CHEMISTRY

E – LEARNING NOTE

SECOND TERM

CLASS: SS3

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SECOND TERM E-LEARNING NOTES

SUBJECT: CHEMISTRY **CLASS: SSS 3**

SCHEME OF WORK

WEEKS TOPICS/CONTENTS

1. Revision/Nuclear chemistry: (i) Distinction between nuclear reactions and chemical reactions (ii) Half – life.

2. Nuclear reaction- fissional fusion in nuclear reactors (ii) Natural and artificial radioactivity – devices used in detecting radiation (iii) Effects and application of radioactivity.

3. Shapes and molecules: (i) Hybridization – as mixing of orbital: Sp^3, Sp^2, Sp hybrid orbitals (ii) Overlap of orbitals – sigma bonds as head on overlap and pi – bonds as sideways overlap. (iii) Simple shapes of molecules – BCl_3, C_2H_2O, $BeCl_2$ and C_2H_2.

4. Petroleum or crude oil: (i) Origin and composition of crude oil. (ii) Exploration and drilling (iii) Fraction distillation of petroleum and major fractions (iv) location of Nigerian refineries (v) Cracking and reforming (vi) Economic importance of petroleum.

5. Quantitative (Volumetric) Analysis: (i) Acid/Base indicators as weak organic acids/base. (ii) colour of indicators in acid and base (iii) pH range of methyl orange and phenolphthalein. (iv) Titration – determination of concentrations, purity, water of crystallization and composition.

6. Qualitative Analysis: (i) Identification of ions i.e. cation and anions (Preliminary and confirmation) (ii) Test for gases – H_2, O_2, CO_2, NH_3 etc. (iii) Flame test (iv) Test for starch, simple sugar, protein, fats and oils. (v) Hydrolysis of salts

7. Revision.

8 – 10. **MOCK EXAMINATION.**

THIRD TERM

WASSCE/NECO EXAMINATION

WEEK ONE

TOPIC: RADIOACTIVITY AND NUCLEAR ENERGY

Radioactivity

Radioactivity is the spontaneous emission of radiation by an element. Such an element is called a radioactive element. The phenomenon could only be explained in terms of special changes that involved the nuclei of atoms.

Discovery of radioactivity

The phenomenon was discovered by Henri Becquerel, a Physicist, in 1896 when he noticed that a crystal of Uranium salt spontaneously emitted radiation which could penetrate through opaque materials to affect a photographic plate. His further experiments showed that all compounds of uranium exhibit this property; he therefore concluded that the uranium atoms were responsible for the emission and he called the phenomenon radioactivity.

Later researches by Pierre and Marie Curie led to the discovery of thorium, polonium and radium. More than 40 naturally occurring radioactive element have however been found by scientist.

Characteristics of radioactivity

- A radioactive substance emits radiation continuously and spontaneously
- The rate of emission of radiation is not affected by temperature and pressure
- Unlike light ray, the radiation can penetrate through opaque matter
- The radiation, like visible light rays, affect photographic plate
- The radiation ionizes gases through which it passes, causing fluorescence in certain substances like zinc sulphide, and leaving tracks in a cloud chamber.
- Radioactivity is usually associated with a release of very great amount of energy known as nuclear energy.

Differences between nuclear reaction and ordinary chemical reaction

Nuclear reaction Chemical reaction
1. It involves the nucleus of the atom It involves the electrons of the atom
2. It involves very high energy change It involves low energy change
3. It involves the decomposition of the nucleus It involves the transfer, loss, gain and sharing of electrons
4. The rates are not affected by temperature and pressure
The rates are affected by temperature and pressure
5. No breaking or making of bond involved It involves the breaking of old bonds and making of new ones
6 They are irreversible They could be reversible or irreversible

TYPES OF RADIATION

Radioactive radiation consists of 3 main components of different penetrating power namely –alpha(α-), beta(β-)and gamma(γ) rays. These 3 components can be separated and distinguished by their behavior in an electrostatic field.

Alpha rays

These are fast moving stream of positively charged particles, having a mass number of 4, an atomic number of 2 and two units of +ve charge. Thus, each alpha particle is a helium nucleus $^{4}_{2}He$. Since they are positively charged and fairly heavy, alpha particles are deflected slightly towards the negative plate in an electrostatic field.

Properties of alpha rays

1. They are positively charged.
2. They have low penetrating power.
3. They travel only a few centimeters in air
4. They are stopped or absorbed by thin sheet of paper or aluminium foil which is only 0.1mm thick.
5. They exert a very powerful ionizing effect upon any gas through which they pass.
6. They cause fluorescence in some materials e.g ZnS

Beta Rays

These are very fast moving streams of electrons with velocities close to that of visible light. Since they are negative charge and have a relatively small mass, they are deflected toward the positive plates in an electrostatic field. Each Beta particle has a mass number of zero, and a charge of -1 an represented by the symbol

Properties

They are negatively charged.

They have more penetrating power than alpha particles being able to cover a range of 3m in air, pass through a foil, 5mm thick or a lead sheet of 1mm thick.

They are much less effective at ionizing gasses due to their smaller mass and kinetic energy. The ionization power in air is about one-thousandth of that of alpha particles.

They cause florescence in substances like anthracence but not zinc sulphide.

Gamma Rays

Gamma rays are not particles but electromagnetic waves similar to visible light and x-rays but with very short wavelengths of about 5×10^{-9}m.

Properties

1. They travel with the speed of light and are unaffected by an electrostatic field.
2. They have neither mass nor charge.
3. They have highly energetic and can travel for about 100m in air and 0.5m in iron or lead. They have the highest penetrating power of the three particles.
4. They have high penetrating power i.e. can penetrate thick shields such as a lead block of several centimeters thick.
5. They are even less effective in ionizing gases than beta rays. They have the least ionizing power among the three particles.

Summary of the properties of alpha, beta and gamma rays

	Alpha ray	Beta ray	Gamma ray
Nature	Helium nuclei ^4_2He	Electron $^o_{-1}e$	Electromagnetic radiation
Electrical Charge	+2	-1	No charge
Mass	4 units	$^1/_{1840}$ units	No mass
Velocity	About $^1/_{20}$ the speed of light	Varies (from 3 – 99% of the speed of light)	Speed of light
Relative penetration	1	100	10,000
Absorber	Thin paper	Metal plate	Large lead Block

X – rays

X – rays are electromagnetic waves, likes visible light, but with a shorter wavelength. They are produced by allowing fast – moving electrons to bombard metals such as tungsten. The fast moving electrons knock out electros from the inner shells of the metals atoms. The knocked – out electrons are then replaced by electrons moving in from the outer shells. The movement of electrons is accompanied by the emission of x – rays.

Properties and uses of x – rays

1. X – rays can penetrate readily through most solids substances such as wood, foils, flesh and paper, which are opaque to visible light. Hard x – rays have greater penetrating power than soft x – rays.
2. Soft x – rays are used in medicine to photograph human parts while hard x – rays are used for destroying cancerous cells.
3. In chemistry, x – rays are used to study the arrangement of particles in crystal lattices and in big organic molecules like proteins.

DETECTION OF RADIATION

1. Geiger – Muller counter
2. Crooke's sprinthariscope (scintillations)
3. Diffusion cloud chambers
4. The pulse(wulf) electroscope
5. Solid state detector
6. Photographic plate
7. Dekatron counter
8. Ratermater (scaler)

Different types of devices have been developed over the years for detecting radiation. The most commonly used detectors are the Geiger-Muller counter, the scintillation counter and photographic plate or solution, the diffusion cloud chamber.

Geiger- Muller counter

The Geiger - Muller counter is based on the ionizing effect of radiation on gases. The device consists of an ionizing chamber in which two metal electrodes are sealed, and which is filled with a gas, usually argon, at very low pressure together with a little bromine vapour. A potential difference of about 450 volts is maintained between the electrodes. When an ionizing particle or radiation enters the chamber, some argon atoms are ionized. The electrons produced then drift to the positive terminus while the positive ions migrate to the negative one. A small current, known as a pulse current, is obtained for a short while. This current is amplified and may be detected by suitable equipment, for example, in form of

1. Audible clicks from a loudspeaker;
2. Movement of the needle of a rate meter; or
3. Reading recorded in the register of a scaler.

Geiger – Muller counter can also be used to measure the intensity of radiation because, the count rate is proportional to the intensity of the radiation.

Radioactive disintegration

The spontaneous disintegration of the nucleus of an atom is known as radioactivity. When a certain quantity of a radioactive material disintegrates spontaneously the word **decay** is used. During the decay, there is usually an emission of alpha – or beta particles. Sometimes, gamma rays also accompany the emission of these particles. The outcome of the disintegration is that the parent nucleus (nucleus undergoing disintegration) undergoes a change in the atomic number and become the nucleus of a different element. The new nucleus is called the daughter nucleus and the process is called the transmutation of an atom.

In a radioactive decay, the mass number of the disintegrating elements must be equal to the sum of mass number of radiation lost and that of the resulting elements. Examples of radioactive decay are Alpha decay, Beta decay, and Gamma decay.

Radioactive decay is a random process and the rate depends on the radioactive material. The rate cannot be altered by any physical or chemical process. Meanwhile, in all cases the element disintegrates at a certain definite rate which follows an exponential law whereby a certain definite fraction of the atoms present in the element disintegrates every second.

Alpha Decay: When the nucleus of an atom loses an α-particle .i.e. a helium nucleus ( ) during disintegration, the atomic number of the atom is reduced by two units and its mass number by four units, e.g. when an atom of uranium 238, loses an alpha particle, it will become an atom of thorium ℎ. The nuclear reaction is written thus:

ℎ + (α-partcle)

Beta Decay: this kind of radioactive change is equivalent to the splitting of a neutron in the atomic nucleus of the radioactive element into an electron and a proton which remains in the nucleus. The mass number does not change but the atomic number increases by one.

For example, if a thorium nucleus ℎ emits a β particle, its nucleus changes into a nucleus of the element protactinium whose mass number is the same as that of thorium but whose atomic number is increased by one unit from 90 to 91.

ℎ + β-particle

Or + β-particle

Gamma Decay: In gamma decay, only energy is released and no change in the mass number or atomic number. It accompanies α or β decay.

+ β-particle + γ-rays.

Radioactive decay series

Most of the times, the neclei of the daughter element formed by transmutation is itself munstable, and will undergo further disintegration after some times which may vary from few microseconds to millions of years. Thus, a series of changes may occur until a stable nuclues is finally formed. Examples include the uranium series, thorium series and actinum series, each of which named after the longest-lived element in the series.

Element and radiation emitted Isotope Half-life
Uranium
Α 4.5×10_6years
Thorium
Β ℎ 24.1 days
Protactinium
Β 1.18 minutes
Uranium
Α 2.5×10_5years
Thorium

A ℎ $8.0\times10_4$years
Radium
A 1622 years
Radon
A 3.8 days

Half Life as a Factor of Stability of Nucleus

The half life of a radioactive element is the time taken for half of the total number of atoms in a given sample of elements to decay. For example, the half-life of radium-226 is 1622 years. This means that if we have 1 million radium atoms at the beginning, then at the end of 1622 years, 500,000 atoms would be disintegrated, leaving 500,000 undecayed radium atoms. In the next 1622 years, half the remaining atoms i.e. 250,000 would be disintegrated, leaving 250,000 undecayed atoms of radium and so on.

The radioactive isotopes of most common light elements have short half-life (a few days or weeks) and decay rapidly to vanishing point. That is why they are not found in nature to any noticeable extent.

The stability of an atomic nucleus is related to the ratio on neutrons to protons in the nucleus. Atoms with neutron-proton ratio less than 1 or greater than 1.5 tend to be unstable and undergo radioactive radiation.

Nuclear Chemistry and Reactions

Nuclear chemistry is concerned with reactions that involve nuclei taking part. When nuclear particles like proton, neutrons, alpha and beta particles as well as electrons and gamma rays are used as bullets for bombarding the nuclei of some atoms, one or two of the following events may take place:

a) Artificial radio isotopes may be created
b) Atomic transmutation may occur

This transmutation is the process by which radioactive elements change into different elements.

