## Chemistry Content

### 1. Experimental Chemistry

(a) Experimental design

- name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes, measuring cylinders and gas syringes
- suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases and measurement of rates of reaction.

(b) Methods of purification and analysis

- describe methods of separation and purification for the components of mixtures, to include:
  - (i) use of a suitable solvent, filtration and crystallisation or evaporation
  - (ii) distillation and fractional distillation
  - (iii) paper chromatography
- suggest suitable separation and purification methods, given information about the substances involved in the following types of mixtures:
  - (i) solid-solid
  - (ii) solid-liquid
  - (iii) liquid-liquid (miscible)
- interpret paper chromatograms (the use of Rf values is not required)
- deduce from given melting point and boiling point data the identities of substances and their purity

(c) Identification of ions and gases

- describe the use of aqueous sodium hydroxide and aqueous ammonia to identify the following aqueous cations: aluminium, ammonium, calcium, copper(II), iron(II), iron(III), lead(II) and zinc (formulae of complex ions are not required)
- describe tests to identify the following anions: carbonate (by the addition of dilute acid and subsequent use of limewater); chloride (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate); iodide (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate); nitrate (by reduction with aluminium in aqueous sodium hydroxide to ammonia and subsequent use of litmus paper) and sulfate (by reaction of an aqueous solution with nitric acid and aqueous barium nitrate)
- describe tests to identify the following gases: ammonia (using damp red litmus paper); carbon dioxide (using limewater); chlorine (using damp litmus paper); hydrogen (using a burning splint); oxygen (using a glowing splint) and sulfur dioxide (using acidified potassium manganate(VII)).

### 2. The Particulate Nature of Matter

(a) Kinetic particle theory

- describe the solid, liquid and gaseous states of matter and explain their interconversion in terms of the kinetic particle theory and of the energy changes involved

(b) Atomic structure

- state the relative charges and approximate relative masses of a proton, a neutron and an electron
- describe, with the aid of diagrams, the structure of an atom as containing protons and neutrons

(nucleons) in the nucleus and electrons arranged in shells (energy levels) (knowledge of s, p, d and f classification is not required; a copy of the Periodic Table will be available)

- define proton (atomic) number and nucleon (mass) number
- interpret and use symbols such as $^{11}_{6}C$
- define the term isotopes
- deduce the numbers of protons, neutrons and electrons in atoms and ions given proton and nucleon numbers.

(c) Structure and properties of materials

- describe the differences between elements, compounds and mixtures

(d) Ionic bonding

- describe the formation of ions by electron loss/gain in order to obtain the electronic configuration of a noble gas
- describe the formation of ionic bonds between metals and non-metals, e.g. NaCl; $MgCl_2$
- relate the physical properties (including electrical property) of ionic compounds to their lattice structure.

(e) Covalent bonding

- describe the formation of a covalent bond by the sharing of a pair of electrons in order to gain the electronic configuration of a noble gas
- describe, using 'dot-and-cross' diagrams, the formation of covalent bonds between non-metallic elements, e.g. $H_2$; $O_2$; $H_2O$; $CH_4$; $CO_2$
- deduce the arrangement of electrons in other covalent molecules
- relate the physical properties (including electrical property) of covalent substances to their structure and bonding.

**3. Formulae, Stoichiometry and the Mole Concept**

- state the symbols of the elements and formulae of the compounds mentioned in the syllabus
- deduce the formulae of simple compounds from the relative numbers of atoms present and vice versa
- deduce the formulae of ionic compounds from the charges on the ions present and vice versa
- interpret chemical equations with state symbols
- construct chemical equations, with state symbols, including ionic equations
- define relative atomic mass, Ar
- define relative molecular mass, Mr, and calculate relative molecular mass (and relative formula mass) as the sum of relative atomic masses
- calculate stoichiometric reacting masses and volumes of gases (one mole of gas occupies 24 $dm^3$ at room temperature and pressure); calculations involving the idea of limiting reactants may be set (Knowledge of the gas laws and the calculations of gaseous volumes at different temperatures and pressures are not required.)
- apply the concept of solution concentration (in mol / $dm^3$ or g / $dm^3$) to process the results of volumetric experiments and to solve simple problems (Appropriate guidance will be provided where unfamiliar reactions are involved. Calculation on % yield and % purity)

