SS3 CHEMISTRY SECOND TERM E-NOTE

- NUCLEAR CHEMISTRY (I)
- NUCLEAR CHEMISTRY (II)
- SIMPLE MOLECULES AND THEIR SHAPES
- PETROLEUM OR CRUDE OIL
- VOLUMETRIC (QUANTITATIVE) ANALYSIS
- QUALITATIVE ANALYSIS

Week 1
Topic: Nuclear Chemistry

Nuclear Reactions

Rutherford in 1919 transmitted nitrogen isotope into an oxygen isotope. The nitrogen was subjected to the action of swift alpha – particles derived from radium salt.

Transmutation is the process by which radioactive elements change into different elements.

Nuclear reaction is a process in which two nuclei or nuclear particles collide, to produce different products than the initial particles.

Nuclear fission and nuclear fusion both are nuclear phenomena that release large amounts of energy, but they are different processes which yield different products. Learn what nuclear fission and nuclear fusion are and how you can tell them apart.

Nuclear Fission

Nuclear fission takes place when an atom’s nucleus splits into two or more smaller nuclei. These smaller nuclei are called fission products. Particles (e.g., neutrons, photons, alpha particles) usually are released, too. This is an exothermic process releasing kinetic energy of the fission products and energy in the form of gamma radiation. Fission may be considered a form of element transmutation since changing the number of protons of an element essentially changes the element from one into another.

Nuclear Fission Example:

23592U + 10n → 9038Sr + 14354Xe + 310n

Nuclear Fusion

Nuclear fusion is a process in which atomic nuclei are fused together to form heavier nuclei. Extremely high temperatures (on the order of 1.5 x 107°C) can force nuclei together. Large amounts of energy are released when fusion occurs.

Nuclear Fusion Examples

The reactions which take place in the sun provide an example of nuclear fusion:

11H + 21H → 32He

32He + 32He → 42He + 211H

11H + 11H → 21H + 0+1β

Comparison between Nuclear Fission and Fusion

	Nuclear Fission	Nuclear Fusion
Definition:	Fission is the splitting of a large atom into two or more smaller ones.	Fusion is the fusing of two or more lighter atoms into a larger one.
Natural occurrence of the process:	Fission reaction does not normally occur in nature.	Fusion occurs in stars, such as the sun.

Byproducts of the reaction: Fission produces many highly radioactive particles. Few radioactive particles are produced by fusion reaction, but if a fission “trigger” is used, radioactive particles will result from that.

Conditions: of the substance and high-speed neutrons are required. High density, high temperature environment is required.

Energy Requirement: Takes little energy to split two atoms in a fission reaction. Extremely high energy is required to bring two or more protons close enough that nuclear forces overcome their electrostatic repulsion.

Energy Released: The energy released by fission is a million times greater than that released in chemical reactions; but lower than the energy released by nuclear fusion. The energy released by fusion is three to four times greater than the energy released by fission.

Nuclear weapon: One class of nuclear weapon is a fission bomb, also known as an atomic bomb or atom bomb. One class of nuclear weapon is the hydrogen bomb, which uses a fission reaction to “trigger” a fusion reaction.

Comparison of Nuclear Reaction and Ordinary Chemical Reaction

Nuclear Reaction Ordinary Chemical Reaction

During nuclear reactions, the nuclei of atoms undergo change and therefore new elements are formed as a result of such reactions. During chemical reactions, elements do not lose their identity. In these reactions, only the electrons in the outermost shell of atoms participate whereas the nuclei of atoms remain unchanged.

Reactivity of an element towards nuclear reactions is nearly independent of oxidation state of the element. For example, Ra element or Ra2+ ion in RaC2 behave s similarly during nuclear reactions. Reactivity of an element towards chemical reactions depends upon the oxidation state of the element. In ordinary chemical reactions, Ra and Ra2+ behave quite differently.

In nuclear reactions, isotopes behave quite differently. For example, U-235 undergoes fission quietly readily but U-238 does not. Different isotopes of an element have nearly same chemical reactivity.

Rate of a nuclear reaction is independent of temperature and pressure. Rate of a chemical reaction is largely affected by temperature and pressure.

A nuclear reaction cannot be reversed. A chemical reaction can be reversed.

Nuclear reactions are accompanied by large energy changes. Chemical reactions are accompanied by relatively small energy changes.
Assessment
What is the most significant difference between Nuclear fission and fusion?

What does Transmutation mean?

Week 2

Topic: Nuclear Chemistry (II)

Introduction to Radioactivity

Antoine Henri Becquerel, a French scientist, 1896, was conducting an experiment which started with the exposure of a uranium-bearing crystal to sunlight. Once the crystal had sat in the sunshine for a while, he placed it on a photographic plate. As he had anticipated, the crystal produced its image on the plate. Becquerel theorized that the absorbed energy of the sun was being released by the uranium in the form of x-rays. The husband and wife team of Pierre and Marie Curie in 1898 became interested in Becquerel's discovery. While experimenting with their own uranium-containing ore, they came up with the term "radioactivity" to describe the spontaneous emissions that they studied. This word is still used today to describe this special characteristic of some elements (radioisotopes).

While comparing the activity of pure uranium to a uranium ore sample, they found that the ore was significantly more radioactive than the pure material. They concluded that the ore contained additional radioactive components besides the uranium. This observation led to the discovery of two new radioactive elements which they named polonium and radium.

Radioactivity is the spontaneous disintegration of atomic nuclei. In other word, Radioactivity is the energy and mass released by spontaneous changes in the nucleus of an atom.

Radiation is energy that travels (‘radiates’) as waves or particles. Heat, light, sound, microwaves, radar, radio waves, X-rays, alpha and beta particles, and gamma rays are all forms of radiation.

All substance is made of atoms. These have electrons (e) around the outside, and a nucleus in the middle. The nucleus consists of protons (p) and neutrons (n), and is extremely small. In some types of atom, the nucleus is unstable, and will decay into a more stable atom.

Unstable atomic nuclei will spontaneously decompose to form nuclei with a higher stability. The decomposition process is called radioactivity. The energy and particles which are released during the decomposition process are called radiation. When unstable nuclei decompose in nature, the process is referred to as natural radioactivity. When the unstable nuclei are prepared in the laboratory, the decomposition is called induced radioactivity.

Types and Nature of Radiation

There are three different types of radiation: the alpha, beta and gamma. They have different penetrating powers.

radio

Alpha Radiation

Alpha radiation consists of a stream of positively charged particles, called alpha particles (α), which have an atomic mass of 4 and a charge of +2 (a helium nucleus). When an alpha particle is ejected from a nucleus, the mass number of the nucleus decreases by four units and the atomic number decreases by two units. For example:

23892U → 42He + 23490Th

The helium nucleus is the alpha particle.

Properties of Alpha Particles (α)

They are positively charged
They have low penetrating power (low energy) and because of their longer wavelengths, they cannot pass through a piece of paper
They have very powerful ionizing effects upon any gas through which they pass
They also cause some substances like zinc sulphide to fluorescence.