Artificial Transmutation

Due to the fact that large amount of heat is released from radioactive disintegration, the scientists devised a means of tapping, controlling, harnessing and using this great amount of energy. This results in artificial transmutation since the natural transmutation is not subject to human control i.e. spontaneous. In 1919, Lord Rutherford succeeded in transmuting a nitrogen isotope into an oxygen isotope by bombarding the nitrogen isotope with alpha particles.

+ +
Proton

Many atomic transmutations can be carried out by bombarding various elements with **fast-moving atomic particles like neutrons, protons, deuterons (nuclei of deuterium atoms) and alpha particles.** The neutron is a very effective bombarding particle because it is heavy and has no charge.

Generally, when light elements are bombarded by neutrons, new elements are formed by ejecting charged particles e.g.

+ +
Neutron

But, if the nucleus being bombarded is heavy, it captures the neutron to produce an isotope of the original element. +

Nuclear Fission

Nuclear fission is a process in which the nucleus of a heavy element is split into two nuclei of nearly equal mass with a release of energy and radiation.

In 1939, Halm a German nuclear scientist discovered that atomic nucleus of isotopes of uranium could absorb a neutron and then break into two (this process is called atomic fission) e.g.

+ + + 2 + energy

He observed that the total products of fission have a mass slightly less than that of the total initial material. This difference of mass is radiated as energy, the amount of energy being stated by the equation of Einsten: $E = mc_2$ where E= energy in joules, m= mass in Kg, c = velocity of light in s_{-1}.

In any nuclear fission, a large amount of energy is released. This release of energy has now been harnessed in nuclear reactions which are used in power stations and nuclear submarines.

Nuclear Fusion

Nuclear fusion is a process in which two or more light nuclei fuse or combine to form a heavier nucleus with a release of energy and radiation.

It is the opposite of nuclear fission. Greater energy is released during nuclear fusion than during nuclear

fission because of the differences in the binding energies of the isotope.
+ + + energy
This process is applied in the making of hydrogen bombs. The sun and stars also obtain their energy from nuclear fusion reactions.

Uses Of Radioactive Isotopes

1. **Medical Uses:** for the treatment of cancer, small quantities of gamma emitting radioactive isotope like cobalt 60 are used for the treatment of tumors as their radiation destroys cancerous cells. Iodine – 131 and phosphorus -32 are used in treating cancer of the thyroid gland and leukemia respectively. Also alpha rays can kill bacteria with little or no temperature rise in the affected material. They are therefore used in the sterilization of hospital equipment and in the pasteurization of foods.
2. **Agricultural purposes**: radiation is used in insect and pest control. For example, the male pupae of an undesirable insect are sterilized by radiation, so that sterile male adults are produced. They are then released in large numbers to mate with the native female adults which will lay unfertilized eggs.
3. **Radioactive tracers**: since a radioactive isotope is continually giving out radiation, it is possible by means of a sensitive counter to trace its position and measure its concentration and thus follow its course through a series of changes or reactions when a small quantity of it is mixed with its stable isotope as both of them will behave the same way and participate in the same reaction. This technique has been used to study many metabolic processes in both plants and animals e.g. the uptake of iodine by the thyroid gland using iodine-131 and the course of photosynthesis using carbon-14 in the form of carbon(IV)oxide. It is also used in medicine for the tracing of the movement of materials or food through the alimentary canal.
4. The radioactive isotopes are also used in generating electricity from nuclear reaction occurring in nuclear power stations.
5. **In Radiological Dating:** Radioactive carbon isotope (with half life of about five thousand years) is used for dating organic materials. In this method the radioative contents of the specimen is measured and its age is determined from this value and the half life of the isotope. The presence of very long – lived radioisotope (e.g uranium 238 with a half life of 4.5×10^9 years) in the earth crust is utilized by geologists to estimate the age of rocks and archaeological objects. It is also used in distinguishing genuine antiquities from fake ones.

Assignment
Briefly discuss the following
- Atomic pile and atomic bomb
- Binding energy
- Nuclear energy for power

WEEK TWO

TOPIC: ASTRONOMICAL CHEMISTRY

Age of the earth

The most exact method for determining the age of the earth is the study of the radioactivity of certain minerals in which one or more radioactive elements decay to form other elements. As the radioactive element decays, its quantity in a particular rock decreases while the quantity of the daughter element increases. Scientist are able to calculate the age of the rock or mineral from
- The decay rates of the radioactive element and
- The ratios of the parent and daughter elements.

The radioactive isotopes most commonly used for these studies include carbon-14, rubidium-87, potassium-40, uranium-235, uranium-238 and thorium-232. The quantities are measure by radiation detectors. Studies using this method show that the oldest known rock on earth was formed nearly 4.0×10^9 years ago. Based on this, we can say that the Earth is between 4.5×10^9 to 5.0×10^9 years.

Structure of the earth.
The earth is made up of three parts;
1. The atmosphere which is the layer of air that surrounds the planet
2. The hydrosphere which is the part composed of water and
3. The lithosphere which is the solid part

Atmosphere

The atmosphere comprises of the troposphere, stratosphere, mesosphere, thermosphere and exosphere. It is the gaseous part of the earth crust consisting of about 78% nitrogen, 21% oxygen and 1% other gases including carbon(IV) oxide, water vapour and rare gases. The atmosphere extends to a height of more than 450km from the surface of the earth.

The troposphere is the lowest layer (up to about 10km at the poles and about 17km at the equator above the earth's surface). Great changes in temperature and vapour content of the air takes place here. Cloud formation, the rains, thunder and lightning occur here.

The stratosphere is the zone of horizontal air movement. It extends to about 45km above the surface of the earth (from the end of the troposphere). The temperature increases from about -60$_0$C at an altitude of 10km to
0$_0$C at about 45km. this is due to the absorption of ultraviolent radiation by the ozone layer in the stratosphere.

The mesosphere extends from the 45km to about 75km above the earth's surface. The air is less dense than that of the stratosphere. The temperature varies from 0$_0$C at an altitude of 45km to -90$_0$C at about 75km.

Extending from 75km to about 400km above the earth's surface is the thermosphere (or ionosphere). The air in this layer is thin. The region beyond 400km is known as the exosphere. The air in this layer is extremely thin and consists mainly of hydrogen. The layer continues indefinitely and eventually merges with the sun's atmosphere.

Hydrosphere

This is the liquid part of the earth crust. About 71% of the earth's surface is composed of water. Approximately 98% of the water is in form of salt – water in oceans and seas. The earth is the only planet in the solar system that contains large amount of water.

Lithosphere

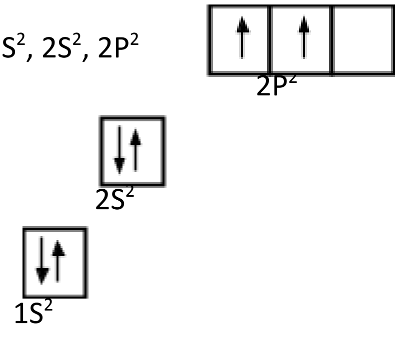
The lithosphere is composed of rocks and soil. It may be considered to be made up of three parts; the crust, mantle and core. The outermost part is called the crust and extends to a depth of about 30km in the continental areas and about 8km in the main ocean floors. After the crust is the mantle. The mantle is about 2900km thick and is thought to be plastic i.e. neither solid nor liquid. The core, surrounded by the mantle is composed of

WEEK 3

HYBRIDIZATION IN CARBON

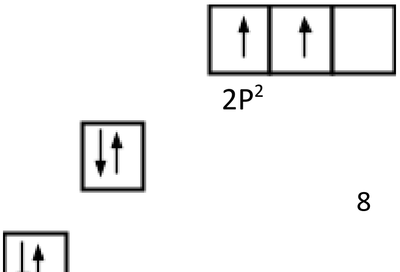
Carbon belongs to group four in the periodic table of elements. The atomic number of carbon is six and its electronic configuration is written as:

$1S^2, 2S^2, 2P^2$



In all organic compounds, carbon exercise a covalency of four. This is obtained by unpairing the paired 2S orbital electrons and promoting this to the empty 2Pz orbital to give the excited state configuration. Thus, we can distinguish between the ground and excited state configurations:

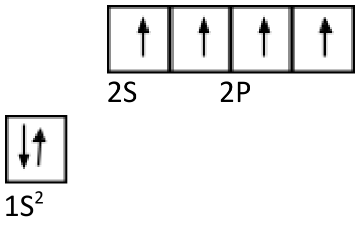
Ground State configuration



2S^2

1S^2

Excited Sate Configuration:



It is the mixture of these four orbitals in the excited state (2S and three 2P) containing an electron each that gives carbon its tetravalency in all organic compounds.
The mixing of atomic orbitals to form equivalent molecular orbital is called **hybridization**. The product of hybridization are called hybrid or molecular orbitals which are of equivalent energies. Three modes of hybridization have been identified in carbon.
These are Sp^3, Sp^2 and Sp.

Sp^3 Hybridization

In this type, one 2S atomic orbital is mixed with three 2P orbitals to form four Sp^3 hybrid orbitals, in which each orbital is pointing towards a corner of a regular tetrahedron shape. The bond angle is 109.5^0. when these orbitals are used in bonding, they form very strong bonds called sigma bonds.

This type of hybridization is found in all saturated compounds, for example as in all Alkanes. Let take ethane (C_2H_6) as an example (the four hybrid orbitals are displayed on each carbon atom as well as the S-orbital of hydrogen atoms)

Sp^2 Hybridization

In Sp^2 hybridization, one 2S atomic orbital is mixed with two of the three 2P orbitals to form four Sp^2 hybrid orbitals, which is triangular in shape with a bond angle of 120^0. when these orbitals are used in bonding, they form very strong bonds called sigma bonds. However the unused 2Pz orbital can overlap laterally to form another bond which is weaker than sigma bond. It is called a Pi bond. These two bonds (Sigma and Pi) give compound containing 2P^2 hybrized carbon atoms double bonds. This type of hybridization is found in all Alkenes. Example ethene (C_2H_4).

Sp Hybridization

In Sp hybridization, one 2S atomic orbital is mixed with one of the three 2P orbitals to form four Sp hybrid orbitals, which is linear in shape with a bond angle of 180^0. when these orbitals are used in bonding, they form very strong bonds called sigma bonds. However the unused 2Py and 2Pz orbital can overlap laterally to form another bonds which is weaker than sigma bond. It is called a Pi bond. These bonds (Sigma and two Pi) give compound containing 2P hybrized carbon atoms triple bonds. This type of hybridization is found in all Alkynes. Example ethyne (C_2H_2).

WEEK 4

TOPIC: PETROLEUM AND CRUDE OIL.

CONTENTS:

1. HYDROCARBON AND ITS MAIN CLASSES
2. CRUDE OIL AND NATURAL GAS- FRACTIONAL DISTILLATION OF CRUDE OIL AND USES OF PETROLEUM FRACTIONS
3. CRACKING OF PETROLEUM FRACTIONS, REFORMING, OCTANE NUMBER AND KNOCKING
4. IMPORTANCE OF CRUDE OIL AND PETROCHEMICALS

PERIOD 1: HYDROCARBON AND ITS MAIN CLASSES

Hydrocarbons, as the name implies, are compounds of only two elements; hydrogen and carbon. There are many such organic compounds.

Hydrocarbons are usually classified into two main groups namely, saturated and unsaturated hydrocarbons.

1. Saturated hydrocarbons (Alkanes). The alkanes have the general molecular formula $C_nH_{2n+2.}$. Members of this group include Methane, CH_4, ethane, C_2H_6, propane, C_3H_8, butane, $C_4H_{10.}$ The structure of butane is given below.

