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Course Guide

Welcome to this chemistry course. We suppose that many of you are taking this course because you want to strengthen your 'background in chemistry. Armed with this strong background in chemistry, you can then proceed to advanced programmes in chemistry. The training of biologists, geoscientists, medical doctors, nurses, soil scientists, food scientists, chemical engineers, petroleum engineers and many others requires that students in those areas have a good exposure in chemistry.
We have packaged this chemistry course in such a way that you will learn chemistry using a technique peculiar to the open learning system. This technique has been adopted by the National Open University of Nigeria ; a most of the courses offered to students.

Three different sets of course materials are provided

A Course Guide which spells out the broad details of the foundation chemistry course including the aims and objectives.

There are forty five study units grouped into three main sections referred to as volumes

Volume Two: Physical and Inorganic Chemistry Volume Three: Organic Chemistry.
A set of recommended Chemistry textbooks is listed at the end of each study unit.

Chemical reactions and equations

References.

[...]

Using empirical formula to calculate unknown atomic mass of an element.

The Kinetic Theory and States of Matter ------

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11 1

The kinetic theory The postulate of the kinetic theory The kinetic theory and practical evidences The kinetic theory and the state of matter.

Energy and Energy Changes in Chemical and Physical Processes ----Energy changes in chemical processes The thermochemical equations

Types of heat of reaction Standard heat of formation Standard heat of combustion Standard heat of neutralisation Standard heat of solution Enthalpy of change of state Determination of the heat of reaction Changes in Chemical and Physical Processes The Free Energy and Spontaneous Reactions.

[...]

Chemistry is the study of matter and chemists in their investigations, study the properties and transformations of matter. Many materials that we use everyday, directly or indirectly are products of chemical research and examples of useful products of chemical reactions are limitless.
What then is matter? Matter is anything that has mass and occupies space.

What are the building blocks of matter and what laws govern the interaction of matter?

The above are some of the questions that will be answered in this unit.
• Define atoms, molecules, elements and compounds.
• Differentiate between atoms and molecules as well as elements and compounds.
• Explain why matter is said to be electrical in nature.
• State the postulates of Dalton's atomic theory and explain modifications to it.
• List and give relative masses and charges of the subatomic particles.
• State the laws of chemical combinations.
• Write chemical symbols and formulae for common elements and compounds.
• Determine chemical formulae from experimental data.
• Write and balance simple chemical equations.
Elements, Compounds and Mixtures An element is a pure substance, which cannot be split up into simple substances by a chemical reaction. A pure substance that can be broken down into elements is called a compound.

The Particulate Nature of Matter

Experiments show that very small quantities of matter have the same chemical properties or characteristics as larger ones of the same type e.g. a small iron nail and a big iron rod have the same chemical characteristics.
For example both will rust when exposed to air and moisture and both will conduct heat and electricity.
The smallest unit of an element that has the properties and characteristics of the element is the

atom.
The atom is the smallest unit of an element that can take part in a chemical reaction.

Some important modifications to the theory are

Matter is composed of more fundamental particles, some of which are electrically neutral, some carry positive charge and some negative charge. This implies that the atom is divisible.
All atoms of the same element are not identical. The existence of atoms of the same element having different masses have been proved with the use of an instrument called mass spectrometer. Atoms of the same element having different masses are called isotopes.

Relative Mass

Relative Charge Chemistry is a quantitative science and it is always desired to know the relative masses of substances that react as pure elements or compounds. The measurement of masses of atoms is not possible because they are very small. Their masses can however be compared to give relative atomic and molecular masses of elements and compounds.

[...]

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Hydrogen, oxygen and chlorine elements exist in nature as diatomic molecules. i.e. units consisting of two atoms that are chemically bound together. The Latin names for copper, lead and gold are in bracket.

Relative mass of Ca and S in the compound

Relative atomic mass of Ca i.e.
relative atomic mass of S.
The formula of the compound is CaS.
Having determined the relative atomic mass of the elements that make up the compound, you can proceed to determine the empirical formula of the compound.

Relative number of Pb : S

18 : .419 i.e Formula of compound is PbS.
Now determine a formula of a compound of calcium, carbon and oxygen with 40 percent Ca, and 48 percent Other laws of chemical combination In the previous section, the law of constant composition is stated. Two more laws will be discussed in this section.

00g carbon will combine with

= 1.33: 2.667
1 : 2 simple ratio.
Chemical Reactions and Equations A chemical reaction involves the reshuffling of atoms from one set of combinations to another. In the reshuffling, one compound is converted to another. The smallest units that can take part in chemical reactions are the atoms and molecules. A chemical equation is often used to summarise the reaction that has taken place. A chemical equation gives the reactants and products of the reaction and the quantities of the reactants and products in correct ratio in accordance with the law of conservation of matter. Sometimes chemical equations give the physical states of the reactants and products.

What are isotopes?

Natural chlorine consists of 75 percent of chlorine-35 and 25 percent of chlorine-37 isotopes. Calculate the relative atomic mass of chlorine element.
Explain why matter is neutral though it contains negative particles in its structure.
Bajah, S T., Teibo, B. 0. ; Onwu, G and Obikwere, A. . Senior Chemistry Textbooks I
Osei Yaw Ababio . New School Chemistry. Onitsha Africana-Fep Publishers.
and 2.
In the last unit the concept of atoms and molecules was introduced and discussed. Dalton's theory proposed that atoms are indivisible units of matter. The atom is the smallest unit of matter that can take part in a chemical change. Dalton's atomic theory satisfactorily explained the laws of chemical combination but could not explain why substances react the way they do. Why is oxygen able to react with maximum of two atoms of hydrogen as in water? Why do some elements exist only as diatomic molecules? Why are some elements very reactive and some

inert? Dalton's law could not explain electrolysis neither could it explain the different masses of atoms of the same element.
Today we believe that the atom has a substructure of its own.

Coulombs

+1.602x10-19—1.602x10-' 9 electron charge
Atoms of different elements have varying numbers of protons, electrons and neutrons. The atomic number is the number of protons in an atom of the element and for a neutral atom, the atomic number is also the number of electrons.

