CONTENTS

NOTES

Nomenclature

The proposals in 'Signs, Symbols and Systematics (The Association for Science Education Companion to 5-16 Science, 1995)' will generally be adopted. Reference should be made to the joint statement on chemical nomenclature issued by the GCE boards. In particular, the traditional names sulphate, sulphite, nitrate, nitrite, sulphurous and nitrous acids will be used in question papers.

It is intended that, in order to avoid difficulties arising out of the use of *l* as the symbol for litre, use of dm^3 in place of *l* or litre will be made.

In chemistry, *full structural formulae (displayed formulae)* in answers should show in detail both the relative placing of atoms and the number of bonds between atoms. Hence $–CONH_2$ and $–CO_2H$ are not satisfactory as full structural formulae, although either of the usual symbols for the benzene ring is acceptable.

Units, significant figures

Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

SCIENCE

GCE ORDINARY LEVEL
5152 SCIENCE (PHYSICS, CHEMISTRY)

AIMS

These are not listed in order of priority.

The aims are to:

1. provide, through well designed studies of experimental and practical science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge to

1.1 become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import;
1.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life;
1.3 be suitably prepared for studies beyond Ordinary level in pure sciences, in applied sciences or in science-dependent vocational courses.

2. develop abilities and skills that

2.1 are relevant to the study and practice of science;
2.2 are useful in everyday life;
2.3 encourage efficient and safe practice;
2.4 encourage effective communication.

3. develop attitudes relevant to science such as

3.1 accuracy and precision;
3.2 objectivity;
3.3 integrity;
3.4 enquiry;
3.5 initiative;
3.6 inventiveness.

4. stimulate interest in and care for the environment.

5. promote an awareness that

5.1 the study and practice of science are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations;
5.2 the applications of science may be both beneficial and detrimental to the individual, the community and the environment;
5.3 the use of information technology is important for communications, as an aid to experiments and as a tool for implementation of experimental and theoretical results.

ASSESSMENT OBJECTIVES

A Knowledge with Understanding

Students should be able to demonstrate knowledge and understanding in relation to:

1. scientific phenomena, facts, laws, definitions, concepts, theories;
2. scientific vocabulary, terminology, conventions (including symbols, quantities and units contained in '*Signs, Symbols and Systematics', Association for Science Education,* 1995);
3. scientific instruments and apparatus, including techniques of operation and aspects of safety;
4. scientific quantities and their determination;
5. scientific and technological applications with their social, economic and environmental implications.

The subject content defines the factual material that candidates need to recall and explain. Questions testing these objectives will often begin with one of the following words: *define, state, describe, explain* or *outline.* (See the glossary of terms.)

B Handling Information and Solving Problems

Students should be able - in words or by using other written, symbolic, graphical and numerical forms of presentation - to:

1. locate, select, organise and present information from a variety of sources;
2. translate information from one form to another;
3. manipulate numerical and other data;
4. use information to identify patterns, report trends and draw inferences;
5. present reasoned explanations for phenomena, patterns and relationships;
6. make predictions and hypotheses;
7. solve problems.

These assessment objectives cannot be precisely specified in the subject content because questions testing such skills may be based on information, which is unfamiliar to the candidate. In answering such questions candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *predict, suggest, calculate,* or *determine.* (See the glossary of terms.)

C Experimental Skills and Investigations

Students should be able to:

1. follow a sequence of instructions;
2. use techniques, apparatus and materials;
3. make and record observations, measurements and estimates;
4. interpret and evaluate observations and experimental results;
5. plan investigations, select techniques, apparatus and materials;
6. evaluate methods and suggest possible improvements.

Weighting of Assessment Objectives

Theory Papers *(Papers 1, 2 and 3)*

A *Knowledge with Understanding*, approximately 60% of the marks with approximately 30% allocated to recall.

B *Handling Information and Solving Problems*, approximately 40% of the marks.

Practical Assessment *(Paper 5)*

Paper 5 is designed to test appropriate skills in *C, Experimental Skills and Investigations.*
In one or more of the questions in Paper 5, candidates will be expected to suggest a modification or an extension, which does not need to be executed. Depending on the context in which the modification/extension element is set, the number of marks associated with this element will be in the range of 10% to 20% of the total marks available for the practical test.

Scheme of Assessment

Candidates are required to enter for Papers 1, 2, 3 and 5.

Paper	Type of Paper	Duration	Marks	Weighting
1 2	Multiple Choice Structured and Free Response (Physics)	1 h 1 h 15 min	40 65	20.0% 32.5%
3	Structured and Free Response (Chemistry)	1 h 15 min	65	32.5%
5	Practical Test	1 h 30 min	30	15.0%

Science (Physics, Chemistry), Syllabus 5152
Paper 1 will be based on the Physics and Chemistry sections of the syllabus.
Paper 2 will be based on the Physics section of the syllabus.
Paper 3 will be based on the Chemistry section of the syllabus.
Paper 5 will be based on the Physics and Chemistry sections of the syllabus.

Theory papers

Paper 1 (1 h, 40 marks), consisting of 40 compulsory multiple choice questions of the direct choice type providing approximately equal coverage of the *two* appropriate sections of the syllabus.

Paper 2 (1 h 15 min, 65 marks), consisting of *two* sections.
Section A will carry 45 marks and will contain a number of compulsory structured questions of variable mark value.
Section B will carry 20 marks and will contain *three* free response questions, each of 10 marks. Candidates are required to answer any *two* questions.
The questions will be based on the Physics section of the syllabus.