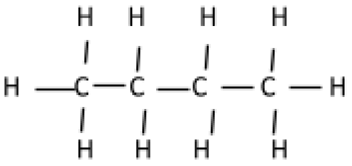
2. Unsaturated hydrocarbons (Alkenes and alkynes). The alkenes have the general formula is C_nH_{2n}. Members of this group include ethene, C_2H_4 propene, C_3H_6butene, C_4H_8etc

Hydrocarbons can be classified into:

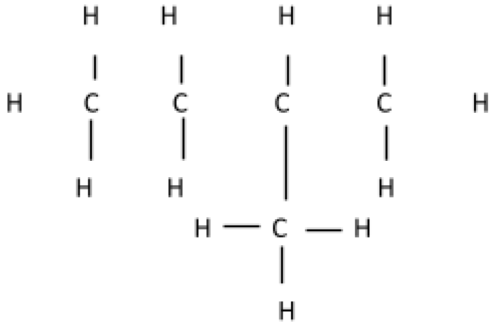
1. Aliphatic compounds
2. Aromatic compounds

Aliphatic compounds are classified into two sub-classes: 1. Acyclic compounds 2. Cyclic compounds

In acyclic compoundsthe molecules are made up of straight chain carbon atoms or branch chain e.g.Butane (a straight chain compound)

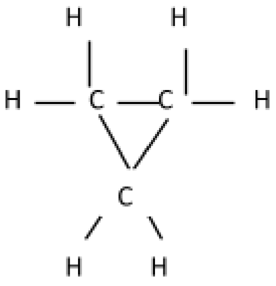


2 methyl butane (a branched chain compound)



In cyclic compoundsthe end carbon atoms of an open aliphatic chain can also join together to form a closed system or ring e.g.

Cyclopropane



AROMATIC COMPOUNDS

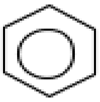
Aromatic compounds are Benzene or derivative of benzene (that is compounds whose structures are based on the structure of benzene)

Due to resonance exhibit by the structures of benzene, i.e.

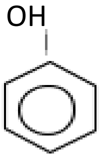
(ii)

The structure of benzene would be (i) or (ii)

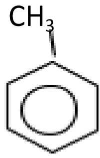
Conventionally the structure of benzene is now a hexagon with a ring within it.



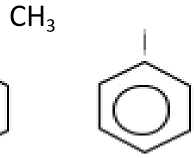
Examples of other derivatives of benzene,



Phenol

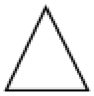
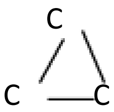


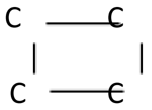
Toluene

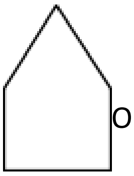
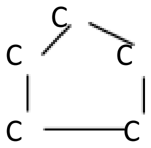


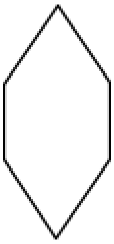
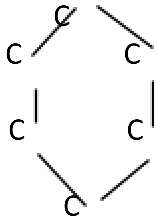
Xylene

EVALUATION:
Name the following aliphatic compounds.

(1)  OR 

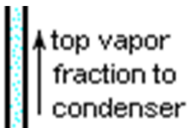
(2)  OR 

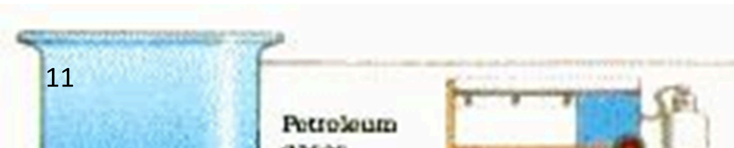
(3)  OR 

(4)  OR 

PERIOD 2: CRUDE OIL AND NATURAL GAS, REFINING OF CRUDE OIL AND USES OF PETROLEUM FRACTIONS
Another name for crude oil is petroleum. It is the chief source of hydrocarbons. Crude oil occurs as a dark, sticky, viscous liquid. It is believed that crude oil is formed by the gradual decomposition of the remains of marine plants and animals that became incorporated in the sediment and rocks formed at the bottom of the sea.
Crude oil is a mixture of gaseous, liquid and solid alkanes, cycloalkanes, aromatic hydrocarbons etc.
Natural gas; Natural gas is usually found together with crude oil; and water in traps or reservoirs in between some layers of rocks at the bottom of the sea. Natural gas consists mainly of methane. It is used as a domestic and industrial fuel.
In Nigeria crude oil is found in Oloibiri in 1956. In Niger Delta, Calabar and in Burutu in Delta state.
REFINING OF CRUDE OIL AND USES OF PETROLEUM FRACTIONS
Crude oil must be refined to make useful fuels and chemicals. The crude petroleum taken from the oil fields to refineries is processed in three stages: separation, conversion and purification.
Fractional Distillation of oil
Petroleum products are the fractions obtained directly from the fractionating tower where the crude oil has been refined by fractional distillation. The separation of petroleum fractions is based on the differences in their boiling points. The amin products or fractions are shown in the table below:

	Fraction	No. of Carbon atoms	Boiling points	Uses
1.	Petroleum gas	C_1- C_4	Below 40^{O}c	Fuel and manufacture of other organic compounds
2.	Petrol or gasoline	C_5-C_{10}	40 - 200^{O}C	Used as fuel in motor cars and generators
3.	Kerosene or Paraffin oil	C_{11}- C_{15}	200 – 250^{O}C	Used as aviation fuels in aircraft and also as fuel for lantern
4.	Diesel or light gas oil	C_{16} – C_{20}	250 -350^{O}C	Used as fuels in engines or buses, trains, boats, tractors etc.
5.	Lubricating oil	C_{20} –C_{30}	350 – 500^{O}C	Used in candle making, creams, hair care products.





FRACTIONAL DISTILATION OF CRUDE OIL

EVALUATION:

1. Explain the formation of crude oil.
2. Mention four fractions of petroleum and their uses

PERIOD 3: CRACKING OF PETROLEUM FRACTIONS, REFORMING, OCTANE NUMBER AND KNOCKING

CRACKING AND REFORMING

The quality of petrol obtained from the Fractional distillation of crude oil is about 20% by volume.

Cracking is therefore employed so as to provide more petrol, since its demand is high and as a source of alkenes.

CRACKING: cracking is the process whereby large molecules of heavy oils are broken into smaller molecules (light oils) at high temperature, pressure and in the presence of a catalyst. Usually petroleum fractions with more than eleven carbon atoms in their molecules can be cracked.

During cracking, ethene, C_2H_4 is produced; it is the major raw material in the petrochemical industry.

CRACKING TECHNIQUES

The two main cracking processes are: thermal cracking and catalyst cracking.

There is also a less common cracking known as hydro cracking.

1. THERMAL CRACKING: Thermal cracking involves heating heavy oils, such as lubricating oil, diesel oil and kerosene to about 600^0C under pressure; it leads to the decomposition and formation of a mixture of more volatile alkanes, alkenes and hydrogen. The mixture is then separated by fractional distillation. e.g.

$$\underset{\text{Kerosene}}{C_{11}H_{28}} \longrightarrow \underset{\text{(Alkane) petrol}}{C_8H_{18}} + \underset{\text{Alkene propene)}}{C_3H_6}$$

2. CATALYTIC CRACKING: in catalytic cracking, the heavy oil is heated to about 500^0C under reduced pressure and in the presence of natural clay (a mixture of silicon (iv) oxide and aluminium oxide) as the catalyst. Under these conditions, a mixture of alkanes and alkenes, which can be separated by fractional distillation, is obtained e.g.

$C_{18}H_{38} \longrightarrow C_6H_{14} + C_8H_{16} + 2C_2H_4$

Note: note that the products of cracking depend on the starting material and the reaction conditions, such as temperature, pressure and the nature of the catalyst used.

In hydro cracking, hydrogen is passed into the reaction mixture during the cracking process. Under this condition, only the lower saturated alkanes are obtained.

REFORMING: In reforming the molecules do not crack but are reformed or reshaped. In reforming straight chain alkanes are converted catalytically into branched chain isomers, cycloalkanes and benzene, the purpose is to convert low grade petro to higher grades, i.e. improve the quality. Reforming techniques includes:

ISOMERISATION, CYCLIZATION AND AROMATIZATION

DIFFERENCE BETWEEN CRACKING AND REFORMING

1. Cracking involves breaking large molecules of petrol fractions into smaller molecule, while reforming involves rearrangement of atoms in the molecules of petroleum fraction to obtain branched and cylic hydrocarbons.
2. Cracking can be achieved thermally or catalytically, while reforming is in the presence of a catalyst.
3. Cracking occurs at a temperature higher than that of reforming.
4. Cracking is employed to increase the quantity of petrol, while reforming is to improve its quality.

OCTANE NUMBER OR RATING

Each grade of gasoline (petrol) is rated according to the term octane number. The octane rating or number is based on the proportions of the straight chain heptane, C_7H_{16} and the branched- chain 2,2,4 –Trimethylpentane, an isomer of C_8H_{18} called iso-octane in petrol. When petrol with a high proportion of straight chain, heptane is used in the engine of a vehicle, the combustion will not be smooth, and can knock the engine, i.e. damage the engine, while petrol with a high proportion of the branched chain 2,2,4-Trimethylpentane burns smoothly and does not cause knocking in engines. The higher the octane number of petrol, the lower the knocking tendency.

EVALUATION:

1. What is the advantage of catalytic cracking over thermal cracking.
2. Mention the methods of reforming gasoline.
3. Mention two ways of improving the octane number of petrol.

PERIOD 4: IMPORTANCE OF CRUDE OIL AND PETROCHEMICALS

In Nigeria, natural gas is used as fuel for heavy duty vehicles and engines. The gas power stations Ughelli and Sapele use natural gas to generate electricity.

Economic importance: Nigeria proposes to set up a liquefied natural gas plant. This will enable Nigeria not only to increase its natural gas consumption at home, but also to express the gas.

Petroleum and natural gas are now used in increasing amounts to produce many organic compounds e.g. Ethanol, ethane, propane 1,2,3-triol, benzene, toluene. These are in turn used to make large- molecule organic compounds like plastics, synthetic rubber, insecticides, detergents, synthetic fibres like nylon and dacron. The oil industry has provided employment in various aspects at the industry.

EVALUATION:

1. Name some places in the Niger Delta in Nigeria where crude oil is found.
2. Write short not on this: IMPORTANCE OF HYDROCARBONS.

GENERAL EVALUATION

OBJECTIVE TEST:

1. Oil deposits in Nigeria are (a) on land and offshore (b) only offshore (c) mainly imported (d) downstream
2. Fractional distillation involves the following process (a) boiling (b) boiling and condensation (c) boiling, evaporation and condensation (d) condensation and collection
3. Which is the odd- one out of? (a) petroleum ether, petroleum gases, kerosene (b) gas oil and diesel lubricating oil (c) petroleum ether and bitumen (d) Haematite and asphalt
4. Which of the following is a source of hydrocarbons? (a) Haemitite (b) marble (c) coal (d) slag
5. Crude oil can be obtained in Nigeria in the following places except. (a) Afam (b) Abata (c) Owaza (d) Kano

ESSAY QUESTIONS

1. Describe how you would show that crude oil is not a single compound.
2. (a) What are hydrocarbons? (b) Give three examples and their main sources in nature.
3. With the help of a diagram, briefly describe the industrial fractionation of petroleum.
4. Write short notes on (a) crude oil (b) Natural gas
5. Name four fractions of petroleum stating their uses.

WEEKEND ASSIGNMENT:

Read the topic 'Fractional distillation of crude oil'

WEEKEND ACTIVITY:

On a cardboard sheet draw how crude oil and natural gases are formed.

PRE READING ASSIGNMENT:

Read all the notes for this third term.

WEEK 5

VOLUMETRIC ANALYSIS

INTRODUCTION

Volumetric analysis is an aspect of quantitative analysis which involves the measurement of the volume of reacting solutions in order to find the masses of substances dissolved in them.in other words, two solutions are given; one is a solution of an acid and other a solution of a base .one of them is a standard solution and you are required, by titration to standardize the other.

The other aspect of quantitative analysis is gravimetric analysis, which involves weighing and determining the masses of reactants and products of a chemical reaction.