Beta Radiation

Beta radiation is a stream of electrons, called beta particles (β). When a beta particle is ejected, a neutron in the nucleus is converted to a proton, so the mass number of the nucleus is unchanged, but the atomic number increases by one unit. For example:

23490Th→ 0-1e + 23491Pa

Properties of Beta Particles (β)

The electron is the beta particle.
These rays are fast-moving stream of electrons
They are negatively charged
They are therefore deflected to the positive plate in an electric field
They have higher penetrating power than alpha particles with their shorter wavelength. They would not only pass through a piece of paper but also through a piece of aluminium which are metallic.
They have low ionizing effect on gases
They cause fluorescence in substances like anthracene but not zinc sulphide

Gamma Radiation

Gamma rays are high-energy photons with a very short wavelength (0.0005 to 0.1 nm). The emission of gamma radiation results from an energy change within the atomic nucleus. Gamma emission changes neither the atomic number nor the atomic mass. Alpha and beta emission are often accompanied by gamma emission, as an excited nucleus drops to a lower and more stable energy state.

Properties of Gamma Rays (ϓ)

They are not particles but electromagnetic waves similar to light but are of shorter wavelength than light rays and have higher frequency.

They have neither mass nor charge

They are therefore not deflected in an electric field

They travel at the speed of light

They have very high penetrating power. Out of the three types of radioactive emission, they are the most penetrating.

They have the least ionizing power

Penetration of radiation

radio 1

Detection of Radiation

Diffusion Cloud Chamber

The Diffusion Cloud Chamber is used to view high energy alpha particles, lower energy beta particles, and electrons produced by gamma rays interacting with gas molecules. The Chamber allows for the viewing of cosmic rays without the need for dry ice or external illumination. Historically the Cloud Chamber was the first particle detector for making ionizing particles visible. Its working principle is based on supersaturated vapour. This vapour shows tracks of condensated alcohol while being penetrated by ionizing particles. Vapour clouds build up along the particle tracks, which are sometimes thin and long, sometimes thick and round or bulbous. They may appear gradually or pop up all of a sudden or move very fast like a projectile splintering into all directions.

radio 2

Geiger – Muller Counter

The Geiger-Muller counter is a particle detector designed to detect ionizing radiation, such as alpha and beta as well as gamma radiation (although with significantly lower sensitivity than other types of detectors). It was invented by the German physicist Hans Geiger (co-discoverer of the atom nucleus) and later improved by his student Walther Muller, therefore the name Geiger-Muller counter. It is probably one of the most famous radiation detectors, mostly due to its simplicity and the distinctive audible clicks produced with the detection of individual particles.

Alternatively, except for its use in the detection of ionizing radiation, the Geiger counter is also used as a random number generator.

The main element of a Geiger counter is the Geiger-Muller tube, which is basically a chamber filled with inert gas or a mix of organic vapor and halogens. The tube contains two electrodes, the anode and the cathode, which are usually coated with graphite. The anode is represented by a wire in the center of the cylindrical chamber while the cathode forms the lateral area. One end of the cylinder, through which the radiation enters the chamber, is sealed by a mica window.

As ionizing radiation coming from the surrounding medium passes through the mica window and enters the Geiger-Muller tube, it ionizes the gas inside, transforming it into positively charged ions and electrons. The electrons eventually migrate towards the anode of the tube detector, while the positively charged ions accelerate towards the cathode. As the positive ions move towards the cathode, they collide with the remaining inert gas thus producing more ions through an avalanche effect. When this happens an electrical current is established between the two electrodes. The current is amplified and the resulting flow of electrons can be used to produce sound, light flashes or meter readings.

radio 3

Scintillation Counter
Certain minerals, such as zinc sulphide fluoresce or glow when exposed to radiation. The glow is made up of tiny flashes of light or scintillation and these may be seen under a microscope or counted with suitable device.

Radioactive Decay

Radioactive decay is the spontaneous radioactive disintegration of an atomic nucleus, resulting in the release of energy. Some atoms are stable. Others are unstable and ‘decay’, emitting radiation to achieve a stable state. The emissions from an unstable atom’s nucleus, as it decays, can be in the form of alpha, beta or gamma radiation.

When an atom decays, it changes into another isotope, or form, of the same element or into a completely different element, in a process called transmutation. Different isotopes of the same element differ in the number of neutrons in their nuclei. Some elements reach stability via a series of steps through several isotopes, or ‘daughter products’.

One example is uranium-238 (U-238), which, through the process of radioactive decay, will eventually become a stable isotope of lead. However, this process takes billions of years. Along the way, as the U-238 isotope’s initial energy declines, it will transmute via a series of elements, each more stable than the last – thorium, radium, radon, polonium and bismuth – before it stabilizes as lead.

Alpha decay

In alpha decay, a positively-charged particle is emitted from the nucleus of an atom. This alpha particle consists of two protons and two neutrons (the same structure as a helium-4 nucleus). Although alpha particles are normally highly energetic, they travel only a few centimeters in air and are stopped by a sheet of paper or the outer layer of dead skin.

Beta decay

In beta decay, a particle is emitted from the nucleus of an atom. This beta particle is an electron with either negative or positive electric charge. Beta particles may travel metres in air and several millimetres into the human body. Most beta particles may be stopped by a small thickness of a light material such as aluminium or plastic.

Gamma decay

Gamma decay occurs because the nucleus of an atom is at too high an energy state. The nucleus ‘falls down’ to a lower energy state, emitting a high energy photon known as a gamma particle in the process. Gamma particles travel in a wave-like pattern at the speed of light. They can only be stopped by a dense material such as lead, steel, concrete or several metres of water.

Half Life of Radioactive Elements

The half-life of a radioactive element is the time that it takes for one half of the atoms of that substance to disintegrate into another nuclear form. The decay of an isotope can be measured by its half life. These can range from mere fractions of a second, to many billions of years.

Element	Most Stable Isotope	Half-life of Most Stable Isotope
Polonium	Po-209	102 years
Astatine	At-210	8.1 hours
Radon.	Rn-222	3.82 days
Radium	Ra-226	1600 years
Thorium	Th-229	7.54 x 104 years
Uranium	U-236	2.34 x 107 years
Protactinium	Pa- 234	1.18 minutes

Example Rate of Radioactive Decay Problem

22688Ra, a common isotope of radium, has a half-life of 1620 years. Knowing this, calculate the first order rate constant for the decay of radium-226 and the fraction of a sample of this isotope remaining after 100 years.

Solution

The rate of radioactive decay is expressed by the relationship: k = 0.693/t1/2

Where k is the rate and t1/2 is the half-life.

Plugging in the half-life given in the problem: k = 0.693/1620 years = 4.28 x 10-4/year

Radioactive decay is a first order rate reaction, so the expression for the rate is:

log10 X0/X = kt/2.30

Where X0 is the quantity of radioactive substance at zero time (when the counting process starts) and X is the quantity remaining after time t. k is the first order rate constant, a characteristic of the isotope that is decaying. Plugging in the values:

log10 X0/X = (4.28 x 10-4/year)/2.30 x 100 years = 0.0186

Taking antilogs: X0/X = 1/1.044 = 0.958 = 95.8% of the isotope remains

Uses of Radioactivity

Radioactivity tracers are commonly used in the medical field and also in the study of plants and animals.
Radiation is used and produced in nuclear reactors, which controls fission reactions to produce energy and new substances from the fission products.
Radiation is also used to sterilize medical instruments and food.
Radiation is used by test personnel who monitor materials and processes by non-destructive methods such as x-rays.