Paper 3 (1 h 15 min, 65 marks), consisting of *two* sections.
This paper will have the same structure as Paper 2, but will be based on the Chemistry section of the syllabus.

Practical assessment

Paper 5 (1 h 30 min, 30 marks) consisting of *one* or *two* compulsory questions on each of the *two* Sciences.
The use of reference material, other than the Chemistry Practical Notes, is not permitted.
In one or both questions, candidates will be expected to suggest a modification or extension, which does not need to be executed.

SUBJECT CONTENT

Asterisks (*) placed alongside learning outcomes indicate areas of the syllabus where it is anticipated that teachers might use applications of information technology (IT), as appropriate. It should be appreciated that the list is not exhaustive.

Physics Section

It is important that throughout the course, attention should be drawn to showing the relevance of concepts to the students' everyday life and to the natural and man-made world.

Students are expected to have adequate mathematical skills to cope with the curriculum.

SECTION I:GENERAL PHYSICS

1. Physical Quantities and Units

Content

1.1 Measurement of length and time

Learning Outcomes:

Candidates should be able to:

(a) describe how to measure a variety of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier as necessary

(b) describe how to measure a variety of time intervals by means of clocks and stopwatches, including the period of a simple pendulum

2. Kinematics

Content

2.1 Speed, velocity and acceleration

2.2 Graphical analysis of motion

2.3 Free-fall

Learning Outcomes:

Candidates should be able to:

(a) state what is meant by *speed* and *velocity*

(b) state what is meant by *uniform acceleration* and calculate the value of an acceleration using *change in velocity/time taken*

(c) interpret given examples of non-uniform acceleration

(d) *plot and *interpret a distance-time graph and a speed-time graph

(e) *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

(f) *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

(g) *calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration

(h) 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

Content

3.1 Motion

3.2 Friction

Learning Outcomes:

Candidates should be able to:

(a) describe the ways in which a force may change the motion of a body

(b) recall the relationship *resultant force = mass* x *acceleration*

(c) *apply the relationship between resultant force, mass and acceleration to new situations or to solve related problems

(d) explain the effects of friction on the motion of a body

4. Mass, Weight and Density

Content

4.1 Mass and weight

4.2 Density

Learning Outcomes:

Candidates should be able to:

(a) state that mass is a measure of the amount of substance in a body

(b) state that mass of a body resists a change in the state of rest or motion of the body

(c) recall the relationship *weight = mass* x *gravitational field strength*

(d) apply the relationship between weight, mass and gravitational field strength to new situations or to solve related problems

(e) recall the relationship *density = mass/volume*

(f) apply the relationship between density, mass and volume to new situations or to solve related problems

5. Turning Effect of Forces

Content

5.1 Moments

5.2 Centre of gravity

5.3 Stability

Learning Outcomes:

Candidates should be able to:

(a) describe the moment of a force in terms of its turning effect and give everyday examples in terms of moments

(b) recall the relationship *moment of a force (or torque) = force* x *perpendicular distance from the pivot*

(c) apply the relationship between moment of a force, force and perpendicular distance from the pivot to new situations or to solve related problems

(d) state the principle of moments for a body in equilibrium

(e) apply the principle of moments to new situations or to solve related problems

(f) describe qualitatively the effect of the position of the centre of gravity on the stability of simple objects

6. Energy, Work and Power

Content

6.1 Energy conversion and conservation

6.2 Work

6.3 Power

Learning Outcomes:

Candidates should be able to:

(a) show understanding that kinetic energy, elastic potential energy, gravitational potential energy and chemical potential energy are examples of different forms of energy

(b) state the principle of the conservation of energy

(c) apply the principle of the conservation of energy to new situations or to solve related problems

(d) state that kinetic energy $E_k = \frac{1}{2} mv^2$ and gravitational potential energy $E_p = mgh$ (for potential energy changes near the Earth's surface)

(e) apply the relationships for kinetic energy and potential energy to new situations or to solve related problems

(f) recall the relationship *work done* = *force* x *distance moved in the direction of the force*

(g) apply the relationship between work done, force and distance moved in the direction of the force to new situations or to solve related problems

(h) recall the relationship *power* = *work done/time taken*

(i) apply the relationship between power, work done and time taken to new situations or to solve related problems

SECTION II: THERMAL PHYSICS

7. Transfer of Thermal Energy

Content

7.1 Conduction

7.2 Convection

7.3 Radiation

Learning Outcomes:

Candidates should be able to:

(a) describe, in molecular terms, how energy transfer occurs in solids

(b) describe, in terms of density changes, convection in fluids

(c) show understanding 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

(d) apply the concept of thermal energy transfer to everyday applications

8. Temperature

Content

8.1 Principles of thermometry

8.2 Liquid-in-glass thermometers

Learning Outcomes:

Candidates should be able to:

(a) explain how the volume of a fixed mass of liquid may be used to define temperature scale and state examples of other such properties

(b) explain the need for fixed points and state what is meant by *ice point* and *steam point*

(c) discuss the structure, sensitivity, range, linearity and responsiveness of liquid-in-glass thermometers

9. Thermal Properties of Matter

Content

9.1 Melting, boiling and evaporation

Learning Outcomes:

Candidates should be able to:

(a) describe melting/solidification and boiling/condensation as processes of energy transfer without a change in temperature

(b) explain the difference between boiling and evaporation

SECTION III: WAVES

10. General Wave Properties

Content

10.1 Describing wave motion

10.2 Wave terms

10.3 Longitudinal and transverse waves

Learning Outcomes:

Candidates should be able to:

(a) describe what is meant by *wave motion* as illustrated by vibrations in ropes and springs and by waves in a ripple tank

(b) define *speed, frequency, wavelength*, *period* and *amplitude*

(c) recall the relationship *velocity* = *frequency* x *wavelength*

(d) apply the relationship between velocity, frequency and wavelength to new situations or to solve related problems

(e) *compare transverse and longitudinal waves and give suitable examples of each

11. Light

Content

11.1 Reflection of light

11.2 Refraction of light

11.3 Thin converging lenses

Learning Outcomes:

Candidates should be able to:

(a) define the terms used in reflection, including *normal*, *angle of incidence* and *angle of reflection*

(b) state that, for reflection, *the angle of incidence is equal to the angle of reflection* and use this principle in constructions, measurements and calculations

(c) define the terms used in refraction, including *angle of incidence*, *angle of refraction* and *normal*

(d) recall the relationship *sin i/sin r = constant*

(e) apply the relationship between *sin i* and *sin r* to new situations or to solve related problems

(f) define *refractive index* of a medium in terms of the ratio of speed of light in a vacuum and in the medium

(g) describe the action of a thin converging lens on a beam of light

(h) define the term *focal length*

(i) *draw ray diagrams to illustrate the formation of real and virtual images of an object by a thin converging lens

(j) describe the use of a single lens as a magnifying glass

12. Electromagnetic Spectrum

Content

12.1 Properties of electromagnetic waves

Learning Outcomes:

Candidates should be able to:

(a) state that all electromagnetic waves are transverse waves that travel with the same high speed in vacuo and state the magnitude of this speed

(b) describe the main components of the electromagnetic spectrum

13. Sound

Content

13.1 Sound waves

13.2 Speed of sound

Learning Outcomes:

Candidates should be able to:

(a) describe the production of sound by vibrating sources

(b) describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction and deduce that:

(i) a medium is required in order to transmit these waves

(ii) the speed of sound differs in air, liquids and solids

(c) state the approximate range of audible frequencies

(d) describe a direct method for the determination of the speed of sound in air and make the necessary calculation

(e) explain how the loudness and pitch of sound waves relate to amplitude and frequency

(f) describe how the reflection of sound may produce an echo

SECTION IV: ELECTRICITY AND MAGNETISM

14. Static Electricity

Content

14.1 Principles of electrostatics

Learning Outcomes:

Candidates should be able to:

(a) state that there are positive and negative charges and that charge is measured in coulombs

(b) state that unlike charges attract and like charges repel

15. Current Electricity

Content:

15.1 Electric current

15.2 Electromotive force

15.3 Potential Difference

15.4 Resistance

Learning Outcomes:

Candidates should be able to:

(a) state that current is a rate of flow of charge and that it is measured in amperes

(b) recall the relationship *charge* = *current* x *time*

(c) apply the relationship between charge, current and time to new situations or to solve related problems

(d) define electromotive force (e.m.f.) as the work done by a source in driving a unit charge around a complete circuit

(e) state that the potential difference (p.d.) across a circuit component is measured in volts

(f) state the definition that *resistance = p.d./current*

(g) apply the relationship $R = V/I$ to new situations or to solve related problems

(h) describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations

(i) recall the relationship of the proportionality between resistance and the length and cross-sectional area of a wire

(j) *apply the relationship between resistance, length and cross-sectional area of a wire to new situations or to solve related problems

(k) recall the formulae for the effective resistance of a number of resistors in series and for two resistors in parallel

(l) apply the formulae for the effective resistance of a number of resistors in series and for two resistors in parallel to new situations or to solve related problems

(m) *sketch and interpret the *V/I* characteristic graphs for a metallic conductor at constant temperature and a filament lamp

16. D.C. Circuits

Content

16.1 Current and potential difference in circuits

16.2 Series and parallel circuits

Learning Outcomes:

Candidates should be able to:

(a) *draw circuit diagrams with power sources (cell or battery), switches, lamps, resistors (fixed and variable), fuses, ammeters and voltmeters

(b) state that the current at every point in a series circuit is the same

(c) apply the principle of current in a series circuit to new situations or to solve related problems

(d) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit

(e) apply the principle of the sum of potential differences in a series circuit to new situations or to solve related problems

(f) state that the current from the source is the sum of the currents in the separate branches of a parallel circuit

(g) apply the principle of current in a parallel circuit to new situations or to solve related problems

(h) state that the potential difference across the separate branches of a parallel circuit is the same

(i) apply the principle of potential difference in a parallel circuit to new situations or to solve related problems

(j) apply the relevant relationships, including $R = V/I$ and those for potential differences in series and in parallel, resistors in series and in parallel, in calculations involving a whole circuit

17. Practical Electricity

Content

17.1 Electric power and energy

17.2 Dangers of electricity

17.3 Safe use of electricity in the home

Learning Outcomes:

Candidates should be able to:

(a) describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters

(b) recall the relationships $P = VI$ and $E = VIt$

(c) apply the relationships for electrical power and energy to new situations or to solve related problems

