in the reaction influences the rate of reaction. For instance if iron, zinc and gold metals are placed in different beaker continually Hydro chloric acid, there will be rapid evolution in the beaker containing the acid and zinc metal wherein the beaker containing Iron metal and the acid there will be slower evolution of hydrogen gas and in the beaker containing gold metal and the acid solution there will be no reaction.

2. Effect of concentration / pressure (gases) of reactants: If reactant particles are crowded in a particular place, their frequency of collision will be faster than if the particles are far from one another. Thus, the more the concentration of reactant particles the higher the rate of reaction.

Pressure affects the concentration of gaseous reactant, the higher the pressure of gaseous reactants, the higher the frequency of collision of the particles the higher the rate of reaction.

3. Effect of surface area of the reactants: the more exposed the area of contact of reacting particles to each other the faster the rate of reaction. For solid reactants the exposed surface area must be increased by subdividing or breaking the solid into smaller pieces.

Where the reactants are gases, liquids or solids dissolved in solution, the thoroughness of mixing is of vital importance so as to ensure maximum contact between the reactants.

4. Effect of temperature of reaction mixture: The higher the temperature the higher the rate of reaction of most reactions. When the temperature of a chemical reaction is increased, the number of particles with energies equal to or greater than the activation energy increases. Also the kinetic energy of the reactant particles increase which implies increase in frequency of effective collision and increase in the rate of reaction.

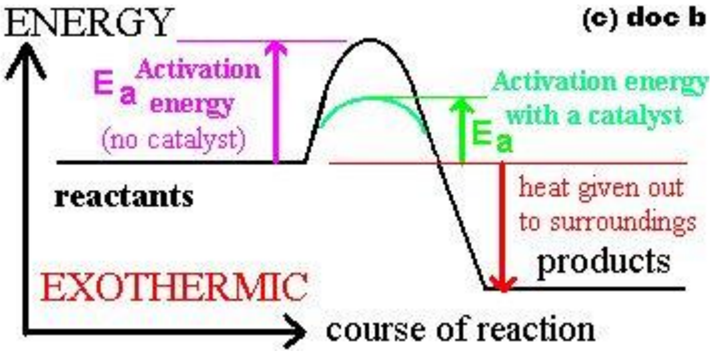
5. Effect of the presence of light: Reactions whose rates are affected by light are called photochemical reactions. They are thus able to overcome the activation energy barrier and react rapidly by a chain reaction.

Examples: i. The decomposition of hydrogen peroxide
ii. The reactions between methane and chlorine Photosynthesis
iii. The conversion of silver halides to grey metallic silver
iv. The halogenations of alkanes

6. Effect of catalyst: catalyst will alter the rate of a chemical reaction but itself does not undergo any permanent change at the end of the reaction.

Catalysts that speed up the rate of a chemical reaction are called positive catalyst. They lower the activation energies of the reactant particles by providing alternative pathway so more reactant particles are able to collide effectively to produce more products. E.g.

Manganese(IV) oxide, MnO_2 catalysts is used in the production of oxygen thermal decomposition of $KClO_3$



EVALUATION

List and explain 5 factors that affect the rate of chemical reaction.

PERIOD 3: TYPES OF CHEMICAL REACTIONS: ENDOTHERMIC AND EXOTHERMIC REACTIONS

An endothermic reaction is one during which heat is absorbed from the surrounding. Most decomposition processes are endothermic reaction. Dissolution of ammonium chloride, ammonium tetraoxosulphate(vi) etc are endothermic process. In endothermic reaction, the enthalpy of product(s) is greater than that of reactant(s). change in enthalpy is equal to the sum of heat of product minus the sum of heat of reactant i.e $\Delta H = \sum H_P - \sum H_R$. Where $\sum H_P$ is sum of heat of products and $\sum H_R$ is sum of heat of reactants. Enthalpy change in this regard is positive. i.e $\Delta H = +ve$

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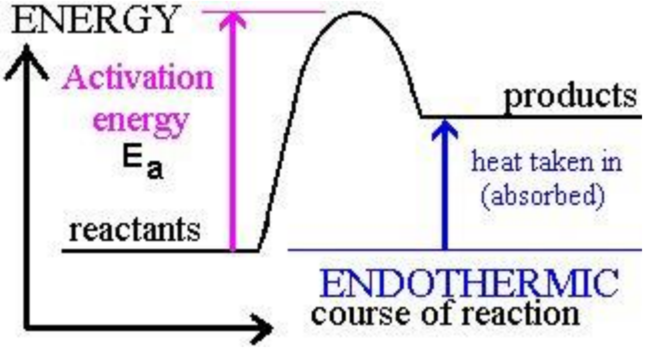
Examples of Endothermic reaction

(a) $N_{2(g)} + O_{2(g)} \longrightarrow 2NO_{(g)}$ $\Delta H = +180.6 KJmol^{-1}$

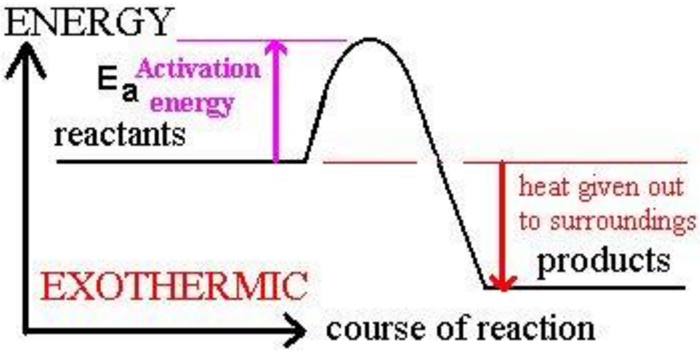


Exothermic reaction is one during which heat is released to the surrounding. Examples of exothermic reaction is combustion reaction. Dissolution of H_2SO_4, NaOH, KOH, neutralization and $AlCl_3$ are exothermic process. In exothermic reaction, the enthalpy of product(s) is less than that of reactant(s). change in enthalpy is equal to the sum of heat of product minus the sum of heat of reactant i.e $\Delta H = \sum H_P - \sum H_R$. Where $\sum H_P$ is sum of heat of products and $\sum H_R$ is sum of heat of reactants. Enthalpy change in this regard is negative. i.e ΔH = -ve

(b) Example of exothermic reaction.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

$$\Delta H = - 408KJmol^{-1}$$



Note: The negative and the positive signs indicated in the above figures indicate exothermic and endothermic reactions respectively

Heat of formation: Heat of formatiom of a compound is the heat change that occurs when one mole of a compound is formed from its elements in their standard states. The standard condition are 25^{O}c and 1 atm. The heat of formation of water is -286kJmol^{-1}. The equation is given below: $H_{2(g)} + ½O_{2(g0} \rightarrow H_2O_{(l)}$ $\Delta H_f = -286kJmol^{-1}$

Heat of combustion: This is the heat evolved when one mole of a substance is completely burnt in oxygen under state condition. The heat of combustion of carbon is -393kJmol^{-1}

Example:

Calculate the heat of reaction in the equation below given that the heat of combustion of carbon and hydrogen are -393kJmol^{-1} and -286kJmol^{-1} respectively and heat of formation of butane is -125kJmol^{-1}.

$C_4H_{10(l)} + \frac{13}{2}O_{2(g)} \longrightarrow 4CO_2 + 5H_2O_{(l)}$

Solution

$\triangle H = \sum H_P - \sum H_R$

$= [-393+(-286)] - (-125+0)$

$= -2877kJmol^{-1}$

NOTE: The enthalpy of formation of an element is zero

EVALUATION

1. Differentiate between exothermic and endothermic reaction.

GENERAL EVALUATION

OBJECTIVE TEST:

1. Endothermic reaction may be defined as except

   (a) Reaction in which heat is absorbed
   (b) Reaction in which heat is released'
   (c) Reaction in which $\triangle H$ is positive
   (d) Reactant than energy of the reactant.

2. Rate of chemical reaction depends on the following factors except.

   (a) Rate at which gas is evolved
   (b) Rate at which products are formed
   (c) Rate at which colour of reactions change.
   (d) Rate at which the reactants diminish.

3. The unit of rate of chemical reaction is (a) $Moldm^{-3}S^{-1}$ (b) $Mol^{-1}S^{-1}$ (c) Mol^{-1} (d) $Smol^{-1}$

4. The rate of a reaction is proportional to the number of effective collisions occurring per second between the reactants. This statement is associated with the.

   (a) Kinetic theory (b) rate law (c) atomic theory (d) collision theory

5. Which of the following statement is not true about the reaction between dilute hydrochloric acid and marble chips calcium trioxocarbonate(IV)?

(a) It is faster after three seconds than it is after ten seconds.

(b) It slows down with time.

(c) It eventually stops.

(d) It proceeds at a constant rate

ESSAY QUESTIONS

1. Use the arguments of the collision theory to explain how the following factors affect the rate of a chemical reaction. (i) concentration (ii) surface area

2. (a) State in three short sentences the main ideas of the collision theory.

3. State how the rate of a chemical reaction is affected by the following factors.

    (a) Concentration (b) surface area

4. (i) What is a catalyst?

    (iii) Write a relevant equation to show the industrial process in which V_2O_5 was used as a catalysts.

5. Explain briefly how temperature affects the rate of a chemical reaction.

WEEK 4

TOPIC: CHEMICAL REACTIONS

CONTENTS:

1. CHEMICAL EQUILIBRIUM:

2. CHARACTERISTICS OF A CHEMICAL SYSTEM AT EQUILIBRIUM,

3. LE CHATELIER'S PRINCIPLE AND FACTORS AFFECTING EQUILIBRIUM OF CHEMICAL REACTION

4. EQUILIBRIUM CONSTANT, KC

PERIOD 1: CHEMICAL EQUILIBRIUM

Studies have shown that some reactions are such that all the reactants are never completely converted into products. In such reactions, the products are converted into the reactant as they are been formed.