**4. Energy Changes**

- describe the term exothermic as a process or chemical reaction which transfers energy, often in the form of heat, to the surroundings and may be detected by an increase in temperature, e.g. the reaction between sodium hydroxide and hydrochloric acid
- describe the term endothermic as a process or chemical reaction which takes in energy, often in the form of heat, from the surroundings and may be detected by a decrease in temperature, e.g. the dissolving of ammonium nitrate in water

**5. Chemical Reactions**

(a) Speed of reaction

- describe the effect of concentration, pressure, particle size and temperature on the speeds of reactions and explain these effects in terms of collisions between reacting particles
- interpret data obtained from experiments concerned with speed of reaction.

(b) Redox

- define oxidation and reduction (redox) in terms of oxygen/hydrogen gain/loss
- define redox in terms of electron transfer and changes in oxidation state
- describe the use of aqueous potassium iodide and acidified potassium manganate(VII) in testing for oxidising and reducing agents from the resulting colour changes.

**6. Acids, Bases and Salts**

(a) Acids and bases

- describe the meanings of the terms acid and alkali in terms of the ions they produce in aqueous solution and their effects on Universal Indicator
- describe how to test hydrogen ion concentration and hence relative acidity using Universal Indicator and the pH scale
- describe the characteristic properties of acids as in reactions with metals, bases and carbonates
- describe the reaction between hydrogen ions and hydroxide ions to produce water, $H^+ + OH^- \rightarrow H_2O$, as neutralization
- describe the importance of controlling the pH in soils and how excess acidity can be treated using calcium hydroxide
- describe the characteristic properties of bases in reactions with acids and with ammonium salts
- classify oxides as acidic, basic, amphoteric or neutral based on metallic/non-metallic character.

(b) Salts

- describe the techniques used in the preparation, separation and purification of salts (methods for preparation should include precipitation and titration together with reactions of acids with metals, insoluble bases and insoluble carbonates)
- suggest a method of preparing a given salt from suitable starting materials, given appropriate information.

## 7. The Periodic Table

(a) Periodic trends

- describe the Periodic Table as an arrangement of the elements in the order of increasing proton (atomic) number
- describe how the position of an element in the Periodic Table is related to proton number and electronic structure
- explain the similarities between the elements in the same group of the Periodic Table in terms of their electronic structure
- describe the change from metallic to non-metallic character from left to right across a period of the Period Table
- describe the relationship between group number, number of valency electrons and metallic/ non-metallic character
- predict the properties of elements in Group I and Group VII using the Periodic Table.

(b) Group properties

- describe lithium, sodium and potassium in Group I (the alkali metals) as a collection of relatively soft, low-density metals showing a trend in melting point and in their reaction with water
- describe chlorine, bromine and iodine in Group VII (the halogens) as a collection of diatomic, nonmetals showing a trend in colour, state and their displacement reactions with solutions of other halide ions
- describe the lack of reactivity of the noble gases in terms of their electronic structures.

## 8. Metals

(a) Properties of metals

- describe the general physical properties of metals as solids having high melting and boiling points, malleable, good conductors of heat and electricity in terms of their structure
- describe alloys as a mixture of a metal with another element, e.g. brass; stainless steel
- identify representations of metals and alloys from diagrams of structures

(b) Reactivity series

- place in order of reactivity calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to the reactions, if any, of the metals with water, steam and dilute hydrochloric acid
- deduce the order of reactivity from a given set of experimental results

(c) Extraction of metals

- describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series.

(d) Recycling of metals

- describe metal ores as a finite resource and hence the need to recycle metals, e.g. recycling of iron
- discuss the social, economic and environmental issues of recycling metals.