Assessment

Radiation is detected by the following except
a. diffusion cloud chamber
b. scintillation counter
c. Geiger-Muller counter
d. pulse current
……….. they came up with the term “radioactivity” to describe the spontaneous emissions that they studied.
a. Becquerel
b. Pierre and Marie Currie
c. Geiger Muller

d. Marsden
Radioactive decay is expressed in terms of
a. rate of radioactive absorption
b. rate of radioactive stability
c. position of element in the periodic table
d. half life
The following characteristics belong to one of the basic nuclear particles (i) – Low penetrating (ii) – Powerful ionizing power on gases (iii) – Particulate
a. Alpha particles
b. Beta particles
c. Gamma rays
d. X-ray
Radioisotopes have wide application in
a. medicine
b. industries
c. agriculture
d. all of the above

Week 3

Topic: Simple Molecules and their Shapes

Polar and non-polar molecules

Chemical bonding is the result of either an atom sharing one or more outer orbit electrons with another atom or an atom taking outer orbit electrons from the atom with which it is bonding. Normally, an atom has an even distribution of electrons in the orbits or shells, but if more end up on one side that the other in a molecule, there can be a resulting electrical field in that area.

Water is a polar molecule because of the way the atoms bind in the molecule such that there are excess electrons on the Oxygen side and a lack or excess of positive charges on the Hydrogen side of the molecule.

simple m

Water is a polar molecule with positive charges
on one side and negative on the other.

Examples of polar molecules of materials that are gases under standard conditions are:

Ammonia (NH3)
Sulfur Dioxide (SO2)
Hydrogen Sulfide (H2S).
Also, Ethanol is polar, since its oxygen molecule draws electrons towards it due to its high electro-negativity, causing a negative charge around itself.

Non-polar molecules

A non-polar molecule is one that the electrons are distributed more symmetrically and thus does not have an abundance of charges at the opposite sides. The charges all cancel out each other.

simple m1

The electrical charges in non-polar Carbon Dioxide are evenly distributed

Examples of non-polar liquids

Most hydrocarbon liquids are non-polar molecules. Examples include:

Toluene
Gasoline

Alkynes are non-polar because they cannot be dissolved in water, as do polar molecules. However, alkynes but do dissolve in other non-polar substances. A rule is that like substances dissolve in like substances.

Examples of non-polar gases

Common examples of non-polar gases are the noble or inert gases, including:

Helium (He)
Neon (Ne)
Krypton (Kr)
Xenon (Xe)
Other non-polar gases include:

Hydrogen (H2)
Nitrogen (N2)
Oxygen (O2)
Carbon Dioxide (CO2)
Methane (CH4)
Ethylene (C2H4)
Since Chloroform is more soluble in fats than in water, it is also classified as non-polar.

Rule for Solutions

The rule for determining if a mixture becomes a solution is that polar molecules will mix to form solutions and non-polar molecules will form solutions, but a polar and non-polar combination will not form a solution.

Water is a polar molecule and oil is a non-polar molecule. Thus they won’t form a solution. On the other hand, since alcohol is a polar molecule, it will form a solution with water.

From these examples, we note that three factors determine whether a molecule is polar and non-polar. These are

The polarity of the covalent bond
The number and position of lone pairs
The shape of the molecule
General Structures of Crystals

The external shape of a crystal is the result of the spatial arrangement of the particles that make up the crystal. The three-dimensional arrangement of the particles is called the crystal lattice. The crystal lattice may be considered to be made up of unit cells which are each the smallest portion of the crystal lattice which shows the complete pattern of the particles in their relative positions

simple m2

There are three kinds of unit cells based on the cubic structure. These are as follow:

Simple cubic: These are structures in which the particles are placed one at each corner of the cube.
Face-centred cubic: These are structure in which there is a particle at each corner and one in the centre of each face of the cube
Body-centred cubic: These are structure in which there is a particle at each corner and one at the centre of the cube.
Covalent Compounds – Simple Molecules

Form between non-metal atoms. Each bond consists of a shared pair of electrons, and is very strong. Covalently bonded substances fall into two main types:

Simple molecules and
Giant covalent structures.
Simple molecules

simple m3

These contain only a few atoms held together by strong covalent bonds. An example is carbon dioxide (CO2), the molecules of which contain one atom of carbon bonded with two atoms of oxygen.

Properties of Simple Molecular Substances

Low melting and boiling points – This is because the weak intermolecular forces break down easily.
Non-conductive – Substances with a simple molecular structure do not conduct electricity. This is because they do not have any free electrons or an overall electric charge.
Hydrogen, ammonia, methane and water are also simple molecules with covalent bonds. All have very strong bonds between the atoms, but much weaker forces holding the molecules together. When one of these substances melts or boils, it is these weak ‘intermolecular forces’ that break, not the strong covalent bonds. Simple molecular substances are gases, liquids or solids with low melting and boiling points.

Covalent bonding – Giant Covalent structures

Giant covalent structures contain a lot of non-metal atoms, each joined to adjacent atoms by . The atoms are usually arranged into giant regular lattices – extremely strong structures because of the many bonds involved. The graphic shows the molecular structure of diamond and graphite: two allotropes of carbon, and of silica (silicon dioxide).

simple m4

From left to right – graphite, diamond, silica

Properties of Giant Covalent Structures

Very high melting points – Substances with giant covalent structures have very high melting points, because a lot of strong covalent bonds must be broken. Graphite, for example, has a melting point of more than 3,600ºC.

Variable conductivity – Diamond does not conduct electricity. Graphite contains free electrons, so it does conduct electricity. Silicon is semi-conductive – that is, midway between non-conductive and conductive.

Graphite

Graphite is a form of carbon in which the carbon atoms form layers. These layers can slide over each other, so graphite is much softer than diamond. It is used in pencils, and as a lubricant. Each carbon atom in a layer is joined to only three other carbon atoms. Graphite conducts electricity.

Diamond

Diamond is a form of carbon in which each carbon atom is joined to four other carbon atoms, forming a giant covalent structure. It is the best example of covalent solid, which is usually octahedral in shape. As a result, diamond is very hard and has a high melting point. It does not conduct electricity. Diamond is the hardest substance known.

Silica

Silica, which is found in sand, has a similar structure to diamond. It is also hard and has a high melting point, but contains silicon and oxygen atoms, instead of carbon atoms.

The fact that it is a semi-conductor makes it immensely useful in the electronics industry: most transistors are made of silica.

Molecular Shape

While Lewis dot structures can tell us how the atoms in molecules are bonded to each other, they don’t tell us the shape of the molecule. In this section, we’ll discuss the methods for predicting molecular shape. The most important thing to remember when attempting to predict the shape of a molecule based on its chemical formula and the basic premises of the VSPER model is that the molecule will assume the shape that most minimizes electron pair repulsions. In attempting to minimize electron pair repulsions, two types of electron sets must be considered: electrons can exist in bonding pairs, which are involved in creating a single or multiple covalent bond, or non-bonding pairs, which are pairs of electrons that are not involved in a bond, but are localized to a single atom.

