3 Subject content

All candidates should be taught the Core subject content. Candidates who are only taught the Core subject content can achieve a maximum of grade C. Candidates aiming for grades A* to C should be taught the Extended subject content. The Extended subject content includes both the Core and the Supplement.

Scientific subjects are, by their nature, experimental. Learners should pursue a fully integrated course which allows them to develop their practical skills by carrying out practical work and investigations within all of the topics listed.

1 The particulate nature of matter

1.1 The particulate nature of matter

Core	Supplement
• State the distinguishing properties of solids, liquids and gases	
• Describe the structure of solids, liquids and gases in terms of particle separation, arrangement and types of motion	
• Describe changes of state in terms of melting, boiling, evaporation, freezing, condensation and sublimation	• Explain changes of state in terms of the kinetic theory
• Describe qualitatively the pressure and temperature of a gas in terms of the motion of its particles	
• Show an understanding of the random motion of particles in a suspension (sometimes known as Brownian motion) as evidence for the kinetic particle (atoms, molecules or ions) model of matter	• Describe and explain Brownian motion in terms of random molecular bombardment • State evidence for Brownian motion
• Describe and explain diffusion	• Describe and explain dependence of rate of diffusion on molecular mass

2 Experimental techniques

2.1 Measurement

Core

- Name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes and measuring cylinders

2.2 Purity

2.2.1 Criteria of purity

Core

- Demonstrate knowledge and understanding of paper chromatography
- Interpret simple chromatograms
- Identify substances and assess their purity from melting point and boiling point information
- Understand the importance of purity in substances in everyday life, e.g. foodstuffs and drugs

Supplement

- Interpret simple chromatograms, including the use of R_f values
- Outline how chromatography techniques can be applied to colourless substances by exposing chromatograms to substances called locating agents. (Knowledge of *specific* locating agents is **not** required.)

2.2.2 Methods of purification

Core

- Describe and explain methods of purification by the use of a suitable solvent, filtration, crystallisation and distillation (including use of a fractionating column). (Refer to the fractional distillation of petroleum in section 14.2 and products of fermentation in section 14.6.)
- Suggest suitable purification techniques, given information about the substances involved

3 Atoms, elements and compounds

3.1 Atomic structure and the Periodic Table

Core

- State the relative charges and approximate relative masses of protons, neutrons and electrons
- Define *proton number* (atomic number) as the number of protons in the nucleus of an atom
- Define *nucleon number* (mass number) as the total number of protons and neutrons in the nucleus of an atom
- Use proton number and the simple structure of atoms to explain the basis of the Periodic Table (see section 9), with special reference to the elements of proton number 1 to 20
- Define *isotopes* as atoms of the same element which have the same proton number but a different nucleon number
- State the two types of isotopes as being radioactive and non-radioactive

Supplement

- Understand that isotopes have the same properties because they have the same number of electrons in their outer shell

continued

3.1 Atomic structure and the Periodic Table continued

Core

- State one medical and one industrial use of radioactive isotopes
- Describe the build-up of electrons in 'shells' and understand the significance of the noble gas electronic structures and of the outer shell electrons. (The ideas of the distribution of electrons in s and p orbitals and in d block elements are **not** required.)

Note: a copy of the Periodic Table, as shown in the Appendix, will be available in Papers 1, 2, 3 and 4.

3.2 Structure and bonding

3.2.1 Bonding: the structure of matter

Core

- Describe the differences between elements, mixtures and compounds, and between metals and non-metals
- Describe an alloy, such as brass, as a mixture of a metal with other elements

3.2.2 Ions and ionic bonds

Core

- Describe the formation of ions by electron loss or gain
- Describe the formation of ionic bonds between elements from Groups I and VII

Supplement

- Describe the formation of ionic bonds between metallic and non-metallic elements
- Describe the lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions

3.2.3 Molecules and covalent bonds

Core

- Describe the formation of single covalent bonds in H_2, Cl_2, H_2O, CH_4, NH_3 and HCl as the sharing of pairs of electrons leading to the noble gas configuration
- Describe the differences in volatility, solubility and electrical conductivity between ionic and covalent compounds

