Detailed unit content

In this specification bold text refers to higher tier only content. Italic text refers to practical investigations, which students are required to demonstrate an understanding of.

Throughout the unit

0.1 Recall the formulae of elements and simple compounds in the unit

0.2 Represent chemical reactions by word equations **and simple balanced equations**

0.3 **Write balanced chemical equations including the use of state symbols (s), (l), (g) and (aq) for a wide range of reactions in this unit**

0.4 Assess practical work for risks and suggest suitable precautions for a range of practical scenarios for reactions in this unit

0.5 Demonstrate an understanding that hazard symbols used on containers:

a indicate the dangers associated with the contents

b inform people about safe working procedures with these substances in the laboratory

Topic 1

The Earth's sea and atmosphere

1.1 Recall that the gases produced by volcanic activity formed the Earth's early atmosphere

1.2 Recall that the early atmosphere contained:

a little or no oxygen

b a large amount of carbon dioxide

c water vapour and small amounts of other gases

1.3 Explain why there are different sources of information about the development of the atmosphere which makes it difficult to be precise about the evolution of the atmosphere

1.4 Describe how condensation of water vapour formed oceans

1.5 Describe how the amount of carbon dioxide in the atmosphere was reduced by:

a the dissolution of carbon dioxide into the oceans

b the later incorporation of this dissolved carbon dioxide into marine organisms which eventually formed carbonate rocks

1.6 Explain how the growth of primitive plants used carbon dioxide and released oxygen by photosynthesis and consequently the amount of oxygen in the atmosphere gradually increased

1.7 *Investigate the proportion of oxygen in the atmosphere*

1.8 Describe the current composition of the atmosphere and interpret data sources showing this information

1.9 Demonstrate an understanding of how small changes in the atmosphere occur through:
- a volcanic activity
- b human activity, including the burning of fossil fuels, farming and deforestation

Topic 2

Materials from the Earth

2.1 Describe that igneous rocks, such as granite, are:
- a formed by the solidification of magma or lava
- b made of crystals whose size depends on the rate of cooling

2.2 Describe chalk and limestone as examples of sedimentary rocks

2.3 Describe how sedimentary rocks are formed by the compaction of layers of sediment over a very long time period

2.4 Recall that sedimentary rocks:
- a may contain fossils
- b are susceptible to erosion

2.5 Describe marble as an example of a metamorphic rock

2.6 Describe the formation of metamorphic rocks by the action of heat and/or pressure, including the formation of marble from chalk or limestone

2.7 Recall that limestone, chalk and marble exist in the Earth's crust and that they are all natural forms of calcium carbonate

2.8 Demonstrate an understanding of the balance between the demand for limestone and the economic, environmental and social effects of quarrying it

2.9 Demonstrate an understanding of the commercial need for quarrying calcium carbonate on a large scale, as a raw material, for the formation of glass, cement and concrete

2.10 Describe the thermal decomposition of calcium carbonate into calcium oxide and carbon dioxide

2.11 *Investigate the ease of thermal decomposition of carbonates, including calcium carbonate, zinc carbonate and copper carbonate*

2.12 Describe the ease of thermal decomposition of different metal carbonates

2.13 Demonstrate an understanding that:
- a atoms are the smallest particles of an element that can take part in chemical reactions
- b during chemical reactions, atoms are neither created nor destroyed
- c during chemical reactions, atoms are rearranged to make new products with different properties from the reactants

2.14 Describe the effect of water on calcium oxide

2.15 Describe how calcium hydroxide dissolves in water to form a solution, known as limewater

2.16 Demonstrate an understanding that the total mass before and after a reaction in a sealed container is unchanged, as shown practically by a precipitation reaction

2.17 Explain how calcium oxide, calcium hydroxide and calcium carbonate can be used to neutralise soil acidity

2.18 Explain how calcium carbonate can be used to remove acidic gases from coal-fired power station chimneys, reducing harmful emissions and helping to reduce acid rain

Topic 3

Acids

3.1 Recall that hydrochloric acid is produced in the stomach to:

a help digestion

b kill bacteria

3.2 Describe indigestion remedies as containing substances that neutralise excess stomach acid

3.3 *Investigate the effectiveness of different indigestion remedies*

3.4 Recall that acids are neutralised by:

a metal oxides

b metal hydroxides

c metal carbonates

to produce salts (no details of salt preparation techniques or ions are required)

3.5 Recall that:

a hydrochloric acid produces chloride salts

b nitric acid produces nitrate salts

c sulfuric acid produces sulfate salts

3.6 Describe electrolysis as a process in which electrical energy, from a d.c. supply, decomposes compounds, by considering the electrolysis of dilute hydrochloric acid to produce hydrogen and chlorine (explanations of the reactions at the electrodes are not required)

3.7 *Investigate the electrolysis of dilute hydrochloric acid*

3.8 Describe the chemical test for hydrogen

3.9 Describe the chemical test for chlorine

3.10 Recall that chlorine can be obtained from sea water by electrolysis (explanations of the reactions at the electrodes are not required)

3.11 Describe chlorine as a toxic gas and that this leads to potential hazards associated with its large-scale manufacture

3.12 Describe the use of chlorine in the manufacture of bleach and of the polymer poly(chloroethene) (PVC)

3.13 Recall that water can be decomposed by electrolysis to form hydrogen and oxygen

3.14 Describe the chemical test for oxygen

Topic 4

Obtaining and using metals

4.1 Recall that:

a most metals are extracted from ores found in the Earth's crust

b unreactive metals are found in the Earth as the uncombined elements

4.2 Describe how most metals are extracted from their ores by:

a heating with carbon, illustrated by iron

b electrolysis, illustrated by aluminium

(knowledge of the blast furnace or the electrolytic cell for aluminium extraction are not required)