(d) calculate the cost of using electrical appliances where the energy unit is the kW h

(e) state the hazards of using electricity in the following situations
- (i) damaged insulation
- (ii) overheating of cables
- (iii) damp conditions

(f) explain the use of fuses in electrical circuits and of fuse ratings

(g) explain the need for earthing metal cases and for double insulation

(h) state the meaning of the terms *live, neutral* and *earth*

(i) describe how to wire a mains plug

(j) explain why switches and fuses are wired into the live conductor

18. Magnetism

Content

18.1 Laws of magnetism

18.2 Magnetic properties of matter

Learning Outcomes:

Candidates should be able to:

(a) state the properties of magnets

(b) describe induced magnetism

(c) distinguish between magnetic and non-magnetic materials

(d) describe electrical methods of magnetisation and demagnetisation

(e) describe the plotting of magnetic field lines with a compass

(f) distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)

19. Electromagnetic Induction

Content

19.1 Principles of electromagnetic induction

19.2 The a.c. generator

19.3 The transformer

Learning Outcomes:

Candidates should be able to:

(a) *deduce from Faraday's experiments on electromagnetic induction or other appropriate experiments:

(i) that a changing magnetic field can induce an e.m.f. in a circuit

(ii) that the direction of the induced e.m.f. opposes the change producing it

(iii) the factors affecting the magnitude of the induced e.m.f.

(b) describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings (where needed)

(c) *sketch a graph of voltage output against time for a simple a.c. generator

(d) describe the structure and principle of operation of a simple iron-cored transformer as used for voltage transformations

(e) recall the equations $V_p/V_s = N_p/N_s$ and $V_p I_p = V_s I_s$ (for ideal transformers)

(f) apply the relationships between V_p , V_s , N_p , N_s , I_p and I_s to new situations or to solve related problems

SECTION V: NUCLEAR PHYSICS

20. Nucleus

Content

20.1 Composition of a nucleus
20.2 Proton number and nucleon number
20.3 Nuclide notation

Learning Outcomes:

Candidates should be able to:

(a) describe the composition of the nucleus in terms of protons and neutrons

(b) define the terms *proton number* (*atomic number*), Z and *nucleon number* (*mass number*), A

(c) explain the term *nuclide* and use the nuclide notation ${}^{A}_{Z}X$

21. Radioactivity

Content

21.1 Detection of radioactivity
21.2 Characteristics of the three types of emission
21.3 Nuclear reactions
21.4 Half-life
21.5 Uses of radioactive isotopes including safety precautions

Learning Outcomes:

Candidates should be able to:

(a) name the common detectors for alpha-particles, beta-particles and gamma-rays (structure and mode of operation of the detectors are **not** required)

(b) *show understanding that radioactive emissions occur randomly over space and time

(c) distinguish between the three kinds of emissions in terms of
 (i) their nature
 (ii) their relative ionising effects
 (iii) their relative penetrating powers

(d) explain what is meant by *radioactive decay*, using equations (involving symbols) to represent changes in the composition of the nucleus when particles are emitted

(e) explain what is meant by the term *half-life*

(f) apply their understanding of half-life to solve simple problems which might involve information in tables or decay curves

(g) describe how radioactive materials are handled, used and stored in a safe way

Chemistry Section

It is important that, throughout the course, attention should be drawn to:

(i) the finite life of the world's resources and hence the need for recycling and conservation;

(ii) economic considerations in the chemical industry, such as the availability and cost of raw materials and energy;

(iii) the social, environmental, health and safety issues relating to the chemical industry;

(iv) the importance of chemicals in industry and in everyday life.

1. Experimental Chemistry

Content

1.1 Experimental design

1.2 Methods of purification and analysis

1.3 Identification of ions and gases

It is expected that any course in Chemistry will be based on experimental work. Teachers are encouraged to develop appropriate practical work for their students to facilitate a greater understanding of the subject.

Learning Outcomes:

Candidates should be able to:

(a) name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes, measuring cylinders and gas syringes

(b) suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases and measurement of rates of reaction

(c) describe methods of purification by the use of a suitable solvent, filtration and crystallisation, distillation (including the description but **not** use of fractional distillation - refer to the fractional distillation of crude oil and fermented liquor)

(d) suggest suitable methods of purification, given information about the substances involved

(e) describe paper chromatography and interpret chromatograms

(f) deduce from the given melting points and boiling points the identities of substances and their purity

(g) 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)

(h) 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 lead(II) nitrate), nitrate (by reduction with aluminium and aqueous sodium hydroxide to ammonia and subsequent use of litmus paper) and sulphate (by reaction of an aqueous solution with nitric acid and aqueous barium nitrate)

(i) 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 sulphur dioxide (using acidified potassium dichromate(VI))

2. Kinetic Particle Theory

Learning Outcomes:

Candidates should be able to:

(a) *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

3. Atomic Structure

Content

3.1 Atomic structure

3.2 Isotopes

Learning Outcomes:

Candidates should be able to:

(a) state the relative charges and approximate relative masses of a proton, a neutron and an electron

(b) *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) - no knowledge of s, p, d and f classification will be expected; a copy of the Periodic Table will be available in Papers 1, 3 and 5

(c) define *proton number* (*atomic number*) and *nucleon number* (*mass number*)