The most popular aspect of Volumetric analysis is the acid – base (neutralization) reactions. The technique of determination is by titration. Other aspects are redox and precipitation reaction.

APPARATUS USED IN VOLUMETRIC ANALYSIS ARE:

The burette, pipette, beaker, flasks, funnel, wash bottle, chemical balance, dropping pipette and retort stand.

Basic definitions in volumetric analysis

I.TITRATION: It is the technique for carrying out volumetric analysis.

II.CONCENTRATION: The concentration of a solution is the amount of solute in a given volume of the solution.

III.STANDARD SOLUTION: It is a solution containing a known amount of solute in a known volume of solution. An example of a standard solution is a molar solution.

IV.MOLAR SOLUTION: It is a solution which contains one mole of solute in 1dm^{3}solution.

V.BUFFER SOLUTION: It is a solution which resists a change in p^H or H$^+$upon further addition of acid or alkali. Buffers are usually made of solutions of a weak acid and its conjugate base or a weak base and its conjugate acid. The weak acid usually has a p^H value lower than 7 and is therefore used to buffer systems in the basic region. Examples of buffers solution and their p^H ranges over which they are effective are given below:

BUFFER SYSTEM	P^H RANGE
Ethanoic acid/Sodium ethanoate(CH_3COOH/CH_3COON_A)	4.25-5.25
Trioxocarbonate(iv)(carbonic) acid/Sodium hydrogentrioxocarbonate	5.87-6.87
Ammonia/Ammonium chloride(NH_3/NH_4Cl)	8.75-9.75
Sodiumtrioxocarbonate/sodiumhydrogentrioxocabonate	9.75-10.75

MOLAR MASS: This is the mass of one mole of a substance expressed in grams. Its unit is gram per mole.

END POINT: This is the point at which the chemical reaction is complete during titration. The end point is detected with the help of an indicator.

INDICATORS: These are weak organic acids or bases whose colors change with pH of the solution. Indicators are widely used in monitoring titration involving colorless solutions of acids and bases.

DIFFERENT INDICATORS AND THEIR COLOURS IN DIFFERENT MEDIA

INDICATOR	COLOUR IN ACIDIC MEDIUM	COLOUR IN ALKALINE MEDIUM	COLOUR AT END POINT
Methyl Orange	Pinkish red	yellow	Orange

Phenolphthalein	Colorless	red	colorless
Litmus	Red	blue	Pink/purple
Methyl red	Pink	yellow	orange
Screened methyl orange	Purple(violet)	green	grey
Bromothymol blue	Yellow	blue	green

UNIVERSAL INDICATOR: This is a mixture of indicators used either as solution on a test paper to test the p^H value of a solution. The pH scale is shown below:

Red pink yellow green blue indigo (deep blue) violet (bluish purple)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Acidity increases Alkalinity decreases

EFFECT OF WRONG USE OF INDICATOR

The success of a titration exercises depend on the use of the correct indicator. Wrong use of indicator will definitely give wrong result. For instance, let's consider a case of the titration of a solution of a wrong acid say HClwith that of a weak base say Na_2CO_3, methyl orange is the suitable indicator, but if phenolphthalein indicator is used instead, the end point will appear when only half of the weak base has been used up. This can then be represented with the following equation.

$$HCl + Na_2CO_3 \xrightarrow[\text{Indicator}]{\text{Phenolphthalein}} NaHCO_3 + NaCl$$

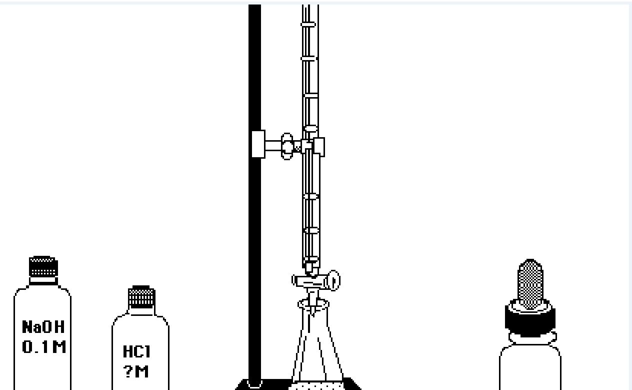
This happened because the phenolphthalein is sensitive to a weak acid such as Na_2CO_3.

TITRATION	EXAMPLE	P^H RANGE	SUITABLE INDICATOR
1.Strongacid vs. strong base(3-11)	$H_2SO_{4(aq)}$ and $KOH_{(aq)}$	3.5 – 9.5	Any indicator is suitable.
2.Weak acid vs. strong base(7-11)	$H_2C_2O_4$and NaOH	7.0-9.5	phenolphthalein
3.strong acid vs. Weak base(3-7)	$HCl_{(aq)}$and$NH_{3(aq)}$ or $K_2CO_{3(aq)}$ or $Na_2CO_{3(aq)}$ or $Ca(OH)_{2(aq)}$	3.5-7.0	Methyl orange or screened Methyl orange
4 Weak acid vs. Weak base	$CH_3COOH_{(aq)}$ and $NH_{3(aq)}$	No sharp change	No suitable indicator. Or phenol red.

IMPORTANCE OF VOLUMETRIC ANALYSIS

Standardize unknown solution
Calculate molar mass, water of crystallization and solubility.
Determine the purity of substances.
Determine the masses of substances dissolved.
Faster and more convenient

GENERAL PROCEDURES AND PRECUTIONS DURING ACID –BASE TITRATION



STEPS INVOLVES IN FILLING THE BURETTE WITH DILUTE ACIDES

STEP1. Clamp the burette in a vertical position to avoid error due to parallax while taking reading. Rinse it with the given acid solution, alloing part of the acid to pass through the tap and the jet. Then cloe the tap.

STEP2. With the funnel at the top of the burrette, fill the burettewith acid to a desired level ensure that the jet is filled with acid to avoid air bubbles inside it.tightly close the buette tap to avoid leakages. Remove the funnel toavoid droplets of acid from it.Hold a piece of white paper behind the burette so that the acid level is clearly shown and note the reading of the burette.

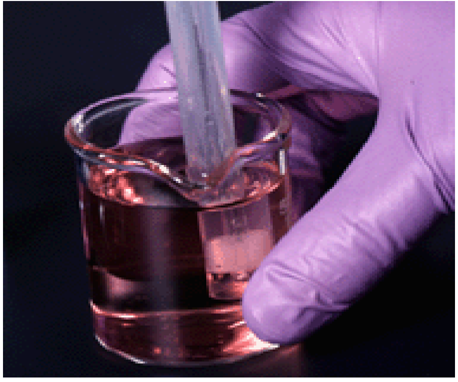
STEPS INVOLVES IN MEASURING 25.00Cm^3 (20.00Cm^3) of standard base solution.

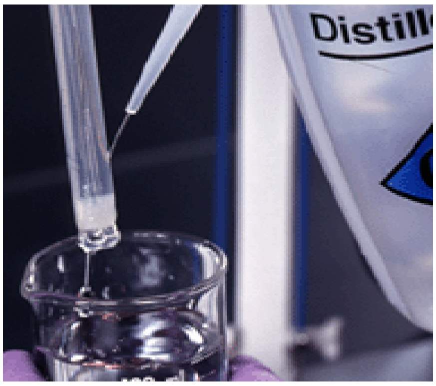
STEP1. Collect four conical flasks and wash with distiled water only. Make sure that none of the flasks contain any acid or alkali.

STEP2. Rinse the pipette with the given base solution.

STEP3. Suck the base solution into the pipette until the level is about 1cm^3 or2cm^{3}above the forefinger. Gently release the pressure until the bottom of the concave meniscus is at the graduation mark,with the eye level aligned.

STEP4. While filing the pipette ensure that the jet lies well inside the base solution to aviod air bubbles in the pipette.





STEP5. Run the base solution into one of the conical flasks.the sides of the flask should not be splased with the solution as the splasings may not be neutralised by acid later in the experiment. To removethe little alikali retained at the tip of the pipette after delivery,do not blow out thepipette or shake out the last drop of the solution but allow the pipette to drain for about 15 seconds and then allowthe tip of the pipette to touch bottom of the flask.

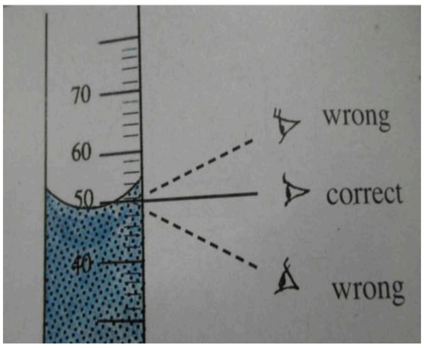
STEP6. Fill the remaing conical flasks as stated above.

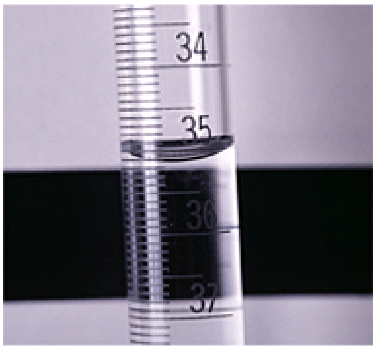
(C)STEPS IN INVOLVES IN TITRATION OF THE ALIKALI SOLUTION WITH DILUTED ACID SOLUTION.

STEP1. Add 2 drops of the given indicator to each conical flask to obtain a shape end-point.

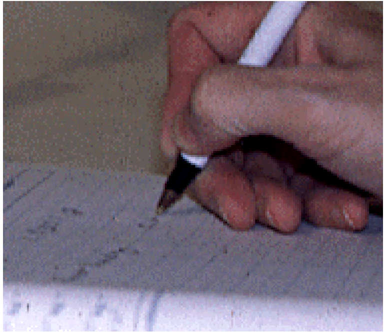
STEP2. Place one of the conical flasks on a piece of white paper or white tile beneath the burette to aideasy recognition of colour change at the end point.Run in the acid from the burette addingabout 1.00cm^3 at a time. Shake the conical flask gently during titration to ensure homogeneity of the two solutions but aviod spillage of the reacting solutiopns. Note the level of the acid when the colour of the indicator changes.this first titration is the trial or roug titration.

STEP3. Repeat the above procedures for the base in other three conical flasks.Take burette readings at the lowest concave meniscus for each titration.





These should be taken at the eyes levels to avoid error of parallax.the volmes of the acids used in the second,third and fourth accurate titrations should agree within ±0.20cm^3 and should always be recorded to two places of decimals. These make a concordant orconcurrent results to be obtained.Record all your readings as they are taken and do not try to remember them or write on scripts of papers.



TITRATION PRECUTIONS

1. The burette must be clamped vertically or not tilted.
2. Wash the burette and pipette with water andrinse with distiled water.
3. Rinse the burette with acid,the pipette with base (alkali)before putting these solutions into them.
4. Ensure no air bubbles in the burette or pipette.
5. Remove the funnel after putting the acid into the burette(if a funnel is used).

6. The content of the pipette should be allowed to run into the conical flask without blowing air into it.
7. Use a drop or two (small amount)of indicators.
8. Read the lower meniscus.
9. Ensure the tap of the burette is not leaking.

NOTE: Most examination bodies have different ways of assessing students practical skills and report writing procedures. For instance, the following are some of the penalities.
(i) Use of pencil;   -2marks
(ii) Alteration(cancillation) on table of titrevalues; -2marks foreach,maximum of -4marks.
(iii) No unit or wrong unit on table; -1mark.
(iv) Non concordant values(i.e.difference greater than pluse or minus 0.2)for average titre value; -1mark.

STEPS IN RECORDING OBSERVATIONS MADE DURING ACID- BASE TITRATION EXPERIMENT

i.Construct the specimen table:Example

Burette Readings in cm^3	**Trial or Rough**	**1st**	**2nd**
Final Burette reading	24.80	24.00	24.00
Initial Burette reading	0.00	0.00	0.00
Volume of Acid used	24.80	24.00	24.00

ii.Determine the average volume of acid used (i.e. average titer value).