The VSPER Model—Determining Molecular Shape

Total number of single bonds, double bonds, and lone pairs on the central atom	Structural pair geometry	Shape
2	Linear	
3	Trigonal planar	
4	Tetrahedral	
5	Trigonal bipyramidal	
6	Octahedral	

The above table represents a single atom with all of the electrons that would be associated with it as a result of the bonds it forms with other atoms plus its lone electron pairs. However, since atoms in a molecule can never be considered alone, the shape of the actual molecule might be different from what you'd predict based on its structural pair geometry. You use the structural pair geometry to determine the molecular geometry by following these steps:

Draw the Lewis dot structure for the molecule and count the total number of single bonds, multiple bonds, and unpaired electrons.
Determine the structural pair geometry for the molecule by arranging the electron pairs so that the repulsions are minimized (based on the table).
Use the table above to determine the molecular geometry.
For instance, look at methane, which is CH_4:

simple m5

So as you can see, lone pairs have more repulsive force than do shared electron pairs, and thus they force the shared pairs to squeeze more closely together.

As a final note, you may remember that we mentioned before that only elements with a principal energy level of 3 or higher can expand their valence and violate the octet rule. This is because d electrons are necessary to make possible bonding to a fifth or sixth atom. In XeF_4, there are two lone pairs and four shared pairs surrounding Xe, and two possible arrangements exist:

simple m6

In the axial arrangement, shared pairs are situated “top and bottom.” In the equatorial arrangement, shared pairs surround Xe. The equatorial arrangement is more stable since the lone pairs are 180˚ apart and this minimizes their repulsion. In both molecular arrangements, the electronic geometry is octahedral, with 90˚ angles. The top figure has a molecular geometry known as “seesaw,” while the bottom figure has a molecular geometry that is more stable, known as square planar.

Example

Draw the dot formula for SeF_4 and determine the hybridization at Se.

Explanation

First determine the number of valence electrons this molecule has: SeF_4 has 6 + 4(7) = 34 valence electrons, which is equal to 17 pairs of electrons.

Selenium is surrounded by four fluorines and a lone pair of electrons. That’s five sites of electron density, which translates into sp^3d hybridization. Se is from the fourth period, so it may have an expanded octet.

So, to recap, focus on the number of binding “sites” or areas of concentrated electron density:

Two areas of electron density: linear, planar molecule

Three areas of electron density: trigonal planar molecule

Four areas of electron density: tetrahedral molecule

Five areas of electron density: trigonal bipyramidal molecule

Six areas of electron density: octahedral molecule

Molecular Polarity

In chemical bonds, polarity refers to an uneven distribution of electron pairs between the two bonded atoms—in this case, one of the atoms is slightly more negative than the other. But molecules can be polar too, and when they are polar, they are called dipoles. Dipoles are molecules that have a slightly positive charge on one end and a slightly negative charge on the other. Look at the water molecule. The two lone electron pairs on the oxygen atom establish a negative pole on this bent molecule, while the bound hydrogen atoms constitute a positive pole. In fact, this polarity of water accounts for most of water's unique physical properties. However, molecules can also contain polar bonds and not be polar. Carbon dioxide is a perfect example. Both of the C—O bonds in carbon dioxide are polar, but they're oriented such that they cancel each other out, and the molecule itself is not polar.

Assessment

These are factors which determine whether a molecule is polar or non-polar except
a. shape of the molecule
b. number of lone pairs in an atom
c. number of electronegative elements present
d. polarity of covalent bond
These are examples of unit cell cubic structure
a. simple cubic structure
b. non-linear cubic structure
c. face-centered cubic structure
d. body centered cubic structure
These are intermolecular bonds or attractions except
a. metallic bond
b. dipole – dipole attractions

c. van-der Waal’s forces
d. hydrogen bond
List the properties of simple molecular substances

Week 5
Topic: Petroleum or Crude Oil

Crude Oil

Crude oil or Petroleum is the chief source of hydrocarbons. Petroleum which means rock oil in Latin occurs as a dark, sticky, viscous liquid. It is found in huge underground deposits in many parts of the world. Natural gas is usually found together with it. Petroleum is a mixture of gaseous liquid and solid alkanes, alkenes, cycloalkanes, aromatic hydrocarbons and others. Natural gas consists mainly of methane. Crude oil is a mixture of hydrocarbons. It exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities.

Crude oil occurs in large quantities in Nigeria, especially in Bayelsa, Edo, Imo, rivers, Delta, Abia, Ondo and Cross river state. It is dark brown in colour though its composition and consistency vary from place to place. In fact, different oil producing areas yield significantly different varieties of crude oil. We have light and heavy crude oil. The light one has low metal and sulphur content, light in colour and flows easily. It is very expensive. The heavy one has high metal and sulphur content and must be heated to become fluid. It is less expensivePetroleum is a naturally occurring, yellow-to-black liquid found in geological formations beneath the Earth’s surface, which is commonly refined into various types of fuels. Components of petroleum are separated using a technique called fractional distillation.

It consists of hydrocarbons of various molecular weights and other organic compounds

Origin of Crude Oil and Natural Gas

They are formed from the remains of marine algae and animals. When these tiny aquatic organisms died, their remains gradually settled on the seabeds. Over the years, the remains became covered by mud, silt and other sediments. As the sediments piled up, their mass exerted a great pressure on the lower layers, changing them to hard sedimentary rocks. During this process, bacterial activity, heat and pressure probably changed the plant and animal remains into crude oil and natural gas.

Refining of Crude Oil

Petroleum or crude oil occurs naturally. it contains many useful products also called fractions. These are separated by the method of fractional distillation. This process of obtaining useful fractions from petroleum is called refining.

The process of dividing petroleum into fractions with different boiling range volatilities and free from impurities is called refining.
The process of turning petroleum into a useful form is done in a crude oil refinery. The steps for making crude oil into oil, petrol or whatsoever are fractional distillation, cracking and reforming.

Petroleum is refined by fractional distillation. The process of separating a mixture into a series of fractions of different volatilities by means of distillation is known as fractional distillation.
In the process of fractional distillation, a mixture of different liquids is evaporated followed by condensation. Different liquids are evaporated according to their boiling point and they are collected in different chambers of distillation tower

crude oil

Fractional Distillation of Crude Oil

Fractional distillation differs from distillation only in that it separates a mixture into a number of different parts, called fractions. A tall column is fitted above the mixture, with several condensers coming off at different heights. The column is hot at the bottom and cool at the top. Substances with high boiling points condense at the bottom and substances with low boiling points condense at the top. Like distillation, fractional distillation works because the different substances in the mixture have different boiling points.

Fractions of petroleum from refining are petroleum gases (Methane, butane, etc.), petrol or gasoline, kerosene, diesel, lubricating oil and bitumen (asphalt). Because they have different boiling points, the substances in crude oil can be separated using fractional distillation. The crude oil is evaporated and its vapours allowed to condense at different temperatures in the fractionating column. Each fraction contains hydrocarbon molecules with a similar number of carbon atoms.

The mixture is inserted at the bottom, where mostly everything will condense as the temperature is 350°C and more. The condensed crude oil will rise to the next fraction above, which has a very high temperature as well, but a slightly smaller one. Only the part of the mixture, which boiling point is under the temperature of the fraction, will condense and rise to the next fraction. The part of the mixture, whose boiling point is higher than the temperature inside the distillation fraction, will stay there and be pumped out.

Crude oil is heated until it boils and then the hydrocarbon gases are entered into the bottom of the fractionating column. As the gases go up the column the temperature decreases.