(e) Iron

- describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace
- describe the essential conditions for the corrosion (rusting) of iron as the presence of oxygen and water; prevention of rusting can be achieved by placing a barrier around the metal, e.g. painting; greasing; plastic coating;

**9. Air**

- describe the volume composition of gases present in dry air as being approximately 78% nitrogen, 21% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide
- name some common atmospheric pollutants, e.g. carbon monoxide; methane; nitrogen oxides (NO and $NO_2$); ozone; sulfur dioxide; unburned hydrocarbons
- state the sources of these pollutants as
  - (i) carbon monoxide from incomplete combustion of carbon-containing substances
  - (ii) nitrogen oxides from lightning activity and internal combustion engines
  - (iii) sulfur dioxide from volcanoes and combustion of fossil fuels
- discuss some of the effects of these pollutants on health and on the environment
  - (i) the poisonous nature of carbon monoxide
  - (ii) the role of nitrogen dioxide and sulfur dioxide in the formation of 'acid rain' and its effects on respiration and buildings

**10. Organic Chemistry**

(a) Fuels and crude oil

- name natural gas, mainly methane, and petroleum as sources of energy
- describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation
- name the following fractions and state their uses
  - (i) petrol (gasoline) as a fuel in cars
  - (ii) naphtha as the feedstock and main source of hydrocarbons used for the production of a wide range of organic compounds in the petrochemical industry
  - (iii) paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines
  - (iv) diesel as a fuel for diesel engines
  - (v) lubricating oils as lubricants and as a source of polishes and waxes
  - (vi) bitumen for making road surfaces

(b) Alkanes

- describe a homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, e.g. melting and boiling points; viscosity; flammability
- describe the alkanes as a homologous series of saturated hydrocarbons with the general formula $C_nH_{2n+2}$
- draw the structures of branched and unbranched alkanes, $C_1$ to $C_3$, and name the unbranched alkanes methane to propane

- describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of combustion and substitution by chlorine.

(c) Alkenes

- describe the alkenes as a homologous series of unsaturated hydrocarbons with the general formula $C_nH_{2n}$
- draw the structures of branched and unbranched alkenes, $C_2$ to $C_3$, and name the unbranched alkenes ethene to propene
- describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process
- describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine
- describe the properties of alkenes (exemplified by ethene) in terms of combustion, polymerization and the addition reactions with bromine, steam and hydrogen
- state the meaning of polyunsaturated when applied to food products
- describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product
- describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer
- state some uses of poly(ethene) as a typical plastic, e.g. plastic bags; clingfilm
- deduce the structure of the addition polymer product from a given monomer and vice versa
- describe the pollution problems caused by the disposal of non-biodegradable plastics.

(d) Alcohols

- describe the alcohols as a homologous series containing the –OH group
- draw the structures of alcohols, $C_1$ to $C_3$, and name the unbranched alcohols methanol to propanol
- describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids
- describe the formation of ethanol by fermentation of glucose.

(e) Carboxylic acids

- describe the carboxylic acids as a homologous series containing the $–CO_2H$ group
- describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium manganate(VII).

## Physics Content

### 1. Physical Quantities, Units and Measurements

- show understanding that all physical quantities consist of a numerical magnitude and a unit
- recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K)
- use the following prefixes and their symbols to indicate decimal sub-multiples and multiples of the SI units: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G)
- show an understanding of the orders of magnitude of the sizes of common objects ranging from a typical atom to the Earth
- state what is meant by scalar and vector quantities and give common examples of each
- add two vectors to determine a resultant by a graphical method
- describe how to measure a variety of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier scale as necessary
- describe how to measure a short interval of time including the period of a simple pendulum with appropriate accuracy using stopwatches or appropriate instruments.