Thus:Average Titre:- $\frac{24.00 + 24.00}{2} = 24.00cm^3$

Depending on the differences in readings of the titre values. All your readings must have their units, i.e.cm^3.

NOTE: This value and that of the table should be recorded to two places of decimal.

iii. SIGNIFICANT FIGURES

Sudent should learn to round off their calculation numbers to three significant figures,since they are using foure figure table for their calculations.

Significant figures start from non-zero digit and all other digits that follow including zero are considered Significant. As usual the digits, 5,6,7,8,9 are rounded up while 1,2,3,4,are round off.

Examples:

Numbers	Rounded off
299.30	299 to 3 S.f
0.0128	0.0128 to 3 S.f
6.0246	6.02 to 3 S.f

NOTE : for the sake of the examination,prepere your table on a sheet of paper and then neatly transfer it in INK to the answer sheet.

EXAMPLE 1

A is a solution of tetraoxosulphate {vi} acid.
B is a solution containing 0.0500 mole of anhydrous Na_2CO_3 per dm3.
(a)Put A in the burette and titrate 20.00 or 25.00 cm3 portions of B using methyl orange as the indicator. Record the size of your pipette. Tabulate the burette readings, and calculate the average volume of the acid used. (b)
From your result and data provided, calculate the
i. Amount of Na2CO3 IN 25.00 CM3 OF B used
ii. Concentration of A in moldm^{-3}
iii. Concentration of A in gdm^{-3}
iv. Number of hydrogen ions in 1.00dm3 of A. {Avogadro number = 6.02x1023 mol1}
The equation of reaction is: $H_2SO_4\{aq\} + Na_2CO_3\{aq\} \longrightarrow Na_2SO_4 \{aq\} + H_2O + CO_2$
{H =1,O=16, S=32}

SOLUTION

A Volume of pipette: 25cm^{-3}

Titration results {Hypothetical data}

Burette reading	1cm^3	II cm^3	IIIcm^3

Final	24.75	49.15	25.70
Initial	0.00	24.75	1.35
Volume of acid used	24.75	24.40	24.35

Average volume of acid used from titrations II and III:

$\frac{24.40+24.35}{2}$ = $\frac{48.75}{2}$ = 24.38cm^3

NOTES: Only the titre values from titrations I and II can be used in averaging, since they are within ± 0.20cm3 of each other. …Rough of first titre can also be used in averaging, if it is within ± 0.20cm3 of any other titre value, and is not crossed.-----Do not round up 24.38cm3 to 24.40cm3

(b)To calculate the amount of Na2CO3IN 25.00CM3 Given: concof B = 0.050moldm3 :Volume = 25/1000dm3

Amount = Conc {moldm3 x Volume {dm3} = 0.050x25/1000 = 0.00125mol

To calculate the concentration of A in moldm3: The various titration variables are:

CA = xmoldm3; VA = 24.38CM3; Na = 1, CB = 0.050moldm3 VB = 25CM3: nB =1

Method 1: proportion method {from the first principle}

From the balanced equation of reaction:

1mol of Na_2CO_3 = 1 mol of H_2SO_4

. ∴ 0.00125mol Na2CO = 0.00125molH2so4

i.e. 24.38cm3 of A contained 0.00125 mol H2SO4

$\therefore 1000cm3\ of$ A contained {0.00125 x 1000} /24.38 mol = 0.0513mol.Hence, concentration of A is 0.0513mol moldm3.

Method 2:

Mathematic formula method

From the data above, it is safe to use the mole ratio expression, in order to calculate the concentration CA of A, which the required variable.

Using $C_A V_A / C_B V_B$ = nA/nB

Substituting; C_A X 24.38/0.050 X25 =1/1

Making C_A the subject of the formula

∴ CA =1 X0.050X25 /24.38 X1 = 0.0513 moldm-3

(iii) To calculate the concentration of A in gdm-3:

Using conc. {gdm-3} x Molar mass {gmol-1}

Concentration of H2SO4, moldm-3 =0.0513moldm-

Molar mass H2SO4, = 2 {1.0} + 32.0 + 4{16.0

= 2.0 +32.0 +64.0 = 98.0gmol-1

Substituting; Mass conc = 0.0513 x98 = 5.0274gdm-3.

=5.03gdm-3 {3 sig fig.}

(Iv).Number of hydrogen ions in 1.00dm3 of A

1 dm3 of A contained 0.0513mol of H2SO4.

H2SO4 ionizes in water completely thus:

H_2SO_4 (a q) $\longrightarrow$ $2H^+SO_4^{2-}$(a q)

1mol 2mol

From the equation;

1 mole of H2SO4 produces2 x 0.0513 moles of H^+ = 0.103 mol 0f H+

But 1 mole of H+ contains 6.02 x 1023 ions;

Therefore, 0.103 x 6.02 x 1023 ions =6.02 x10 23 ions.{3 sig fig.]

STOICHIOMETRY OF REACTION: This is the study of the quantitative relationship implied by chemical reactions. Stoichiometry is the term used to describe calculations involving mass – volume relationship between atoms in a compound and between molecules and atoms

participating in a chemical reaction.
The stoichiometry of the reaction can also be defined as the mole ratio in which the reactants combine and the products are formed.
Experiments are designed to determine the stoichiometry of reactions and these include.

- Precipitation reaction
- Displacement of hydrogen from acid
- Displacement of metallic ions
- Synthesis of metallic oxides
- Reduction of metallic oxides

The titration experiment is used to study the stoichiometry of the reaction of acids with bases/alkalis.

Mole ratio and mass relationship

Consider the equation;
$Mg_{(s)} + 2HCl_{(aq)}\ MgCl_{(aq)} + H_{2(g)}$
No. Of moles 1 2 1 1
Mole ratio 1 : 2 1 : 1
Molar mass 24g 36.5g 95g 2g
Reacting mass 24g 2 x (36.5) 95g 2g
From the relationship above;
Reacting mass = no of moles x molar mass
:- No. of moles = reacting mass 1
Molar mass

Other formulae for moles are

No. of moles = no of elementary particles 2
Avogadro's number
No. of moles = molar concentration x Volume (in cm_3) 3
1000

By combining formulae 1 and 3, an important formulae is obtained;

No. of mole = reacting mass = molar concentration x volume
Molar mass 1000
:- reacting mass = molar concentration x volume
Molar mass 1000
Hence; Molar concentration = reacting mass x 1000 4
Molar mass x volume
Equation 4 is very important when calculating the concentration of a solution with volumes other than $1000cm_3$ ($1dm_3$)

Example

1. How many moles are contained in 50g of Magnesium trioxocarbonate (IV)? (Mg=24, C=12, O=16)
Solution
Molar mass of $MgCO_3$ = 24 + 12 + (3 x 16) = 84g/mol
Reacting mass = 50g
No. of moles = reacting mass/molar mass
= 50/84 = 0.6 moles
2. Calculate the number of moles of $CaCl_2$ that can be obtained from 30g of $CaCO_3$ in the presence of excess HCl. [Ca=40, C=12, O=16, H=1, Cl=35.5]

Solution

$CaCO_{3(s)} + 2HCl_{(aq)}\ CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
Mole ratio 1 : 2 1 : 1 : 1
Molar mass of $CaCO_3$ = 100g/mol
Molar mass of $CaCl_2$ = 111g/mol
From the equation;
1 mole of $CaCO_3$ produced 1 mole of $CaCl_2$
100g of $CaCO_3$ produced 111g of $CaCl_2$

:- 30g of $CaCO_3$ will produce 30 x 111 = 33.3g of $CaCl_2$

100

Convert 33.3g of $CaCl_2$ to moles;

No of moles = reacting mass/molar mass

= 33.3/111 = 0.3 moles

3. What mass of Na_2CO_3 is needed to prepare 1 dm_3 of a 0.3M solution.

Solution

Molar mass of Na_2CO_3 = 106g/mol

Note: 0.3 M means that 0.3 mole of Na_2CO_3 is contained in $1dm_3(1000cm_3)$ solution.

:- No. of moles = reacting mass/molar mass

0.3 = mass/106

Mass = 0.3 x 106 = 31.8g

Calculations involving gas volume

1. In the industrial preparation of trioxonitrate (V) acid, ammonia gas is burned in oxygen in the presence of a catalyst according to the following equation;

$4NH_{3(g)} + 5O_{2(g)}\ 4NO_{(g)} + 6H_2O_{(g)}$

If $250cm_3$ of NH_3 are burned completely, what volume of (a) oxygen is used up? (b) NO is produced

Solution

(a)

Equation of the reaction;

$4NH_{3(g)} + 5O_{2(g)}\ 4NO_{(g)} + 6H_2O_{(g)}$

From the equation;

4 moles of NH_3 ≡ 5 moles of O_2

Thus 4 volume of NH_3 ≡ 5 volumes of O_2

Therefore 250 volumes of NH_3 ≡ 250 x 5 = 312.50 cm_3 of O_2

4

(b)

From the equation;

4 volumes of NH_3 ≡ 4 volumes of NO

:- 250 volumes of NH_3 ≡ 250 volumes of NO

= $250cm_3$

2. What volume of dry oxygen gas (measured at s.t.p) will be produced from the decomposition of 3.50g potassium trioxochlorate (V)?

Solution

Equation of the reaction;

$2KClO_{3(s)}\ 2KCl_{(s)} + 3O_{2(g)}$

From the equation;

2 moles of $KClO_3$ produced 3 moles of O_2

2 moles of $KClO_3$ = 2 x 122.5g = 245g

Molar volumes of O_2 at s.t.p. = $22.4dm_3$

:- 3 moles of O_2 occupies 3 x 22.4 = $67.2dm_3$

Hence 245g of $KClO_3$ produced $67.2dm_3$ of O_2

:- 3.50g of $KClO_3$ will produce 3.50 x 67.2 = $0.96dm_3$ of O_2

245

3. Calculate the volume of carbon (IV) oxide at 35_0C and 720mmHg pressure which could be obtained by heating 19g of copper (II) trioxocarbonate (IV) [$CuCO_3$ = 123.5, CO_2 = 44, molar volume of a gas at s.t.p. = $22.4dm_3$]

Solution

Equation of the reaction;

$CuCO_{3(s)}\ CuO_{(s)} + CO_{2(g)}$

From the equation;

1 mole of $CuCO_3$ ≡ 1 mole of CO_2

Amount (in moles) of $CuCO_3$ that reacted = 19/123.5 (i.e reacting mass/molar mass) = 0.15moles

:- 0.15 moles of $CuCO_3$ yields 0.15 moles of CO_2

But at s.t.p, 1 mole of CO_2 occupies 22.4dm^3

:- 0.15 moles of CO_2 occupies 0.15 x 22.4 = 3.36dm^3

1

Using the general gas equation;

$P_1V_1 = P_2V_2$

T_1 T_2

Where; P_1 = 760mmHg, V_1 = 3.36dm^3 (i.e. 3360cm^3), T_1 = 273K

P_2 = 720mmHg, V_2 = ? T_2 = 350C = 308K

$V_2 = P_1V_1T_2$ = 760 x 3360 x 308

T_1P_2 273 x 720

V_2 = 4001cm^3

Calculations involving liquid volumes

1. Calculate the volume of 0.1M ammonia which could be obtained by heating 2.7g of ammonium chloride with excess sodium hydroxide and absorbing all the ammonia evolved.

Solution

Equation of the reaction;

$NH_{4(s)} + NaOH_{(aq)}\ NaCl_{(aq)} + NH_{3(g)} + H_2O_{(l)}$

From the equation

1 mole of NH_4Cl produces 1 mole (22.4dm^3) of NH_3

Amount of NH_4Cl that reacted = 2.7/53.5 (i.e. reacting mass/molar mass) = 0.05moles

:- 0.05 moles of NH_4Cl produces 0.05 moles of NH_3

Using the formula

Number of moles = molar conc. X volume (cm^3)

1000

Where; number of moles = 0.05 moles

Molar conc. = 0.1M

Volume = ?