A reaction is said to be **reversible**, if it can be made to proceed forward and backward, under a given set of conditions.

For a chemical reaction involving a gas to be reversible, it must be carried out in a closed vessel, i.e. an isolated or closed system. Two opposing arrows in a chemical equation represent a reversible reaction:

a) $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$

b) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

c) $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

Such reactions usually have relatively low activation energies for the reverse reactions.

A reaction in which the products cannot readily be combined to give the reactants is said to be **irreversible**. In such a reaction, a single arrow is used pointing to the product(s), e.g. combustion reactions

a) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

b) $2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$

Such reactions usually have relatively high activation energies for the reverse reaction.

REACTIONS AT EQUILIBRIUM

Dynamic Equilibrium

When the rates of forward and backward reactions in a reversible reaction are equal, the reaction is said to be at equilibrium. At equilibrium, both the forward and backward reactions are still going on, but because there rates are the same, the concentrations of the reactants and products do no longer change with time. Hence, chemical equilibrium is dynamic and not static.

How to Identify a Reaction at Equilibrium

At equilibrium, certain observable properties become constant depending on the type of reaction. Such properties include;

- ✓ Concentrations of the reactants and products;
- ✓ Pressure of gases;
- ✓ Density or intensity of colour of a solution;
- ✓ Temperature of the system.

EVALUATION

1. When is a reaction said to be reversible?
2. Describe a natural process that is reversible.

PERIOD 2: CHARACTERISTICS PROPERTIES OF A SYSTEM AT EQUILIBRIUM

1. Equilibrium is dynamic; that is,

- ➢ The reactants and products are present at equilibrium, i.e. equilibrium can be achieved from either direction:

  $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

  $2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$

2. The concentrations of the reactants and the products, pressure, density or intensity of colour, and the temperature of the system are constant- depending on the type of the reaction.

3. The rate of forward and backward reactions are equal.

4. The equilibrium position is not affected by the presence of the catalyst, it only quickens the rate at which equilibrium is achieved.

5. At equilibrium, the free energy change, ΔG, of the reaction is zero.
6. A system at equilibrium will resist a change.

Information Obtained from an Equilibrium Equation

Consider a typical reversible reaction:

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \quad \Delta H = -92kJ$

The following information can be obtained:

1. The two opposing reactions are occurring at the same time – as indicated by the opposing double arrow.
2. The two opposing reactions are at equilibrium.
3. The amounts, in moles, of the reactants and products at equilibrium are proportional to the stoichiometry in the balanced equation.
4. The forward reaction is exothermic (ΔH is negative; hence, the backward (or reverse) reaction will be endothermic (ΔH is positive), i.e.

$2NH_{3(g)} \rightleftharpoons N_{2(g)} + 3H_{2(g)} \quad \Delta H = +92kJ$

EVALUATION

1. What is meant by an equilibrium system?
2. Give **three** properties of a chemical system at equilibrium.

LE CHATELIER'S PRINCIPLE

Le Chatelier's principle stares that if an external constraint such as a change to temperature, pressure or concentration is imposed on a chemical system in equilibrium, the equilibrium will shift so as to annul or neutralize the constraint.

FACTORS AFFECTING EQUILIBIUM OF A CHEMICAL REACTION

1. **EFFECT OF A CHANGE IN TEMPERATURE** e.g. For the following systems at equilibrium

(a) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} \quad \triangle \quad H = -395.7\ KJmol^{-1}$

The forward equation is exothermic i.e. it involves increase in temperature whereas the backward equation is endothermic or it involves decrease in temperature.

If the temperature of the system is increased:

Increase in the temperature of the system will shift the equilibrium position o backward reaction, that is, reactant formation is favoured.

Increasing the temperature of the system will shift the equilibrium position to the left, favouring the backward reaction i.e. reactants formation (i.e. SO_2 and O_2).

If the temperature of the system is decreased:

Decrease in the temperature of the system will cause the equilibrium position to shift to the right favouring the forward reaction, that is, product formation.

(b) $N2(g) + O_2 \rightleftharpoons 2NO(g) \quad \Delta H = +90.4KJmol^{-1}$

When the system is at equilibrium, the forward reaction is endothermic and the backward reaction is exothermic.

If the temperature of the system is increased:

Increase in the temperature of the system will cause the equilibrium position to shift to the right favouring forward reaction. i.e. product formation.

If the temperature of the system is decreased:

Decrease in the temperature of the system will cause the equilibrium position to shift to the left favouring the backward reaction.

2. **EFFECT OF A CHANGE IN PRESSURE:**

For a change in pressure to affect a chemical system in equilibrium.

(a) One of the reactants in the or products in the reversible reaction must be gaseous.

(b) The total number of gaseous molecules on the left side of the equation must be different from the total number of moles of gaseous molecules on the right side.

For the following systems at equilibrium

(a) $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$

The forward reaction is from high pressure to low pressure and the backward reaction is from low pressure to high pressure.

Increase in pressure of the system:

When the pressure of the system is increased the equilibrium position will shift to the right favouring the forward reaction that is, the product formation.

Decrease in the pressure of the system:

When the pressure of the system is decreased the equilibrium position will shift to the left favouring the backward reaction that is reactant formation.

(b) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

When the system is at equilibrium, the forward reaction involves an increase in the pressure of the system and the backward reaction involved a decrease in the pressure of the system.

If the pressure of the system is decreased:

A decrease in the pressure of the system will cause the equilibrium position to shift to the right favouring the forward reaction that is, product formation.

If the pressure of the system is increased:

An increase in the pressure of the system will cause the equilibrium position to shift to the left favouring the backward reaction that is, reactant formation

(c) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

A change in pressure will not affect this system at equilibrium because the number of moles of the reactants is the same as the number of moles of the product.

(d) $3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$

A change in pressure will not affect this system at equilibrium because the number of moles of gaseous reactant and product is the same.

3. **EFFECT OF A CHANGE IN CONCENTRAION**

E.g. $3Fe(s) + 4H_2O\ (g) \rightleftharpoons Fe_3O4(s) + 4H_2(g)$

If the concentration of any of the reactants is increased the equilibrium position will shift to the right but if it is decreased it will shift to the left.

Also removal of any of the reactant or product will also cause the equilibrium position to shift. E.g. removal of hydrogen gas from the system will cause the equilibrium position to shift to the right.

4. **EFFECT OF A CATALYST**

Addition of a catalyst to a system in equilibrium will not affect the equilibrium position. Instead, addition of catalysts will only make equilibrium state to be reached attained faster.

EQUILIBRIUM CONSTANT, K_C

In a reversible reaction, there is a fixed relationship, at constant temperature, between the concentrations in moldm^{-3} of the products and the reactants. This relationship is accounted for in the study carried out by Guldberg and Waage. This law, known as the Law of Mass Action states that at constant temperature, the rate of reaction is proportional to the active masses (concentration raise to the power of its coefficient) of each of the reactants.

EXPRESSION OF EQUILIBRIUM CONSTANT, K_C

In a reaction: $aA + bB \rightleftharpoons cC + dD$

The equilibrium constant K_C is expressed as follows:

$K_C = \frac{[C]^c[D]^d}{[A]^a[B]^B}$. In the cause of a chemical reaction, it the concentration of gases and aqueous species the normally change. The concentrations of solid and pure liquid are always constant, hence, thay cannot appear in equilibrium constant expression.

<u>Note</u>: The species <u>must</u> be written in a square bracket as shown above e.g. in the reaction:

(a) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

The equilibrium expression

$$K_C = \frac{[SO_3]2}{[SO_2]2[O_2]}$$

(b) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

$$K_C = \frac{[\mathrm{NH3}]^2}{[\mathrm{N2}]^2\,[H_2]}$$

(c). $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

$K_C = [CO_2]$

IMPORTANCE OF K_C

KC determines the yield of chemical reaction at equilibrium. If Kc is greater than one, it more product is formed 1.e forward reaction is favoured. But if Kc is less than one, it less product is formed (poor yield) i.e backward reaction is favoured. Kc is temperature dependent and change with change in temperature.

RELATIONSHIP BETWEEN KC AND △G

Free energy (G) is the energy for doing useful work. Gibb's free energy cannot be measured directly but the change in free energy is usually measured. Change in free energy determines the spontaneity of a given reaction. For a spontaneous reaction, △G is negative.

$\triangle G = -RTInKc$. Where n = no of mole of specie, R = gas constant ($8.314Jmol^{-1}K^{-1}$ and T = temperature in Kelvin

EVALUATION:

1. Write the expression for the equilibrium constant K_C for the following

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

(b) $2CO_{(g)} + O_{2(g)} \rightleftharpoons 2CO_{2(g)}$

GENERAL EVALUATION:

OBJECTIVE TEST:

1. Two boys balanced in a sea-saw game is an example of

(a) Static equilibrium (b) dynamic equilibrium (c) homogenous equilibrium (d) mutual equilibrium

2. In the reaction, $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

(a) The reaction is in physical equilibrium

(b) Contact process

(c) The reaction is the rate determining step

3. In the decomposition of $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

The reaction will attain dynamic equilibrium

(a) When the reaction is in open system
(b) When the reaction is heated strongly
(c) When the reaction is in a closed system
(d) When the reaction is catalysed

4. Factors affecting equilibrium reaction include the following except.

(a) Pressure (for solid system)

(b) Concentration

(c) Temperature

(d) Pressure (for gaseous system)

5. All except one is not a condition for considering pressure in an equilibrium system.

(a) There must be concentration gradient between the reactants and the products.

(b) The reactants could be gas while the products may be solids

(c) Both products and reactants must be gaseous.