4.3 Explain why the method used to extract a metal is related to its position in the reactivity series and cost of the extraction process

4.4 *Investigate methods for extracting a metal from its ore*

4.5 Describe oxidation as the gain of oxygen and reduction as the loss of oxygen

4.6 Recall that the extraction of metals involves reduction of ores

4.7 Recall that the oxidation of metals results in corrosion

4.8 Demonstrate an understanding that a metal's resistance to oxidation is related to its position in the reactivity series

4.9 Discuss the advantages of recycling metals, including economic implications, and how recycling preserves both the environment and the supply of valuable raw materials

4.10 Describe the uses of metals in relation to their properties, including:

a aluminium

b copper

c gold

d steel

4.11 Use models to explain why converting pure metals into alloys often increases the strength of the product

4.12 Demonstrate an understanding that iron is alloyed with other metals to produce alloy steels with a higher strength and a greater resistance to corrosion

4.13 **Describe how alloying changes the properties of metals, including:**

a **smart or shape memory alloys, including nitinol, an alloy of nickel and titanium**

b **gold alloys with higher strength, including fineness (parts per thousand) and carats to indicate the proportion of pure gold**

4.14 **Demonstrate an understanding that new materials are developed by chemists to fit new applications, such as the creation of new shape memory alloys for use, for example, in spectacle frames and as stents in damaged blood vessels**

Topic 5

Fuels

5.1 Describe hydrocarbons as compounds that contain carbon and hydrogen only

5.2 Describe crude oil as a complex mixture of hydrocarbons

5.3 Describe the separation of crude oil into simpler, more useful mixtures by the process of fractional distillation (details of fractional distillation are not required)

5.4 Recall the name and uses of the following fractions:

a gases, used in domestic heating and cooking

b petrol, used as fuel for cars

c kerosene, used as fuel for aircraft

d diesel oil, used as fuel for some cars and trains

e fuel oil, used as fuel for large ships and in some power stations

f bitumen, used to surface roads and roofs

5.5 Describe that hydrocarbons in different fractions differ from each other in:

a the number of carbon and hydrogen atoms their molecules contain

b boiling points

c ease of ignition

d viscosity

5.6 Describe how the complete combustion of hydrocarbons:

a involves the oxidation of the hydrocarbons

b produces carbon dioxide and water

c gives out energy

5.7 Describe the chemical test for carbon dioxide (using limewater)

5.8 Explain why the incomplete combustion of hydrocarbons can produce carbon and carbon monoxide

5.9 Describe how carbon monoxide behaves as a toxic gas

5.10 Demonstrate an understanding of the problems caused by incomplete combustion producing carbon monoxide and soot in appliances that use carbon compounds as fuels

5.11 Explain why impurities in some hydrocarbon fuels result in the production of sulfur dioxide

5.12 Demonstrate an understanding of some problems associated with acid rain caused when sulfur dioxide dissolves in rain water

5.13 Describe how various gases in the atmosphere, including carbon dioxide, methane and water vapour, trap heat from the Sun and that this keeps the Earth warm

5.14 Demonstrate an understanding that the Earth's temperature varies and that human activity may influence this

5.15 Demonstrate an understanding that the proportion of carbon dioxide in the atmosphere varies, due to human activity, and that chemists are investigating methods to control the amount of the gas in the atmosphere by:

a iron seeding of oceans

b converting carbon dioxide into hydrocarbons

5.16 Evaluate how far the correlation between global temperature and the proportion of carbon dioxide in the atmosphere provides evidence for climate change

5.17 Describe biofuels as being possible alternatives to fossil fuels

5.18 Recall that one example of a biofuel is ethanol obtained by processing sugar cane or sugar beet and that it can be used to reduce the demand for petrol

5.19 Evaluate the advantages and disadvantages of replacing fossil fuels with biofuels, including:

a the fact that biofuels are renewable

b that growing the crops to make biofuels requires land and may affect the availability of land for growing food

c the balance between the carbon dioxide removed from the atmosphere as these crops grow and the carbon dioxide produced when they are transported and burned

5.20 Demonstrate an understanding of the factors that make a good fuel, including:

a how easily it burns

b the amount of ash or smoke it produces

c the comparative amount of heat energy it produces (calculations involving conversion to joules are not required)

d how easy it is to store and transport

5.21 Recall that a simple fuel cell combines hydrogen and oxygen to form water and that this reaction releases energy

5.22 Evaluate the advantages and disadvantages of using hydrogen, rather than petrol, as a fuel in cars

5.23 Describe petrol, kerosene and diesel oil as non-renewable fossil fuels obtained from crude oil and methane as a non-renewable fossil fuel found in natural gas

5.24 *Compare the temperature rise produced when the same volume of water is heated by different fuels*

5.25 Recall that alkanes are saturated hydrocarbons, which are present in crude oil

5.26 Recall the formulae of the alkanes methane, ethane and propane, and draw the structures of these molecules to show how the atoms are bonded together (no further knowledge of bonding is required in this unit)

5.27 Recall that alkenes are unsaturated hydrocarbons

5.28 Recall the formulae of the alkenes ethene and propene and draw the structures of their molecules to show how the atoms are bonded together (no further knowledge of bonding is required in this unit)

5.29 Describe how bromine water is used to distinguish between alkanes and alkenes

5.30 Describe how cracking involves the breaking down of larger saturated hydrocarbon molecules (alkanes) into smaller, more useful ones, some of which are unsaturated (alkenes)

5.31 **Explain why cracking is necessary, including by using data on the composition of different crude oils and the demand for fractions in crude oil**