The hydrocarbon gases condense back into liquids and the fractions are removed from the sides of the column. The different fractions have different uses.The smaller the hydrocarbon molecule, the further it rises up the column before condensing.

The fractionating column operates continuously. The temperatures shown are approximate. A sample of crude oil may be separated in the laboratory by fractional distillation. The collection vessel is changed as the temperature rises to collect the different fractions.

Cracking

After the fractional distillation process, the separated mixtures have to be cracked down. This means that a long molecule will be split up in smaller parts.
Firstly, single bonds will be broken down. This results into some lone electrons. The lone electrons form double bonds. Thus, hydrogen will disconnect from the carbon atom. Hydrogen (H_2) remains as a side product. The loss of hydrogen in these smaller organic molecules is logical, because when they are lost, more lone electrons remain with what the previous lone electrons can make a bond.

petroleum 2

Reforming

After cracking, the molecules are ready to undergo the reforming process.
This is given by the octane number. The octane number is very important in petrol. It tells what the percentage of pure heptane (in the earlier days it was octane – that is why it is called octane number) in petrol is. This is of great importance for the chemical behaviour. The quality of petrol is improved by adding mixtures to pure heptane. The chains of heptane are heated up (where platinum is used as a catalyst). So they can change. After the heating process, it shows a higher amount of branched chains. This increases the octane number.

Example: When the petrol you buy has a 98 in the name, then it means that 98% are branched chains and 2% of the mixture is pure heptane (or another pure molecule).

Octane Number

The octane number or octane rating of petrol is a measure of the proportion of branched chain hydrocarbons in a given blend of gasoline (petrol).

In other words, Octane number is a standard which determines the knocking ability and quality of gasoline. Higher is the octane number of a gasoline, lower is the knocking it produces.

Gasoline is composed of C7 – C9 hydrocarbons i.e. heptanes, octane and nonane. These hydrocarbons are present in their straight chain or branched chain isomers. It has been shown that straight chain hydrocarbons burn too rapidly in the car engine thus, causing irregular motion of the pistons which results in rattling noise. This rattling noise is known as “Knocking”.

Knocking

Knocking is a sharp metallic sound produced in the internal combustion engine. Knocking is caused by the low octane number of gasoline

Synthetic Petrol

Synthetic petrol is made from materials such as coal, coke and hydrogen which do not occur in crude petroleum. Synthetic petrol can be gotten from two sources

From coal: When powdered coal is heated with hydrogen in the presence of iron or tin as catalyst at 500oC and 200 atmospheric pressure, it is converted into an oily mixture of hydrocarbons. The mixture is separated by distillation into a petrol fraction boiling at 200oC and a heavy oily residue which can be further treated with fresh coal to obtain more petrol

From Coke: When steam is passed over heated coke at 1000oC, a mixture containing equal volumes of carbon (II) oxide and hydrogen known as water gas is obtained

C(s) + H2O(l) ——> CO(g) + H2(g)

The water gas can be hydrogenated to a mixture of hydrocarbons by adding hydrogen and passing it over finely divided nickel as catalyst at 200oC. About half of the product is petrol, the less volatile fraction is used as fuel for diesel engines

Fractions of Crude Oil

Petroleum gases – These gases are liberated at the top of the column at temperatures below 40o They are mainly hydrocarbons consisting of one of four carbon atoms per molecule, e.g methane, ethane, propane, butane and ethane. They are used mainly as fuels for homes and industries and for manufacture of products like hydrogen, sulphide and ethyne

Petroleum ethers and ligroin – This is the mixture of very volatile liquids consisting of hydrocarbons with five or seven carbon atoms per molecule. The petroleum ether or light petroleum distils over between 2oC to 60oC, while the ligroin or light naphtha distils over between 60oC to 100o

Petrol – Petrol or gasoline is a mixture of hydrocarbons consisting of four to twelve carbon atoms per molecule. It is a volatile liquid which distils over in the temperature range of 40oC to 200o Petrol is used as a fuel for aeroplanes and motor vehicles. It is a good solvent for paints and grease

Kerosene – Kerosene contains hydrocarbons with twelve to eighteen carbon atoms per molecule. It distils over in the temperature of 200oC to 250o it is a fairly volatile liquid and is used as a fuel for lighting and heating and for driving tractors and some modern jet engines. It is a good solvent for paint and grease

Gas oil and Diesel oil – They have twenty to twenty five carbon atoms per molecule. They distil over in the temperature of 250oC to 350o They are mainly used as fuel for heating and diesel engines and as raw materials of the cracking process

Lubricating oils – They are heavy oils. They consist of hydrocarbons with more than twenty five carbon atoms per molecule. They distil over in the temperature of 350oC to 500o They are viscous liquids used for lubricating moving parts of engines and machines. Grease belongs to this group. Vaseline and paraffin wax are solid long chain hydrocarbons which are obtained from re-distillation of heavy oils.

Bitumen and other residues – these are solid residues left behind at temperatures above 500o Bitumen are used for surfacing roads and airfields while other residues may be used as fuel, in protective paints and water proofing roofs.

Assessment

……… is the chief source of hydrocarbons

………. of petrol is a measure of the proportion of branched chain hydrocarbons in a given blend of gasoline (petrol).

……….. involves the separation of a mixture into a number of different parts, called fractions.
……….. is a sharp metallic sound produced in the internal combustion engine
Mention 4 fractions of crude oil

Week 6
Topic: Volumetric Analysis

Introduction

Volumetric analysis is an analytical method or procedure for working out the titre or concentration of an analyte in a solution. This is done by measuring the volume of a standard solution of an appropriate reagent whose precise concentration is already known.

Preparing A Standard Solution

A standard solution is a solution in which its concentration is known.
The steps taken in preparing a standard solution are:
Determine the volume and concentration that you want to prepare.
Calculate the mass of solute needed to give the required volume and concentration.
Weigh the solute
Dissolve the solute completely dissolved in distilled water and then transfer it to a volumetric flask partially filled with distilled water.
Add distilled water to the calibration mark of the volumetric flask.
Invert the flask and shake it to make sure thorough mixing.
volumetric

Acid Base Titration

Some materials used during acid – base titration and precautions in using some of them

weighing balance
chemical balance
pipette
burette
retort stand
filter paper
funnel
white tile
standard volumetric flask
conical flask
Pipette

rinse the pipette with the solution it will be measured with e.g. base
avoid air bubbles in the pipette
make sure the mark to be read is at same level with your eye
do not blow the last drop on the burette
Burette

rinse the burette with acid or allow it to drain after rinsing
make sure the burette jar is filled
avoid air bubbles in the burette
make sure that burette is not leaking4remove the funnel befor taking your reading
avoid inconsistent burette reading
Conical flask

do not rinse with any of the solutions used in the titration but with distilled water
wash down with distilled water any drop of the solution that stick by the sides of the conical flask
Concentration of a Solution

The concentration of a solution tells you how much solute is dissolved in 1 unit volume of solution.
The volume of a solution is measured in dm^3 (litres) 1 dm^3 = 1000 cm^3.
The amount of solute can be measured in grams or moles.