(d) The reaction takes place in a closed system

ESSAY QUESTIONS

1. What is the effect of each of the following on the equilibrium position of the system indicated below?

$A_{(s)} + B_{(g)} \rightleftharpoons C_{(g)} \quad \Delta H = -xKLmol^{-1}$

(a) Cooling the system
(b) Removing
(c) As soon as it is formed

2. Write the expression of equilibrium constant for

$2AB_{2(g)} + B_{2(g)} \rightleftharpoons 2AB_{3(g)}$

3. Consider the reaction represented by the equation

$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ $\Delta H = +57.2KJmol^{-1}$

(a) When is the reaction said to be at equilibrium

(b) Mention two conditions that can favour the forward reaction.

(c) Name the principle involved in (b) above

(d) Addition of catalyst.

WEEK 5

TOPIC: STOICHIOMETRY

1. S.I. UNIT OF QUANTITIES: LENGTH, MASS VOLUME ETC

2. BASIC CONCEPTS: MOLE, MOLAR QUANTITIES, MOLALITY, STANDARD TEMPERATURE AND PRESSURE (S.T.P.)

3. CALCULATIONS INVOLVING MASS AND VOLUME

4. MORE CALCULATIONS ON MASS AND VOLUME RELATIONSHIP.

PERIOD 1: S.I. UNIT OF QUANTITIES: LENGTH, MASS VOLUME ETC

S.I. UNITS OF QUANTITIES.

S.I. unit means international system [used to describe units of measurements from French ‘system international’] S.I. units

For example

QUANTITY	SYMBOL	UNITS
Length	L	m, cm
Mass	M	g or kg
Molar mass	M	$gmol^{-1}$
Volume	V	cm^3, dm^3
Amount	N	mol
Molar concentration	L	$mol.dm\text{-}^3$
Mass concentration	P	gdm^{-3}
Avogadro’s law	L	mol^{-1}
Avogadro’s number	N	------
N.B molar mass	M	$g.mol^{-1}$

Relationship between quantities

(a) M = $\frac{m}{n}$ i.e molar mass = $\frac{mass}{amount}$

Molar volume = $\frac{mass}{amount}$

(b) Molar volume = $\frac{Numbers}{amount} = \frac{N}{A}$

(c) Avogadro's constant = L = $\frac{N}{A}$ == $\frac{Numbers}{amount}$

TYPES OF MASS AND VOLUME PROBLEMS

There are two types of mass and volume relationship problems namely:

1. Mass- mass problem:

In this type of problem, the reacting mass of substance and its molar mass is usually given and we may be required to determine the mass of another substance produced and its molar mass also given. The reversed form of this is when the mass of another substance product produced is given and one is asked to find the mass of the substance which produced it.

2. Mass- gas volume problem:

In this case, you may be given a certain reacting mass of a reactant and required to find the volume of another substance produced at S.T.P. or under any other conditions. The reverse of this type is when you are given the volume of a certain gas liberated at S.T.P or other conditions and the gas produced.

***Note*:** This method is related to simple proportion as in mathematics.

3. Gas volume – gas volume problem

In this class of reactions, only the volumes of the reactants and products are involved in the calculations.

4. Mass – Liquid volume problem

In this type, the mass I given and the volume of liquid has to be determined.

5. Liquid volume – volume problem

In this group of calculations, one volume is given while another is to be found.

EVALUATION

1. What is a mole of a chemical substance?

2. Mention two elementary units of a chemical substance.

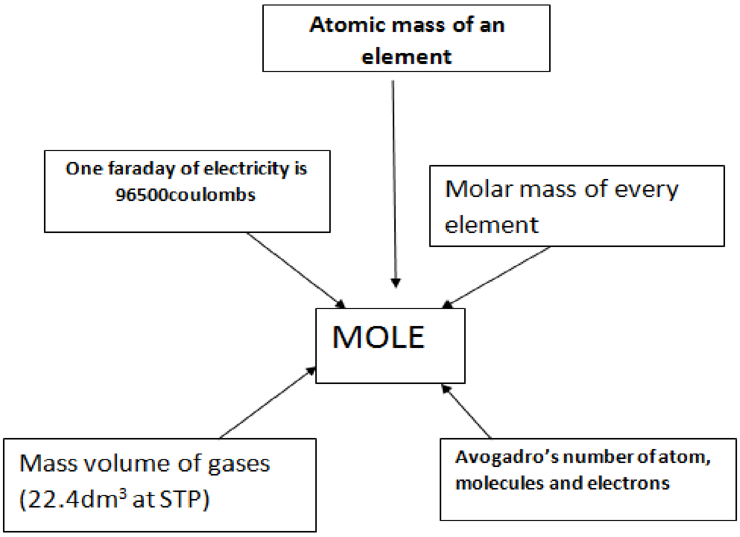
3. What mass, in grams, of aluminium contains the same number of atoms as in 12.0 g of carbon? (C = 12.0, Al = 27.0).

PERIOD 2: BASIC MOLE CONCEPT

Definition: *A mole is the amount of a chemical substance that contains as many elementary particles as there atoms in 12.0 g of C-12 isotope.* It means that a mole of an element are collections of its atoms such that the total mass in grams, is numerically equal to its relative atomic mass. That is: if 1 mole of carbon atoms weighs 12.0 g, then, 1 mole of oxygen atoms will weigh 16.0 g; 1 mole of sodium atoms will weigh 23.0 g, e.t.c. The number of elementary units or particles in 1 mole of a chemical substance is constant, and it is called **Avogadro's constant, L.** It is numerically equal to 6.02×10^{23}=. Hence:

- 1 mole of carbon atoms weighs 12.0 g and contains 6.02×10^{23} atoms.
- 1 mole of sodium atoms weighs 23.0 g and contains 6.02×10^{23} atoms.
- 1 mole of sulphur atoms weighs 32.0 g and contains 6.02×10^{23} atoms.

- The molar mass of every element contains the number of atoms.
- The molar mass of every compound contains the number of molecule
- One faraday of electricity (9630 coulombs) is said to have flowed past a point in a circuit when this number of electrons have flowed through.
- The molar volume of every gas, 22.4 dm^3 at s.t.p contains this umber of molecules. One mole of very particle, atom, molecule, ion or electron contains the Avogadro's number of particles.



The formula of a compound tells us the elements present in it. It also tells us the elements present in it. It also tells us the amounts of the different elements present in it. These amounts are usually expressed as a mole ratio of the different elements in the compounds.

For example:

Formula

Element present	**Sodium**	**sulphur**	**oxygen**
Number of Moles	**2**	**1**	**4**
Mole ratio	**2**	**1**	**4**

A balanced equation of a chemical reaction tells us the relationship of the amounts of the reactants to one another and for the products is known as of stoichiometry reactions.

MOLE RATIO AND MASS RELATIONSHIP

Again, a mole is the amount of substance which contains and many elementary particles as there are carbon atoms in 0.012kg of carbon-12.

The mole is the amount of substance which contains as many formula units as their atoms in 12gram of carbon-12.

The numerical coefficients of a balanced equation represent the numbers of moles of reactants and products. From coefficient, we get the mole ratio of the reactants and product in a reaction. For example

Equation 1

$$H_2SO_{4(aq)} \longrightarrow 2H^+ + SO_{4(aq)}$$

Number of moles	1	2	1
Mole ratio	1	2	1

Therefore, the mole ratio in which reactants combine and products are formed gives the stoichiometry of the reaction

Equation 2.

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(s)} + H_{2(g)}$$

Number of moles	1	2	1	1
Mole ratio	1 :	2	1 :	1
Molar mass	24g	36.5g	95g	2g
Reacting mass	24g	(36.5 ×2)	95g	2g

From the equation 2, we see that

Amount × molar mass = reacting mass

Amount = $\frac{reacting\ mass}{molar\ mass}$

Molality- molality is defined as the amount of substance (in mole) of solute divided by the mass in kilogram of the solvent

Molality = $\frac{mole}{mass\ in\ kg.}$

Molality should not be confused with molarity as they are both measures of concentration of solutions but Molarity is the ratio of moles to the volume while molality is the ratio of the moles to the mass of the solution. Molality is the number of solute per kilogram of solvent. It is important that the mass of solvent issued and not the mass of the solutions.

WORKED EXAMPLE

1. A 4 g of sugar cube (sucrose) – $C_{12}H_{22}O_{11}$ is dissolved in a 350*mol* teacup of 8^0OC water. What is the molality of the sugar solution?

(Given- density of water at 80^0 =0.975gmol^{-1})

Solution

Molality is the number of moles of solute per kilogram per solvent.

Step 1: Determine the number of moles of sucrose in 4g

Molar mass = 12(12) + 1(22) + 16(11)

= 144 + 22 + 176

= *342 gmol^{-1}*

Divide this amount into the size of the sample.

$$\frac{4g}{342gmol^{-1}} = 0.0117\text{mol}$$

Step 2 Determine mass of solvent in kg

Density = $\frac{mass}{volume}$;   mass = density × volume

Mass = 0.975gmol ×350mol

Mass = 341.25g

Change gramme to kilogramme = 0.341kg

Step 3: Determine the molarity of the sugar solution

$$\text{Molality} = \frac{mol\ of\ solute}{mol\ of\ solvent\ molarity} = \frac{0.0117mol}{0.341kg}$$

Molality = 0.034molkg^{-1}

EVALUATION

1. How many molecules are there in 14g of nitrogen at s.t.p.? [N=14. Avogadro's number = 6.02×10^{23}]

2. What amount, in mole, of copper is deposited when 13.0g of zinc reacts with excess copper(II) tetraoxosulphate(VI) solution according to the following reaction?