5.32 Describe the cracking of liquid paraffin in the laboratory

5.33 Recall that:

a many ethene molecules can combine together in a polymerisation reaction

b the polymer formed is called poly(ethene)

(conditions and mechanisms not required but **equations required**)

5.34 Describe how other polymers can be made by combining together other monomer molecules, to include poly(propene), poly(chloroethene) (PVC) and PTFE

5.35 Relate uses of the polymers poly(ethene), poly(propene), poly(chloroethene) (PVC) and PTFE to the properties of the compounds

5.36 Recall that most polymers are not biodegradable, persist in landfill sites and that many produce toxic products when burnt

5.37 Explain how some problems associated with the disposal of polymers can be overcome:

a by recycling

b by developing biodegradable polymers

Unit C2: Discovering chemistry

Overview

Content and How Science Works overview

Everything in the world, including us, is made of atoms. There are just over 100 different elements and most of these elements exist as more than one type of atom. These atoms can combine together to form a huge number of different compounds. An understanding of how the atoms are bonded together helps us to explain the properties of these compounds and to predict how new compounds may behave.

The purpose of this unit is to give students a more extensive understanding of chemistry by introducing them to some important basic ideas. In particular, they will appreciate how chemistry has progressed through a series of discoveries and advances in understanding.

Practical work in this unit will give students opportunities to plan practical ways to answer scientific questions; devise appropriate methods for the collection of numerical and other data; assess and manage risks when carrying out practical work; collect, process, analyse and interpret primary and secondary data; draw evidence-based conclusions; and to evaluate methods of data collection and the quality of the resulting data.

Work on the structure of atoms, the periodic table and the formation of ionic, covalent and metallic bonds provides opportunities to use models to explain ideas and processes, and to communicate scientific information using scientific conventions and symbols, including diagrams of electronic configurations and balanced chemical equations.

Students will have the opportunity to work quantitatively when studying relative formula masses, percentage compositions and percentage yields.

Work on the periodic table, flame tests and the discovery of noble gases provides opportunities to look at how scientific ideas have changed over time and some ways in which chemists can make new discoveries. Students can also consider how new scientific ideas are validated.

Students have the opportunity to consider the advantages, disadvantages and risks of the applications of some of the substances studied, including the use of barium sulfate in 'barium meals', the use of chromatography by food chemists and forensic scientists, and the uses of noble gases. They will look at the reasons why reactions do not always give the theoretical yield, and how the chemical industry can contribute to sustainability by improving yields and utilising waste products.

In Topic 1 students will gain a thorough knowledge and understanding of the structure of atoms, which will enable them to understand the arrangement of elements in the periodic table and the terms atomic number, mass number and relative atomic mass.

An understanding of the formation and nature of ionic bonds, gained in Topic 2, will enable students to understand the properties of these compounds and their usefulness in making salts. Students will begin to appreciate that, in solutions, the ions present behave independently. This will enable students to grasp the basis of simple qualitative analysis, carry out some reactions and consider some applications.

An understanding of the formation and nature of covalent bonds, gained in Topic 3, will enable students to understand the properties of these compounds and see the distinction between covalent compounds consisting of simple molecules and those consisting of giant molecules. Students will also look at some important separation techniques, such as fractional distillation and paper chromatography.

In Topic 4 students study three groups of the periodic table: a group of metals (group 1), a group of non-metals (group 7) and the noble gases (group 0). They will gain an elementary knowledge of the structure of metals which, together with the knowledge gained in Topics 2 and 3, will enable them to differentiate four types of substances by their bonding and properties and therefore to make predictions about substances not familiar to them.

Topic 5 gives students an understanding of two general aspects of chemical reactions: the heat energy changes that accompany reactions and the rates of reactions. They can understand how industrial chemists try to make products quickly and efficiently by controlling reaction conditions.

In Topic 6 students learn how to determine empirical formulae through practical experiments and how to use formulae and equations to determine the amounts of substances involved in reactions. Finally, students should understand why practical yields are always lower than calculated yields.

Assessment overview

This unit is externally assessed, through a one hour, 60 mark tiered written examination, containing six questions.

The examination will contain a mixture of questions styles, including objective questions, short answer questions and extended writing questions.

Practical investigations in this unit

Within this unit, students will develop an understanding of the process of scientific investigations, including that investigations:

- use hypotheses which are tested
- require assessment and management of risks
- require the collection, presentation, analysis and interpretation of primary and secondary evidence including the use of appropriate technology
- should include a review of methodology to assess fitness for purpose
- should include a review of hypotheses in the light of outcomes.

The following specification points are practicals which exemplify the scientific process and may appear in the written examination for this unit:

1.7 *Investigate the proportion of oxygen in the atmosphere*

2.12 *Prepare an insoluble salt by precipitation*

3.4 *Classify different types of elements and compounds by investigating their melting points and boiling points, solubility in water and electrical conductivity (as solids and in solution) including sodium chloride, magnesium sulphate, hexane, liquid paraffin, silicon(IV) oxide, copper sulphate, and sucrose (sugar)*

4.12 *Investigate displacement reactions of halogens reacting with halide ions in solution*

5.1 *Measure temperature changes accompanying some of the following types of change:*

- a *salts dissolving in water*
- b *neutralisation reactions*
- c *displacement reactions*
- d *precipitation reactions*

5.7 *Investigate the effect of temperature, concentration and surface area of a solid on the rate of a reaction such as hydrochloric acid and marble chips*

6.3 *Determine the empirical formula of a simple compound, such as magnesium oxide*

The following are further suggestions for practical work within this unit:

- *Investigate the properties of a group of elements eg Group 2*
- *Investigate the properties of typical ionic compounds*
- *Test predictions of whether a precipitate forms when soluble salts are combined*
- *Carry out a series of ion tests to identify unknown compounds*
- *Build models of simple covalent molecules*
- *Investigate the typical properties of simple and giant covalent compounds*
- *Use paper chromatography to separate inks, food dyes etc*
- *Investigate the properties of metals*
- *Carry out an activity to show that transition metal salts have a variety of colours*
- *Investigate heat energy changes in neutralisation and/or displacement reactions*
- *Investigate the rate of reactions, such as magnesium and hydrochloric acid; or sodium thiosulfate and hydrochloric acid*

- *Investigate the effect of potential catalysts on the rate of decomposition of hydrogen peroxide*
- *Determine the formula of copper oxide by reduction of the oxide to copper*
- *Determine the formula of a hydrated salt such as barium chloride or copper sulfate by heating to drive off water of crystallisation*
- *Prepare a substance and calculate the % yield, given the theoretical yield*

The Controlled Assessment Task (CAT) for the GCSE in Chemistry will be taken from any of these practicals (specification points and further suggested practicals). This task will change every year, so future CATs will be chosen from this list.

Detailed unit content

In this specification bold text refers to higher tier only content. Italic text refers to practical investigations, which students are required to demonstrate an understanding of.

Throughout the unit

0.1 Recall the formulae of elements and simple compounds in the unit

0.2 Represent chemical reactions by word equations and simple balanced equations

0.3 Write balanced chemical equations including the use of state symbols (s), (l), (g) and (aq) for a wide range of reactions in this unit

0.4 Assess practical work for risks and suggest suitable precautions for a range of practical scenarios for reactions in this unit

0.5 Demonstrate an understanding that hazard symbols used on containers:

a indicate the dangers associated with the contents

b inform people about safe-working procedures with these substances in the laboratory

Topic 1

Atomic structure and the periodic table

1.1 Explain how Mendeleev:

a arranged the elements, known at that time, in a periodic table by using properties of these elements and their compounds

b used his table to predict the existence and properties of some elements not then discovered

1.2 Classify elements as metals or non-metals according to their position in the periodic table

1.3 Describe the structure of an atom as a nucleus containing protons and neutrons, surrounded by electrons in shells (energy levels)

1.4 Demonstrate an understanding that the nucleus of an atom is very small compared to the overall size of the atom

1.5 Describe atoms of a given element as having the same number of protons in the nucleus and that this number is unique to that element

1.6 Recall the relative charge and relative mass of:

a a proton

b a neutron

c an electron

1.7 Demonstrate an understanding that atoms contain equal numbers of protons and electrons

1.8 Explain the meaning of the terms
- a atomic number
- b mass number
- c relative atomic mass

1.9 Describe the arrangement of elements in the periodic table such that:
- a elements are arranged in order of increasing atomic number, in rows called periods
- b elements with similar properties are placed in the same vertical column, called groups

1.10 **Demonstrate an understanding that the existence of isotopes results in some relative atomic masses not being whole numbers**

1.11 **Calculate the relative atomic mass of an element from the relative masses and abundances of its isotopes**

1.12 Apply rules about the filling of electron shells (energy levels) to predict the electronic configurations of the first 20 elements in the periodic table as diagrams and in the form 2.8.1

1.13 Describe the connection between the number of outer electrons and the position of an element in the periodic table

Topic 2

Ionic compounds and analysis

2.1 Demonstrate an understanding that atoms of different elements can combine to form compounds by the formation of new chemical bonds

2.2 Describe how ionic bonds are formed by the transfer of electrons to produce cations and anions

2.3 Describe an ion as an atom or group of atoms with a positive or negative charge

2.4 Describe the formation of sodium ions, Na^+, and chloride ions, Cl^-, and hence the formation of ions in other ionic compounds from their atoms, limited to compounds of elements in groups 1, 2, 6 and 7

2.5 Demonstrate an understanding of the use of the endings –ide and –ate in the names of compounds

2.6 Deduce the formulae of ionic compounds (including oxides, hydroxides, halides, nitrates, carbonates and sulfates) given the formulae of the constituent ions

2.7 **Describe the structure of ionic compounds as a lattice structure:**
- a **consisting of a regular arrangement of ions**
- b **held together by strong electrostatic forces (ionic bonds) between oppositely-charged ions**

2.8 Describe **and explain** the properties of ionic substances including sodium chloride and magnesium oxide, limited to:

a melting points and boiling points

b whether they conduct electricity as solids, when molten and in aqueous solution

2.9 Recall the general rules which describe the solubility of common types of substances in water:

a all common sodium, potassium and ammonium salts are soluble

b all nitrates are soluble

c common chlorides are soluble except those of silver and lead

d common sulfates are soluble except those of lead, barium and calcium

e common carbonates and hydroxides are insoluble except those of sodium, potassium and ammonium

2.10 Demonstrate an understanding that insoluble salts can be formed as precipitates by the reaction of suitable reagents in solution

2.11 Demonstrate an understanding of the method needed to prepare a pure, dry sample of an insoluble salt

2.12 *Prepare an insoluble salt by precipitation*

2.13 Use solubility rules to predict whether a precipitate is formed when named solutions are mixed together and to name the precipitate

2.14 Recall that the insoluble salt, barium sulfate, is given as a 'barium meal' to X-ray patients because

a it is opaque to X-rays

b it is safe to use as, although barium salts are toxic, its insolubility prevents it entering the blood