### 2. Kinematics

- state what is meant by speed and velocity
- calculate average speed using distance travelled / time taken
- state what is meant by uniform acceleration and calculate the value of an acceleration using change in velocity / time taken
- interpret given examples of non-uniform acceleration
- plot and interpret a distance-time graph and a speed-time graph
- deduce from the shape of a distance-time graph when a body is:
  - (i) at rest
  - (ii) moving with uniform speed
  - (iii) moving with non-uniform speed
- deduce from the shape of a speed-time graph when a body is:
  - (i) at rest
  - (ii) moving with uniform speed
  - (iii) moving with uniform acceleration
  - (iv) moving with non-uniform acceleration
- calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration
- state that the acceleration of free fall for a body near to the Earth is constant and is approximately 10 $m/s^2$.

### 3. Dynamics

- apply Newton's Laws to:
  - (i) describe the effect of balanced and unbalanced forces on a body
  - (ii) describe the ways in which a force may change the motion of a body (stating of Newton's laws is not required)

- identify forces acting on an object and draw free-body diagram(s) representing the forces acting on the object (for cases involving forces acting in at most 2 dimensions)
- recall and apply the relationship resultant force = mass × acceleration to new situations or to solve related problems
- explain the effects of friction on the motion of a body.

**4. Mass, Weight and Density**

- state that mass is a measure of the amount of substance in a body
- state that mass of a body resists a change in the state of rest or motion of the body (inertia)
- state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction
- define gravitational field strength, g, as gravitational force per unit mass.

**5. Turning Effect of Forces**

- describe the moment of a force in terms of its turning effect and relate this to everyday examples
- recall and apply the relationship moment of a force (or torque) = force × perpendicular distance from the pivot to new situations or to solve related problems
- state the principle of moments for a body in equilibrium
- apply the principle of moments to new situations or to solve related problems
- show understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity
- describe qualitatively the effect of the position of the centre of gravity on the stability of objects.

**6. Pressure**

- define the term pressure in terms of force and area
- recall and apply the relationship pressure = force / area to new situations or to solve related problems

**7. Energy, Work and Power**

- show understanding that kinetic energy, potential energy (chemical, gravitational, elastic), light energy, thermal energy, electrical energy and nuclear energy are examples of different forms of energy
- state the principle of the conservation of energy and apply the principle to new situations or to solve related problems
- state that kinetic energy $E_k = ½ mv^2$ and gravitational potential energy Ep = mgh (for potential energy changes near the Earth's surface)
- apply the relationships for kinetic energy and potential energy to new situations or to solve related problems
- recall and apply the relationship work done = force × distance moved in the direction of the force to new situations or to solve related problems
- recall and apply the relationship power = work done / time taken to new situations or to solve related problems

**8. Kinetic Model of Matter**

- compare the properties of solids, liquids and gases
- describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules
- describe the relationship between the motion of molecules and temperature.

**9. Transfer of Thermal Energy**

- show understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature
- describe, in molecular terms, how energy transfer occurs in solids
- describe, in terms of density changes, convection in fluids
- explain that energy transfer of a body by radiation does not require a material medium and the rate of energy transfer is affected by:
  - (i) colour and texture of the surface
  - (ii) surface temperature
  - (iii) surface area
- apply the concept of thermal energy transfer to everyday applications.

**10. Thermal Properties of Matter**

- describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)
- describe melting / solidification and boiling / condensation as processes of energy transfer without a change in temperature
- explain the difference between boiling and evaporation.

**11. General Wave Properties**

- describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by waves in a ripple tank
- show understanding that waves transfer energy without transferring matter
- define speed, frequency, wavelength, period and amplitude
- state what is meant by the term wavefront
- recall and apply the relationship velocity = frequency × wavelength to new situations or to solve related problems
- compare transverse and longitudinal waves and give suitable examples of each.

**12. Light**

- recall and use the terms for reflection, including normal, angle of incidence and angle of reflection
- state that, for reflection, the angle of incidence is equal to the angle of reflection and use this principle in constructions, measurements and calculations
- recall and use the terms for refraction, including normal, angle of incidence and angle of refraction
- recall and apply the relationship sin i / sin r = constant to new situations or to solve related problems
- define refractive index of a medium in terms of the ratio of speed of light in vacuum and in the medium

- explain the terms critical angle and total internal reflection
- describe the action of a thin converging lens on a beam of light
- define the term focal length for a converging lens
- draw ray diagrams to illustrate the formation of real and virtual images of an object by a thin converging lens.