Supplement

- Describe the electron arrangement in more complex covalent molecules such as N_2, C_2H_4, CH_3OH and CO_2
- Explain the differences in melting point and boiling point of ionic and covalent compounds in terms of attractive forces

3.2.4 Macromolecules

Core

- Describe the giant covalent structures of graphite and diamond
- Relate their structures to their uses, e.g. graphite as a lubricant and a conductor, and diamond in cutting tools

Supplement

- Describe the macromolecular structure of silicon(IV) oxide (silicon dioxide)
- Describe the similarity in properties between diamond and silicon(IV) oxide, related to their structures

3.2.5 Metallic bonding

Supplement

- Describe metallic bonding as a lattice of positive ions in a 'sea of electrons' and use this to describe the electrical conductivity and malleability of metals

4 Stoichiometry

4.1 Stoichiometry

Core

- Use the symbols of the elements and write the formulae of simple compounds
- Deduce the formula of a simple compound from the relative numbers of atoms present
- Deduce the formula of a simple compound from a model or a diagrammatic representation
- Construct word equations and simple balanced chemical equations
- Define *relative atomic mass*, A_r, as the average mass of naturally occurring atoms of an element on a scale where the ^{12}C atom has a mass of exactly 12 units
- Define *relative molecular mass*, M_r, as the sum of the relative atomic masses. (*Relative formula mass* or M_r will be used for ionic compounds.)

  (Calculations involving reacting masses in simple proportions may be set. Calculations will **not** involve the mole concept.)

Supplement

- Determine the formula of an ionic compound from the charges on the ions present
- Construct equations with state symbols, including ionic equations
- Deduce the balanced equation for a chemical reaction, given relevant information

4.2 The mole concept

Supplement

- Define the *mole* and the *Avogadro constant*
- Use the molar gas volume, taken as 24 dm^3 at room temperature and pressure
- Calculate stoichiometric reacting masses, volumes of gases and solutions, and concentrations of solutions expressed in g/dm^3 and mol/dm^3. (Calculations involving the idea of limiting reactants may be set. Questions on the gas laws and the conversion of gaseous volumes to different temperatures and pressures will **not** be set.)
- Calculate empirical formulae and molecular formulae
- Calculate percentage yield and percentage purity

5 Electricity and chemistry

5.1 Electricity and chemistry

Core

- Define electrolysis as the breakdown of an ionic compound, molten or in aqueous solution, by the passage of electricity
- Describe the electrode products and the observations made during the electrolysis of:
  - molten lead(II) bromide
  - concentrated hydrochloric acid
  - concentrated aqueous sodium chloride
  - dilute sulfuric acid

  between inert electrodes (platinum or carbon)
- State the general principle that metals or hydrogen are formed at the negative electrode (cathode), and that non-metals (other than hydrogen) are formed at the positive electrode (anode)
- Predict the products of the electrolysis of a specified binary compound in the molten state
- Describe the electroplating of metals
- Outline the uses of electroplating

Supplement

- Relate the products of electrolysis to the electrolyte and electrodes used, exemplified by the specific examples in the Core together with aqueous copper(II) sulfate using carbon electrodes and using copper electrodes (as used in the refining of copper)
- Describe electrolysis in terms of the ions present and reactions at the electrodes in the examples given
- Predict the products of electrolysis of a specified halide in dilute or concentrated aqueous solution
- Construct ionic half-equations for reactions at the cathode

continued

5.1 Electricity and chemistry continued

Core

- Describe the reasons for the use of copper and (steel-cored) aluminium in cables, and why plastics and ceramics are used as insulators

Supplement

- Describe the transfer of charge during electrolysis to include:
  - the movement of electrons in the metallic conductor
  - the removal or addition of electrons from the external circuit at the electrodes
  - the movement of ions in the electrolyte
- Describe the production of electrical energy from simple cells, i.e. two electrodes in an electrolyte. (This should be linked with the reactivity series in section 10.2 and redox in section 7.4.)
- Describe, in outline, the manufacture of:
  - aluminium from pure aluminium oxide in molten cryolite (refer to section 10.3)
  - chlorine, hydrogen and sodium hydroxide from concentrated aqueous sodium chloride

  (Starting materials and essential conditions should be given but not technical details or diagrams.)