2.15 Describe tests to show the following ions are present in solids or solutions:

a Na^+, K^+, Ca^{2+}, Cu^{2+} using flame tests

b CO_3^{2-} using dilute acid and identifying the carbon dioxide evolved

c SO_4^{2-} using dilute hydrochloric acid and barium chloride solution

d Cl^- using dilute nitric acid and silver nitrate solution

2.16 Recall that chemists use spectroscopy (a type of flame test) to detect the presence of very small amounts of elements and that this led to the discovery of new elements, including rubidium and caesium

Topic 3

Covalent compounds and separation techniques

3.1 Describe a covalent bond as a pair of electrons shared between two atoms

3.2 Recall that covalent bonding results in the formation of molecules

3.3 Explain the formation of simple molecular, covalent substances using dot and cross diagrams, including:

- a hydrogen
- b hydrogen chloride
- c water
- d methane
- e **oxygen**
- f **carbon dioxide**

3.4 *Classify different types of elements and compounds by investigating their melting points and boiling points, solubility in water and electrical conductivity (as solids and in solution) including sodium chloride, magnesium sulphate, hexane, liquid paraffin, silicon(IV) oxide, copper sulfate, and sucrose (sugar)*

3.5 Describe the properties of typical simple molecular, covalent compounds, limited to:

- a low melting points and boiling points, in terms of weak forces between molecules
- b poor conduction of electricity

3.6 Demonstrate an understanding of the differences between the properties of simple molecular, covalent substances and those of giant molecular, covalent substances, including diamond and graphite

3.7 **Explain why, although they are both forms of carbon and giant molecular substances, graphite is used to make electrodes and as a lubricant, whereas diamond is used in cutting tools**

3.8 Describe the separation of two immiscible liquids using a separating funnel

3.9 Describe the separation of mixtures of miscible liquids by fractional distillation, by referring to the fractional distillation of liquid air to produce nitrogen and oxygen

3.10 Describe how paper chromatography can be used to separate and identify components of mixtures, including colouring agents in foodstuffs

3.11 Evaluate the information provided by paper chromatograms, including the calculation of R_f values, in a variety of contexts, such as the food industry and forensic science

Topic 4

Groups in the periodic table

4.1 Classify elements as alkali metals (group 1), halogens (group 7), noble gases (group 0) and transition metals based on their position in the periodic table

4.2 Describe the structure of metals as a regular arrangement of positive ions surrounded by a sea of delocalised electrons

4.3 Describe and explain the properties of metals, limited to malleability and the ability to conduct electricity

4.4 Recall that most metals are transition metals and that their typical properties include:

a high melting point

b the formation of coloured compounds

4.5 Demonstrate an understanding that elements and compounds can be classified as:

a ionic

b simple molecular covalent

c giant molecular covalent

d metallic

and that each type of substance has different physical properties, including relative melting point and boiling point, relative solubility in water and ability to conduct electricity (as solids and in solution)

4.6 Describe alkali metals as:

a soft metals

b metals with comparatively low melting points

4.7 Describe the reactions of lithium, sodium and potassium with water to form hydroxides which are alkaline, and hydrogen gas

4.8 Describe the pattern in reactivity of the alkali metals lithium, sodium and potassium with water, use this pattern to predict the reactivity of other alkali metals **and explain the pattern**

4.9 Recall the colours and physical states of the halogens at room temperature

4.10 Describe the reaction of halogens with metals to form metal halides

4.11 Recall that halogens react with hydrogen to produce hydrogen halides which dissolve in water to form acidic solutions

4.12 *Investigate displacement reactions of halogens reacting with halide ions in solution*

4.13 Describe the relative reactivity of the halogens as shown by their displacement reactions with halide ions in aqueous solution

4.14 Describe the noble gases as chemically inert, compared with the other elements, and demonstrate an understanding that this lack of reactivity can be explained by the electronic arrangements in their atoms

4.15 Demonstrate an understanding that the discovery of the noble gases was due to chemists:

a noticing that the density of nitrogen made in a reaction differed from that of nitrogen obtained from air

b developing a hypothesis about the composition of the air

c performing experiments to test this hypothesis and show the presence of the noble gases

4.16 Relate the uses of the noble gases to their properties, including:

a inertness (including providing an inert atmosphere for welding and in filament lamps)

b low density (including filling balloons)

c non-flammability

4.17 Use the pattern in a physical property of the noble gases, such as boiling point or density, to estimate an unknown value for another member of the group

Topic 5

Chemical reactions

5.1 *Measure temperature changes accompanying some of the following types of change:*

a *salts dissolving in water*

b *neutralisation reactions*

c *displacement reactions*

d *precipitation reactions*

5.2 Define an exothermic change or reaction as one in which heat energy is given out, including combustion reactions or explosions

5.3 Define an endothermic change or reaction as one in which heat energy is taken in, including photosynthesis or dissolving ammonium nitrate in water

5.4 Describe the breaking of bonds as endothermic and the making of bonds as exothermic

5.5 Demonstrate an understanding that the overall heat energy change for a reaction is:

a exothermic if more heat energy is released making bonds in the products than is required to break bonds in the reactants

b endothermic if less heat energy is released making bonds in the products than is required to break bonds in the reactants

5.6 **Draw and interpret simple graphical representations of energy changes occurring in chemical reactions (no knowledge of activation energy is required)**

5.7 *Investigate the effect of temperature, concentration and surface area of a solid on the rate of a reaction such as hydrochloric acid and marble chips*

5.8 Recall that the rates of chemical reactions vary from very fast, explosive reactions to very slow reactions

5.9 Describe the effect of changes in temperature, concentration and surface area of a solid on the rate of reaction

5.10 Describe how reactions can occur when particles collide **and explain how rates of reaction are increased by increasing the frequency and/or energy of collisions**

5.11 **Demonstrate an understanding that not all collisions lead to a reaction, especially if particles collide with low energy**