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23 Atomic Models

The nuclear atom The presence of subatomic particles posed challenge to early scientists. It was necessary to propose a model for the atom. J. J. Thompson proposed that the atom could be viewed as positive matter in which electrons are uniformly distributed to make it neutral at every point. This view was dropped because of the findings of two other scientists, Rutherford and Marsden. They bombarded a thin gold foil with fast moving alpha particles. They found that most of the alpha particles pass through the foil undeflected. Some were deflected as large angles while very few were sent back on their paths. Alpha particles are positively charged and many of them passing through the foil undeflected suggested that most of the gold foil was empty space.
Fig. 2.2: Scattering ofa-particles by a metal foil. Deflection ofd particles by atomic nuclei
Rutherford, using the findings in the above experiment proposed a model for the atom. He proposed that the atom consisted of a tiny positively charged nucleus. The nucleus is centrally placed in the atom and the electrons surround it. The very small number of deflections of alpha particles suggest that the nucleus occupies a very small portion of the atom. For heavy particles such as the alpha particle to be so deflected suggests that the nucleus is a centre of heavy mass and positive charge.

[...]

The electronic structure 2, 8,1 denotes 2 electrons in the K shell, 8 in the L shell and 1 in the M shell.

Carbon Phosphorus and potassium

Which of the elements in the table will have similar chemical properties with phosphorus.

[...]

You will observe that these ions have closed or full shell electron arrangements and are stable ions. This observation and the full shell arrangements for the inert gases, suggest that a full shell electron arrangement is a stable electron arrangement.
Matter is electrical in nature. This is supported by results of experimental investigations by early scientists.
Three fundamental particles are present in the atom. The positive charge and mass are in a small centre of the atom.

Si and Cl

Which of the listed elements in above are likely to: be metals.
be non-metals have similar properties with carbon.
form univalent ion of the type X.
have divalent ion of the type M 2 .
Bajah, S. T., Teibo, B. 0., Onwu G. and Obikwere A. . Senior Secondary Chemistry Textbook 2.

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Osei Yaw Ababio. . New School Chemistry. Onitsha. Africana-FEP Publishers.
The nucleus is the centre of positive charge and mass in an atom. The number of positive charges in the nucleus of a neutral atom determines the number of electrons that surround the nucleus. The arrangement of the electrons around the nucleus determines the chemical properties of the element.
Presently there is no theory that predicts the stability of the nucleus but a number of empirical observations suggest that the presence of neutrons account partly for nuclear stability.

Isotope Natural abundance

14r, trace Nuclear Reactions Nuclear reactions involve changes in the composition of nuclei leading to the conversion of one element to another.

90 Th

Uranium 238, the uranium isotope having an atomic mass of 238 is radioactive. It breaks down emitting particles of Thorium and Helium.
Radioactivity Some nuclei are unstable and will spontaneously emit radiations. This is called radioactivity and is an example of a nuclear reaciton.
Very heavy metals with atomic number greater than 83 are radioactive. Some isotopes of light elements are also radioactive. A radioactive isotope is called a radioisotope . Examples of radioisotopes are
Radioisotopes decay at different rates. The half-life is a measure of the stability of a radioisotope.

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Half life is the time it takes for half of the radioactive substance to decay.
and 92 U have half lives of 5570 and 4.47 x 109 years respectively.

[...]

For heavy elements, neutron bombardment is more common because they are neutral and are not repelled by nuclei with the use of particle accelerators.

+ 3n Uses of Radioactivity Radioactivity has a large number of uses which include

Treatment of cancer.
Sterilising hospital equipment and instruments.
Controlling the thickness of paper, metals and plastics.

Hazards of Radioactivity

Gamma radiation is used to destroy cancerous cells. This is one use gamma radiaiton is put into. F-radiation also destroys healthy cells as well and too much exposure to it can do more harm than good. The extent of damage depends on the energy and type of radiation. The effect of radiation is also cumulative and small doses over a long period of time will also cause serious damage to biological systems.
Radioactive waste is very dangerous and must be disposed properly to avoid necessary exposure to its hazards.

27 C o19K

Rajah, S. T., Teibo, B. 0., Onwu, G. and Obikwere A., . Senior Secondary Chemistry Textbook 2 Lagos Longman Publishers.
Chemical Bonding 1: Electrovalent, Covalent and Co-ordinate Covalent When elements combine, compounds are formed. The forces that hold atoms together in compounds are called chemical bonds. The combination of chemical elements to give a compound is a chemical reaction.
Some elements are very reactive and exist in nature only in combined states, e.g. sodium in sodium chloride and calcium in calcium trioxocarbonate . Few elements are relatively imreactive and exit rarely as free elements. They are called noble or rare elements, e.g. no compound of helium, argon and neon exists. Most elements have intermediate reactivity and exist as free elements as well as in chemical compounds e.g. carbon occurs as graphile and diamond as well as in petroleum and many organic compounds.

Li* + e F, +e

F-Li* + F-[•.

[...]

The formula of LiF written as above is the electron dot formula .

Na* + e Cl +e

Na* + Cl-Na[Ct As can be seen from the examples, the loss and gain of electrons result in inert gas configurations for the cation and anion. Except for helium, He the inert gas configuration corresponds to eight electrons in the outershell.The electronic theory of valency as postulated by Kossel and Lewis 1716 was prompted by the remarkable stability of the rare gas elements.

[...]

Now explain the bonding between sodium and oxygen. Write the formula of the compound.
It is incorrect to speak of a molecule of an ionic compound like NaCI or LiF. Ionic compounds are usually solid a its: sting of regular arrangement of equal number of positive and negative charges. For Lif and NaCI there will oe equal numbers of cations and anions.
This regular arrangement of cations and anions in the solid crystal is called the lattice. The structure of sodium chloride is illustrated in the Fig 4.1 chlorine ion, Clsodium ion, Na The basic unit of the crystal lattice Fig 4.1 Lattice structure in sodium chloride
Electrovalent compounds are usually crystalline solids, generally soluble in water but generally insoluble in organic solvents like ether or kerosene, usually high melting point compounds, good conductors of electricity when molten or in aqueous solution but not when solid.
the manner of bondage between non ionic or non polar atoms.