0.1 = 0.05 x volume

1000

Volume of NH_3 = 0.1 x 1000 = 500cm^3

0.5

2. Calculate the volume of 2M hydrochloric acid which could be obtained by dissolving 560cm^3 hydrogen chloride gas (measured at s.t.p.) in water. [molar volume of gas at s.t.p = 22.4dm^3]

Solution

22400cm^3 hydrogen chloride gas = 1 mole of hydrogen chloride gas at s.t.p

:- 560 cm^3 of hydrogen chloride gas = 560 x 1 = 0.025moles

22400

The number of moles of hydrogen chloride gas = 0.025 moles

The concentration of hydrochloric acid formed is = 2M

Volume of the acid formed = ?

Number of moles = molar conc. X volume (cm^3)

1000

0.025 = 2 x volume

1000

Volume = 0.025 x 1000 = 12.5cm^3

2

Calculation involving masses

1. Calculate the mass of carbon(IV) oxide produced by burning 104g of ethyne (C=12, O=16, H=1)

Solution

Equation of the reaction

$2C_2H_{2(g)} + 5O_{2(g)}\ 4CO_{2(g)} + 2H_2O_{(g)}$

From the equation;

2 moles of ethyne produces 4 moles of CO_2

i.e. 2 x 26g of ethyne produces 4 x 44g of CO_2

52g of ethyne produces 176g of CO_2

:- 104g of ethyne produces 104 x 176 = 352g of CO_2

52

2. What mass of lead (II) trioxonitrate (V) would be required to yield 12g of lead (II) chloride on the addition of excess sodium chloride solution? (Pb = 207, N=14, O=16, Na=23, Cl=35.5)

Solution

Equation of the reaction

$Pb(NO_3)_{2(aq)} + 2NaCl_{(aq)}\ PbCl_{(s)} + 2NaNO_{3(aq)}$

331g 278g

From the equation

278g of PbCl is produced from 331g of $Pb(NO_3)_2$

:- 12g of PbCl will be produced 12 x 331 = 14.29g of $Pb(NO_3)_2$

278

Assignment

Answer question 6 (theory) on page 145 of Essential Chemistry

Tutorial questions

1. In a certain reaction, 15.0g of impure magnesium sample reacted with excess hydrochloric acid liberating 8.6 dm^3 of hydrogen gas at s.t.p.

i. Write a balanced equation for the reaction

ii. Calculate the:

- mass of pure magnesium in the sample
- Percentage purity of the magnesium sample
- Number of chloride ions produced in the reaction.

[Mg = 24.0, volume at s.t.p. = 22.4dm^3, Avogadro's constant = 6.02 x 10^{23} mol^{-1}]

2. What is the volume of 0.25$moldm^{-3}$ solution of KOH that would yield 6.5g of solid KOH on evaporation? [K = 39.0, O = 16.0, H = 1.00]

3. Consider the reaction represented by the following equation:

$Na_2CO_{3(aq)} + 2HCl_{(aq)}\ 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

What volume of 0.02 $moldm^{-3}$ $Na_2CO_{3(aq)}$ would be required to completely neutralize 40cm^3 of 0.10 $moldm^{-3}$ $HCl_{(aq)}$?

4a. Find the volume of oxygen produced by 1 mole of potassium trioxochlorate (V) at s.t.p in the following reaction.

$2KClO_{3(s)}\ 2KCl_{(s)} + 3O_{2(g)}$

b. Find the mass of sodium trioxocarbonate (IV) needed to give 22.4dm3 of carbon (IV) oxide at s.t.p in the following reaction.

$Na_2CO_{3(s)} + 2HCl_{(aq)}\ 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

[Na = 23, O = 16, C = 12, molar volume of gas at s.t.p = 22.4dm^3]

5. What mass of anhydrous sodium trioxocarbonate (IV) is present in 500cm3 of 0.1moldm-3 of the solution? [Na = 23, C = 12, O = 16]

ACID-BASE REACTION

Determination of the composition of substances either qualitatively or quantitatively is very important in chemistry. The two approaches to the quantitative analysis are volumetric and gravimetric approaches. Volumetric analysis is commonly used because it is faster and more convenient, although less accurate than gravimetric analysis.

TITRATION: it is the method employed in volumetric analysis. The method involves adding a solution to a known volume of another solution until the chemical reaction between them is completed. The completion is shown by a colour change in the resulting solution or in an added indicator. Usually, a standard solution must be used to react with a solution of unknown concentration. The reacting volumes of the solutions are the used to calculate the unknown concentration of the solution.

Definition of terms in volumetric analysis.

End point: this is the point at which the neutralization reaction is just complete. The change in the colour of the indicator is used to monitor the end point.

Indicators: They are weak organic acids or bases which produce different colours in solution according to the hydrogen ion, H^+ concentration in that solution.

Mass concentration: It is the amount in grams of solute present in 1 dm^3 ($1000cm^3$) of the solution. It is expressed in g/dm^3. It is calculated with the formula;

Mass conc. = molar concentration x molar mass

Molar concentration (Molarity): It is the amount in moles of solute per dm^3 ($1000cm^3$) of solution. It is expressed in mol/dm^3. It is calculated with the formula;

Molarity (Molar conc.) = mass conc

Molar mass

Standard solution: This is a solution of known concentration.

Molar solution: A molar solution of a compound is the one which contains one mole or the molar mass of the compound in $1dm^3$ ($1000cm^3$) of the solution.

Volumetric analysis usually involves the titration of;

- Acid against base or trioxocarbonate (IV)
- Oxidizing agent against reducing agent
- One substance against another substance giving a precipitate.

Materials used in acid base titration include;

- Weighing bottle
- Chemical balance
- Pipette
- Burette
- Retort stand
- Filter paper
- Funnel
- White tile
- Standard volumetric flask
- Conical flask

CALCULATIONS IN VOLUMETERIC ANALYSIS

Volumetric analysis is used to:

- Standardize unknown solution i.e. to get the concentration of a solution whose concentration is not known
- Determine the purity of substances
- Calculate the molar mass of a compound
- Calculate the molar concentration of a compound
- Calculate the mass concentration of a compound
- Number of ions/particles present in a solution
- Water of crystallization in a solution
- Solubility of a compound

The procedures for all these determinations are similar to that of acid-base titration. The following formula is important in volumetric analysis.

$C_AV_A = n_a$

C_BV_B n_b

Where:

C_A = Molarity (molar concentration) of acid

V_A = Volume of acid

n_a = number of moles of acid

C_B = Molarity (molar concentration) of base

V_B = Volume of base

n_b = number of moles of base

PRACTICAL CLASS

Experiment to determine the concentration of hydrochloric acid using standard sodium hydroxide solution

Assignment.

What are the precautions observe during acid-base titration?

A. Calculations on molar solution

1. Calculate (a) the mass of anhydrous sodium trioxocarbonate (IV) present in $300cm_3$ of 0.1M solution (b) the number of Na_2CO_3 particles present in the solution. (Na = 23, C = 12, O = 16)

Solution

(a)

Molar mass of Na_2CO_3 = 106g/mol

Molar conc. = 0.1 M

Mass conc. = ?

But mass conc = molar conc. X molar mass

:- mass conc = 0.1 x 106 =10.6g

This means that 10.6g of Na_2CO_3 is contained in $1000cm_3$ ($1dm_3$) of 0.1 M Na_2CO_3 solution

:- in $300cm_3$ of the solution we have

300 x 10.6

1000

= 3.18g

Alternative method (formula method)

Molar mass of Na_2CO_3 = 106g/mol

Molar conc. = 0.1 M

Volume = $300cm_3$

Reacting mass = ?

Molar conc. = reacting mass x 1000

Molar mass x volume

0.1 = reacting mass x 1000

106 x 300

Mass = 106 x 300 x 0.1 =3.18g

1000

(b)

Number of moles (n) = number of elementary particles

Avogadro's number

Number of particles = number of moles x Avogadro's number

Since reacting mass = 3.18g

Number of moles = reacting mass = 3.18 = 0.03 moles

Molar mass 106

:- number of Na_2CO_3 particles = 0.03 x 6.02 x 10_{23} = 0.181 x 10_{23}

2. Calculate the volume of 0.25M solution of H_2SO_4 that will contain a mass of 4.5g of the acid. [H=1, S=32, O=16]

Solution

Molar conc. = 0.25M

Molar mass of H_2SO_4 = 98g/mol

Mass conc. = molar conc. X molar mass

= 0.25 x 98 = $24.5g/dm_3$

i.e. 24.5g of H_2SO_4 is contained in $1000cm_3$ of the solution

:- 4.5g of H_2SO_4 will be contained in

4.5 x 1000 = $184cm_3$

24.5

Alternative method (formula method)

Molar mass ofH_2SO_4 = 98g/mol

Molar conc. = 0.25 M

Volume = ?

Reacting mass = 4.5g

Molar conc. = mass x 1000

Molar mass x volume

0.25 = 4.5 x 1000

98 x vol

Volume = 4.5 x 1000 = 184 cm$_3$

0.25 x 98

3. Calculate the volume of hydrogen chloride gas at s.t.p. that would yield 1.2dm$_3$ of 0.15M aqueous hydrogen chloride solution. (molar volume of all gases at s.t.p. = 22.4dm$_3$)

Solution

Molar conc. Of HCl solution is 0.15M i.e. dm$_3$ of the HCl solution contains 0.15 moles of HCl.

:- 1.2dm$_3$ of the solution will contain

1.2 x 0.15 = 0.18moles of HCl

1

But 1 mole of HCl gas at s.t.p occupies 22.4dm$_3$

:- 0.18 moles at s.t.p will occupy 0.18 x 22.4 = 4.03dm$_3$

1

4.03 dm$_3$ of HCl gas at s.t.p would be required to yield 1.2dm$_3$ of 0.15M aqueous solution.

Alternative method (formula method)

Molar conc = 0.15M

Molar mass of HCl = 36.5g/mol

Volume = 1.2dm$_3$ = 1200cm$_3$

Reacting mass = ?

Molar conc. = mass x 1000

Molar mass x volume

0.15 = mass x 1000

36.5 x 1200

Mass = 0.15 x 36.5 x 1200 = 6.57g

1000

At s.t.p 36.5g of HCl occupies 22.4dm3

:- 6.57g of HCl will occupy 6.57 x 22.4 = 4.03dm$_3$

36.5

B. Calculations on standardization

4. A is 0.05 mol/dm$_3$ of H_2SO_4. B is sodium trioxocarbonate (IV) solution. If 37.5cm$_3$ of the acid was required to neutralize 25.00cm$_3$ of the trioxocarbonate, calculate;

a. conc. Of B in mol/dm$_3$

b. conc of B in g/dm$_3$

c. volume of CO_2 librated at s.t.p. during the titration

(Na = 23, C = 12, O = 16, S = 32)

Equation of the reaction;

$H_2SO_{4(aq)} + Na_2CO_{3(aq)}\ Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$

Solution

(a)

$C_A = 0.05$mol/dm$_3$ $V_A = 37.5$cm$_3$ $n_a = 1$

$C_B = ?$ $V_B = 25$cm$_3$ $n_b = 1$

$C_AV_A = n_a$

C_BV_B n_b

0.05 x 37.5 = 1

CB x 25 1

CB = 0.05 x 37.5 x 1 = 0.075mol/dm$_3$

25 x 1

(b)

Mass conc. = molar conc. X molar mass

= 0.075 x 106

= 7.95g/dm$_3$

Note: the molar mass of Na_2CO_3 is 106g/mol

(c)
From the equation;
1 mole of Na_2CO_3 liberated 1 mole of CO_2
:- 0.075 moles of Na_2CO_3 would liberate 0.075 x 1 = 0.075 moles of CO_2
1
At s.t.p, 1 mole of CO_2 occupies 22.4dm$_3$
:- 0.075 mole will occupy 0.075 x 22.4 = 1.68dm$_3$
1
Hence, 1.68dm$_3$ of CO_2 was liberated during the reaction.