6 Chemical energetics

6.1 Energetics of a reaction

Core

- Describe the meaning of *exothermic* and *endothermic* reactions
- Interpret energy level diagrams showing exothermic and endothermic reactions

Supplement

- Describe bond breaking as an endothermic process and bond forming as an exothermic process
- Draw and label energy level diagrams for exothermic and endothermic reactions using data provided
- Calculate the energy of a reaction using bond energies

6.2 Energy transfer

Core

- Describe the release of heat energy by burning fuels
- State the use of hydrogen as a fuel
- Describe radioactive isotopes, such as ^{235}U, as a source of energy

Supplement

- Describe the use of hydrogen as a fuel reacting with oxygen to generate electricity in a fuel cell. (Details of the construction and operation of a fuel cell are **not** required.)

7 Chemical reactions

7.1 Physical and chemical changes

Core

- Identify physical and chemical changes, and understand the differences between them

7.2 Rate (speed) of reaction

Core

- Describe and explain the effect of concentration, particle size, catalysts (including enzymes) and temperature on the rate of reactions
- Describe the application of the above factors to the danger of explosive combustion with fine powders (e.g. flour mills) and gases (e.g. methane in mines)
- Demonstrate knowledge and understanding of a practical method for investigating the rate of a reaction involving gas evolution
- Interpret data obtained from experiments concerned with rate of reaction

Note: Candidates should be encouraged to use the term *rate* rather than *speed*.

Supplement

- Devise and evaluate a suitable method for investigating the effect of a given variable on the rate of a reaction
- Describe and explain the effects of temperature and concentration in terms of collisions between reacting particles. (An increase in temperature causes an increase in collision rate **and** more of the colliding molecules have sufficient energy (activation energy) to react whereas an increase in concentration only causes an increase in collision rate.)
- Describe and explain the role of light in photochemical reactions and the effect of light on the rate of these reactions. (This should be linked to section 14.4.)
- Describe the use of silver salts in photography as a process of reduction of silver ions to silver; and photosynthesis as the reaction between carbon dioxide and water in the presence of chlorophyll and sunlight (energy) to produce glucose and oxygen

7.3 Reversible reactions

Core

- Understand that some chemical reactions can be reversed by changing the reaction conditions. (Limited to the effects of heat and water on hydrated and anhydrous copper(II) sulfate and cobalt(II) chloride.) (Concept of equilibrium is **not** required.)

Supplement

- Predict the effect of changing the conditions (concentration, temperature and pressure) on other reversible reactions
- Demonstrate knowledge and understanding of the concept of equilibrium

7.4 Redox

Core

- Define *oxidation* and *reduction* in terms of oxygen loss/gain. (Oxidation state limited to its use to name ions, e.g. iron(II), iron(III), copper(II), manganate(VII).)

Supplement

- Define *redox* in terms of electron transfer
- Identify redox reactions by changes in oxidation state and by the colour changes involved when using acidified potassium manganate(VII), and potassium iodide. (Recall of equations involving $KMnO_4$ is **not** required.)
- Define *oxidising agent* as a substance which oxidises another substance during a redox reaction. Define *reducing agent* as a substance which reduces another substance during a redox reaction.
- Identify oxidising agents and reducing agents from simple equations

8 Acids, bases and salts

8.1 The characteristic properties of acids and bases

Core

- Describe the characteristic properties of acids as reactions with metals, bases, carbonates and effect on litmus and methyl orange
- Describe the characteristic properties of bases as reactions with acids and with ammonium salts and effect on litmus and methyl orange
- Describe neutrality and relative acidity and alkalinity in terms of pH measured using Universal Indicator paper (whole numbers only)
- Describe and explain the importance of controlling acidity in soil

Supplement

- Define *acids* and *bases* in terms of proton transfer, limited to aqueous solutions
- Describe the meaning of weak and strong acids and bases

8.2 Types of oxides

Core

- Classify oxides as either acidic or basic, related to metallic and non-metallic character

Supplement

- Further classify other oxides as neutral or amphoteric

8.3 Preparation of salts

Core

- Demonstrate knowledge and understanding of preparation, separation and purification of salts as examples of some of the techniques specified in section 2.2.2 and the reactions specified in section 8.1