[...]

Note that the positive charge is now controlled by the entire molecule.

RN

1,N does not apply here. Why? It is a complex ion and has charges located on a group of atom.
In this unit we have discussed two major types of bonding; the electrovalent and covalent bonding.

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properties of a compound depend on the type of bond between the constituent of atoms. Electrovalent compounds consist of cations and anions in their solid structure When an ionic solid dissolves in water or is melted, these ions become free. This explains why ionic compounds are good electrolytes when molten or in solution.

[...]

Explain its significance in covalent bonding.
coin120111811 that win cOnduer - electricK'whiii Meltet that will dissolve in water to produce ions.

Chemical Bonding II: Metallic and

There are three maj or types of bonds, electrovalent, covalent and metallic. Each bond type gives charabteristic properties to the compounds that are formed.
In a previous unit we discussed electrovalent and covalent bonding. While electrovalent bonding is between metals and non metals, covalent bonding is between non-metals. In the formation of electrovalent and covalent bonds valence electrons play very important roles and each valence shell of the bonded atoms attain inert gas stable configuration.

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Na or 1s2 252 2p6 3s' or 152 2s2 2p6 3s2 or 1s 2 252 2p6 3s2 3p'

`sea' or 'cloud' of electrons constitute the metallic bond. The above explanation of metallic bonding implies that the lattice forms a single large crystal. This accounts for the high strength of metals.

1s2 2s2 2p6 3s'

Sodium is a softer metal than magnesium because for sodium only one valence electron per atom but for magnesium two electrons are donated per atom to the electron cloud.

Usually have shiny surface

Now explain why metals have these three listed properties.
High strength ductility . e CO2 .
The movement of electrons around an atom can lead to a momentary shift of more electrons to one side of the molecule than the other. During this shift an imbalance in charge exists with one side of the molecule slightly positive and the other slightly negative. The positive end will attract the negative end of another molecule close to it. This attraction constitute a bond. This attractive force may be strong but because it is for a short time its effect is generally very small.
The magnitude of this force increases with increasing number of electrons This force is present between all molecules atoms and ions.

[...]

Hydrogen sulphide The following are important observations from the table.

NaAt

P5Cl-Energy The tendency of an atom in a molecule to attract bonded electrons to itself is termed the electronegativity of the atom. Generally, small atoms attract electrons more than large ones and are therefore more electronegative.

Ar ti

Re.

Cs

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In this unit you have learned a number of periodic properties that is evident when elements are arranged as a periodic function of atomic number.

&6 Summary

What you have learned in the unit concerns the classification of elements in the Periodic Table based on electronic configuration of atoms. It has served to introduce you to the variation of atomic properties atomic size and radius, ionization energy, electron affinity .and electronegativity, in the Periodic Table.
Use the electronic configuration to explain the occurrence of periods and groups in the Periodic Table.
Define ionization energy and electronegativity and explain their trends in the Periodic Table.

The Mole Defined The mole is the amount of any substance that contains as many elementary particles as there are atoms in

12kg of carbon-12. Now 0.012kg of carbon - 12 contains the Avogadro number of atoms, so one mole of a substance is that amount which contains Avogadro number of particles.

= 4g

15 . 999 x 6.02 3 mass of 1 mole 0 atoms – 12 x 6.02 x 10"

[...]

Hydrogen gas Calculate the following for 4.5g of water: number of moles.

18g of water =1 mole

:. 4.5g of water =
A x 4.
= 0.
1 mole s 6.02 x 10' particles.*.

[...]

Finding the Formula of a Compound This involves the calculation of the quantities of the elements involved in the formation of the compounds.

24g Mg combines with 16g 0 to form

40g of magnesium oxide.
1 mole of magnesium combines with 1 mole of oxygen in magnesium oxide Formula = MgO

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molar mass = 24 + 16 = 40g.

3g Zn and

1 mol of Zn combines with I mol of oxygen formula = ZnO.

01 formula = Hg C12

Calculate the percentage of oxygen in water.

[...]

Using Empirical Formula to Calculate Unknown Atomic Mass of an Element The empirical formula of non metallic oxide is X02 where X stands for the chemical symbol of the element with unknown atomic mass.

Mass of oxygen in the compound mole of oxygen =

= 1.60 – 0.80 from the formula X0, ratio X : 0 is 1:2

2 mol 0 combine with I mole x

- . 0.8g
25 mol X mol X = 0.

Take the Iasi example

Suppose 3.6g of FeO reacts with enough CO, and only 2.2g of Fe is formed.%yield =- vield from experiment x 100 yield expected

Fe +

2 = 0.05 mole CO needed = 0.05
Volume CO needed at S.T.P.
= 0.05 x 22.4 dm3
= 0.
What mass of Fe is formed by complete reaction of 5.6dm 3 of CO at S.T.P. in the above reaction.
= 0.
1 : 1 : 1 mole Fe formed= 0.

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05 mole of CaC2

What is percentage of water of crystallisation in CuSO 4 .5H 2 0 and Na2 CO3 .10H2 0

The percentage composition by mass of a compound of sodium, sulphur and oxygen are

percent respectively. Water of crystallisation is 50 percent . Determine the formula of

Bajah, S.T., Teibo B.O., Onwu, G. and Obikwere A. . Senior Secondary Chemistry Textbook 1. Lagos.
Osei Yaw Ababio . New School Chemistry. Onitsha. Africana-Fep Publishers.

In the last unit, the mole was defined and the mole concept used in calculations. The mole concept is particularly useful in predicting yield and calculating yield from experiments.

The molar and molal solutions A solution that contains one mole of solute in

It is required to prepare 250.00 cm' of 1.0 mol dm-3 solution of glucose .

5 mol glucose is required mol x molar mass mass of glucose=

A molal solution contains 1 mole in 1 kg of the solvent A molal solution is prepared by dissolving 1 mole of the solute in 1000g of solvent.