$Zn_{(s)} + CuSO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + Cu_{(s)}$ [Cu=63.5, Zn =65]

3. Calculate the volume of chloride at s.t.p. that would be required to react completely with 3.70g of dry slaked lime according to the following equation: $Ca(OH)_{2(g)} + Cl_{2(g)} \rightarrow CaCl_2 + H_2O$ [H=1; O=16; Ca=40; 1mole of gas occupies 22.4dm3 at s.t.p.]

PERIOD 3: CALCULATION INVOLVING MASS AND VOLUME

Example 1: **mass- mass problem**

1. What mass of copper is deposited when 6.5g of granulated zinc reacts with excess copper(II) tetraoxosulphate(vi) solution according to the following equation

$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4 + Cu(s)$

Cu = 64, Zn =65

Given: molar mass of Zn =65gmol-, molar

Mass of Cu = 64gmol-1

Reacting mass of Zn=6.5g

$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$

From the above, 65g of Zn deposited 64g of Cu.

1g of Zn will deposit $\left\{\frac{64}{65}\right\} g$bof cu

65g of Zn will deposit $\left\{\frac{64 \times 65}{65 \times 1}\right\}$g of cu

= 6.4g

2. What volume of carbon(IV) oxide is produced at s.t.p. when 2.5g of calcium trioxocarbonate (iv) reacts with excess acid according to the following equation

$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$

[$CaCO_3$ = 100, molar volume of gas at s.t.p= 22.4dm_3]

Solution

$CaCO_3$ +2HCl $\longrightarrow$ $CaCl_2 + H_2O + CO_2$

100g 22.4dm_3

From the equation, 100g of $CaCO_3$ produces 22.4 dm_3 of CO_2

∴ 1g of $CaCo_3$ will produce $\frac{22.4 \text{ dm3}}{100}$ of CO_2

= 0.56dm^3

EVALUATION

1. $CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(s)}$.

From the equation above, calculate the mass in grams of calcium hydroxide produced by 5.6g of calcium oxide. [Ca = 40, O = 16, H = 1].

2. What volume in dm^3 will 0.5g of H_2 occupy at s.t.p? [H = 1, 1 mole of gas at s.t.p = 22.4dm^3].

3. Consider the reaction represented by the following equation: $2NaCl_{(s)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2HCl_{(g)}$. Calculate the volume of HCl gas that can be obtained at s.t.p. from 5.85 g of sodium chloride. [Na = 23.0, Cl = 35.5, Molar volume of gas s.t.p. = 22.4 dm^3]

PERIOD 4: MORE CALCULATIONS ON MASS- VOLUME

Phosphorous burns in the limited supply of air to form phosphorous(iii) oxide, P_4O_6 and in unlimited supply of air to form phosphorous(v) oxide P_4O_{10}.If 3.3g of phosphorus(III) oxide is formed

(a) what mass oxygen from air is used?

(b) How many molecules of oxygen are contained in this mass?

(c) How many molecules of phosphorous are converted to the oxide?

(d) How many molecules of oxygen are needed to convert this oxide into phosphorous v oxide?

(e) What volume would the oxygen in (d) above occupy at s.t.p.?

Solution:

(a) $P_4 + 3O_2 \longrightarrow P_4O_6$

Molar mass of $P_4 = 31 \times 4 = 124 gmol^{-1}$

$O_2 = 16 \times 2 = 32$ g.mol^{-1}

$P_4O_6 = \{(31 \times 4) + (16 \times 6\} = 220$ gmol^{-}

(a) 220g of P_4O_6 used (32 ×3) 96g of oxygen

∴ 3.3 of P_4O_6 requires $\frac{3.3 \times 96}{220}$ g of oxygen

= 1.44g

(b) 1.44g of oxygen $= \frac{1.44}{32}$ mole

1 mole contain 6.02×10^{23} molecules

Number of moles in 1.44g of oxygen $= \frac{1.44}{32} \times 6.02 \times 10^{23}$

$= 2.71 \times 10^{23}$ molecules

(c) Mass of phosphorous in 3.3g of P_4O_6 = (3.3 – 1.44)g

= 1.86g

1.86 g of phosphorous is $\frac{1.86}{124}$ mole

The number of molecules in (c) above i.e. 1.86g of phosphorus

$= \frac{1.86}{124} \times 6.02 \times 10^{23} = 9.03 \times 10^{21}$ molecules

(b) $P_4O_6 + 2O_2 \longrightarrow P_4O_{10}$

220 of P_4O_6 require 2 moles of oxygen

3.3g of P_4O_6 will require $\frac{3.3 \times 2 moles\ of\ oxygen}{220}$

Number of molecules of oxygen contained in this

$\frac{3.3 \times 2 \times 6.02 \times 10^{23}}{220}$ $m$olecule

= 1.81×10^{22}molecules

(c) 6.02×10^{23} molecules occupy $22.4dm^3$ at s.t.p

1.81×10^{22} molecule occupy $\frac{1.81 \times 10^{22}}{6.02 \times 10^{23}} \times 22.4dm^3$

= $0.067\ dm^3$ or $6.73.49\ cm^3$

EVALUATION

1. Calculate the mass of sodium trioxocarbonate(IV) produced by the complete decomposition of 16.8g of sodium hydrogen trioxocarbonate(IV) (H= 1, O= 16, Na= 23, S= 33).

2. On carrying out a chemical analysis discovered that the component of egg shells is $CaCO_3$. If 25.0 cm^3 of 0.700 $moldm^{-3}$ HCl reacted with all the $CaCO_3$ in a sample of egg shells, calculate the:

(i) mass of $CaCO_3$ in the egg shells; (ii) volume of CO_2 evolved at s.t.p.

The equation for the reaction is:

$$CaCO_{3(aq)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

(H = 1.00; O = 16.0; Ca = 40.0; 1 mole of gas occupies $22.4dm^3$ at s.t.p.)

GENERAL EVALUATION

OBJECTIVE TEST:

1. What volume of steam is produced when 10g of propyne is burnt in excess oxygen at s.t.p?
(a) 44.8dm (b) 11.2 dm^3 (c) 22.4 dm^3 (d) 11.2cm^3

2. What mass of anhydrous sodium trioxocarbonate(iv), Na_2CO_3, present in 500cm^3 of 0.1 moldm^{-3}?[Na = 23, C= 12, O = 16] (a) 10.6g (b) 212g (c) 53 (d) 106g.

3. The mass of potassium hydroxide required to make 300.00cm^3 of 0.4moldm^{-3} solution is [KOH = 56.0] A.26.88 g B. 13.44 g C. 6.72 g D. 3.36 g

4. A solution of sodium hydroxide containing 6.0g in 250cm^3 of solution has a concentration of A. 0.04 mol. dm^3 B. 0.60 mol. dm^3 C. 0.96 mol. dm^3 D. 0.15 mol. dm^3 [molar mass of NaOH = 40g mol.$^{-1}$

5. The volume occupied by 17g of H_2S at s.t.p. is [H=1.00, S=32.0, Molar volume =22.4 dm^3] A. 11.2 dm^3 B.17.0 dm^3 C. 34.0 dm^3 D. 44.8 dm^3

ESSAY QUESTIONS

1. If 11 g of a gas occupies 5.6 dm^3 at s.t.p. calculate the vapour density [1 mole of a gas occupies 22.4 dm^3 at s.t.p]

2. 100 cm^3 of a gas at 27°C exert a pressure of 750mnHg. Calculate its pressure. If its volume is increased to 250 cm^3 at 127°C.

3. What is an S.I unit?

4(a) Write down five examples of quantities with their S.I units. (b) Define mole.

5. What volume will 22.4dm$_3$ of oxygen measured at 25°C and and 1.12×10^5 Nm occupy at standard pressure of 1.01×10^5 Nm.

6. What volume of steam is produced when 10g of propyne is burnt in excess?

WEEK 6

Topic: Acid- base reactions

CONTENT:

1. COMMON ACID –BASE INDICATORS AND THEIR pH RANGE

2. ACID-BASE TITATION

3. HEAT OF NEUTRALIZATION (INTRODUCTORY) CONSTRUCTION OF WOODEN RETORT STAND

PERIOD 1: 1: COMMON ACID –BASE INDICATORS AND THEIR pH RANGE

Acid-base indicator is a weak organic acid or weak organic base (organic dyes) which shows colour change depending on the pH of the solution or organic dye which show one colour in acidic medium and another colour in basic medium. It can defined as an organic dye which as colour in ionized state and another colour in unionized state. Examples of indicators are methyl orange, phenolphthalein, methyl red etc.

CHOICE OF INDICATOR FOR ACID-BASE TITRATION

The choice of an indicator for acid-base titration depends on the pH of the mixture at equivalent point and the pK of the indicator. When a strong acid is titrated against a strong base, at the equivalent point, the salt formed does not under hydrolysis and so any suitable indicator can be used. The salt formed when strong acid is titrated against a weak base undergoes hydrolysis to produce excess hydrogen ions. This makes the solution acidic and any indicator that shows colour change in acidic medium is used in the case. Methyl orange changes colour within a pH of 2.9---4.6 and so suitable for this titration. The salt formed when weak acid is titrated against strong base undergoes hydrolysis to produce excess hydroxide ions making the solution alkaline. Phenolphthalein changes colour in basic medium and so suitable to the kind of titration.