2 units of concentration used in chemistry are g dm-3 and mol dm-3
Concentration in g dm-3

Concentration is the number of moles of solute per liter of solution.
A concentration of 10 g dm-3 means there is 10 g of solute dissolved in1 dm3 of solution.
Concentration=Mass of solute (g) / Volume of solution (dm3)

Example 1:
Calculate the concentration of the solution if 28g of NaOH is dissolve in 250cm3 of water.
Answer:
Mass of solute = 28g
Volume of solvent = $250cm^3 = 0.25dm^3$

Concentration = Mass / Volume

=28g / 0.25dm3

=112g/dm3

Concentration in mol dm-3 (Molarity)

Molarity is probably the most commonly used unit of concentration. It is the number of moles of solute per liter of solution.
A concentration of 2 mol dm-3 means there are 2 moles of solute dissolved in 1 dm3 of solution.
Molarity=Mole of solute(mol) / Volume of solution(dm3)

Example 2:
What is the molarity of a solution made when water is added to 0.2 mol of CaCl2 to make 100 cm^3 of solution? [RAM: Ca = 40; Cl = 35.5]

Answer:
Number of mole of solute = 0.2 mol

Volume of solvent = 100 cm^3 = 0.1 dm^3

Molarity = Number of Mole / Volume

= 0.2mol / 0.1dm3

=2mol/dm3

Conversion of Concentration Unit

volumetric2

The chart above shows how to convert the units of concentration from g dm-3 to mol dm-3 and vice versa.
The molar mass of the solute is equal to the relative molecular mass of the solute.
Example 3:
The concentration of a Potassium chloride solution is 14.9 g dm-3. What is the molarity (mol dm-3) of the solution? [Relative Atomic Mass: Cl = 35.5; K = 39]

Answer:
Relative Formula Mass of Potassium Chloride (KCl)
= 39 + 35.5 = 74.5

Molar Mass of Potassium Chloride = 74.5 g/mol

Molarity of Potassium Chloride

Molarity = ConcentrationMolar Mass=14.9gdm−374.5gmol−1=0.2mol/dm3

Molarity and Number of Moles

Number of mole of solute in a solution can be calculated by using the following formula

n=MV / 1000

where
n = number of mole of solute
M = molarity of the solution
V = volume of the solution in cm3

Example 4

How many moles of zinc sulphate is present in 200cm3 of 0.1 mol dm-3 zinc sulphate solution?

Answer:

Molarity, M = 0.1 mol dm-3
Voloume, V = 200cm3

n=MV / 1000

n= (0.1)(200) / 1000 = 0.02mol

Example 5

A solution of barium hydroxide have molarity 0.1 mol dm-3. What is the concentration of the solution in g dm-3? [Relative Atomic Mass: Ba = 137; O = 16; H = 1]

Answer:

Relative Formula Mass of barium hydrokxide, Ba(OH)2
= 137 + 2(16+1) = 171

Molar Mass of Potassium Chloride = 171 g/mol

Concentration = Molarity × Molar Mass

=0.1mol/dm3 × 171gmol−1 = 17.1gmol−1

Solubility of substance

The term solubility refers to the maximum amount of material that will dissolve in a given amount of solvent at a given temperature to produce a stable solution.

Calculations on Solubility

Examples 1: If 12.2 g of lead(II) trioxonitrate(V) were dissolved in 21 g of distilled water at 20oC, calculate the solubility of the solute in mol dm-3.

Solution:

Molar mass of Pb(NO3)2 = 331 g

12.2 g of Pb(NO3)2 = 12.2/331 = 0.037 mole

21 g of water at 20oC dissolved 0.037 mole of Pb(NO3)2

1000 cm3 of water at 20 oC dissolved 1000 x 0.037 / 21

= 1.76 moles of Pb(NO3)2

At 20oC, the solubility of Pb(NO3)2 in water is 1.76 mol dm-3

Using formula Method

Solubility = mass/molar mass x 1000/vol

= 12.2/331 x 1000/21

= 1.7751 mol dm-3

= 1.76 mol dm-3

Example 2: The solubility of potassium trioxonitrate (V) is exactly 1800 g per 1000 g water at 83oC and 700 g per 1000 g water at 40oC. Calculate the mass of potassium trioxonitrate (V) that will crystallize out of solution if 155 g of the saturated solution at 83 oC is cooled to 40oC.

Solution:

	Solvents	+	Solution	= Solution
Masses involved at 83oC	1000 g		1800 g	= 2800 g
Masses involved at 40oC	1000 g		700 g	= 1700 g

Solute deposited on cooling from 83oC to 40oC = 2800 – 1700 = 1100 g

On cooling from 83oC to 40oC,

2800 g of saturated solution deposit 1100 g of solute

155 g of saturated solution will deposit = 1100 x 155 / 2800

= 60.89 g of solute

A titration calculation

The method for titration calculations is the one you have used for mole calculations already:

Write a balanced equation for the reaction.
Find the number of moles of the known substance.
Use the balanced equation to find the number of moles of the unknown substance.
Work out the mass, concentration or volume of the unknown.
The formula:

MAVA/MBVB = NA/NB

MA = Molarity of acid in mol/dm3

VA = Volume of the acid in cm3

MB = Molarity of base in mol/dm3

VB = Volume of the base in cm3

NA = Number of moles of acid

NB = Number of moles of base

Example 1: Calculate:

(a) the mass of anhydrous Na2CO3 present in 300cm3 of 0.1M

(b) the number of Na2CO3 particles present in the solution (Na = 23, C = 12, O = 16)

Solution:

(a) Molarity of the Na2CO3 solution = 0.1 M

Molar mass of Na2CO3 = 23 x 2 + 12 + 16 x 3 = 106g/mol

Concentration (g/dm3) = Molarity x molar mass

0.1 x 106

= 10.6g/dm3

This means 1000cm3 of 0.1M solution contain 10.6g of Na2CO3

300cm3 of 0.1 M solution will contain: 300 x 10.6 / 1000

= 3.18g of Na2CO3

(b) Number of Na2CO3 particles = molarity x 6.02 x 1023

0.1 x 6.02 x 1023

= 0.602 x 1023

This means 1000cm3 of 0.1 M solution contain 0.602 x 1023 Na2CO3 particles

300cm3 of 0.1M solution contain

Example 2: 20.30cm3 of hydrochloric acid solution was titrated against 25cm3 of 0.1M sodium hydroxide solution. Calculate:

(i) the concentration of the acid in mol/dm3

(ii) the concentration of the acid in g/dm3

Solution:

Equation of reaction

HCl (aq) + NaOH (aq) ———> NaCl (aq) + H2O (l)

1 : 1

(i) MA =?, MB = 0.1 M, VA = 20.30cm3, VB = 25cm3, NA = 1, NB = 1

MAVA/MBVB = NA/NB

MA = MBVB NA / VA NB

MA = 0.1 x 25 x 1 / 20.30 x 1

MA = 0.123 mol/dm3

(ii) Molarmass of Acid = 36.5 g/mol, Concentration of Acid in mol/dm3 = 0.123 mol/dm3

Concentration of Acid in g/dm3 = Concentration of Acid in mol/dm3 x Molarmass

= 0.123 x 36.5

= 4.49 g/dm3

Assessment

Calculate the concentration of the solution if 25g of NaOH is dissolve in 500cm3 of water.