Calculation of mole and mass in solution When the concentration of a solution is expressed in moldnr 3 , it is possible to calculate the amount in moles

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and grams of the solute in a volume of solution.You must remember that though a solution has one concentration, the amount of solute will be different for different volumes of the solution.

Amount

= 64.5 x 58.5 g

Mole NaOH = Conc x V

= 0.10 x 25 = 2.5 x 10-3

Determination of percentage purity The mole concept can be applied in volumetric analysis for the determination of percentage purity of an acid or an alkali sample g of sodium hydroxide dissolved in

0 moldm-3 trioxonitrate acid for complete neutralisation using methyl orange indicator.

9 x 10'

:.

[...]

Many times it is required to make a dilute solution from a relatively concentrated solution of the same substance in the same solvent.

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Example A bottle of commercial tetraoxosulphate =

Mole of acid required for the preparation of 2.0dm 3 of 0.05 mol dm-3 solution moldm 3 x Volume

1■4, v c = Md Vd V — volume of commercial acid

Md — concentration of dilute acid Vd — volume of dilute acid.

[...]

By equating the millimoles, the volume of the concentrated acid required is calculated.

[...]

During electrolysis chemical reactions occur and substances are discharged or liberated at the electrodes.

2 x 1023 x e where e is the electronic charge

The mole concept and the efficiency of an electrolytic process This can be assessed by comparing amount of reaction that occurred at the electrode with the quantity of electricity passed.

Theoretical volume% efficiency

= 89 percent.
This unit concludes the discussion and applications of the mole concept. More applications of the concept will still be in subsequent units.

Calculate the number of moles of sodium hydroxide in g of the solid

50cm3 of 0.1 mol dnr 3 solution.

x 10" NaOH particles Calculate the mass of Na ; CO3 in 100cm3 of

A solution contains 2.82 g of MOH in 500crr 3 of solution, where M is a metal of unknown atomic mass. 25.0cm3 of the solution of MOH require 25.1cni of 0.10 mol dnr 3 HCl solution for complete neutralisation. Calculate the atomic mass of and identify M.
Bajah, S. T., Teibo, B. 0., Onwu, G and Obikwere, A. . Senior Secondary Chemistry Textbooks 1 & 2 .
Osei Yaw Ababio . New School Chemistry . Onitsha. Africana-FEP Publishers.
The Kinetic Theory and States of Matter In unit 1 you learnt that matter is made up of tiny

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particles, called atoms or molecules.

Can you now explain why accidents with very fast moving bodies are very fatal?

The postulate of the kinetic theory The postulate of the kinetic theory is this, that the particles of matter are continually moving and so possess kinetic energy.

Measurement of molecular velocities with the help of scientific instruments

Scientists have been able to measure velocities of molecules and detect their exact positions at definite times.
Natural phenomena Brownian motion This is the irregular movement of suspended particles caused by constant collision with molecules of the suspending medium. A suspension of sulphur powder in water when viewed under a microscope will demonstrate Brownian motion. Brown was the first scientist to observe this behaviour, hence the name Brownian motion.
Diffusion Diffusion describes the movement or spread of substances from a region of high to low concentration.
Diffusion occurs in solids, liquids and gases. A drop of liquid bromine in a closed jar of air vaporises and spreads evenly throughout the jar. A crystal of a soluble coloured solid when dropped in water will after sometime colour the entire volume of water.
e.g. CuSO 4 .5H 20 . Diffusion is fastest in gases and slowest with solids.
Osmosis This is a special type of diffusion that involves movement of water particles. The swelling of bean seed in water is an example of osmosis.
All the above evidences confirm that particles of matter are in motion as postulated by the kinetic theory.
113 The Kinetic Theory and The States of Matter The particles of matter in a solid are closely packed and firmly held together by strong forces of attraction.

Evaporation

There is a decrease in liquid volume as a result of loss of vapour molecules during vaporisation. This is evaporation. Evaporation is most rapid at the boiling because the liquid particles have maximum kinetic energies.

Sublimation

Certain substances e.g. ammonium chloride and solid carbon do not melt when they are heated but change directly from a solid to a gas.

Dri nuo 0 soiling

_.„.
j Gas g /II.

Energy required

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Heating and Cooling Graphs These are plots of temperature change with the time of heating or cooling.

Solid Solid —> Liquid

-20 Time Fig 1.1.3 Heating water When a change of state is taking place e.g. solid-liquid or liquid- gas, the temperature remains constant despite the continue supply of heat. This energy which is not used to raise the temperature is called the latent heat .
The latent heat is used to supply the particles energy to overcome the cohesive forces in the liquid or solid state.

1 Differentiate between melting and freezing vaporisation and condensation

2 Explain the effect of the sample size on a typical heating or cooling graph.
The boiling points of substances A,B,C,D are 100,60,20, and 30PC respectively.

The Gas Laws

Boyle's and Charles' Laws and the General Gas Equations In the previous unit the kinetic theory was used to explain the physical nature of the different states of matter as well as the changes that occur when matter is heated. Can you recall the following as explained in that unit9 Melting point, boiling point, vaporisation and condensation.

By the end of this unit you should be about to

State the postulates of the kinetic molecular theory for gases.
State the Boyle's and Charles' laws for gases.

Explain the effect of temperature and pressure on the volume of a gas

There is virtually no force of attraction between gas molecules Gas molecules move independent of each other.
These assumptions are only true for an ideal gas.

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Real gases in general do not quite follow the assumptions made for an ideal gas. They constitute what is called the kinetic molecular theory. They specifically deal with the gas molecules.

123 Boyle's Law

Statement of Boyle's law Boyle's law states that at a constant temperature the volume of a given mass of gas is inversely proportional to the pressure.

PV = k Boyle's law can also be stated mathematically as P I V1 = P2 V2

P t is the pressure when gas volume is V 1 and P2 is the pressure when gas volume is V 2 .

Era 'nples

At 25°C and 750mni Hg pressure the volume of a given mass of oxygen is 520cm 3 .