Supplement

- Demonstrate knowledge and understanding of the preparation of insoluble salts by precipitation
- Suggest a method of making a given salt from a suitable starting material, given appropriate information

8.4 Identification of ions and gases

Core

- Describe the following tests to identify:

  aqueous cations:

  aluminium, ammonium, calcium, chromium(III), copper(II), iron(II), iron(III) and zinc (using aqueous sodium hydroxide and aqueous ammonia as appropriate). (Formulae of complex ions are **not** required.)

  cations:

  use of the flame test to identify lithium, sodium, potassium and copper(II)

  anions:

  carbonate (by reaction with dilute acid and then limewater), chloride, bromide and iodide (by reaction under acidic conditions with aqueous silver nitrate), nitrate (by reduction with aluminium), sulfate (by reaction under acidic conditions with aqueous barium ions) and sulfite (by reaction with dilute acids and then aqueous potassium manganate(VII))

  gases:

  ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using lighted splint), oxygen (using a glowing splint), and sulfur dioxide (using aqueous potassium manganate(VII))

9 The Periodic Table

9.1 The Periodic Table

Core

- Describe the Periodic Table as a method of classifying elements and its use to predict properties of elements

9.2 Periodic trends

Core

- Describe the change from metallic to non-metallic character across a period

Supplement

- Describe and explain the relationship between Group number, number of outer shell electrons and metallic/non-metallic character

9.3 Group properties

Core

- Describe lithium, sodium and potassium in Group I as a collection of relatively soft metals showing a trend in melting point, density and reaction with water
- Predict the properties of other elements in Group I, given data, where appropriate
- Describe the halogens, chlorine, bromine and iodine in Group VII, as a collection of diatomic non-metals showing a trend in colour and density and state their reaction with other halide ions
- Predict the properties of other elements in Group VII, given data where appropriate

Supplement

- Identify trends in Groups, given information about the elements concerned

9.4 Transition elements

Core

- Describe the transition elements as a collection of metals having high densities, high melting points and forming coloured compounds, and which, as elements and compounds, often act as catalysts

Supplement

- Know that transition elements have variable oxidation states

9.5 Noble gases

Core

- Describe the noble gases, in Group VIII or 0, as being unreactive, monoatomic gases and explain this in terms of electronic structure
- State the uses of the noble gases in providing an inert atmosphere, i.e. argon in lamps, helium for filling balloons

10 Metals

10.1 Properties of metals

Core

- List the general physical properties of metals
- Describe the general chemical properties of metals, e.g. reaction with dilute acids and reaction with oxygen
- Explain in terms of their properties why alloys are used instead of pure metals
- Identify representations of alloys from diagrams of structure

10.2 Reactivity series

Core

- Place in order of reactivity: potassium, sodium, calcium, magnesium, zinc, iron, (hydrogen) and copper, by reference to the reactions, if any, of the metals with:
  - water or steam
  - dilute hydrochloric acid

  and the reduction of their oxides with carbon
- Deduce an order of reactivity from a given set of experimental results

Supplement

- Describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction, if any, with:
  - the aqueous ions
  - the oxides

  of the other listed metals
- Describe and explain the action of heat on the hydroxides, carbonates and nitrates of the listed metals
- Account for the apparent unreactivity of aluminium in terms of the oxide layer which adheres to the metal

10.3 Extraction of metals

Core	Supplement
• Describe the ease in obtaining metals from their ores by relating the elements to the reactivity series	• Describe in outline, the extraction of zinc from zinc blende
• Describe and state the essential reactions in the extraction of iron from hematite	
• Describe the conversion of iron into steel using basic oxides and oxygen	
• Know that aluminium is extracted from the ore bauxite by electrolysis	
• Discuss the advantages and disadvantages of recycling metals, limited to iron/steel and aluminium	• Describe in outline, the extraction of aluminium from bauxite including the role of cryolite and the reactions at the electrodes

10.4 Uses of metals

Core	Supplement
• Name the uses of aluminium: – in the manufacture of aircraft because of its strength and low density – in food containers because of its resistance to corrosion	• Explain the uses of zinc for galvanising and for making brass
• Name the uses of copper related to its properties (electrical wiring and in cooking utensils)	
• Name the uses of mild steel (car bodies and machinery) and stainless steel (chemical plant and cutlery)	• Describe the idea of changing the properties of iron by the controlled use of additives to form steel alloys