(d) interpret and use symbols such as $^{12}_{6}C$

(e) define the term *isotopes*

(f) deduce the numbers of protons, neutrons and electrons in atoms and ions given proton and nucleon numbers

4. Structure and Properties of Materials

Learning Outcomes:

Candidates should be able to:

(a) describe the differences between elements, compounds and mixtures

5. Ionic bonding

Content

5.1 Ion formation

5.2 Ionic bond formation

Learning Outcomes:

Candidates should be able to:

(a) *describe the formation of ions by electron loss/gain in order to obtain the electronic configuration of an inert gas

(b) *describe the formation of ionic bonds between metals and non-metals (e.g. $NaCl$; $MgCl_2$)

(c) relate the physical properties (including electrical property) of ionic compounds to their lattice structure

6. Covalent Bonding

Content

6.1 Covalent bond formation

6.2 Physical properties of covalent substances

Learning Outcomes:

Candidates should be able to:

(a) *describe the formation of a covalent bond by the sharing of a pair of electrons in order to gain the electronic configuration of an inert gas

(b) 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 and CO_2)

(c) deduce the arrangement of electrons in other covalent molecules

(d) relate the physical properties (including electrical property) of covalent substances to their structure and bonding

7. Formulae, Stoichiometry and the Mole Concept

Content

7.1 Formulae

7.2 Equations

7.3 Stoichiometric calculations

Learning Outcomes:

Candidates should be able to:

(a) state the symbols of the elements and formulae of the compounds mentioned in the syllabus

(b) deduce the formulae of simple compounds from the relative numbers of atoms present and vice versa

(c) deduce the formulae of ionic compounds from the charges on the ions present and vice versa

(d) interpret chemical equations with state symbols

(e) construct chemical equations, with state symbols, including ionic equations

(f) define *relative atomic mass*, A_r

(g) define *relative molecular mass*, M_r

(h) *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 (questions on the gas laws and the calculations of gaseous volumes at different temperatures and pressures will **not** be set)

(i) *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)

8. Energy from Chemicals

Content

8.1 Exothermic and endothermic reactions

Learning Outcomes:

Candidates should be able to:

(a) *describe the meaning of enthalpy change in terms of exothermic (ΔH negative) and endothermic (ΔH positive) reactions

(b) *describe bond breaking as an endothermic process and bond making as an exothermic process

9. Chemical Reactions

Content

9.1 Speed of reaction

9.2 Redox

Learning Outcomes:

Candidates should be able to:

(a) *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

(b) *interpret data obtained from experiments concerned with speed of reaction

(c) define *oxidation* and *reduction* (redox) in terms of oxygen/hydrogen gain/loss

(d) define *redox* in terms of electron transfer and changes in oxidation state

(e) describe the use of aqueous potassium iodide and acidified potassium dichromate(VI) in testing for oxidising and reducing agents from the resulting colour changes

10. The Chemistry and Uses of Acids, Bases and Salts

Content

10.1 Characteristic properties of acids and bases

10.2 Preparation of salts

Learning Outcomes:

Candidates should be able to:

(a) describe the meanings of the terms *acid* and *alkali* in terms of the ions they contain or produce in aqueous solution and their effects on Universal Indicator paper

(b) describe how to test hydrogen ion concentration and hence relative acidity using Universal Indicator paper and the pH scale

(c) describe the characteristic properties of acids as in reactions with metals, bases and carbonates

(d) describe the importance of controlling the pH in soils and how excess acidity can be treated using calcium hydroxide

(e) describe the characteristic properties of bases as in reactions with acids and with ammonium salts

(f) classify oxides as acidic, basic or amphoteric, based on metallic/non-metallic character

(g) *describe the techniques used in the preparation, separation and purification of salts as examples of some of the techniques specified in Section 1.2 - methods for preparation should include precipitation and titration, together with reactions of acids with metals, insoluble bases and insoluble carbonates

(h) suggest a method of preparing a given salt from suitable starting materials, given appropriate information

11. The Periodic Table

Content

11. 1 Periodic trends

11. 2 Group properties

Learning Outcomes:

Candidates should be able to:

(a) describe the Periodic Table as an arrangement of the elements in the order of increasing proton number (atomic number)

(b) describe the change from metallic to non-metallic character from left to right across a period of the Periodic Table

(c) *describe the relationship between group number, number of valency electrons and metallic/non-metallic character

(d) *predict the properties of elements in Group I, VII and the Transition elements using the Periodic Table

(e) 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

(f) describe chlorine, bromine and iodine in Group VII (the halogens) as a collection of diatomic non-metals showing a trend in colour, state and their displacement reactions with solutions of other halide ions

(g) describe the elements in Group 0 (the noble gases) as a collection of monatomic elements that are chemically unreactive and hence important in providing an inert atmosphere (e.g. argon and neon in light bulbs; helium in balloons; argon in the manufacture of steel)

(h) describe the lack of reactivity of the noble gases in terms of their electronic structures

12. Properties of Metals

Content

12.1 Physical properties

12.2 Alloys

Learning Outcomes:

Candidates should be able to:

(a) describe the general physical properties of metals as solids having high melting and boiling points, being malleable and good conductors of heat and electricity, in terms of their structure

(b) describe alloys as a mixture of a metal with another element (e.g. brass; stainless steel)

(c) identify representations of metals and alloys from diagrams of structures

13. Reactivity Series

Content

13.1 Order of reactivity

Learning Outcomes:

Candidates should be able to:

(a) 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

(b) deduce the order of reactivity from a given set of experimental results

14. Extraction of Metals

Content

14.1 Metal ores

14.2 Recycling metals

Learning Outcomes:

Candidates should be able to:

(a) describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series

(b) describe metal ores as a finite resource and hence the need to recycle metals

(c) discuss the social, economic and environmental advantages and disadvantages of recycling metals

15. Iron

Content

15.1 The blast furnace

15.2 Steel

15.3 Prevention of rusting

Learning Outcomes:

Candidates should be able to:

(a) describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace

(b) describe steels as alloys which are a mixture of iron with carbon or other metals and how controlled use of these additives changes the properties of the iron (e.g. high carbon steels are strong but brittle, whereas low carbon steels are softer and more easily shaped)

(c) state the uses of mild steel (e.g. car bodies; machinery), and stainless steel (e.g. chemical plant; cutlery; surgical instruments)

(d) 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; galvanising)

(e) describe the sacrificial protection of iron by a more reactive metal in terms of the reactivity series where the more reactive metal corrodes preferentially (e.g. underwater pipes have a piece of magnesium attached to them)

16. Aluminium

Learning Outcomes:

Candidates should be able to:

(a) state the uses of aluminium and relate the uses to the properties of this metal and its alloys (e.g. the manufacture of aircraft; food containers; electric cables)

17. Atmosphere and Environment

Content

17.1 Air

17.2 Water

Learning Outcomes:

Candidates should be able to:

(a) describe the volume composition of gases present in dry air as 79% nitrogen, 20% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide

(b) state the uses of oxygen (e.g. in making steel; oxygen tents in hospitals; together with acetylene, in welding)

(c) name some common atmospheric pollutants (e.g. carbon monoxide; methane; nitrogen oxides (NO and NO_2); ozone; sulphur dioxide; unburned hydrocarbons)

(d) 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) sulphur dioxide from volcanoes and combustion of fossil fuels

(e) 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 sulphur dioxide in the formation of 'acid rain' and its effects on respiration and buildings

(f) outline the purification of the water supply in terms of:

(i) filtration to remove solids

(ii) chlorination to disinfect the water

(g) state that seawater can be converted into drinkable water by desalination

18. Organic Chemistry

Content

18.1 Crude oil

Learning Outcomes:

Candidates should be able to:

(a) state that naphtha fraction from crude oil is the main source of hydrocarbons used as the feedstock for the production of a wide range of organic compounds

(b) describe the issues relating to the competing uses of oil as an energy source and as a chemical feedstock

19. Fuels

Content

19.1 Natural gas and petroleum as energy sources

19.2 Fractional distillation

Learning Outcomes:

Candidates should be able to:

(a) name natural gas, mainly methane, and petroleum as sources of energy

(b) describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation

(c) name the following fractions and state their uses :
- (i) petrol (gasoline) as a fuel in cars
- (ii) paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines
- (iii) diesel as a fuel for diesel engines
- (iv) lubricating oils as lubricants and as a source of polishes and waxes
- (v) bitumen for making road surfaces

*The use of molecular models is recommended to enable students to appreciate the three dimensional structures of molecules.

20. Alkanes

Content

20.1 Homologous series

20.2 Properties of alkanes

Learning Outcomes:

Candidates should be able to:

(a) describe an 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)

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

21. Alkenes

Content

21.1 Cracking

21.2 Saturated and unsaturated hydrocarbons

Learning Outcomes:

Candidates should be able to:

(a) 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

(b) describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine

(c) describe the properties of alkenes in terms of combustion and the addition reactions with bromine, steam and hydrogen

(d) state the meaning of *polyunsaturated* when applied to food products

(e) describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetables oils to form a solid product

22. Alcohols

Content

22.1 Combustion and oxidation

22.2 Ethanol and its uses

Learning Outcomes:

Candidates should be able to:

(a) describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids

(b) describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose

(c) state some uses of ethanol (e.g. solvent; fuel; constituent of alcoholic beverages)

23. Carboxylic acids

Content

23.1 Ethanoic acid formation

Learning Outcomes:

Candidates should be able to:

(a) describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium dichromate(VI)

(b) describe the reaction of ethanoic acid with ethanol to form the ester, ethyl ethanoate

24. Macromolecules

Content

24.1 Monomers and polymers

24.2 Man-made fibres

24.3 Pollution

24.4 Natural macromolecules

Learning Outcomes:

Candidates should be able to:

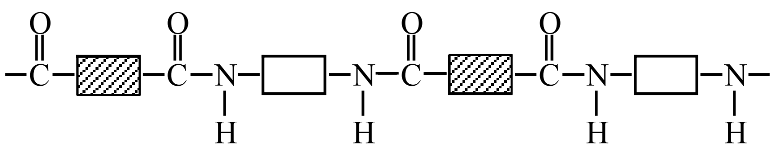
(a) describe macromolecules as large molecules built up from small units, different macromolecules having different units and/or different linkages

(b) describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer

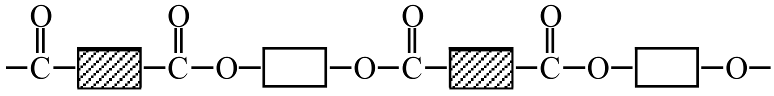
(c) state some uses of poly(ethene) as a typical plastic (e.g. plastic bags; clingfilm)