5.12 Recall the effect of a catalyst on the rate of reaction

5.13 Demonstrate an understanding that catalytic converters in cars:

a have a high surface area to increase the rate of reaction of carbon monoxide and unburnt fuel from exhaust gases with oxygen from the air to produce carbon dioxide and water

b work best at high temperatures

Topic 6

Quantitative chemistry

6.1 Calculate relative formula mass given relative atomic masses

6.2 Calculate the formulae of simple compounds from reacting masses and understand that these are empirical formulae

6.3 *Determine the empirical formula of a simple compound, such as magnesium oxide*

6.4 Calculate the percentage composition by mass of a compound from its formula and the relative atomic masses of its constituent elements

6.5 **Use balanced equations to calculate masses of reactants and products**

6.6 Recall that the yield of a reaction is the mass of product obtained in the reaction

6.7 Demonstrate an understanding that the actual yield of a reaction is usually less than the yield calculated using the chemical equation (theoretical yield)

6.8 Calculate the percentage yield of a reaction from the actual yield and the theoretical yield

6.9 Demonstrate an understanding of the reasons why reactions do not give the theoretical yield due to factors, including:

a incomplete reactions

b practical losses during the preparation

c competing, unwanted reactions

6.10 Demonstrate an understanding that many reactions produce waste products which:

a are not commercially useful

b can present economic, environmental and social problems for disposal

6.11 **Demonstrate an understanding that chemists in industry work to find the economically most favourable reactions where**

a **the percentage yield is high**

b **all the products of the reaction are commercially useful**

c **the reaction occurs at a suitable speed**

Unit C3: Chemistry in action

Overview

Content and How Science Works overview

One of the attractive features of chemistry is that a knowledge and understanding of the basic ideas reduces the amount of learning required and provides the satisfaction of making successful predictions because the knowledge and understanding can be applied in a wide variety of ways in the laboratory and in industry.

The purpose of this unit is to provide students with opportunities to apply what they have learnt in C1 and C2. This consolidates their knowledge and understanding before commencing an AS / A level course, or gives them the satisfaction of feeling that they have achieved something worthwhile in their GCSE chemistry course. They will realise that they can study and understand qualitative and quantitative inorganic analysis, electrolysis, equilibrium and organic chemistry, seeing the importance and relevance of what they have learned for industrial as well as for laboratory processes.

Practical work in this unit will give students opportunities to plan practical ways to answer scientific questions; devise appropriate methods for the collection of numerical and other data; assess and manage risks when carrying out practical work; collect, process, analyse and interpret primary and secondary data; draw evidence-based conclusions; and evaluate methods of data collection and the quality of the resulting data.

Work on electrolysis, reversible reactions and dynamic equilibrium, and the structures of molecules in homologous series, provides students with opportunities to use models to explain ideas and processes, and to communicate scientific information using scientific conventions and symbols.

Students will have the opportunity to work quantitatively when carrying out mole calculations and working with volumes of gases, and when writing balanced chemical equations and half equations.

Work on ion tests and the quantitative testing of water allows students to consider the role chemistry plays in providing safe drinking water. Studying the uses of sodium, the purification of copper, the use of electroplating, the manufacture of fertiliser and the production of ethanol, vinegar, esters and soap shows students the importance of the chemical industry in providing useful materials.

Students have the opportunity to consider the advantages, disadvantages and risks of the applications of some of the substances studied, including problems caused by hard water, the over-use of fertilisers, the social effects of alcoholic drinks and the uses of esters. They will consider the economic factors involved in choosing reaction conditions for the Haber process and in choosing the method used to produce ethanol. They will also consider issues of sustainability, such as the need to recycle some materials.

In Topic 1, building on their work in C2, candidates will extend their knowledge of tests for ions to enable them to identify unknown salts and will see how qualitative analysis has relevance to chemists working in fields such as forensic science.

In Topic 2 students will learn that amounts of substances are expressed in moles and, having carried out titrations, will do calculations to determine concentrations of dissolved substances. They will also learn how to prepare soluble salts and understand that using an excess of a reactant is practically convenient but that simple titration has to be used when the reactant is soluble. They will also see how the presence of some dissolved salts can cause water to be hard and to appreciate the problems this raises.

Having learnt that electrolysis results in the decomposition of aqueous solutions of salts, students can use their knowledge of ions in Topic 3 to understand and make predictions about such processes and to write half equations for the reactions occurring at the electrodes. Purification of copper and electroplating demonstrate the relevance, in industry, of what they have learnt.

In Topic 4 the introduction of molar volume and of Avogadro's law enables students to do quantitative work related to volumes of gases. They are then able to consider dynamic equilibria and how changing conditions affects equilibrium yield and rate of attainment of equilibrium. This will lead them to focus on the Haber process and the manufacture of fertilisers.

In Topic 5 students will widen their knowledge of organic chemistry and begin to understand the beauty of organic chemistry, where a little knowledge can go a long way. They will study ethanol, ethanoic acid and ethyl ethanoate leading, through the concept of homologous series, to the series of alcohols, carboxylic acids and esters. An appreciation that oils and fats are esters leads to the production of soaps.

Assessment overview

This unit is externally assessed, through a one hour, 60 mark tiered written examination, containing six questions.

The examination will contain a mixture of questions styles, including objective questions; short answer questions and extended writing questions.

Practical investigations in this unit

Within this unit, students will develop understanding of the process of scientific investigations, including that investigations:

- use hypotheses which are tested
- require assessment and management of risks
- require the collection, presentation, analysis and interpretation of primary and secondary evidence including the use of appropriate technology
- should include a review of methodology to assess fitness for purpose
- should include a review of hypotheses in the light of outcomes.