11 Air and water

11.1 Water

Core	Supplement
• Describe chemical tests for water using cobalt(II) chloride and copper(II) sulfate	• Discuss the implications of an inadequate supply of water, limited to safe water for drinking and water for irrigating crops
• Describe, in outline, the treatment of the water supply in terms of filtration and chlorination	
• Name some of the uses of water in industry and in the home	

11.2 Air

Core	Supplement
• State the composition of clean, dry air as being approximately 78% nitrogen, 21% oxygen and the remainder as being a mixture of noble gases and carbon dioxide	• Describe the separation of oxygen and nitrogen from liquid air by fractional distillation
• Name the common pollutants in the air as being carbon monoxide, sulfur dioxide, oxides of nitrogen and lead compounds	
• State the source of each of these pollutants: – carbon monoxide from the incomplete combustion of carbon-containing substances – sulfur dioxide from the combustion of fossil fuels which contain sulfur compounds (leading to 'acid rain') – oxides of nitrogen from car engines – lead compounds from leaded petrol	• Describe and explain the presence of oxides of nitrogen in car engines and their catalytic removal
• State the adverse effect of these common pollutants on buildings and on health and discuss why these pollutants are of global concern	
• State the conditions required for the rusting of iron	
• Describe and explain methods of rust prevention, specifically paint and other coatings to exclude oxygen	• Describe and explain sacrificial protection in terms of the reactivity series of metals and galvanising as a method of rust prevention

11.3 Nitrogen and fertilisers

Core	Supplement
• Describe the need for nitrogen-, phosphorus- and potassium-containing fertilisers	• Describe and explain the essential conditions for the manufacture of ammonia by the Haber process including the sources of the hydrogen and nitrogen, i.e. hydrocarbons or steam and air
• Describe the displacement of ammonia from its salts	

11.4 Carbon dioxide and methane

Core

- State that carbon dioxide and methane are greenhouse gases and explain how they may contribute to climate change
- State the formation of carbon dioxide:
  - as a product of complete combustion of carbon-containing substances
  - as a product of respiration
  - as a product of the reaction between an acid and a carbonate
  - from the thermal decomposition of a carbonate
- State the sources of methane, including decomposition of vegetation and waste gases from digestion in animals

Supplement

- Describe the carbon cycle, in simple terms, to include the processes of combustion, respiration and photosynthesis

12 Sulfur

12.1 Sulfur

Core

- Name some sources of sulfur
- Name the use of sulfur in the manufacture of sulfuric acid
- State the uses of sulfur dioxide as a bleach in the manufacture of wood pulp for paper and as a food preservative (by killing bacteria)

Supplement

- Describe the manufacture of sulfuric acid by the Contact process, including essential conditions and reactions
- Describe the properties and uses of dilute and concentrated sulfuric acid

13 Carbonates

13.1 Carbonates

Core

- Describe the manufacture of lime (calcium oxide) from calcium carbonate (limestone) in terms of thermal decomposition
- Name some uses of lime and slaked lime such as in treating acidic soil and neutralising acidic industrial waste products, e.g. flue gas desulfurisation
- Name the uses of calcium carbonate in the manufacture of iron and cement

14 Organic chemistry

14.1 Names of compounds

Core

- Name and draw the structures of methane, ethane, ethene, ethanol, ethanoic acid and the products of the reactions stated in sections 14.4–14.6
- State the type of compound present, given a chemical name ending in *-ane*, *-ene*, *-ol*, or *-oic acid* or a molecular structure

Supplement

- Name and draw the structures of the unbranched alkanes, alkenes (not *cis-trans*), alcohols and acids containing up to four carbon atoms per molecule
- Name and draw the structural formulae of the esters which can be made from unbranched alcohols and carboxylic acids, each containing up to four carbon atoms

14.2 Fuels

Core

- Name the fuels: coal, natural gas and petroleum
- Name methane as the main constituent of natural gas
- Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation
- Describe the properties of molecules within a fraction
- Name the uses of the fractions as:
  - refinery gas for bottled gas for heating and cooking
  - gasoline fraction for fuel (petrol) in cars
  - naphtha fraction for making chemicals
  - kerosene/paraffin fraction for jet fuel
  - diesel oil/gas oil for fuel in diesel engines
  - fuel oil fraction for fuel for ships and home heating systems
  - lubricating fraction for lubricants, waxes and polishes
  - bitumen for making roads