(d) deduce the structure of the polymer product from a given monomer and vice versa

(e) describe nylon, a polyamide, and *Terylene,* a polyester, as condensation polymers, the partial structure of nylon being represented as:



and the partial structure of *Terylene* as:



(details of manufacture and mechanisms of these polymerisations are not required) *(f)* state some typical uses of man-made fibres such as nylon and *Terylene* (e.g. clothing; curtain materials; fishing line; parachutes; sleeping bags)

(g) describe the pollution problems caused by the disposal of non-biodegradable plastics

(h) identify carbohydrates, proteins and fats as natural macromolecules

(i) describe proteins as possessing the same amide linkages as nylon, but with different monomer units

(j) describe fats as esters possessing the same linkages as *Terylene,* but with different monomer units

NOTES FOR USE IN QUALITATIVE ANALYSIS

Tests for anions

anion	*test*	*test result*
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
iodide (I^-) [in solution]	acidify with dilute nitric acid, then add aqueous lead(II) nitrate	yellow ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulphate (SO_4^{2-}) [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt.

Tests for aqueous cations

cation	*effect of aqueous sodium hydroxide*	*effect of aqueous ammonia*
aluminium (Al^{3+})	white ppt., soluble in excess, giving a colourless solution	white ppt., insoluble in excess
ammonium (NH_4^+)	ammonia produced on warming	—
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt.
copper(II) (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
lead(II) (Pb^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

Tests for gases

gas	*test and test result*
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	turns limewater milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint
sulphur dioxide (SO_2)	turns aqueous potassium dichromate(VI) green

PRACTICAL ASSESSMENT

Scientific subjects are, by nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of Science should include a component relating to practical work and experimental skills. This assessment is provided in Paper 5, as a formal practical test, and is outlined in the **Scheme of Assessment**.

Paper 5 Practical Test

Physics Practical Test

Candidates may be asked to carry out exercises based on:

(a) measurements of lengths with appropriate accuracy by means of tapes, rules, micrometers and callipers, using a vernier as necessary;
(b) measurements of time intervals, including the period of a simple pendulum, by means of clocks and stopwatches;
(c) measurements of temperature by using appropriate thermometers;
(d) measurements of mass and weight by using appropriate balances;
(e) measurements of the volume of a liquid or solid by using a measuring cylinder;
(f) determination of the density of a liquid, of a regularly and irregularly shaped solid, which sinks in water;
(g) the principle of moments;
(h) the law of reflection;
(i) determination of the position of the centre of gravity of a plane lamina;
(j) determination of the position and characteristics of an optical image formed by a plane mirror;
(k) the refraction of light through glass blocks;
(l) measurements of current and voltage by using appropriate ammeters and voltmeters;
(m) determination of the resistance of a metallic conductor using a voltmeter and an ammeter.

This is not intended to be an exhaustive list. Reference may be made to the techniques used in these experiments in the theory papers, but no detailed description of the experimental procedures will be required.

Chemistry Practical Test

Candidates may be asked to carry out exercises based on:

(a) quantitative experiments involving the use of a pipette, burette and an indicator such as methyl orange or screened methyl orange; if titrations other than acid/alkali are set, full instructions and other necessary information will be given;
(b) speeds of reaction;
(c) measurements of temperature based on thermometers with 1 °C graduations;
(d) problems of an investigatory nature, possibly including suitable organic compounds;
(e) simple paper chromatography;
(f) filtration;
(g) tests for oxidising and reducing agents as specified in the syllabus;
(h) identification of ions and gases as specified in the syllabus.

This question paper will contain notes on qualitative analysis for the use of candidates in the examination.

Candidates may also be required to perform simple calculations.

INFORMATION TECHNOLOGY (IT) USAGE IN O LEVEL SCIENCE (5152)

Information Technology (IT) is a term used to cover a number of processes, which have become an indispensable part of modern life. These processes are almost all based on the ability of the microprocessor chip to handle and manipulate large volumes of binary data in a short time. The use of IT is now an important factor in science education and it is hoped that all O level candidates will have the opportunity to experience something of each of the following processes:

1 Data Capture (Hardware)

Sensors and dataloggers can be used in experiments to measure and store a number of physical quantities, which vary with time. Sensors and dataloggers are invaluable where the time-scale of the experiments is either very long or very short. The use of sensors to collect the data allows for more time to be spent on analysis and evaluation, rather than on drawing graphs, which can be time consuming for some students. Sensors and dataloggers could be used for experiments such as those involving measurement of temperature, motion, force and pH.

2 Data Analysis (Software)

The most important type of programme, which allows the analysis of data, is the spreadsheet into which data may be entered manually via the keyboard. This application allows for the immediate changing of variables and continuous information processing.

One of the most important uses of a spreadsheet is that it allows its data to be analysed graphically. Two or more sets of corresponding data can be plotted as histograms or as simple line graphs. For example, the spreadsheet allows students to plot a graph of temperature against time. This is useful for students investigating the factors affecting the rate of heat loss through radiation. In addition, spreadsheets and graphical displays can be used to help students to investigate the effect of temperature on enzyme activity.