The following specification points are practical investigations which exemplify the scientific process and may appear in the written examination for this unit:

1.4 *Identify the ions in unknown salts, using the tests above and in unit C2, specification point 2.15*

2.6 *Evaporate a solution to dryness to determine the mass of solute in a given mass of solution*

2.14 *Carry out an acid-base titration to prepare a salt from a soluble base*

3.8 *Electrolyse sodium chloride solution*

3.12 *Investigate the mass changes at the electrodes during the electrolysis of copper sulfate solution using copper electrodes*

5.2 *Prepare a solution of ethanol by fermentation*

The following are further suggestions for practical work within this unit:

- *Investigate the properties of a group of elements eg Group 2*
- *Describe an experiment to test the hardness of samples of water by shaking the sample with soap solution*
- *Investigate methods for removing hardness in water*
- *Carry out titrations reaction to find an unknown concentration of an acid or alkali in solution*
- *Investigate the migration of ions in eg potassium manganate (VII) solution*
- *Investigate the products of electrolysis of solutions of salts*
- *Electroplate a metal object*
- *Determine the volume of one mole of hydrogen gas by using the reaction of magnesium with hydrochloric acid*
- *Determine the molar volume by measuring the volume and mass of a gas using a heavier gas (eg carbon dioxide)*
- *Investigate simple reversible reactions, such as the decomposition of ammonium chloride*
- *Dehydration of ethanol*
- *Oxidation of ethanol*
- *Reactions of ethanoic acid*
- *Describe an experiment to prepare an ester on a test tube scale*
- *Manufacture of soap*

The Controlled Assessment Task (CAT) for the GCSE in Chemistry will be taken from any of these practicals (specification points and further suggested practicals). This task will change every year, so future CATs will be chosen from this list.

Detailed unit content

In this specification bold text refers to higher tier only content. Italic text refers to practical investigations, which students are required to demonstrate an understanding of.

Throughout the unit

0.1 Recall the formulae of elements and simple compounds in the unit

0.2 Represent chemical reactions by word equations and simple balanced equations

0.3 Write balanced chemical equations including the use of state symbols (s), (l), (g) and (aq) for a wide range of reactions in this unit

0.4 Write balanced ionic equations for a wide range of reactions in this unit and those in unit C2, specification point 2.15

0.5 Assess practical work for risks and suggest suitable precautions for a range of practical scenarios for reactions in this unit

0.6 Demonstrate an understanding that hazard symbols used on containers:

a indicate the dangers associated with the contents

b inform people about safe-working procedures with these substances in the laboratory

Topic 1

Qualitative analysis

1.1 Demonstrate an understanding that analysis may be qualitative or quantitative

1.2 Explain why the test for any ion must be unique

1.3 Describe tests to show the presence of the following ions in solids or solutions as appropriate:

a Al^{3+}, Ca^{2+}, Cu^{2+}, Fe^{2+}, Fe^{3+} using sodium hydroxide solution

b NH_4^+ using sodium hydroxide solution, warming and testing for the ammonia gas produced

c Cl^-, Br^-, I^- using dilute nitric acid and silver nitrate solution

1.4 *Identify the ions in unknown salts, using the tests above and in unit C2, specification point 2.15*

1.5 Demonstrate an understanding that these tests form the basis for testing by chemists:

a working in the water industry to check the purity of drinking water

b for the presence of substances in the blood

Topic 2

Quantitative analysis

2.1 Calculate the concentration of solutions in g dm^{-3}

2.2 Demonstrate an understanding that some areas of the country have dissolved calcium or magnesium ions in their tap water and that the presence of these ions makes the water hard

2.3 Describe problems caused by hard water, including:

- a it does not easily form a lather with soap
- b it reacts with soap to form a precipitate ("scum"), which causes soap to be wasted

2.4 Describe hard water as either temporary or permanent; and describe how boiling removes temporary hardness but not permanent hardness

2.5 Explain how hard water can be softened by removing the dissolved calcium and/or magnesium ions and that this can be done by:

- a boiling (for temporary hard water only)
- b using an ion exchange resin

2.6 *Evaporate a solution to dryness to determine the mass of solute in a given mass of solution*

2.7 **Demonstrate an understanding that the amount of a substance can be measured in grams, numbers of particles or number of moles of particles**

2.8 **Convert masses of substances into moles of particles of the substance and vice versa**

2.9 **Convert concentration in g dm^{-3} into mol dm^{-3} and vice versa**

2.10 Demonstrate an understanding that if soluble salts are prepared from an acid and an insoluble reactant:

- a excess of the reactant can be added to ensure that all the acid is used up
- b the excess reactant can be removed by filtration
- c the solution remaining is only salt and water

2.11 Demonstrate an understanding that if soluble salts are prepared from an acid and a soluble reactant:

- a titration must be used to determine the exact amount of the soluble reactant that reacts with an acid
- b the acid and the soluble reactant can then be mixed in the correct proportions
- c the solution remaining after reaction is only salt and water

2.12 Describe an acid-base titration as a neutralisation reaction where hydrogen ions (H^+) from the acid react with hydroxide ions (OH^-) from the base

2.13 Describe how to carry out simple acid-base titrations using burette, pipette and suitable acid-base indicators

2.14 *Carry out an acid-base titration to prepare a salt from a soluble base*

2.15 **Carry out simple calculations using the results of titrations to calculate an unknown concentration of a solution or an unknown volume of solution required.**

Topic 3

Electrolytic processes

3.1 Explain that electrolytes are ionic substances in the molten state or dissolved in water

3.2 Describe the movement of ions during electrolysis, such that

a positively charged cations migrate to the negatively charged cathode

b negatively charged anions migrate to the positively charged anode

3.3 Demonstrate an understanding that oxidation can involve the loss of electrons and reduction can involve the gain of electrons