How kinetic theory explains Boyle's Law

According to the kinetic molecular theory of gases an increase in pressure of the gas implies an increase in the number of molecular collisions per unit area of the containing vessel.

Vo VT = Volume of the gas at 'PDC

Vo = Volume of gas at 0°C.
According to the above equation, a gas has zero volume at - 273°C. This temperature at which the gas volume is theoretically zero is the lowest temperature that can be reached.

T = t°C + 273

Let us now try using the above formula to complete the table below.
In calculations involving the gas laws, temperature readings must be converted to the Kelvin scale.

Volume of gas T — Kelvin temperature

Where k is a constant.

3 How the Kinetic theory explains Charles' law

According to the kinetic molecular theory, an increase in gas temperature leads to increase in the average kinetic energy of the gas molecules. This will result in more random motion of the molecules. For a fixed mass of gas, the number of gas molecules is constant and at constant

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pressure of gas the number of collisions per unit area of the containing vessel is also constant.

Sometime the above is given as P VPV

PV= nRT.

From the general gas equation pv and R = —nT

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The value of R is 0.082 atm dm' K - ' mot' when pressure is in atmosphere, volume in dm 3 and temperature in Kelvin.

[...]

Using the general gas equation in the form— -_72.

V2 P2

300 x 1.35 x 105— 1.58 x 104 cm3
In this unit the physical behaviour of an ideal gas is summarised in the assumptions of the kinetic molecular theory of gases. Some of the assumptions of the theory may not always be true for real gases, explaining why real gases sometimes deviate from ideal behaviour.

Calculate the pressure of

Osei Yaw Ababio New School Chemistry. Onitsha African-Fep Publishers.
The Gas Laws H Dalton's, Graham's, Avogadro's and Gay Lussac's laws In unit 12 the ideal or perfect gas is described in the postulates of the kinetic theory. The ideal or perfect gas does not exist. It is only hypothetical.
Real gases deviate from ideal behaviour and do not obey the gas laws perfectly. Imagine a real gas subjected to low temperatures and very high pressures.

The partial pressure of a gas in a mixture is the pressure the gas would exert if it occupies the total volume

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of the mixture alone.

For gas B, PBV = nB RT

P cV = tic RT where nA , n8 and 11c are the number of moles of A, B and C in the For gas C, P T.I V = eRrotai where xA follows from the above that the partial pressure of a gas in a mixture is equal to the product of mixture.

Po2 + PN2

= 0.492 + 3.075
How the Kinetic theory explained Dalton's Law When two or more gases mix without a chemical reaction, each gas behaves independently of the other since there are no attractive forces between the molecules. Each gas will exert its own pressure on the container wall. The total pressure of the gas mixture will therefore be the sum of the pressures of the gases in the

[...]

The rate of diffusion is inversely related to the time of diffusion i.e. the higher the rate of diffusion, the shorter the time for a given mass of gas to diffuse.

SO 2 CO2 H2S NO2

Avogadro's Law and its Applications This law states that equal volumes of all gases at the same temperature and pressure contain the same number of molecules.
Avogadro's law provides information on all number of molecules in a given volume of gas and allows for change over from statements relating volumes of gases to statements relating to the number of molecules or moles.
H2,g, + C12 . Applying the Avogadro's law this implies that 1 mole of FI reacts with 1 mole of C12.

[...]

Use Gay Lussac's and Avogadro's law and write a balanced chemical equation for the reaction. Calculate the volume of oxygen gas required at S.T.P. to completely react with 6.4g of sulphur oxide.
This unit concludes our discussion on gases and gas behaviour though the theory used in explaining the laws talks of an ideal or a perfect gas.

Can you relate the above statement to the air in our environment?

0cm3 of nitrogen gas was collected over water at 17°C and 770 mmHg pressure. Calculate the volume of the dry gas at S.T.P. Saturated vapour pressure of water at 17°C is 14 mmHg.
0g of a vapour of a volatile liquid occupies a volume of 0.062dni at 27°C and 757 mmHg. Calculate the molar mass of the liquid substance.
Bajah, S. T., Teibo, B. 0., Onwu, G and Ohikwere, A. . Senior Secondary Chemistry Textbook I .

Define boiling and boiling point

Define the term 'normal boiling point'.
Describe a method to determine the boiling point of a liquid.
The Vapour Pressure of Liquids You will recall that a liquid sample consists of molecules with varying Kinetic energies. Some particles have very high energies while some have low energies. Now consider a liquid sample placed in a closed container in the laboratory. Some energetic particles that are close to the liquid surface will vaporise and constitute a vapour pressure above the liquid. This pressure builds up until the space above the liquid is saturated with vapour. When this happens a dynamic equilibrium is set up between the liquid particles in the vapour and the liquid phase.
The pressure of the vapour under this equilibrium condition is called the saturated vapour pressure of the liquid. It is the maximum vapour pressure of the liquid at that temperature. The SW is not dependent on the liquid volume in the container and it increases with increasing temperature Fig14.1

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— Try and explain this increase with temperature using the Kinetic theory.
Liquids with strong intermolecular forces generally have low saturated vapour pressure than those with weak intermolecular forces.

Methods of Boiling Point Determination

Several methods have been developed for determining the boiling point of liquids. Here we shall consider two methods.

Liebig

• condenser retort stand distillate Fig 14.2 Simple d stillations The liquid is placed in the flask labelled A. When the flask is heated the satured vapour pressure of the liquid increases until it becomes equal to the pressure above the liquid. Boiling occurs and the thermometer records the temperature of the liquid/vapour mixture for liquids that are flammable the heating must be done electrically or indirectly using a liquid bath.

[...]

Arrange the liquids in the order of increasing boiling points.
Arrange in the order of increasing volatility. Give reasons for the order of arrangement.
Define the terms normal boiling point differentiate between boiling and boiling point.
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Solids In unit 11, the general features of the solid state are highlighted and explained using the kinetic theory. You will recall that the closeness and low average kinetic energy of solid particles allow for strong attractive forces keeping particles in fixed positions.