32.30cm3 of hydrochloric acid solution was titrated against 25cm3 of 0.2M sodium hydroxide solution. Calculate: a. the concentration of the acid in mol/dm3 b. the concentration of the acid in g/dm3

If 21.2 g of Calcium Trioxocarbonate were dissolved in 15 g of distilled water at 30oC, calculate the solubility of the solute in mol dm-3.

The concentration of a Potassium chloride solution is 28.9 g dm-3. What is the molarity (mol dm-3) of the solution? [Relative Atomic Mass: Cl = 35.5; K = 39]

Week 8

Topic: Qualitative Analysis

Identification of Ions

There are 10 cations and 4 anions to be studied:

Cation

Sodium	Na+	Iron (II)	Fe2+
Calcium	Ca2+	Iron (III)	Fe3+
Magnesium	Mg2+	Lead(II)	Pb2+
Aluminium	Al3+	Copper (II)	Cu2+
Zinc	Zn2+	Ammonium	NH4+

Anion

Chloride ion	Cl–
sulphate ion	SO42-
nitrate ion	NO3–
carbonate ion	CO3–

Steps in qualitative analysis

qualitative

Colour of Ions

Salt or metal oxide	Solid	Aqueous solution
Salt of Sodium, Calcium, Magnesium, Aluminium, zinc, Lead, ammonium	White	Colourless
Salt of Chloride, sulphate, nitrate, carbonate	White	Colourless
Salt of Copper(II) –		
Copper(II) Carbonate	Green	–
Copper(II) sulphate, Copper(II) nitrate, Copper(II) chloride	Blue	Blue
Copper(II) oxide	Black	–
Salt of Iron (II):		
Iron(II) sulphate; Iron(II) nitrate; Iron(ID chloride	Green	Green
Salt of Iron (III):		
Iron(III) sulphate; Iron(III) nitrate; Iron(III) chloride	Brown	Brown
Zink oxide	Yellow when it is hot and white when it is cold.	–
Lead(II) oxide-	Brown when it is hot and yellow when it is cold.	–
Magnesium oxide, Aluminium oxide	White	Insoluble
Potassium oxide, Sodium oxide, Calcium oxide	White	Colourless

Heating Effect on Carbonate Salts

All carbonates salts except potassium carbonate and sodium carbonate can be decomposed by heat to produce carbon dioxide gas.
Table below shows the effect of heating on metal carbonate.
Carbonate Salt Equation of The Reaction
Potassium carbonate
Sodium carbonate Will not decompose by heat
Calcium carbonate
Magnesium carbonate
Aluminium carbonate
Zinc carbonate
Iron (III) carbonate
Lead(II) carbonate
Copper(II) carbonate Calcium carbonate
$CaCO_3 \rightarrow CaO + CO_2$

Aluminium carbonate

$Al_2(CO_3)_3 \rightarrow Al_2O_3 + 3CO_2$

Copper carbonate

$CuCO_3 \rightarrow CuO + CO_2$Mercury(II) carbonate
Silver carbonate
Aurum(II) carbonateSilver carbonate

$2Ag_2CO_3 \rightarrow 2Ag + 2CO_2 + O_2$Ammonium carbonate$(NH_4)_2CO_3 \rightarrow 2NH_3 + 2CO_2 + H_2O$

Heating Effect on Nitrate Salts

All nitrates salts decompose when heated.
Table below shows the products formed when different nitrate salts are heated.
Nitrate Salt Equation of The Reaction

Ammonium nitrate Ammonium nitrate decompose to nitrogen monoxide and water vapour when heated.
$NH_4NO_3 \rightarrow N_2O + 2H_2O$Potassium nitrate
Sodium nitratePotassium nitrate

$2KNO_3 \rightarrow 2KNO_2 + O_2$

Sodium nitrate

$2NaNO_3 \rightarrow 2NaNO_2 + O_2$Calcium nitrate
Magnesium nitrate
Aluminium nitrate
Zink nitrate
Iron (III) nitrate
Lead(II) nitrate
Copper(II) nitrateMagnesium nitrate

$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$

Iron(III) nitrate

$4Fe(NO_3)_3 \rightarrow 2Fe_2O_3 + 12NO_2 + 3O_2$

Lead(II) nitrate

$2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$Mercury(II) nitrate
Silver(I) nitrate
Aurum(II) nitrateSilver nitrate

$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$

Heating Effect on Sulphate Salts

Most sulphate salts do not decompose by heat. For instance, sodium sulphate, potassium sulphate, and calcium sulphate are not decomposable by heat.
Only certain sulphate salts are decomposed by heat when heated strongly.
For instance:

Strong heating of green crystal iron (II) sulphate will release steam, sulphur dioxide, sulphur trioxide and leave behind a reddish solid iron (III) oxide residue. The steam released comes from the hydrated water of the crystallize salt.

$2FeSO_4.7H_2O \rightarrow Fe_2O_3(p) + SO_2(g) + SO_3(g) + 14H_2O(g)$

Meanwhile, zinc sulphate, copper (II) sulphate, and iron (III) sulphate decompose when heated strongly to evolve sulphur (VI)oxide gas and form a metal oxide.
Example
Zinc sulphate

$ZnSO_4 \rightarrow ZnO + SO_3$
Copper (II) sulphate

$CuSO_4 \rightarrow CuO + SO_3$
Iron (III) sulphate

$Fe_2(SO_4)_3 \rightarrow Fe_2O_3 + 3SO_3$

When ammonium sulphate is heated strongly, this white solid sublimate and is decomposed to form ammonia gas and sulphuric acid.

$(NH_4)_2SO_4 \rightarrow NH_3 + H_2SO_4$

Identifying Gases

Oxygen (Glowing wooden splinter)
A glowing wooden splinter is inserted into the test tube that contain the gas.

The gas rekindles the glowing wooden splinter.

Hydrogen (Lighted Wooden Splinter)
A lighter wooden splinter is brought close to the mouth of the test tube that contain the gas.

A “pop” sound is produced.

Carbon dioxide (Lime Water)
The gas is directed to flow through lime water.

The lime water turn chalky.

Sulphur Dioxide (Potassium Dichromate(VI))
The gas is directed to flow through potassium dichromate(VI) solution.

The orange colour of potassium dichromate(VI) solution become green.

Chlorine (Moist Litmus Paper)
Moist blue litmus paper is inserted into the test tube that contain the gas.

The blue litmus paper turn red and then white.

Ammonia Gas (Moist litmus paper)
Moist red litmus paper is inserted into the test tube that contain the gas.

The red litmus paper turn blue.

Identifying Anions – Carbonate

The carbonate salts react with acid produce carbon dioxide and water. This chemical property of carbonate is used to test the presence of carbonate in a salt.

CO32– + 2H+ → H2O + CO2

During the test, some dilute hydrochloric acid / nitric acid /sulphuric acid is added to the carbonate salt.
qualitative cont

If the salt contain carbonate, effervescence occurs.
If the gas given off is passed through lime water, the lime water will turns chalky.
This indicates that the gas is carbon dioxide, and hence the salt contain carbonate.

Identifying Anions – Sulphate

All salts of sulphate are soluble in water, except lead(II) sulphate, barium sulphate and calcium sulphate.

The insolubility of barium sulphate is used to test for the presence of sulphate in a salt.