3.4 Demonstrate an understanding that reduction occurs at the cathode and that oxidation occurs at the anode in electrolysis reactions

3.5 **Write half equations for reactions occurring at the anode and cathode in examples of electrolysis reactions in this unit**

3.6 Describe the manufacture of sodium by the electrolysis of molten sodium chloride (details of the electrolytic cell are not required)

3.7 Recall that sodium can be used in street lamps and as a coolant in some nuclear reactors

3.8 *Electrolyse sodium chloride solution*

3.9 Explain the formation of the products in the electrolysis of sodium chloride solution

3.10 Describe how the electrolysis of aqueous solutions can give products from ions in water, rather than from ions of the dissolved solid

3.11 Explain the formation of the products in the electrolysis, using inert electrodes, of some electrolytes, including:

a copper chloride solution

b copper sulfate solution

c sodium sulfate solution

d molten lead bromide

3.12 *Investigate the mass changes at the electrodes during the electrolysis of copper sulfate solution using copper electrodes*

3.13 Describe the purification of copper by electrolysis using a pure copper cathode and an impure copper anode

3.14 Explain how electroplating can be used to improve the appearance and/or the resistance to corrosion of metal objects

Topic 4

Gases, equilibria and ammonia

4.1 **Demonstrate an understanding that one mole of any gas occupies 24 dm^3 at room temperature and atmospheric pressure and that this is known as the molar volume of the gas**

4.2 **Use molar volume and balanced equations in calculations involving the masses of solids and volumes of gases**

4.3 **Use Avogadro's law to calculate volumes of gases involved in gaseous reactions, given the relevant equations**

4.4 Recall that nitrogenous fertilisers are manufactured from ammonia and that they promote plant growth

4.5 Demonstrate an understanding of the environmental consequences of the over-use of fertilisers, including excessive plant growth in rivers and lakes

4.6 Recall that chemical reactions are reversible and that the Haber process uses a reversible reaction between nitrogen (extracted from the air) and hydrogen (obtained from natural gas) to form ammonia

4.7 **Demonstrate an understanding of the concept of dynamic equilibrium**

4.8 **Explain how the position of a dynamic equilibrium is affected by changes in:**

- a **temperature**
- b **pressure**

4.9 **Demonstrate an understanding of the consequential effects of these changes on the rate of attainment of equilibrium and of the need to use a catalyst**

4.10 **Describe how, in industrial reactions such as the Haber process, the temperature, pressure and catalyst used produce an acceptable yield in an acceptable time**

Topic 5

Organic chemistry

5.1 Describe how ethanol is produced during the fermentation of carbohydrates, including:

- a that the fermentation mixture is kept warm and under anaerobic conditions
- b that yeast provides an enzyme for this reaction

5.2 *Prepare a solution of ethanol by fermentation*

5.3 Recall that different percentages of ethanol are present in various drinks

5.4 Demonstrate an understanding of the social issues and possible harmful effects of ethanol in alcoholic drinks

5.5 Explain how to obtain a concentrated solution of ethanol by fractional distillation of the fermentation mixture

5.6 **Recall how ethanol can also be manufactured by reacting ethene (from cracking of crude oil fractions) with steam**

5.7 **Evaluate the factors which are relevant to the choice of method used in the manufacture of ethanol, including:**

- a **the relative availability of sugar cane or sugar beet and crude oil**
- b **the quality of the final product and whether it needs further processing**

5.8 **Recall that the dehydration of ethanol results in the formation of ethene**

5.9 Define homologous series as a series of compounds which:

- a have the same general formula
- b show a gradual variation in physical properties as exemplified by their boiling points
- c have similar chemical properties

5.10 Recall the names, formulae and structures of members of the following homologous series:

- a alkanes, up to 4 carbons atoms per molecule
- b alkenes, up to 3 carbons atoms per molecule
- c **alcohols, up to 3 carbons atoms per molecule**
- d **carboxylic acids, up to 3 carbon atoms per molecule**

(no treatment of isomers is required in any of these series)

5.11 Demonstrate an understanding that ethanol can be oxidised to form ethanoic acid and that this reaction occurs in open bottles of wine and in the production of ethanoic acid in vinegar

5.12 Describe the use of vinegar as a flavouring and as a preservative

5.13 Demonstrate an understanding that ethanoic acid is a typical acid, including:

- a its reaction with metals
- b its reaction with bases and carbonates to form salts (ethanoates)
- c its typical effect on indicators

5.14 Describe the reaction of ethanol with ethanoic acid to produce an ester, ethyl ethanoate and water **including writing an equation for this reaction using molecular and structural formulae**

5.15 Describe uses of:

a esters as flavourings and perfumes, as they are pleasant-smelling

b polyesters as fibres to make fabric and as plastics for making bottles (no consideration of the formation of polyester is required)

5.16 Demonstrate an understanding that polyesters can be recycled to form fleece that is used to make clothing

5.17 Recall that oils and fats are esters

5.18 Describe the breaking down of oils and fats, by boiling with concentrated alkali solution, to produce soaps, which are sodium or potassium salts of long carbon chain carboxylic acids

5.19 **Demonstrate an understanding of how a soap removes dirt or grease, including**

a **that part of the soap anion is hydrophobic and dissolves in dirt or grease**

b **that the other part is hydrophilic and dissolves in water**

5.20 **Demonstrate an understanding that liquid oils can be converted to solid fats by catalytic hydrogenation which removes the C=C unsaturation and that this process is used to manufacture margarine**