Solid Classification

Solids are classified as crystalline or amorphous by virtue of the order in particle arrangement.

Solid Properties

Solids are generally characterised by hardness/finnness and high mechanical strength. The mechanical strength of any solid material is determined by the type of bonds holding the particles in position in the solid structure.
The type of force in turn depends on the chemical nature of the units that occupy the fixed position in the lattice. Solids are grouped into four classes based on the nature of the intermolecular forces between the particles of the solid matter.

Can you now explain the following?

An aluminium spoon when placed in hot water soon feels hot to the hand.

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Exposed electrical cables when touched or stepped on can lead to shock or death.

Ionic solids are characterised by the following properties

High melting and boiling points.
They are non conductors of electricity in the solid state but conduct when molten or in solution.

Why do ionic solids conduct electricity in the molten state or in solution and not in the solid form?

The covalent solid The lattice points in covalent solids are occupied by atoms linked together by a Continuous system of covalent bonds.

What are allotropes?

Both of them are also covalent solids but while diamond is hard, have very high density and melting point, graphite is soft, less dense and have a much lower melting point. In both diamond and graphite, the lattice points ar; occupied by carbon atoms. In diamond, carbon atoms are tetrachedrally bonded using Sp' hybridised orbitals. All the four valence electrons of carbon are used in bonding resulting in a rigid three dimensional nr twork. This accounts for the very hard nature of diamond.

[...]

Melting and Melting Point Heating of solid matter increases the average kinetic energy of the particles. You will recall that at a particular temperature characteristic of the solid the particles will acquire sufficient energy and overcome the attractive forces holding them in fixed positions. At this temperature the solid structure collapses and a liquid is formed. This is the melting point. As earlier explained in unit 11, melting of a pure solid sample occurs at a constant temperature and is a test of purity.
The melting point of a solid sample is determined by the capillary tube method. A small amount of the solid sample is put in a glass capillary tube. The capillary tube is attached to a thermometer using a rubber band. The capillary tube is heated in a transparent liquid bath and the temperature at which the solid starts melting is noted. For a pure solid sample, this temperature remains constant until all solid is melted.
Fi. 15.3: Determination ofineltingpoint of naphthalene

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Electrically operated melting point apparatus can also be used but the equipment is fairly expensive. The apparatus is fitted with a thermometer. It also has apartments for placing the capillary tube. After the capillary tube containing the solid sample is put into the apparatus, the apparatus is switched on. As the solid heats up, the process is monitored through a magnifying glass in front of the apparatus until melting occurs.

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AlInaction = E Hp = E

HR where E means summation A chemical reaction is either accompanied by evolution or absorption of heat.

= E 1-1p -EHR

When the total heat content of the products is less than that of the reactants the enthalpy change is less than zero i.e. is -ve. The difference in the heat contents is given off to the surrounding.

Endothermic reaction

The energy change marked E on the diagrams is known as the activation energy. The activation energy is the minimum energy needed by the reactant before reaction can occur. All reactions whether exothermic or endothermic require the activation energy.
When reactions take place between molecules or atoms, it usually involves the breaking of old bonds between atoms or molecules and the formation of new ones. These processes are not consecutive but occur simultaneously, at which point an activated complex is said to be formed. The activated complex is a temporary phase of the reactants whose duration is extremely brief. Enthalpy and enthalpy change depend on the temperature and pressure of the reaction.

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reactions and a concentration of 1.0 moldm -3 for reactions in solution. The heat change measured under the conditions stated above is called the standard heat change.

[...]

Types of Heat of Reaction Reactions are of many types. In this section, the heat change will be defined and named accordingly for formation, combustion, neutralisation and solution.

Can you explain the following about the above reactions?

The heat change differs for the two reactions.

For a given chemical compound there is only one chemical equation that fits the above definition of heat of

Heat of formation is useful in the calculation of heat of reaction.

Standard heat of combustion A14°C

This is the heat evolved when 1 mole of the compound is completely burnt in oxygen under standard conditions.

Mier = EAH°4 of reactants ---+- EAH °e of products

3 Standard heat of Neutralisation, Air..

Products

AH' f= EA1-1°,... of reactants SO, Atio reachon = EAHo non of reactants --4 EAFI'neu of Products Neutralisation is the reaction of an acid with an alkali to give salt and water only. Strong acids and bases are strong electrolytes. They ionise completely in solution. For such acids and bases, neutralisation is the reaction of IP and OH - to give water
This is why the heat of neutralisation is essentially constant for strong acids and bases.
KNO3.
HC1440 + Na OH .0 -- ■ NaC1.0 +H20

Na Clto lattice energy Na+ + Cl-t s0

All soln = Alllattice AH hydration The dissolution process will release heat energy AH hydration > AH lattice otherwise the dissolution process will be an endothermic process.

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Enthalpy of change of state

liquid, liquid —> gas and solid —> gas called melting, vaporisation and sublimation respectively. The molar heat of fusion is the heat energy required to convert a mole of the solid to the liquid at its melting point.

[...]

Avalon ivaporisation Determination of the Heat of Reaction The measurement of absolute enthalpies of compounds is not possible but enthalpy changes can be measured in the laboratory. The measurement of heat changes that accompany reactions is called calorimetry and calorimetry experiments are done in specially insulated containers called calorimeters.

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Stirrer for even temperature polished copper calorimeter lagging poor conductor hot liquid Fig 1.2: Calorimeters The words calorimetry and calorimeter come from the word calorie. A calorie is the amount of heat energy required to raise the temperature of one gram of water through 1° centigrade.

Recall All Reaction = /Atli product —E4Hc reactant

Or AH reaction = Alt of reactants —E4H e of products.
Values of heat of formation and combustion for compounds are available in literature.
Every change, whether physical or chemical is accompanied by energy change.

Alr i of CH4 CH 3C1 are

Illustrate the reaction in on an energy level diagram.