5. Ycm$_3$ of hydrogen chloride gas at s.t.p. were passed into 60cm$_3$ of 0.1moldm$_3$ sodium trioxocarbonate (IV) solution. The excess trioxocarbonate (IV) was neutralized by 20cm$_3$ of 0.05 mol/dm$_3$ H_2SO_4. Calculate (a) the mass of excess Na2CO3 in g/dm$_3$ (b) the value of Y
[molar volume of gas at s.t.p = 22.4dm$_3$, Na_2CO_3 = 106]

Solution
(a)
Equation of the reaction;
$H_2SO_{4(aq)} + Na_2CO_{3(aq)}\ Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$
From the equation;
1 Molar (i.e. 1000cm$_3$ of 1mol/dm$_3$) solution of H_2SO_4 ≡ 1 Molar solution of Na_2CO_3
Thus; 1000cm$_3$ 1M H_2SO_4 ≡ 106g in 1000cm$_3$ Na_2CO_3
1000cm$_3$ 0.05M H_2SO_4 ≡ 106 x 0.05g in 1000cm$_3$ Na_2CO_3
:- 20cm$_3$ 0.05M H_2SO_4 ≡ 106 x 0.05 x 20g in 1000cm$_3$ Na_2CO_3
1000
= 0.106g/dm$_3$ Na_2CO_3
The mass concentration of the excess Na_2CO_3 which reacted with H_2SO_4 = 0.106g/dm$_3$
1000cm$_3$ 1M Na_2CO_3 contains 106g Na_2CO_3
:- 1000cm$_3$ 0.1M Na_2CO_3 contains 10.6g Na_2CO_3
Hence 60cm$_3$ 0.1M Na_2CO_3 contains 10.6 x 60 g Na_2CO_3
1000
= 0.636g/dm$_3$
The mass concentration of the original Na_2CO_3 solution = 0.636g/dm$_3$
:- the mass concentration of Na_2CO_3 neutralized by Ycm$_3$ HCl gas = 0.636 – 0.106 = 0.53g/dm$_3$
(b)
Equation of reaction
$Na_2CO_{3(aq)} + 2HCl_{(aq)}\ 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$
Form the equation
106g of Na_2CO_3 ≡ 2 x 22.4 dm$_3$ of HCl gas at s.t.p
:- 0.53g of Na_2CO_3 ≡ 2 x 22400 x 0.53 cm$_3$
106
= 224cm$_3$
6. A is a dilute tetraoxosulphate (VI) acid. B contains 1.5g of sodium hydroxide per 250cm$_3$ of solution. 25cm$_3$ of B requires 15.5cm$_3$ of A for complete neutralization. Calculate
(a) Concentration of B in mol/dm$_3$
(b) Concentration of A in mol/dm$_3$
The number of hydrogen ion ions in 1.0dm$_3$ of solution A
Solution
Equation of reaction
$H_2SO_{4(aq)} + 2NaOH_{(aq)}\ Na_2SO_{4(aq)} + 2H_2O_{(l)}$
(a)
250cm$_3$ of B contains 1.5g of NaOH
:- 1000cm$_3$ of B will contain 1000 x 1.5g of NaOH
250

= 6.00g/dm^3
Molar conc. Of B = mass conc/molar mass
The molar mass of NaOH = 40g/mol
:-Molar Conc. (Molarity) of B = 6/40
= 0.15mol/dm^3
(b)
$C_AV_A = n_a$
C_BV_B n_b
C_A = ? V_A = 15.5cm^3 n_a = 1
C_B = 0.15mol/dm^3 V_B = 25cm^3 n_b = 2
C_A x 15.5 = 1
0.15 x 25 2
C_A = 0.15 x 25 x 1 = 0.121mol/dm^3
2 x 15.5
(c)
H_2SO_4 $2H^+ + SO_4$
$^{2-}$
1 mole of H_2SO_4 yield 2 moles of H^+
Since the Molarity of H_2SO_4 = 0.121mol/dm^3
The concentration of H^+ in the acid = 2 x 0.121 = 0.242mol/dm^3
Number of H^+ present = number of moles x Avogadro's constant
= 0.242 x 6.02 x10^{23}
= 1.46 x10^{23} hydrogen ions.

Assignment

1. A solution of trioxonitrate (V) acid contained 0.67g in 100cm^3. 31.0cm^3 of this solution neutralized 25cm^3 of a sodium trioxocarbonate (IV) solution. Calculate the concentration of the trioxocarbonate (IV) solution. (HNO_3 = 63, Na_2CO_3 = 106)

Tutorial questions

1. A solution of trioxonitrate (V) acid contained 0.67g in 100cm^3. 31.0cm^3 of this solution neutralized 25cm^3 of a sodium trioxocarbonate (IV) solution. Calculate the concentration of the trioxocarbonate (IV) solution. (HNO_3 = 63, Na_2CO_3 = 106)
2.Calculate the mass of pure sodium chloride that will yield enough hydrogen chloride gas to neutralize 25cm3 of 0.5M potassium trioxocarbonate (IV) solution. (NaCl = 58.5, HCl = 35.5, K_2CO_3 = 138)

C. Calculations of percentage purity

7. A piece of limestone, $CaCO_3$ was added to 1dm^3 of 0.1mol/dm^3 hydrochloric acid. After effervescence had stopped, 31.25cm^3 of the resulting solution required 25cm^3 of 0.05mol/dm^3 sodium hydroxide for complete neutralization. Calculate the mass of limestone added ($CaCO_3$ = 100, HCl=36.5, NaOH = 40)

Solution

Equation of the reaction
$CaCO_{3(s)} + 2HCl_{(aq)}$ $CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
100g 2 x 36.5g
$NaOH_{(aq)} + HCl_{(aq)}$ $NaCl_{(aq)} + H_2O_{(l)}$
Using C_AV_A = na
C_BV_B nb
Where CA = ? VA = 31.25cm^3 na = 1
CB = 0.05moldm^{-3} VB = 25cm^3 nb = 1
C_A x 31.25 = 1
0.05 x 25 1
C_A = 0.05 x 25 x 1 = 0.040mol/dm^3
31.25 x 1
The mass concentration of the acid that react with NaOH therefore = 0.04 x 36.5 = 1.46g/dm^3
But, the original concentration of the acid is 0.1mol/dm^3 = 0.1 x 36.5 = 3.65g/dm^3

:- the concentration of the acid that reacted with $CaCO_3$ = 3.65 – 1.46 = 2.19g/dm_3
From the equation;
$CaCO_{3(s)} + 2HCl_{(aq)}$ $CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
100g of $CaCO_3$ ≡ 73gof HCl
:- Yg of $CaCO_3$ ≡ 2.19g of HCl
Y = 100 x 2.19 = 3g
73
The mass of $CaCO_3$ added to 0.1mol/dm_3 HCl is 3g

D. Calculations on molar mass, water of crystallization and solubility of substances

8. 28.0cm_3 hydrochloric acid of concentration 4.1g/dm_3 neutralized 25.0cm_3 of an unknown alkali YOH, whose concentration was 7.0g/dm_3. Calculate (a) the molar concentration of YOH (b) the relative atomic mass of the element Y. Name the element Y if possible. (HCl = 36.5)

Solution
(a)
Equation of the reaction;
$HCl_{(aq)} + YOH_{(aq)}$ $YCl_{(aq)} + H_2O_{(l)}$
Molar conc. Of HCl = Mass conc/molar mass
= 4.1/36.5 = 0.112mol/dm_3
$C_AV_A = n_a$
C_BV_B n_b
CB = 0.112 x 28 x 1 = 0.125mol/dm_3
25 x 1
:- molar conc. Of YOH = 0.125mol/dm_3
(b)
Molar conc. = mass conc/molar mass
:- 0.125 = 7.0
Y + 16 + 1
Y + 17 = 7.0/0.125
Y = 56 – 17 = 39
The relative atomic mass of Y = 39
The element is Potassium and YOH is KOH

9. Some crystals of washing soda were exposed to the atmosphere for efflorescence to take place. 6.02g of this partly effloresced washing soda, $Na_2CO_3.yH_2O$ were then dissolved in 500cm_3 of water. 25cm_3 of this trioxocarbonate (IV) solution required 32.10cm_3 of 0.097mol/dm_3 hydrochloric acid for complete neutralization. Calculate y. Hence, write the formula of the effloresced washing soda. (Na = 23, H = 1, C = 12, Cl = 35.5, O = 16)

Solution
Equation of then reaction
$Na_2CO_3.yH_2O_{(s)} + 2HCl_{(aq)}$ $2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)} + yH_2O_{(l)}$
$C_AV_A = n_a$
C_BV_B n_b
0.097 x 32.1 = 2
C_B x 25 1
C_B = 0.097 32.1 = 0.0623mol/dm_3
25 x 2
6.02g of $Na_2CO_3.yH_2O$ is contained in 500cm3
:- in 1000cm3 we have 6.02 x 1000 = 12.04g
500
:- the mass concentration of $Na_2CO_3.yH_2O$ is 12.04g/dm3
Molar mass of $Na_2CO_3.yH_2O$ = (106+ 18y)gmol-1
Molar mass = mass conc./molar conc.
106 + 18y = 12.04/0.0623
106 + 18y = 193.26

18y = 193.26 – 106
18y = 87.3
Y = 4.9
Therefore the formula of the effloresced washing soda is $Na_2CO_3.5H_2O$
10. A saturated solution of lead (II) trioxonitrate (V) $Pb(NO_3)_2$, was prepared at 22_0C. 27cm$_3$ of this solution required 46cm$_3$ of sodium chloride, NaCl solution containing 96g/dm$_3$ for complete precipitation. Find the solubility of lead (II) trioxonitrate (V) at 22_0C in (a) mol/dm$_3$ (b) g/dm$_3$
(Na=23, Cl=35.5, Pb=207, N=14, O=16)
Solution
Equation of the reaction
$2NaCl_{(aq)} + Pb(NO_3)_{2(aq)}\ PbCl_{2(s)} + 2NaNO_{3(aq)}$

(a)
Molarity of the NaCl solution = 96/58.5 = 1.641mol/dm$_3$
$C_AV_A = n_a$
$C_BV_B\ n_b$
Where A represent NaCl and B represents $Pb(NO_3)_2$
C_A = 1.641mol/dm$_3$ V_A = 46cm$_3$ n_a = 2
C_B = ? V_B = 27cm$_3$ n_b = 1
1.641 x 46 = 2
C_B x 27 1
C_B = 1.641 x 46 x 1 = 1.398mol/dm$_3$
27 x 2
The solubility of $Pb(NO_3)_2$ at 22_0C = 1.398mol/dm$_3$
(b)
Mass conc = molar conc x molar mass
= 1.398 x 331
= 462.7g/dm$_3$
The solubility of $Pb(NO_3)_2$ at 22_0C = 462.7g/dm$_3$

E. Calculations involving dilution of a solution

11. What volume of 2 mol/dm$_3$ NaOH solution is required to prepare 100cm$_3$ of a solution of NaOH with a concentration of 0.2mol/dm$_3$?

Solution

$M_1V_1 = M_2V_2$
Where; M_1 = initial concentration = 2mol/dm$_3$
V_1 = initial volume = ?
M_2 = final concentration = 100cm$_3$
V_2 = final Volume =0.2
$V_1 = M_2V_2$ = 100 x 0.2
M_1 2
V1 = 10cm$_3$
Thus if 10cm$_3$ of a 2mol/dm$_3$ NaOH solution is diluted with water to 100cm$_3$, it will produce a 0.2mol/dm$_3$ solution of NaOH.

Assignment

1. Water is added to 100cm$_3$ of a 0.25 mol/dm$_3$ NaCl solution to make it up to 1.5dm$_3$. Calculate the concentration of the solution after dilution.