**13. Electromagnetic Spectrum**

- state that all electromagnetic waves are transverse waves that travel with the same speed in vacuum and state the magnitude of this speed
- describe the main components of the electromagnetic spectrum
- state examples of the use of the following components:
  - (i) radiowaves (e.g. radio and television communication)
  - (ii) microwaves (e.g. microwave oven and satellite television)
  - (iii) infra-red (e.g. infra-red remote controllers and intruder alarms)
  - (iv) light (e.g. optical fibres for medical uses and telecommunications)
  - (v) ultra-violet (e.g. sunbeds and sterilisation)
  - (vi) X-rays (e.g. radiological and engineering applications)
  - (vii) gamma rays (e.g. medical treatment)

**14. Sound**

- describe the production of sound by vibrating sources
- describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction
- explain that a medium is required in order to transmit sound waves and the speed of sound differs in air, liquids and solids
- relate loudness of a sound wave to its amplitude and pitch to its frequency
- describe how the reflection of sound may produce an echo, and how this may be used for measuring distances.

**15. Static Electricity**

- state that there are positive and negative charges and that charge is measured in coulombs
- state that unlike charges attract and like charges repel
- describe an electric field as a region in which an electric charge experiences a force
- draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge
- draw the electric field pattern between two isolated point charges

**16. Current of Electricity**

- state that current is a rate of flow of charge and that it is measured in amperes
- distinguish between conventional current and electron flow
- recall and apply the relationship charge = current × time to new situations or to solve related problems
- define electromotive force (e.m.f.) as the work done by a source in driving a unit charge around a

complete circuit

- state that the e.m.f. of a source and the potential difference (p.d.) across a circuit component in measured in volts
- define the p.d. across a component in a circuit as the work done to drive a unit charge through the component
- state the definition that resistance = p.d. / current
- apply the relationship R = V / I to new situations or to solve related problems
- describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations
- recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems
- recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems.

**17. D.C. Circuits**

- draw circuit diagrams with power sources (cell or battery), switches, lamps, resistors (fixed and variable), fuses, ammeters and voltmeters
- state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems
- state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems
- state that the current from the source is the sum of the currents in the separate branches of a parallel circuit and apply the principle to new situations or to solve related problems
- state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems
- recall and apply the relevant relationships, including R = V / I and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit.

**18. Practical Electricity**

- describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters
- recall and apply the relationships P = VI and E = VIt to new situations or to solve related problems
- calculate the cost of using electrical appliances where the energy unit is the kW h
- state the hazards of using electricity in the following situations
  - (i) damaged insulation
  - (ii) overheating of cables
  - (iii) damp conditions
- explain the use of fuses and circuit breakers in electrical circuits and of fuse ratings
- explain the need for earthing metal cases and for double insulation
- state the meaning of the terms live, neutral and earth
- describe the wiring in a mains plug
- explain why switches, fuses, and circuit breakers are wired into the live conductor.

**19. Magnetism and Electromagnetism**

- state the properties of magnets
- describe induced magnetism
- describe electrical methods of magnetisation and demagnetization
- distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)
- draw the magnetic field pattern around a bar magnet and between the poles of two bar magnets
- describe the plotting of magnetic field lines with a compass
- draw the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and / or direction of the current
- describe the application of the magnetic effect of a current in a circuit breaker
- describe experiments to show the force on a current-carrying conductor in a magnetic field, including the effect of reversing
    (i) the current
    (ii) the direction of the field
- deduce the relative directions of force, field and current when any two of these quantities are at right angles to each other using Fleming's left-hand rule
- explain how a current-carrying coil in a magnetic field experiences a turning effect (recall of structure of an electric motor is not required)