Indicators are used in acid-base titration to show the end point when the acid would have materialised the base. Colour changes of common indicator are shown below

Indication	pH range	Colour in acid solution	Colour in the alkaline solution	Neutral or end point	Types of acid base titration
Litmus	50-8.0	Red	Blue	purple	Strong acid and strong base
Methyl	2.9-4.6	Pink	Yellow	orange	S.A and S.B

Orange					or Na_2Co_3 in H_2O
Phenolphthalein	8.2 – 10	Colourless	Pink	colourless	S.A and W.A
Methyl red	4.4 – 6.3	Red	Yellow	orange	S.A and S.B

S.A = Strong acid, S.B = Strong base, W.A = weak base

This is volumetric analysis which aim at estimation of the qualities of certain substances in solution

PERIOD 2 AND 3: ACID- BASE TITRATION

This involves titrating a solution (usually the acid) from the burette into a fixed volume (20 or 25cm^3) of base until the two solutions have completely reacted. The concentration of one of the solution is normally known. An indicator is used to determine the point of complete reaction.

For titration, more dilute solutions containing 0.1moldm^{-3} or 0.05mold^{-3} are used.

STANDARD SOLUTION

In any titration, standard solution must be used to react with a solution of unknown concentration.

A standard solution is a solution of known concentration.

PRIMARY STANDARD

A primary standard is a reagent that is extremely pure, stable and has no water of hydrate. A primary solution is used for the preparation of standard solution. There a primary standard solution is a solution which is prepared from a non-hygroscopic, non-deliquescent and pure substance. Examples are sodium trioxocarbonate(iv), sodium oxalate and benzoic acid

Features of a primary standard

1. High purity

2. Stability

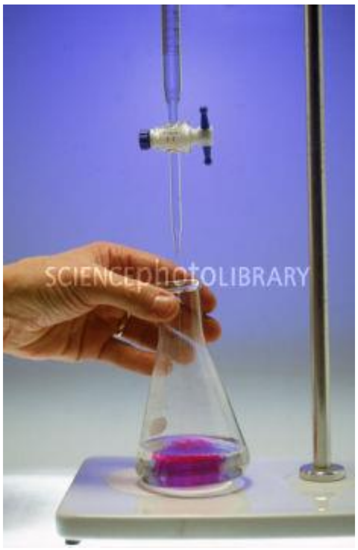
3. High solubility

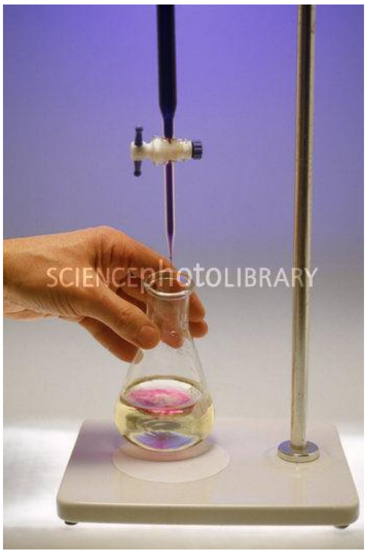
4. High relative molecular mass

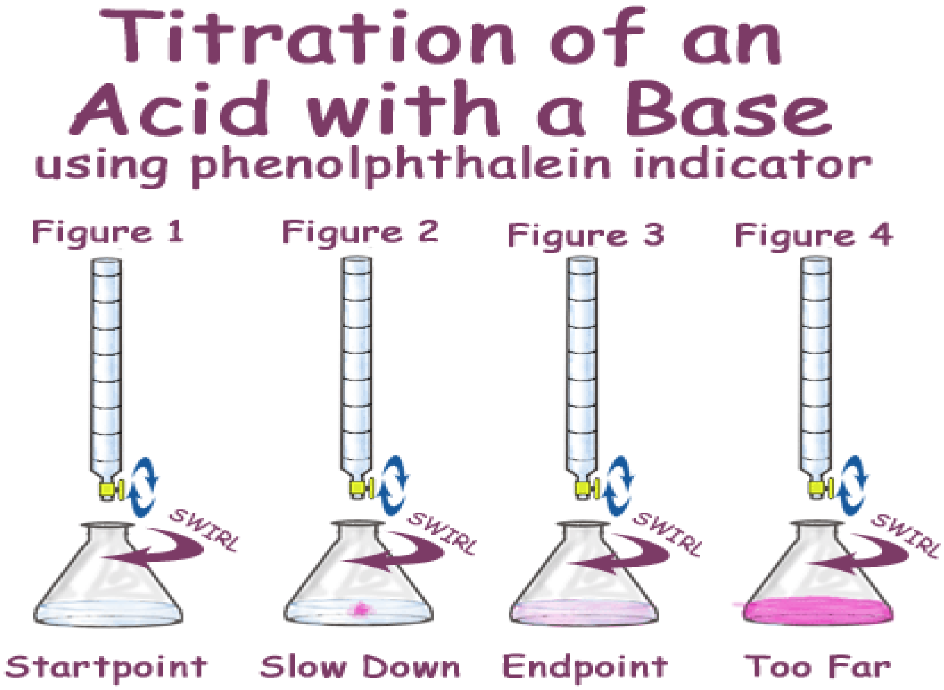
SECONDARY STANDARD

Secondary standard solution refers to a solution that has that has its concentration measured titration with a primary standard solution.

The concentration of a solution is the amount of solute in $1dm^3$ or $1000cm^3$ the solution. It can be expressed as $moldm^{-3}$ or gdm^{-3}







The above diagram is an example of the apparatus used in acid-base titration. Some materials used in acid- base titration are:

1. Weighing bottle
2. chemical balance
3. pipette
4. Burette
5. retort stand
6. filter paper
7. funnel
8. white tile
9. standard volumetric flask
10. conical flask

PRECAUTIONS IN USING THE PIPETTE, BURETTE AND CONICAL FLASK

(a)PIPETTE: (i) Rinse the pipette with the solution it should be used to measure i.e. base

(ii) Avoid air bubbles in the pipette

(iii) Make sure that the mark to be read is at level with your eye.

Do not blow the last drop on the pipette.

(b) BURETTE:

(i) Rinse the burette with acid or allow it to drain after rinsing with distil water

(ii) Make sure the burette jet is filled

(iii) Make sure that the burette is not leaking

(iv)Take your burette readings with your eyes at the same level as the measures to avoid error due to parallax

(v) Remove the funnel before taking your reading

(vi)Avoid incorrect reading.

CONICAL FLASK

1. Do not rinse it with any of the solutions used in the titration but with distilled water.

2. Wash down with distilled water any drop of the solution that stick by the sides of the conical flask during titration.

Example of titration problem solved.

A is a solution of hydrochloric acid containing 4.00g in 1dm^3 of solution B is a solution containing sodium hydrochlorid

(a) Put A into a burette and titrate with 25cm^3 portion of B using methyl orange indicator. Tabulate you burette reaching. Determine the average volume of solution A used

(b) From your result and information provided
  (i) Find concentration of A in moldm^{-3}
  (ii) Find concentration of B in moldm^{-3}
  (iii) Find the amount in mass of NaOH present in 1dm^3 of solution B

Equation of reaction:

$HCl + NaOH \longrightarrow NaCl + H_2O$

[H = 1, Cl= 355, K=39, Na= 23, O = 16]

STUDY ANSWER

Indicator used: methyl orange

Size of pipette: 25cm3

	Rough	Ist Titration	2nd Titration	3rd Titration
Final volume of acid A used in (cm^3)	25.80	25.50	25.40	25.50
Initial volume acid used in(cm^3)	0.00	0.00	0.00	0.00
Volume of solution A used (cm^3)	25.80	25.50	25.40	25.50

Average litre volume (cm^3) =$\frac{25.50+25.40+25.50}{3}$

= =$\frac{76.40}{3}$= 25.45cm^3

B (i) Concentration of HCl of A in moldm^{-3}

Conc. in gdm^{-3} = 4 gdm^{-3}

Molar mass of HCl= 1+35.5 =36.5

Con. In moldm^{-3} of HCl = $\frac{4}{36.5}$= 0.110 moldm^{-3}

b(ii) V_a= 25.45 cm^3

Ca= 0.110 moldm^{-3}

V_b= 25cm^3

C_b =? Of resultant concentration of effect of the two alkalis in solution B.

2HCl + $\frac{KOH+NaOH}{1\ mol}$ HCl + NaCl + 2H_2O

$\frac{Ca\,Va}{Cb\,Vb} = \frac{na}{nb}$

$C_b V_b$: na = Ca Va: nb

Make C_b the subject formula.

$Cb = \frac{Ca\,Va\,nb}{Vb \times na} = \frac{0.110 \times 25.45}{25 \times 2}$

0.0559 $moldm^{-3}$ (38.8 fig)

b(v) Amount in mass of NaOH on $1dm^3$ of solution B

Molar mass of NaOH = 23 +1 + 16=40g/mol

Amount in mass of NaOH in $1dm^3$ of solution B=

40 × 0.0559 $moldm^{-3}$

= 2.23gdm^{-3}

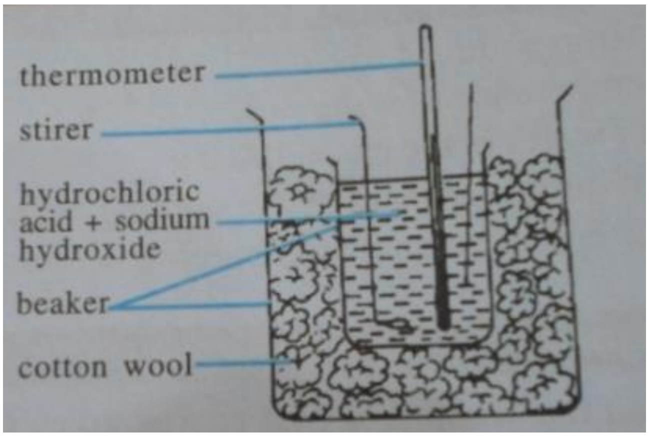
EVALUATION

State five precautions you need to take while using. (a) Pipette (b) burette and 2 precautions while using (c) conical flask

PERIOD 4: HEAT OF NEUTRALIZATION

When an aqueous solution of a acid is added to alkalis, there is an increase in temperature. This increase in temperature is called heat of neutralization.