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Units 2

Changes in Chemical and Physical Processes. The Free Energy and Spontaneous Reactions
The word spontaneous means voluntary or occurring without external influence or assistance. A spontaneous reaction can therefore be defined as a reaction that occurs without external aid or incitement. For example sodium metal reacts explosively with water.

NH4 NO3 —0 NH44

The first process, the reaction of hydrogen with oxygen is an exothermic reaction but yet the reaction of hydrogen with oxygen is not a spontaneous reaction. Recall that for a reaction to occur in a jar of hydrogen gas, a spark must be introduced i.e reaction is aided to occur.

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Objectives

Define entropy and entropy change.
Calculate entropy change from suitable data.

Recall the equation AG = AH — TAS

Entropy and Entropy Change Entropy is a measure of the disorder of a system.

AS reaction Sr — S it and for many reactants and products AS reaction =ES —ES R

For a process that is accompanied by greater disorder the entropy increases and AS is positive. When a process is accompanied by less disorder the entropy decreases and AS is negative.

AS + ve AS + ye

* Steam Solid — liquid, liquid — gas and solid — vapour transitions are accompanied by increased entropy.
Temperature: The higher the temperature, the higher the average kinetic energy .of the particles, the more the random motion and collisions leading to greater disorder.

[...]

Mixing: There is more disorder in a mixture of samples than in each of the pure samples. When a solid dissolves in a liquid entropy increases .

AG' = AH° — TAS° where T = 298K

The free energy determines whether a reaction will occur spontaneously or not. For a spontaneous change AG is less than zero i.e AG — ve. When AG is greater than zero the process is not spontaneous.

Ca C 2 + H 2 0 --+Ca0 *

The reactions above are exothermic reactions and are accompanied by greater disorder.

An endothermic reaction accompanied by a decrease in entropy

Here All is + ve and AS is — ve.

CaC2 +H200

For the above reactions even at absolute zero, AG is greater than zero. They are not spontaneous.
3 An exothermic reaction accompanied by a decrease in entropy For the above group of

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reactions.

This is case when TAS = AH

Above 'c c are spontaneous. The tendency for a spontaneous process decreases with increasing temperature for the process. The equilibrium temperatures are the melting and boiling points respectively..

T = AH

AG is —ve and the reactions are spontaneous. Below T the AG is +ve and the reactions are nonAbove T eq spontaneous reaction. The tendency for a spontaneous reaction increases with increase in temperature.
Solubility of ammonium trioxonitrate increases with increasing temperature. For this reaction to have occurred spontaneous at laboratory temperature suggests that the equilibrium temperature is below the laboratory temperature. In the case of the ice -, water reaction the equilibrium temperature is the melting the melting process is spontaneous point which is about 0°C.

[...]

In each case give a reason for your answer.

92kJ mol

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+ IA 02

This reaction though predicted to be spontaneous by free energy calculations will not occur until a spark is introduced into the mixture of hydrogen and oxygen. Some processes are found to occur instantaneously while some are slow and may go on for years.

Rate of reactions

rate of consumption of Mg, rate of consumption of HC1, rate of formation of MgCl2, rate of formation of H2 .. Monitoring the rates of chemical reactions

ZnC1200 +

Hz In the laboratory two methods can be used to monitor this reaction rate effectively.

If concentration of product at t = 0 = C o

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Where t = 0 when you are starting the measurement.

MC1200 112

Two Methods of monitoring the rate were discussed earlier. Can you recall these methods.

BaC12 + 2NaCI

This is a reaction in which no gas is involved but a precipitate forms as the reactants are used up. The amount of precipitate formed could serve as a method of monitoring its rate. A choice of method for a reaction must therefore be done after careful study of the physical and chemical nature of the reactants and products. Listed below are methods that could be used to monitor rates in some specific situations.

CaC1200 + CO2 + H200

Factors that Affect Reaction Rates Some reactions are very fast while some are slow. The rates of many reactions are changed markedly when the condition of the reactions are altered. Many factors will affect the rate of a chemical reaction. It is important that when studying the effect of one factor on the rates, the others are kept constant. In this way the effect of each factor can be assessed and if possible quantified. Here are factors that can affect the rate of a chemical reaction.
Nature of the reactant In a chemical reaction, bonds are broken in the reactant. Reactants that are strongly bonded are not very reactive because of the high energy needed to initiate the reaction.

Recall that for a gas PV = nRT P — pressure

P= n V — volume T — temperature P = C.'.P a C
R— gas constant C — concentration As pressure increases at constant temperature P increases i.e. concentration increases.
For a reaction occurring between reactants in different physical states, the rate depends on the area of contact between the two states. When the area of contact increases the rate also increases. A lump of lead metal for example reacts very slowly with oxygen gas. When the lead is in powder form, its reaction with oxygen is much faster. This is because of the large area of contact of oxygen gas with the powdered lead.
Catalyst A catalyst is a substance which when added to a reaction system increases the rate of the reaction but is not used up and does not change its chemical nature at the end of the reaction.

CaCO 3 -0 Ca0 +CO2

State the factors that will affect the reaction rate A 10.0g Ca CO3 sample was heated for 4.5mins. The weight of the chip reduced to 6.25g. Calculate the rate of the reaction in mol CaCO3 used up/min mol CaO formed/min
Bajah, S. T., Teibo, B. 0., Onwu G and Obikwere A. . Senior Secondary Chemistry Textbook 2.

Osei Yaw Ababio New School Chemistry. Onitsha. Africana-FEP Publishers.
Chemical Kinetics — Collision Theory and the Activation Energy In unit 3, the rate of a reaction is defined and factors that affect the rate enumerated and discussed. Factors like temperature, concentration, nature and catalyst will affect the rate of all homogeneous reactions.
Other factors like pressure, light and surface area are specific for some types of reaction. One method of expressing reaction rate is the rate of formation of products. The rate at which a product forms from a reaction is of economic importance in industries and factors are always made to bear on reactants not only to improve quality or yield alone but also to increase production rate and reduce time of labour.
In this unit a theory called the collision theory will be discussed and used to explain why some of the enumerated factors in unit 3 have so much effect on the rates of reactions. The concept of activation energy of a reaction and its effect on the rate will also be discussed.
Explain the concept of activation energy.
Draw energy level diagrams to explain the concept of activation energy.
Explain and illustrate the effect of catalyst on the activation energy.
Explain the effects of factors on rate using collision theory.
Explain why chemical reactions occur at different rates.
Activation Energy and the Reaction Rate In a chemical reaction, bonds are broken and formed. An initial energy input is always required to start the reaction. This input of energy activates the reactant molecules to start reacting. This minimum energy that is needed to start a reaction is called the activation energy.
When the reactant molecules acquire the activation energy they form a high energy particle called the activated complex.