14.3 Homologous series

Core

- Describe the concept of homologous series as a 'family' of similar compounds with similar chemical properties due to the presence of the same functional group

Supplement

- Describe the general characteristics of a homologous series
- Recall that the compounds in a homologous series have the same general formula
- Describe and identify structural isomerism

14.4 Alkanes

Core

- Describe the properties of alkanes (exemplified by methane) as being generally unreactive, except in terms of burning
- Describe the bonding in alkanes

Supplement

- Describe substitution reactions of alkanes with chlorine

14.5 Alkenes

Core

- Describe the manufacture of alkenes and of hydrogen by cracking
- Distinguish between saturated and unsaturated hydrocarbons:
  - from molecular structures
  - by reaction with aqueous bromine
- Describe the formation of poly(ethene) as an example of addition polymerisation of monomer units

Supplement

- Describe the properties of alkenes in terms of addition reactions with bromine, hydrogen and steam

14.6 Alcohols

Core

- Describe the manufacture of ethanol by fermentation and by the catalytic addition of steam to ethene
- Describe the properties of ethanol in terms of burning
- Name the uses of ethanol as a solvent and as a fuel

Supplement

- Outline the advantages and disadvantages of these two methods of manufacturing ethanol

14.7 Carboxylic acids

Core

- Describe the properties of aqueous ethanoic acid

Supplement

- Describe the formation of ethanoic acid by the oxidation of ethanol by fermentation and with acidified potassium manganate(VII)
- Describe ethanoic acid as a typical weak acid
- Describe the reaction of a carboxylic acid with an alcohol in the presence of a catalyst to give an ester

14.8 Polymers

14.8.1 Polymers

Core

- Define polymers as large molecules built up from small units (monomers)

Supplement

- Understand that different polymers have different units and/or different linkages

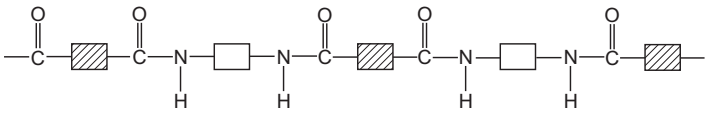
14.8.2 Synthetic polymers

Core

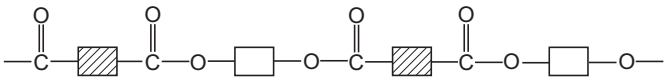
- Name some typical uses of plastics and of man-made fibres such as nylon and *Terylene*
- Describe the pollution problems caused by non-biodegradable plastics

Supplement

- Explain the differences between condensation and addition polymerisation
- Deduce the structure of the polymer product from a given alkene and *vice versa*
- Describe the formation of nylon (a polyamide) and *Terylene* (a polyester) by condensation polymerisation, the structure of nylon being represented as:



and the structure of *Terylene* as:



(Details of manufacture and mechanisms of these polymerisations are **not** required.)

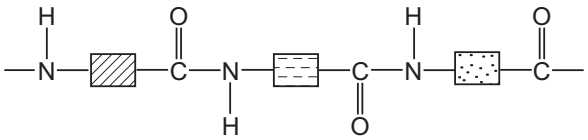
14.8.3 Natural polymers

Core

- Name proteins and carbohydrates as constituents of food

Supplement

- Describe proteins as possessing the same (amide) linkages as nylon but with different units
- Describe the structure of proteins as:



- Describe the hydrolysis of proteins to amino acids. (Structures and names are **not** required.)
- Describe complex carbohydrates in terms of a large number of sugar units, considered as HO—□—OH, joined together by condensation polymerisation, e.g.

- Describe the hydrolysis of complex carbohydrates (e.g. starch), by acids or enzymes to give simple sugars
- Describe the fermentation of simple sugars to produce ethanol (and carbon dioxide). (Candidates will **not** be expected to give the molecular formulae of sugars.)
- Describe, in outline, the usefulness of chromatography in separating and identifying the products of hydrolysis of carbohydrates and proteins