Tutorial questions

1. 2g of a mixture of NaOH and NaCl (as impurity) were dissolved in 500cm3 of water. If 25cm3 of this solution were neutralized by 21cm3 0.1mol/dm3 hydrochloric acid, calculate the percentage of the NaCl impurity. (NaOH = 40, HCl = 36.5, NaCl = 58.5)
2. An excess of a divalent metal M was dissolved in a limited volume of hydrochloric acid. If 576cm$_3$ of hydrogen were liberated at s.t.p, what was the mass of the metal that produced this volume of hydrogen? (M = 24, H=1, molar volume of gas at s.t.p = 22.4dm$_3$)

TOPIC: QUANTITATIVE AND QUALITATIVE ANALYSIS

REDOX TITRATION

The solutions commonly used for redox titration are the oxidizing agents and reducing agents. The following pairs are examples of redox titration;

1. Acidified MnO_4^- with Fe^{2+}
2. Acidified MnO_4^- with $C_2O_4^{2-}$
3. I_2 in KI with $S_2O_3^{2-}$

In redox titration, only the net ionic equation is required e.g.

(a) $2MnO_{4-(aq)} + 5C_2O_4^{2-} + 16H_{+(aq)} \longrightarrow 2Mn_{2+(aq)} + 10CO_{2(g)} + 8H_2O_{(l)}$

(b) $MnO_4^-{}_{(aq)} + 5Fe^{2+}{}_{(aq)} + 8H^+{}_{(aq)} \longrightarrow Mn^{2+}{}_{(aq)} + 5Fe^{3+}{}_{(aq)} + 4H_2O_{(l)}$

(c) $I_{2(aq)} + 2C_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2I^-{}_{(aq)}$

Suitable indicators are used in redox titration to monitor the end point. However, when $KMnO_4$ is the oxidizing agent, an indicator is not required because of the intensity of the $KMnO_4$ colour both before and after the titration.

Example

A is a solution of $KMnO_4$, B is 0.02mol/dm$_3$ of ethanedioic acid and solution C is 0.1mol/dm$_3$ of concentrated H_2SO_4. Titrate solution A against 25cm$_3$ of solution B which has been acidified with 5cm$_3$ of solution C. Average volume of 16.5cm$_3$ of A was required for complete oxidation of solution B.

From the result obtained calculate;

(a) the concentration of solution A in mol/dm$_3$

(b) the concentration of A in g/dm$_3$

Equation of the reaction;

$2MnO_{4(aq)} + 5C_2O_4^{2-}{}_{(aq)} + 16H_{+(aq)} \longrightarrow 2Mn^{2+}{}_{(aq)} + 10CO_{2(g)} + 8H_2O_{(l)}$

[K=39, Mn=55, O=16]

Solution

(a)

$C_{OA}V_{OA} = n_{OA}$

$C_{RA}V_{RA}\ n_{RA}$

Where; C_{OA} = ?, V_{OA} = 16.5cm$_3$, n_{OA} = 2, C_{RA} = 0.02mol/dm$_3$, V_{RA} = 25cm$_3$, n_{RA} = 5

$C_{OA} = C_{RA} \times V_{RA} \times n_{OA}$

$n_{RA} \times V_{OA}$

= 0.02 x 25 x 2

5 x 16.5

= 0.0121mol/dm$_3$

(b)

Molar mass of $KMnO_4$ = 39 + 55 + 64 = 158g/mol

Mass conc. = molar conc. X molar mass

= 0.0121 x 158

= 1.91g/dm$_3$

Note: in the reaction above, $KMnO_4$ was added from the burette until the solution turns permanently pink. That is the end point.

WEEK 6

QUALITATIVE ANALYSIS

This is a type of chemical analysis which is carried out on an unknown substance (a compound or mixture) in order to determine its composition. In inorganic samples, two basic constituents are usually identified. These are **metallic radical (or cations)** and **acidic radicals (or anions).**

IDENTIFICATION OF CATIONS USING $NaOH_{(aq)}$ AND $HH_{3(aq)}$

The basis for the identification rests on the formation of a precipitate, its colour and solubility in excess of the reagent.

Metallic Radicals /Cations	**Precipitate Formed**	**Sodium Hydroxide solution**		**Aqueous ammonia**	
		In Drops	**In Excess**	**In Drops**	**In Excess**
Ca^{2+}	$Ca(OH)_2$	White Precipitate	Insoluble	No Precipitate	No Precipitate
Zn^{2+}	$Zn(OH)_2$	White Precipitate	Soluble	White Gelatinous Precipitate	Soluble (Colourless solution)
Pb^{2+}	$Pb(OH)_2$	White Precipitate	Soluble	White Precipitate	Insoluble
Al^{3+}	$Al(OH)_3$	White Precipitate	Soluble	White Precipitate	Insoluble
Fe^{2+}	$Fe(OH)_2$	Green Gelatinous Precipitate	Insoluble	Green Gelatinous Precipitate	Insoluble
Fe^{3+}	$Fe(OH)_3$	Reddish-Brown Gelatinous Precipitate	Insoluble	Reddish-Brown Gelatinous Precipitate	Insoluble
Cu^{2+}	$Cu(OH)_2$	Blue Gelatinous Precipitate	Insoluble	Pale-Blue Precipitate	Soluble (Deep-blue solution)
NH_4^+	$NH_4(OH)$	No Precipitate	No Precipitate, On heating or warming NH_3 is liberated	No Precipitate	No Precipitate

Note: the observation for both Pb^{2+} and Al^{3+} are similar. To distinguish between them, add aqueous potassium Iodide (KI) or potassium tetraoxochromate (VI) – K_2CrO_4 to samples of both solutions, only Pb^{2+} will give a yellow precipitate. Also, add a few drops of conc. HCl to the solutions, formation of white precipitate which dissolves when warmed but reappear on cooling confirms the presence of Pb^{2+}.

TEST FOR ANIONS

To identify the anions in an unknown salt, carry out the following tests.

S/N ANIONS TEST OBSERVATION AND INFERENCE

1. NO_3^-

Add dilute NaOH solution. Then add a piece of aluminium foil. Warm the mixture. Test the gas liberated with a piece of moist red litmus paper.

Effervescence is observed. The red litmus paper turns blue. NH_3 gas is liberated.

2. CO_3^{2-}

Add dilute HCl. Pass the gas liberated into lime water, Effervescence is observed. A white precipitate of $CaCO_3$ is formed with lime water. CO_2 is liberated.

3. HCO_3^-

Add dilute HCl. Pass the gas liberated into Effervescence is observed. A white lime water precipitate of $CaCO_3$ is formed with lime water. CO_2 is liberated.

4. Cl^-

Add dilute HNO_3. Then add $AgNO_3$ A white precipitate of AgCl is formed

Add dilute HNO_3. Then add $Pb(NO_3)_2$ A white precipitate of $PbCl_2$ is formed

5. SO_4^{2-}

Add dilute HCl, then add Barium Chloride solution. A white precipitate of $BaSO_4$ is formed

6. SO_3^{2-}

Add dilute HCl, warm the mixture. Test the gas liberated with a piece of paper soaked with Acidified $K_2Cr_2O_7$
Effervescence occurs. The acidified $K_2Cr_2O_7$ paper turns green. SO_2 is liberated.

7. S^{2-}

Add diluted HCl. Test the gas liberated with a piece of moist $(CH_3COO)_2Pb$ paper. Effervescence is observed. The moist $(CH_3COO)_2Pb$ paper turns black. H_2S is liberated.

8. I^-

Add dilute HNO_3. Add $AgNO_3$ A yellow precipitate of AgI is formed
Add dilute HNO_3. The add $Pb(NO_3)_2$ A yellow precipitate of PbI_2 is formed.

TEST FOR SOME GASES

Gases	Appearance	Smell	Litmus	Confirmatory Test
H_2O vapour	Colourless	No smell	No effects	Turns white anhydrous $CuSO_4$ blue, turns blue anhydrous $CoCl_2$ pink
O_2	Colourless	No smell	No effects	Rekindle a glowing splint
SO_2	Colourless	Sharp and chocking smell of burning sulphur	Acid	Reduces $KMnO_4$ solution to colourless, $K_2Cr_2O_7$ Solution to green; no yellow sulphur deposited
SO_3	Smoky white fumes	Chocking	Acid	Turns $BaCl_2$ solution on glass rod milky
CO_2	Colourless	No smell	Weak Acid	Turns lime water milky
Cl_2	Pale green	Pungent	Acid and Bleaches	Oxides KI solution to give brown I_2
H_2	Colourless	No smell	No effects	Burns with a Pop sound in air
CO	Colourless	No smell	No effects	Burns with blue flame to gives CO_2
HCl	Steamy fume	Pungent	Acid	Forms dense white fumes with NH_3 gas, turns $AgNO_3$ solution milky
H_2S	Colourless	Smell of rotten eggs	Weakly Acid	Darkens a solution containing Pb^{2+} ; decolourises $KMnO_4$ with yellow sulphur deposited
N_2O	Colourless	Sweetish	No effects	Rekindle a glowing splint
NO	Turns brown	NO_2 is smelt	Neutral	Darkens $FeSO_4$ solution
NO_2	Brown	Strong unpleasant smell	Acid	Darkens $FeSO_4$ solution
NH_3	Colourless	Pungent	Alkaline	Forms dense white fumes with HCl vapour; turns $CuSO_4$ solution to dark blue.

TEST FOR SOME GASES

CONFIRMATORY TEST COLOUR /ODOUR

1. Hydrogen; H_2

-It makes pop sound with a glowing splint
-It burns with blue flame if mixed with air
-Colourless and odourless

2. Ammonia; NH_3

-It turns moist red litmus paper blue.
-It forms white dense fumes of NH_4Cl when in
-Contact with drops of conc. HCl on a glass rod
-Colourless with characteristic
-Choking smell.

3. Carbon (IV) oxide; CO_2

-It turns damp blue litmus paper red.
-It turns lime water milky. The milkiness

-Disappears in excess of CO_2
-Colourless and odourless

4. Hydrogen chloride; HCl
-It turns damp blue litmus paper red.
-When blown across the mouth of test tube, it forms copious fumes.
-When in contact with a drop of NH_3 solution on glass rod, it forms white dense fumes of NH_4Cl
-Colourless and sharp irritating smell

5. Sulphur(IV) oxide; SO_2
-It turns damp blue litmus paper red.
-It turns $K_2Cr_2O_7$ acidified with dilute H_2SO_4 from orange to green.
-It turns acidified $KMnO_4$ from purple to colourless.
-Colourless with pungent/irritating smell like that of burning matches.

6 Hydrogen sulphide; H_2S
-It turns damp blue litmus paper red.
-It turns $K_2Cr_2O_7$ acidified with dilute H_2SO_4
-Colourless with offensive odour like that of rotten egg.
-H_2S from orange to green and produces a yellow precipitate of sulphur.
-It turns acidified $KMnO_4$ from purple to colourless and produces a yellow precipitate of sulphur.

Appearance of Substance

Substance	Colour
Chromium(III), Cr^{3+}	Green
Chromate(VI), $Cr_2O_7^{2+}$	Orange
Manganate(II), Mn^{2+}	Pink (Almost Colourless)
Manganate(VII), MnO_4^-	Dark purple
Iron(II), Fe^{2+}	Pale green
Iron(III), Fe^{3+}	Yellow or Brown in solution
Copper, Cu^{2+}	Blue

Solubility of some salt in water
1. All trioxonitrate(v) salts, NO_3^-
2. All hydrogen trioxocarnate(IV) salts, HCO_3^-
3. All tetraoxosulphate(VI) salts, SO_4^{2-} except those of Ba^{2+}, Ca^{2+}, Ag^+, Pb^{2+}, Hg^{2+}
4. All chlorides, Cl^- , except those of Ag^+, Cu^{2+}, Pb^{2+}
5. All common salts of sodium and potassium
6. All ammonium salts.

Solubility of some salt in water
1. All trioxocarbonate(IV) salts, CO_3^{2-} , except those of Na^+, K^+ and NH_4^+
2. All hydroxides, OH^- , except those of Na^+, K^+ and NH_4^+

FLAME TEST

Observation	Inference
Intense golden yellow	Sodium
Lilac	Potassium
Brick red	Calcium
Light- green	Barium
Blue-green	Copper
Blue	Lead