Heat of neutralization of strong acid and strong alkalis are of the same value. The value of weak acids by strong base and strong acids by weak bases are different and varies due to the fact that energy for the complete ionisation of such weak bases and weak acids before neutralization is drawn from the solution.



PROCEDURE

Measure the temperature of the acid solution and that of the alkali solution before mixing. Find the average temperature of both acid and base.

Determine volumes of acid and alkali to mix in order to get a neutral, solution [by titration]. Mix these volumes (say 50cm^3 of acid + 50cm^3 of alkali; find the temperature of mixture; note the increase in temperature.

If t_1 = temperature of acid, and t_2= temperature of alkalis

Average of the two =$\frac{t1+t2}{2}$ = t_3

If t_4 is the temperature of mixture, then the increase in temperature = $t_4 - t_3 = t_5$

Assume that the solution, have the same density and specific heat as water.

Therefore, mass of mixture=100g

Specific heat of water = 4.2joulesg^{-k}

Heat of neutralization= specific heat x mass x temperature rise=4.2 x 100 × t_5 joules

Heat evolved when 1 mole of each reacts=100 x t_5 x 4.2 x 10joulesmol^{-1}

EVALUATION

1. What is heat of neutralization?

2. State three indicators with their pH ranges.

3. What indicators are as applied in volumetric analysis.

GENERAL EVALUATION

OBJECTIVE TEST :

1. A student prepares 0.5M solution each of hydrochloric and ethanoic acids and then measured their pH the result show that

   (a) pH values are equal
   (b) The solution has a higher pH
   (c) Sum of the pH value is 14
   (d) Ethanoic acid solution has a higher pH

2. What volume of 0.5M H_2SO_4 will exactly neutralize $20cm^3$ of 0.lM NaOH solution?

   (a) $2.0cm^3$ (b) $5.0\ cm^3$ (c) $6.8\ cm^3$ (d) $8.3\ cm^3$ (e) $10.4\ cm^3$

3. Filling the burette for titration involves these except.

   (a) Wash with water (b) rinse with acid (c) eject air bubbles (d) read at eye level

4. In the titration of acid against base solutions, averaging must involve.

   (a) Rough reading (b) concordant reading (c) higher reading (d) all the titres obtained

5. What mass of anhydrous sodium trioxocarbonate(IV), Na_2CO_3; present in $500cm^3$ of $0.1moldm^{-3}$? (Na=23, C=12, O=16)

   (a) 10.6g (b) 212g (c) 5.3g (d) 106g.

ESSAY QUESTIONS

1. (a) In an acid –base titration (i) which solution is normally put in the burette and why. (ii) To which of the solutions is the indicator added? (iii) Why is the conical flask rinsed with distilled water and not with the solution to be place in it?

   (b) What is the colour of methyl orange in (i) distilled water (ii) lime water (iii) vinegar?

2. A is dilute tetraoxosulphate (vi) acid. B contains 1.50g of sodium hydroxide per 250cm^3 of solution. 25 cm^3 of B required 15.5cm^3 of A for complete neutralization

The equation for reaction:

$H_2S0_{4(aq)} + 2NaOH_{(a\ q)} \longrightarrow Na_2SO_{4(aq)} + 2H_{2(l)}$

(a) Calculate:

(i) The concentration of solution B in moldm^{-3} [H=1, O= 16, Na=23]

(ii) The concentration of A in moldm^{-3}

(iii) The number of hydrogen ions in 1.0dm^{-3} of solution A [Avogadro's constant 6.0×10^{23}

(iv) The volume of distilled water that should be added to 25cm^3 of solution A in order to dilute it ten times

b. What would be the colour of methyl orange indicator in:

(i) Solution A (ii) solution B (iii) titration mixtures of A and B at the end point.

3. Calculate the mass concentration in gdm^{-3} of the ions in the following solutions:

(a) Cl^-ions in 0.2 moldm^{-3} sodium chloride solution

(b) NO_3^- ions in 0.75 mol dm^{-3} trioxonitrate (v) acid.

(c) SO_4^{2-} ions in 2moldm^{-3} potassium tetraoxosulphate (vi) solution. Cl= 35.5, N=14, O=16, S=32]

WEEK 8

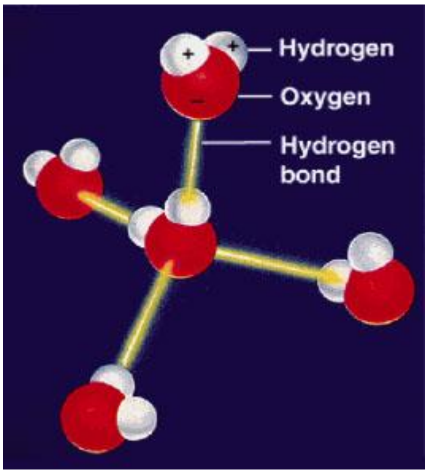
TOPIC: WATER

CONTENT

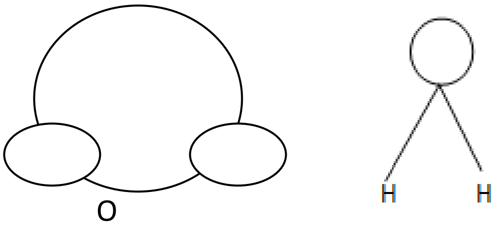
1. Structure of water, Hardness of water and removal of hardness of water
2. Solubility- Basic concept
3. Types of Solutions
4. Factors affecting solubility and uses of solubility curve.

PERIOD 1: STRUCTURE OF WATER, HARDNESS OF WATER AND REMOVAL OF HARDNESS OF WATER

A molecule of water consists of two atoms of hydrogen and one atom of oxygen chemically combined to form a covalent molecule. A molecule of water has a V-shape. The repulsion between the two lone pairs of electrons on the oxygen atom makes the structure of water molecular to be V- shaped



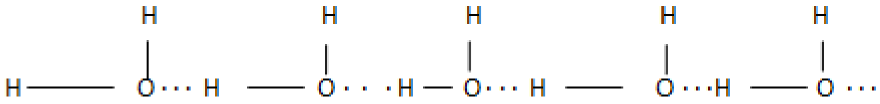
Structure of water



(a) Bonding (b) Shape of water molecule

The shared pair of electrons between each hydrogen atom and oxygen is drawn more electronegative, making the oxygen atom to be partially negatively charged and hydrogen atoms to be partially positively charged. This leads to hydrogen bonding between the molecules of water the attendant relatively high melting point, high boiling point and low vitality.

Hydrogen bonding in water molecules



$$H - \overset{\overset{H}{|}}{O} \cdots H - \overset{\overset{H}{|}}{O} \cdots H - \overset{\overset{H}{|}}{O} \cdots H - \overset{\overset{H}{|}}{O} \cdots H - \overset{\overset{H}{|}}{O} \cdots$$

HARDNESS OF WATER

A hard water is water which will not readily form lather with soap. For example, river water, lake water, stream water and sea water. Hardness of water is due to the presence of calcium, magnesium and iron in water. There are two types of hard water: **temporary hardness** and **permanent hardness**.

TEMPORARY HARDNESS: This is caused by the presence of dissolved calcium or magnesium hydrogen trioxocarbonate(IV), HCO_3^- of Ca, Mg or Fe. Temporary hardness is so called because it is easily removed by boiling.

Removal of temporary hardness: Temporary hardness can be removed by:

1. **Boiling**: The calcium hydrogen trioxocarbonate(IV) which causes the temporary hardness is decomposed by heating.

$$Ca(HCO_3)_2 \xrightarrow{\text{boil}} CaCO_3 + H_2O + CO_2$$

2. **Addition of calculated amount of slaked lime, $CaCOH)_2$**

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

Soluble slightly soluble insoluble

Effects of temporary hardness:

1. **Furring of kettle**: When a kettle or boiler has been used to boil hard water for some time, the inner surface becomes coated with a white fur-like layer. The layer is due to the gradual deposit of $CaCO_3$ from the decomposition of $Ca(HCO_3)_2$

2. **Stalagmites and stalactites**: These are pillars of limestone, $CaCO_3$.

Found in hot caves. They are formed when hard water flow temporary over the top of the cave and drop off water then becomes decomposed by the heat inside the cave, leaving deposits of $CaCO_3$ on the roof and floor of the cave. The deposits that grow downward are termed stalactites and the ones that grow upward are termed stalagmites. Pillars of $CaCO_3$ are formed when both stalactites and stalagmites meet.

PERMANENT HARDNESS: This is caused by the presence of dissolved calcium and magnesium ions in form of soluble tetraoxosulphate(VI) and chlorides and certainly cannot be removed by boiling. When water containing any of these substances is evaporated, a white solid deposit of calcium or magnesium tetraoxosulphate(VI) and/ or calcium trioxocarbonate(IV) is left behind. Calcium trioxocarbonate(IV) causes the 'furring' in kettles that occur in hard water. This furring may be removed by the addition of a dilute acid:

$$2H^+ + CO_3{}^{2-}{}_{(aq)} \longrightarrow CO_{2(g)} + H_2O_{(l)}$$

Blockages in hot water pipes are caused by similar process to the furring of kettles. A thick deposit of limescale builds up.