3 Teaching Aids and Resources (Software)

There are a number of software packages available, including CD-ROMs, which have been designed to assist the teaching of some topics. Some of these software packages can be used as self-learning programmes for an individual student to work through at their own pace while others can be used to provide computer generated images for classroom demonstrations and simulations.

Certain learning outcomes of the syllabus have been marked with an asterisk (*) to indicate the possibility of the application of IT. A brief commentary on some of these outcomes follows. In some cases, software is available commercially; in others, teachers may be able to develop their own. References in the notes below are to learning outcomes.

PHYSICS SECTION

2. Kinematics

(d),(e),(f), and *(g)* offer an opportunity to use computer programs to simulate particle motion, and to demonstrate how quantities such as distance, speed and acceleration are related. Data-capture techniques may also be used in practical work on kinematics.

3. Dynamics

In *(c)*, some examples of the application of Newton's second law may be presented through computer simulations.

10. General Wave Properties

Comparison between transverse and longitudinal waves in *(e)* may be illustrated using computer simulations.

11. Light

Construction of ray diagrams in *(i)* may be effectively demonstrated using computer simulations.

15. Current Electricity

(j) and *(m)* may be presented through computer simulations and data-capture.

16. D.C. Circuits

The analysis of circuit diagrams in *(a)* may be presented using computer simulation techniques.

19. Electromagnetic Induction

Computer simulations, or demonstrations using a cathode-ray oscilloscope, may be used to illustrate *(a)* and *(c).*

21. Radioactivity

Data-capture methods and computer simulations may be used to demonstrate the random nature of radioactive decay in *(b).*

CHEMISTRY SECTION

2. Kinetic Particle Theory

(a) offers an opportunity for the use of computer software to simulate the interconversion of solid, liquid and gaseous states of matter.

3. Atomic Structure

(b) allows the use of computer software to model the structure of an atom.

5. & 6. Ionic Bonding and Covalent Bonding

Computer modelling can be used effectively to help students to visualise the bonding types; structures of ionic and covalent compounds in *(a)* and *(b)* and *6(a)*.

7. Formulae, Stoichiometry and the Mole Concept

Spreadsheets can be used to help students in understanding and performing stoichiometric calculations involving reacting masses and volumes of gases in *(h)* and *(i)*.

8. Energy from Chemicals

Sensors and dataloggers can be used to investigate the heat changes during a chemical reaction.

9. Chemical Reactions

Sensors and dataloggers can be used to investigate the effects of concentration, pressure, particle size and temperature on the speeds of reactions in *(a)*. Spreadsheets and graphical displays can be used effectively to help students in interpreting experimental data concerned with speed of reaction in *(b)*.

10. The Chemistry and Uses of Acids, Bases and Salts

pH sensors and dataloggers can be used to measure and record the pH during acid-base titrations in *(g)*.

11. The Periodic Table

Spreadsheets and graphical displays can be used to investigate the trends and variations of properties within the groups and across the periods of the Periodic Table in *(c)* and *(d)*.

18.–24. Organic Chemistry

Computer modelling software can be used to help students in visualising the bonding types, molecular shapes and structures of alkanes (20), alkenes (21), alcohols (22), carboxylic acids (23) and macromolecules (24).

GLOSSARY OF TERMS USED IN SCIENCE PAPERS

It is hoped that the glossary (which is relevant only to science papers) will prove helpful to candidates as a guide, i.e. it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Define (the term(s)…)* is intended literally. Only a formal statement or equivalent paraphrase being required.

2. *What do you understand by/What is meant by (the term(s)….)* normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in light of the indicated mark value.

3. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.

4. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should not be exceeded.

5. *Explain* may imply reasoning or some reference to theory, depending on the context.

6. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. In the latter instance the answer may often follow a standard pattern, e.g. Apparatus, Method, Measurement, Results and Precaution.

   In other contexts, *describe and give an account of* should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included on the answer. *Describe and explain* may be coupled in a similar way to *state and explain.*

7. *Discuss* requires candidate to give a critical account of the points involved in the topic.

8. *Outline* implies brevity, i.e. restricting the answer to giving essentials.

9. *Predict* or *deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question. Predict also implies a concise answer with no supporting statement required.

10. *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

11. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer, or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.

12. *Find* is a general term that may be variously be interpreted as calculate, measure, determine etc.

13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula.

16. *Estimate* implies a reasoned order magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about the points of principle and about values of quantities not otherwise included in the question.

17. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having the intercept, asymptote or discontinuity at a particular value.

    In diagrams, sketch implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.

18. *Construct* is often used in relation to chemical equations where a candidate is expected to write a balanced equation, not by factual recall but by analogy or by using information in the question.

Special Note
Units, significant figures. Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

The Periodic Table of the Elements

Group

I	II											III	IV	V	VI	VII	0
							1 H Hydrogen 1										4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulphur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La Lanthanum 57 *	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	Po Polonium 84	At Astatine 85	Rn Radon 86
Fr Francium 87	226 Ra Radium 88	227 Ac actinium 89 †															

*58-71 Lanthanoid series
†90-103 Actinoid series

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	163 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	Pa Protactinium 91	U Uranium 92	Np Neptunium 93	Pu Plutonium 94	Am Americium 95	Cm Curium 96	Bk Berkelium 97	Cf Californium 98	Es Einsteinium 99	Fm Fermium 100	Md Mendelevium 101	No Nobelium 102	Lr Lawrencium 103

Key

a **X** b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).