[...]

Explain the effect of a catalyst on the rate of a reaction and draw energy level diagram to illustrate its effect on the reaction profile.
List three properties of a good catalyst.
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CuS0 4 + 5H20

When the hydrated salt is heated, water vapour is given off The blue colour of the hydrated salt changes to white and the crystals turn to powder.

Heating ammonium chloride crystals NH Sl w NH3 + HCL

When ammonium chloride crystals are heated the salt dissociates into ammonia gas and hydrogen chloride gas. As the gases cool, they recombine to form the solid.

Ca CO3 + CO2

Reaction of iron with steam.

3Fe + 4H 2 0

When a chemical reaction occurs spontaneously, it continues until a state of dynamic equilibrium is reached in which both the forward and reverse reactions are taking place at the same rate. The concentrations of the reactants and products no longer change with time.

AH = Teq AS Teq equilibrium temperature AS = AH

T eq The entropy change that accompanies the reversible reaction can be calculated if the enthalpy change is known.

From the above you see that the equilibrium constant is an index of how far the reaction goes in the direction of C and D and D 0

The equilibrium constant for the reverse reaction.

[...]

k and ke are not equal but are related.

At equilibrium AG = 0 and

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Factors Affecting an Equilibrium State The position of equilibrium can be altered by changing the conditions The effect on the equilibrium state caused by a change of certain condition of the reaction is predicted by Le Chatelier's principle.

Le Chatelier's principle and concentration change

If the concentation of one substance is increased, the reaction will move in the direction to use up the added substance. If the added substance is a reactant, the reaction will move in the product direction and if it is a product, the movement will be in favour of the reverse reaction. If the concentration of one substance is reduced the reaction will move in the direction to produce more of the substance removed. If the removed substance is a reactant, the reverse reaction is favoured but if the product is removed the forward reaction is
Based on the above, most equilibrium reactions have been made to go virtually to completion by the removal of products as they are formed.

[...]

The dissociation constant for the acid HX is 1.3 x 10 -5 at 298K.

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References

Bajah, S. T., Teibo, B. 0., Onwu G. and Obikwere, A. . Senior Secondary Chemistry Textbook 2.
Osei Yaw Ababio . New School Chemistry Onitsha. Africana-FEP Publishers.
In unit 5 we learnt that a reversible r- etion tends to a state of dynamic equilibrium. At equilibrium there is a fixed relationship between the molar concentrations of the reactants and products. This last statement is the equilibrium law and the fixed relationship is the equilibrium constant for the reaction at the given •
temperature.

Explain common ion effect

Arrange acids/bases in order of strength when ka values are known.
Calculate pH of acid or alkaline solutions.
Use the concept of hydrolysis to explain the basic and acidic behaviour of some salt solutions.
Explain the action of buffer solutions.
Recall one practical application of common ion effect.
Applications of the Equilibrium Law to Gas Reactions In the Haber process ammonia gas is produced from nitrogen and hydrogen gases. In this large scale production of ammonia, the mixture of one part nitrogen and three parts hydrogen is compressed to very high pressures and passed through the catalyst chamber at 450-500°C. The catalyst is iron mixed with aluminum oxide . The alumina promotes the action of the iron as a catalyst.
2NH 3gr AH — Ve The industrial conditions for the Haber process are explained by Le chatelier's principle.

Applications of the Equilibrium Law to Aqueous Equilibria

Dissociation of weak acids and bases The dissociation of a weak acid or base in water is a reversible reaction.

[...]

k, are the acid and base dissociation constants respectively.

[...]

NH3 or CH3NH2 ? For strong acids and bases dissociation is assumed to be complete.

[...]

In like manner we define p01-1= - log [0111 for water pOH = 7 pH = pOH = 7 for water at 25°C.

When an acid dissolves in water the H1 increases and pH 1-1* 4Ct

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[H1 = .001mol dm-3 pH = – log H .
= – log .
Now calculate pH for .005 H 2SO4 +112 0 + H2 0 --s, NF140H .0 + HCI
HCI is a strong acid but N11 4 01-1 is a weak alkaline. The acid has the upper hand and the resulting solution is acidic to litmus.

CH3 000H

CH 3 C00 weak acid CH3 COONa --> CH3 C 00- Na* highly dissociated When a small amount of H+ is added to the buffer solution the weak acid equilibrium is reversed and undissociated CH3 COOH is formed. This will have little effect on the CH 3 C00in solution because of CH 3 COOfrom the second reaction.

[...]

Cl- is the common ion in this example. The additional Ct ions in solutions will shift the CaCl 2 equilibrium in the reverse direction. More solid will come out i.e solubility of CaC1 2 decreases: The common ion effect can be defined as the decrease in solubility caused by the presence of an ion ofa salt that is added to the solution of the saltfrom an external source.

Agil

[AgCI] = [Age] [CY] = k g, k is the solubility product of AgCI. The importance of the solubility ion concept lies in its bearing upon precipitation from solution of metal ions.
The solubility product of AgC1 at 25°C is 1.1 x 10 -70 mol2din-6 .

For AgCI to be precipitated

[CY] > 1.1 x 10-10 = 1.1 x 109
The amount of CY is so small that a tiny drop of 0.01 molder' sodium chloride solution will give precipitate.
You will recall that this is a test for chlorides.
Reversible reactions are many.

An aqueous solution of FeCI3 is acidic to litmus but a solution of Na 2 CO

Explain the terms.

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