Removal of permanent hardness: permanent hardness as well as temporary hardness can be removed by:

1. Addition of washing soda, ($Na_2CO_3.10H_2O$) crystals

In each type, the calcium or magnesium ion, which actually causes the hardness, is removed as a precipitate and can, therefore, no longer cause hardness.

$$Na_2CO_3.10H_2O + CaSO_4 \longrightarrow CaCO_3 + Na_2SO_4$$

Soluble insoluble

$$Na_2CO_3 + MgSO_4 \longrightarrow MgSO_4 + Na_2SO_4$$

2. Addition of caustic soda, NaOH

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

Soluble insoluble

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

3. Ion- exchange method: Zeolite or permutit is an ion exchange resin used industrially and in the home for softening water. When the hard water is passed through the resin, the sodium ions in it goes into the solution and the calcium and magnesium ions take their place in the complex salt.

$$CaSO_4 \quad + \quad Na_2Y \quad \longrightarrow \quad CaY \quad + \quad NaS_2O_4$$

Soluble resin insoluble

Sodium aluminium trioxosilicate (iv)

EVALUATION

1. Why is water molecule V-shaped?
2. Name the constituent elements in water with their respective number of atoms.
3. What type of chemical combination exists between water molecules?

PERIOD 2: SOLUBILITY

Definition: The Solubility of a solute (solid) in a solvent (liquid) is the concentration of the saturated solution. Solubility can be defined thus:

1. *It is the maximum amount of the solid that dissolves in 1 dm^3 of the solution at a given temperature. It is expressed in $mol.dm^{-3}$.*

2. It is the maximum mass, in grams, of the solid that dissolve in 100 g of the solvent at a given temperature.

When some common salts is added to a beaker of water and the mixture stirred, the salt gradually disappear, and the clear colourless mixture is obtained. The salt is said to have dissolved in the water. Thus, the salt that dissolved in the water is called **solute** and the water that does the dissolving is known as the **solvent** and the product obtained by dissolving the salt in the water is called a **solution**.

Therefore, a solution is a homogenous mixture which is formed when a solute is completely dissolved in a solvent. A solution can be saturated or supersaturated.

Determination of solubility of KNO_3 at 30^oC

Stage 1: Preparing of Saturated Solution

1. Put 100 cm^3 of distilled water in a beaker, add the salt little at a time and warm on a Bunsen burner with stirring. Continue the addition of the salt with stirring and keeping the beaker warm at about 50°C, until the salt can no longer dissolve.

2. Allow the saturated solution to cool to 30°C; this is the saturated solution of the salt at 30°C. It will be noticed that as the hot saturated solution cools, the excess solid in the solution separates out, to give a saturated solution at a lower temperature.

2. Stage 2: Evaporation of Saturated Solution to Dryness.

1. Weigh accurately a clean dry evaporating dish: **x** g.

2. Rinse a 25 cm3 pipette with the saturated solution, in order to warm it.

3. Pipette 25 cm^3 of the saturated solution at 30Oc, as quickly as possible (without pipetting any undissolved solid) into the evaporating dish and re-weigh: **y** g

4. Place the dish on a steam bath and evaporate to dryness. Allow to cool in a charged desiccators, and then re-weigh.

5. Repeat the process of heating and cooling, until a constant mass is obtained: **w** g.

Calculation of the solubility at 30°C

The following hypothetical values will be used to illustrate how to calculate the solubility of a salt.

Data required:

Mass of the evaporating dish:	**x** = 15.20 g
Mass of evaporating dish + 25 cm^3 of saturated solution:	**y** = 40.70 g
Mass of dish + anhydrous salt:	**w** = 20.70 g

Solubility in $mol.dm^{-3}$

Mass of anhydrous salt = (w - x) = (20.70 - 15.20) g = 5.50 g

i.e. 25 cm^3 of saturated solution contain 5.50 g of salt, Hence, 100 cm^3 of saturated solution contain 5.50 x 1000/25 = 220 g of salt.

To convert 220 g to moles

Amount (mol) = (Mass of salt)/ (Molar mass).

Molar mass of KNO_3 = 39 + 14 + 48 = 101 $g.mol^{-1}$

i.e. Amount, in moles = 220/ 101 = 2.18 moles

Therefore, Solubility of KNO_3 at 30°C = 2.18 $mol.dm^{-3}$

Solubility in grams per 100 g of water

Mass of water used = (**y - w**) **=** (40.70 - 20.70) g = 20.0 g

Mass of salt used = (**w – x**) = (20.70 - 15.20) g = 5.50 g

i.e. 20.0 g of water at 30°C saturated 5.50 g of salt

Therefore, 100 g of water will saturate 5.50 x 100/20 g of salt

i.e. 5.50 x 5 g = 27.5 g of salt.

Hence, the solubility of the salt at 30°C is 27.5 g per 100 g of water.

WORKED EXAMPLES

1. If 11.87g of potassium trioxonitrate(V) were dissolved in 43.4 g of distilled water at 60°C, calculate the solubility of the solute in $moldm^{-3}$

Solution:

Molar mass of KNO_3 = 101g

1g of water = 1cm3 of water

Mass of dissolved KNO_3 = 11.87g

Concentration in $moldm^{-3}$. Of dissolved KNO_3 $= \frac{11.87}{101}$

= 0.118$moldm_{-3}$

43.4g or cm^3 of water at 60°C dissolve 0.118 $moldm_{-3}$ of KNO_3

∴ 1000cm^3 of water at 60°C will dissolve:

$\frac{1000 \times 0.118}{43.4}$ = 2.7 $moldm^{-3}$ of KNO_3

Therefore, the solubility of KNO_3 at 60℃ in water is $2.7moldm^{-3}$

EVALUATION

1. Explain the following terms: (a) solute (b) solvent (c) solution
2. What is solubility? List the different types of solution.
3. Calculate the solubility of $Pb(NO_3)_2$ in $moldm^{-3}$ if 12.2g of the solute were dissolved in 21g of distilled water 20℃.

PERIOD 3: TYPES OF SOLUTION

A solution is a homogenous mixture which is formed when a solute is completely dissolved in a solvent. A solution can be saturated, unsaturated or supersaturated.

1. A *saturated solution* is one which contains, at a given temperature, as much solute as it can hold in the presence of the dissolving substance. That is, a given solute dissolves in a given solvent, such that no more of the solute will dissolve in the solvent at the temperature of dissolution.

2. An *unsaturated solution* is one which contains less solute than it can hold at the given temperature.

3. A *supersaturated solution* is one which contains more of the dissolves substance than it can hold at a given temperature, when the saturated solution is in contact with the solid solution. Super saturated solution are unstable. The excess solute can be separated out by slightly shaking the solution or creating centres of crystallization for the excess solute.

Relationship Between solubility and crystallization

The different solubilities of substances are utilized in their purification by the process of crystallization. In manufacturing KNO_3, solutions of KCl and $NaNO_3$ are mixed. The resulting solution is then concentrated at boiling point and the NaCl is then deposited. The equilibrium in the equation is displaced to the right.

$$K^+ + Cl^- + Na^+ + NO_3^- \longrightarrow K^+ + NO_3^- + NaCl$$

The solution is filtered hot and later cooled. KNO_3, with the lowest solubility, crystallizes out first and is purified by recrystallization :

$KCl + NaNO_3 \rightleftharpoons KNO_3 + Na^+ + Cl^-$

A saturated solution is in dynamic equilibrium with the excess solid present in the solution. The dissolution equilibrium can be expressed in terms of an equilibrium constant, e.g. in the case of silver chloride

$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

EVALUATION

1. Define the term *saturated solution.*

2. Distinguish between saturated and unsaturated solutions.

PERIOD 4. FACTORS AFFECTING SOLUBILITY OF SOLIDS IN LIQUIDS

The four factors that influence or affect the solubility of substances are:

1. Nature of solvent: Generally, ionic compounds are more soluble in polar solvent (e.g. water), than in non- polar increases the solubility of the solvent e.g. NaCl is more soluble in water than in ethanol.
2. Nature of the solute: Ionic compounds are more soluble than covalent compounds and vice-versa. For instance, NaCl is more soluble in water than sugar at room temperature.
3. Temperature: In most cases solubility increases with increase in temperature. In endothermic reactions solubility increases with increasing temperature and vice versa e.g. calcium oxide.
4. Common ion effect: The solubility of an ionic compound in water is affected by the presence of another compound if both compounds have the same cation or anions. For example, the solubility of NaCl in water is much higher than its solubility in dilute HCl because there is a common chloride in NaCl and HCl.

Uses of Solubility curves

1. Solubility curves enable pharmacists to determine the amount of solid drugs in a solution of drug mixture of solids
2. It helps separate and purify mixtures of solids.

3. Used to determine the most suitable solvents for the extraction of solutes from natural sources.

EVALUATION:

1. Mention three factors that affect the solubility of a solid in a liquid.
2. Explain the term common ion effect.

GENERAL EVALUTION

OBJECTIVE TEST:

1. A substance that dissolves in a solvent to form a solution is called (a) acid (b) suspension (c) glue (d) solute
2. The shape of a water molecule is: (a) K-shaped (b) V-shaped (c) N-shaped (d) S-shaped (e) Y-shaped
3. Which of the following birds water molecules together? (a) ionic bond (b) covalent bond (c) hydrogen bond (d) van der Waals forces
4. When a crystal was added to its solution, it did not dissolve and the solution remained unchanged, showing that the solution was. (a) concentrated (b) colloidal (c) saturated (d) unsaturated (e) supersaturated
5. Calculate the solubility of KCl in moldm^{-3} at 30°C if 20cm^{3} sample of a saturated solution of KCl contains 4.50g of the salt. (a) 2.5 (b) 3.0 (c) 3.02 (d) 2.03

ESSAY QUESTIONS:

1. If the solubility of $KHCO_3$ is 0.4 moldm^{-3} at room temperature, at 20°C temperature. ($KHCO_3$ = 100g.mol^{-1})
2. (a) What is solubility curve? (b) Sketch a curve to show how the solubility of a gas varies with an increase in temperature. (c) List two uses of solubility curve.
3. Name and explain any three factors that affect the solubility of a solute in a solvent.
4. Explain why a solid dissolves faster in hot water than cold water
5. (a) How is the solubility of a solute determined? (b) If the solubility of $KHCO_3$ at 20°C is 3.10moldm^{-3} determine whether a solution of $KHCO_3$ containing 303gdm^{-3} at 20°C is saturated or unsaturated.