2 cm3 of dilute hydrochloric / nitric acid is added to 2 cm3 of sulphate solution.
This is to check whether carbonate is presence in the solution or not because carbonate may give the same result as sulphate.
If not effervescence, then 2 cm3 of barium chloride is added into the solution.
If sulphate ions are presence, a white precipitate will form. The precipitate is barium sulphate.
This is actually the double decomposition reaction that you have learned in preparation of insoluble salt.
Ba2+ + SO42– → BaSO4

Identifying Anions – Chloride

All the salts of chloride are soluble in water except lead(II) chloride, silver(I) chloride and mercury chloride.The insolubility if silver(I) chloride is used in the test of presence of chloride.

2 cm^3 of dilute nitric acid is added to 2 cm3 solution of chloride ions. This is the check if carbonate ions are presence because carbonate ions may give the same result.

If there is no effervescence, 2 cm^3 of silver nitrate solution is then added into the mixture.
A white precipitate will form if chloride is presence in the salt.
The precipitate is silver chloride
Ag+ + Cl– → AgCl

Identifying Anions – Nitrate

Test 1

Add dilute sodium hydroxide and a little aluminium powder. If a nitrate is present, ammonia gas is produced. The gas can be identified as it turns moist red litmus paper blue.

Test 2

About 2cm3 of dilute sulphuric acid is added into the solution that wants to be tested and then followed by 2cm3 iron (II) sulphate solution.
A few drops of concentrated sulphuric acid are carefully drop through the inclined side of the test tube without shaking the test tube.
A brown ring will form in the middle of the solution.
Explanation: Iron (II) sulphate reduce nitric acid (from the reaction between nitrate ion and concentrated sulphuric acid) to nitrogen monoxide. Afterwards, nitrogen monoxide combines with iron (II) sulphate to form the compound FeSO4.NO which is brown in colour (brown ring).

Identifying Cations – Test with Sodium Hydroxide and Ammonia Solution

Cations can be identified by their reaction with aqueous sodium hydroxide and aqueous ammonia.
Sodium hydroxide and aqueous ammonia produce hydroxide ion which will react with most anion to form precipitate.
NaOH + H2O → Na+ + 2OH– + H+

NH3 + H2O → NH4+ + OH–

Different cations like aluminium Al^{3+}, calcium Ca^{2+}, copper(II) Cu^{2+}, iron(II) Fe^{2+}, iron(III) Fe^{3+}, lead(II) Pb^{2+}, zinc Zn^{2+} produce different coloured precipitates, which may or may not dissolve in excess alkali.
$Zn(OH)_2$, $Al(OH)_3$ and $Pb(OH)_3$ dissolve in excess NaOH solution, this is because $Zn(OH)_2$, $Al(OH)_3$ and $Pb(OH)_3$ are amphoteric, they can react with NaOH to form salt and water.
$Zn(OH)_2 + 2NaOH \rightarrow Na_2ZnO_2 + 2H_2O$
$Al_2(OH)_3 + 3NaOH \rightarrow Na_3Al_2O_3 + 3H_2O$
$Pb(OH)_2 + 2NaOH \rightarrow Na_2PbO_2 + 2H_2O$
Table below shows the summary of the precipitate form by different cation.

	NaOH(ak)	NH_3(ak)
Na^+	–	–
Ca^{2+}	White precipitate.	–
Mg^{2+}	White precipitate.	White precipitate.
Al^{3+}	White precipitate.	

Dissolve in excess NaOH solution.White precipitate.Zn^{2+}White precipitate.

Dissolve in excess NaOH solution.White precipitate.

Dissolve in excess NH_3 solution.Pb^{2+}White precipitate.

Dissolve in excess NaOH solution.White precipitate.Fe^{2+}Dirty green precipitate.Dirty green precipitate.Fe^{3+}Red brown precipitate.Red brown precipitate.Cu^{2+}Blue precipitate.Blue precipitate.

Dissolve in excess NH_3 solution and form a blue solution.NH_4^+—

Identifying Cations – Test with Chloride Ions

Out of the 10 cations, only lead(II) ions will form a precipitate with chloride ions.
This is because lead(II) chloride is insoluble in water.
The chemical reaction is a double decomposition reaction.
$Pb^{2+} + 2Cl^- \rightarrow PbCl_2$

Lead(II) chloride will dissolve in hot water.

	HCl or $NaCl$
Na^+	–
Ca^{2+}	–
Mg^{2+}	–
Al^{3+}	.-
Zn^{2+}	–
Pb^{2+}	White precipitate. Dissolve in hot water
Fe^{2+}	–
Fe^{3+}	–
Cu^{2+}	–
NH_4^+	–

Identifying Cations – Test with Sulphate Ions

Out of the 10 cations, only calcium ions and lead(II) ions will form a precipitate with sulphate ions.

This is because both calcium sulphate and lead(II) sulphate are insoluble in water.

The chemical reaction is a double decomposition reaction.

$Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4$

$Ca^{2+} + SO_4^{2-} \rightarrow CaSO_4$

	H_2SO_4 or Na_2SO_4
Na^+	–
Ca^{2+}	White precipitate.
Mg^{2+}	–
Al^{3+}	–
Zn^{2+}	–
Pb^{2+}	White precipitate.
Fe^{2+}	–
Fe^{3+}	–
Cu^{2+}	–
NH_4^+	–

Identifying Cations – Test with Carbonate Ions

All ions, except sodium ions and ammonium ions will form precipitate with carbonate.

This is because sodium carbonate and ammonium carbonate are soluble in water.

	Na2CO3
Na+	–
Ca2+	White precipitate.
Mg2+	White precipitate.
Al3+	White precipitate.
Zn2+	White precipitate.
Pb2+	White precipitate.
Fe2+	Green precipitate.
Fe3+	Brown precipitate.
Cu2+	Blue precipitate.
NH4+	–

Identifying Cations – Test with Iodide Ions

Iodide ions will form precipitate with lead(II) ions and copper(II) ions.

You only need to know the reaction between lead(II) ions and iodide ions.

The yellow precipitate formed will dissolve in hot water.

Pb2+ + 2I– → PbI2

	KI
Na+	–
Ca2+	–
Mg2+	–
Al3+	–
Zn2+	–
Pb2+	Yellow precipitate. Dissolve in hot water
Fe2+	–
Fe3+	A red brown solution formed.
Cu2+	White precipitate form in brown solution
NH4+	–

Identifying Cations – Tests to Distinguish Iron(II) and Iron(III) ions.

Some Tests to Distinguish Fe2+ ion From Fe3+ Ion

The presence of Fe2+ ion and Fe3+ ion in a salt can be confirmed by using solution of potassium hexacyanoferrate (II), solution of potassium hexacyanoferrate (III) and potassium thiocyanate.

Table below shows the observation of the tests.

Reagent	Observation	Ion presents
Solution of potassium hexacyanoferrate (II)	Light blue precipitate	Fe2+
	Dark Blue precipitate	Fe3+
Solution of potassium hexacyanoferrate (III)	Dark blue precipitate	Fe2+
	Greenish brown solution	Fe3+
Potassium thiocyanate	Pinkish solution	Fe2+
	Blood red solution	Fe3+

Assessment

How can the following gas be tested for

a. Oxygen
b. Hydrogen
c. Chlorine
d. Hydrogen Sulphide

What are the heating effects of the following

a. Carbonate salts
b. Nitrate salts