WEEK 9

TOPIC: AIR

CONTENTS:

1. CONSTITUENTS OF AIR

2. PROPERTIES OF AIR

3. AIR POLLUTION

4. FLAME

PERIOD 1: CONSTITUENTS OF AIR

Air is a mixture of gases, composed mainly of nitrogen and oxygen with small amounts of Carbon (iv) oxide, noble gases and water vapour. The constituents of air can be separated easily by physical methods. Nitrogen accounts for about 4/5 of the atmosphere by volume, while oxygen occupies the remaining 1/5

Percentage composition

The chief natural constituents of air and their percentage composition by volume are as follow:

CONSTITUENT	% BY VOLUME	Importance and uses
Nitrogen	78.09	Acts as important diluent of air to slow down combustion and corrosion
Oxygen	20.95	For cellular respiration and burning
Noble (or rare gas)	0.93	Argon is used to in gas-filled electric lamps because it helps to prevent oxidation in lamp filament. A mixture Krypton and xenon is used in photographer’s flash tube to take high speed pictures

		Helium is used to fill balloons Radon is used for treating cancer Mixture of helium, neon and argon is used in advertisement signs.
Carbon (iv) oxide	0.03	For photosynthesis
Water vapour	Variable(0-1.2)	
Other gases	0.003	

PERIOD 3: PROPERTIES OF AIR

1. Water vapour in air: The presence of water vapour or moisture in the atmosphere is due to the evaporation of water from the oceans, rivers, lakes, sea and water reservoirs. The amount present in air varies with temperature, the prevailing weather and the position of the place.

2. Noble gases in air: Argon is the most abundant of the bobble gases in the air, then neon. Noble gases are generally in reactive. They are used to produce colourful light for advertisement.

3. Carbon (iv) oxide air: The presence of carbon (iv) oxide in air can be proved by the passage of air through aqueous solution of calcium hydroxide (lime water) or KOH. The percentage of carbon (iv) oxide in air is balanced and maintained by the process of respiration and photosynthesis

4. Oxygen in air: oxygen is the most active component of air. It supports life. The process of burning a substance in air is called combustion. Its major reactions include corrosion (rusting), respiration and combustion.

Corrosion: This is the change on metallic surface that is observed after being exposed to air for few days. The corrosion of iron is commonly known as rusting. This can be prevented by (a) Applying grease (b) painting exposed surface (c) coating with metal e.g. chromium

EVALUATION

1. Mention two substances that can be used to remove carbon (iv) oxide from air.

2. List 5 properties of air.

3. What is corrosion? How can it be prevented?

4. State the percentage by volume of CO_2 in the atmosphere.

PERIOD 3: AIR POLLUTION

Air pollution is the released of substances into the atmosphere in quantities that are harmful to lives.

Causes of air pollution

1. COMBUSTION OF FOSSIL FUEL SUCH AS COAL, GASOLINE AND PETROLEUM GASES.

2. RELEASE OF FREONS FROM AEROSOL CANS.

3. RELEASE OF POISONOUS GASES FROM CHEMICAL WARFARE

Air pollutants:

1. Particulate matter: these are materials which exist as micro-sized solids in the air. They include dust, smoke, soot, asbestos, heavy metals particles etc. some of these heavy metals are lead, cadmium, arsenic and mercury. Lead particles are released to the atmosphere from the combustion of petrol in the form of lead (ii) bromide. Exposure to lead pollution over a long period of time is dangerous. This can cause brain damage among children. It also cause irritability, aggressive tendencies and gastric disorder. Mercury causes poison while cadmium causes severe gastric disorder.

2. **Oxides of carbon**: carbon (ii) oxide is released into the atmosphere through incomplete combustion of fossil fuel. It causes brain damage when inhaled even in low concentration. In high concentration, it results to death because it combines with the haemoglobin thereby depriving the body of oxygen. Increased amount of carbon (iv) oxide in the atmosphere leads to increased retention of infra-red rays and hence further warming of the earth-a

phenomenon known as **greenhouse effect.** Therefore carbon (IV) oxide is called greenhouse gas.

3. **Oxides of Sulphur and nitrogen**: Sulphur (IV) oxide is derived from burning of coal, the combustion and refining of petroleum and the smelting of mineral ores for extraction. Once Sulphur (IV) oxide is present in air, it is oxidized by atmospheric oxygen to Sulphur (VI) oxide. The Sulphur (VI) is washed out by rain which converts it to tetraoxosulphate (VI) acid. This is called acid rain. The effect of inhaling the Sulphur (IV) oxide and acid rain are as follow:

(a) Sulphur (IV) oxide causes respiratory disorder.

(b). Acid rain causes death of plants.

(c). Acid rain leads to corrosion of metals, aging of fabrics, stiffening and crack in of leather, and destruction of buildings made of limestone

Nitrogen (ii) oxide causes depletion of ozone layer, and nitrogen (iv) oxide results to acid rain

4. Gaseous hydrocarbons and chlorofluorocarbons: some hydrocarbons in the air are the volatile ones such methane. They have carcinogenic effect in man and animal. Methane is also a greenhouse gas. Chlorofluorocarbons deplete the ozone layer. This exposes the earth to ultra-violet rays which causes skin cancer, sunburns and their ailments.

EVALUATION:

1. What is air pollution?

2. State four air pollutants

3. What is global warming? Name two greenhouse gases.

PERIOD 4: FLAMES

Flames are produced when substances burn. **A flame is a region where gases combine chemically, with the production of heat and light.** The type of flame produced depends on the nature of the substance that is burning. A flame may be luminous (brightly seen and yellow) or non – luminous (barely seen). Types of flame can be explained further using hydrogen, candle and Bunsen flames as examples.

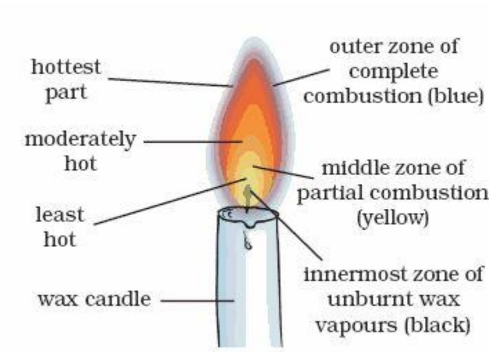
- Hydrogen flame: Hydrogen burns with a very faint, non- luminous flame. The structure is simple, consisting of only regions: the unburnt gas zone and the zone of complete combustion.
- Candle flame: A candle burns with luminous flame four zones can be identified in the flame.

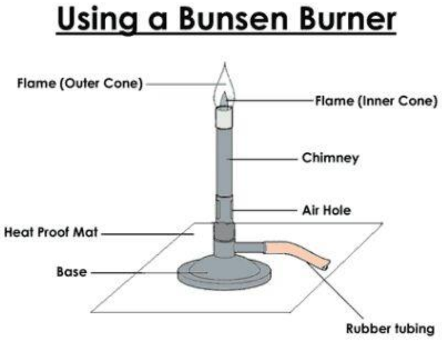
(a) The zone of unburnt gas around the wick

(ii) The bright yellow luminous zone where there is incomplete burning of the hydrocarbon due to insufficient air supply

(iii) The barely visible, non- luminous zone on the outside where complete of carbon particles take place due to sufficient air supply

(iv) The blue zone at the base of the flame which also a region of complete combustion.





- Bunsen flame: A Bunsen burner is built with an air inlet of the base of the burner tube so that a stream of air can be supplied to the flame together with the fuel gas.

  It is important equipment in a school laboratory used for heating. The fuel for the burner is a mixture of hydrocarbon gas (methane and butane) and some hydrogen and carbon (II) oxide

Luminous Bunsen flame: to produce luminous Bunsen flame, the air hole at the base of the burner tube should be closed. The flame produced is high, bright, wavy and yellow but not hot.

Non- luminous Bunsen flame: To produce non- luminous Bunsen flame, the air hole should be kept open. The flame is much hotter, cleaner and more compact than the luminous Bunsen flame.

EVALUATION:

1. Define flame

2. Compare the luminous and non- luminous flame Bunsen flames.

3. Describe the structure of a candle flame and explain the formation the products obtained during the burning.

GENERAL EVALUATION:

OBJECTIVE TEST:

1. These gases burn with blue flames except.

(a) C_2H_2 (b) H_2 (c) CH_4 (d) CO (e) SO_2

2. All these are the causes of luminosity in flames except.

(a) Solid particles (b) size of material (c) solid particles and increased pressure (d) pressure (e) solid particles and increased temperature

3. Which of these is not necessary for metallic corrosion?

(a) SO_2 (b) water (c) heat (d) oxygen (e) CO_2

4. The most abundant noble gas in nature is

(a) Neon (b) Argon (c) Helium (d) Krypton (e) Radon

5. When air is passed through a tube containing finely divided copper, the component of air absorbed is (a) Nitrogen (b) Water vapour (c) noble gas (d) carbon (IV) oxide (e) oxygen

ESSAY TEST:

1. (a) List four examples of noble gases. (b) Compare the structure of luminous and the non-luminous.

2. Give the constituents of atmospheric air, and indicate its approximate percentage composition.

3. Define combustion. Combustion in air would be impossible in the absence of which gas?

4. Draw and label the structures of (a) hydrogen flame (b) candle flame

5. What is rusting and how can it be prevented. (b) Explain any two properties of air.

10. Revision.
11. Examination.