GCSE

WJEC GCSE in
CHEMISTRY

APPROVED BY QUALIFICATIONS WALES

GUIDANCE FOR TEACHING

Teaching from 2016

This Qualifications Wales regulated qualification is not available to centres in England.

Contents

UNIT 1 – CHEMICAL SUBSTANCES, REACTIONS and ESSENTIAL RESOURCES 3

1.1 THE NATURE OF SUBSTANCES AND CHEMICAL REACTIONS 3

1.2 ATOMIC STRUCTURE AND THE PERIODIC TABLE 6

1.3 WATER 15

1.4 THE EVER-CHANGING EARTH 22

1.5 RATE OF CHEMICAL CHANGE 26

1.6 LIMESTONE 35

UNIT 2 – CHEMICAL BONDING, APPLICATION OF CHEMICAL REACTIONS and ORGANIC CHEMISTRY 39

2.1 BONDING, STRUCTURE AND PROPERTIES 39

2.2 ACIDS, BASES AND SALTS 42

2.3 METALS AND THEIR EXTRACTION 52

2.4 CHEMICAL REACTIONS AND ENERGY 64

2.5 CRUDE OIL, FUELS AND ORGANIC CHEMISTRY 65

2.6 REVERSIBLE REACTIONS, INDUSTRIAL PROCESSES AND IMPORTANT CHEMICALS 76

UNIT 1 – CHEMICAL SUBSTANCES, REACTIONS and ESSENTIAL RESOURCES

1.1 THE NATURE OF SUBSTANCES AND CHEMICAL REACTIONS

Spec Statement		Comment
(a)	elements as substances that cannot be broken down into simpler substances by chemical means and as the basic building blocks of all substances	
(b)	elements as substances made up of only one type of atom	
(c)	compounds as substances made of two or more different types of atom that are chemically joined and having completely different properties to its constituent elements	
(d)	how to represent elements using chemical symbols and simple molecules using chemical formulae	
(e)	how to represent simple molecules using a diagram and key	Candidates should know that in a methane molecule, for example, the four hydrogen atoms surround a central carbon atom, rather than all being joined together in a row.
(f)	how to write the formulae of ionic compounds given the formulae of the ions they contain	A table of formulae for common ions (including compound ions) will be included in all examination papers but candidates should be able to apply their knowledge to any given ion.
(g)	relative atomic mass and relative molecular (formula) mass	Candidates should be able to calculate relative molecular (formula) masses using A_r values from the Periodic Table*. The formal definition of relative atomic mass is not required **but higher tier candidates should know how A_r is different to mass number.** ***** Note that the Periodic Table supplied will no longer include mass numbers

(h)	the percentage composition of compounds	Candidates should be able to carry out a range of calculations based on the percentage by mass of each element present in a compound.
(i)	atoms/molecules in mixtures not being chemically joined and mixtures being easily separated by physical processes such as filtration, evaporation, chromatography and distillation	Candidates should understand the principles behind each separation method e.g. in chromatography they should understand that the more soluble a substance, the further it is carried by the solvent.
(j)	chromatographic data analysis and R_f values	Candidates are expected to recall the expression used to calculate R_f values.
(k)	chemical reactions as a process of re-arrangement of the atoms present in the reactants to form one or more products, which have the same total number of each type of atom as the reactants	
(l)	colour changes, temperature changes (exothermic/ endothermic) and effervescence as evidence that a chemical reaction has taken place	Candidates should know that these are indications that a chemical reaction has occurred. The only requirement for recall here is in respect of reactions that are covered within this unit e.g. green copper(II) carbonate turns black on thermal decomposition and the reaction of sodium and water is exothermic and effervesces.
(m)	how to represent chemical reactions using word equations	The emphasis here is on the skill of writing word equations. As above, detailed recall is related to other specification statements.
(n)	how to represent chemical reactions using balanced chemical equations where the total relative mass of reactants and products is equal	The emphasis here is on the skills of writing and balancing chemical equations. Again, detailed recall is related to other specification statements. Candidates should be able to use the state symbols (s), (l), (g) and (aq) but they will not be required to include them in equations unless they are specifically asked to do so.
(o)	the percentage yield of a chemical reaction	Candidates are expected to recall the expression used to calculate percentage yield.

(p)	how to calculate the formula of a compound from reacting mass data	Candidates will not be expected to recall the methods used to collect this type of data but they should show an understanding of the principles involved when a description is provided. They should be able to deal with questions where the percentage composition of the compound is given, as well as examples where actual masses are provided. They should recognise that a formula calculated in this way is known as a simplest formula and as an empirical formula. Candidates must show their working in questions of this type and should be made aware that data collected may possibly suggest a formula different to that which they know to be correct, e.g. incomplete reaction of magnesium with oxygen could provide data that gives Mg_2O as the formula for magnesium oxide.
(q)	how to calculate the masses of reactants or products from a balanced chemical equation	Candidates should think of this as a progression from a balanced symbol equation – and appreciate that considering the masses of reactants and products is a good opportunity to check that an equation is correctly balanced. They will usually be given the balanced equation in examination questions on this section.
(r)	the Avogadro constant and the mole and how to convert amount of substance in grams to moles and vice versa	Candidates are expected to recall the relationship between number of moles and mass in grams. They are not required to recall the Avogadro constant.

1.2 ATOMIC STRUCTURE AND THE PERIODIC TABLE

Spec Statement		Comment
(a)	atoms containing a positively charged nucleus with orbiting negatively charged electrons	
(b)	atomic nuclei containing protons and neutrons	
(c)	the relative masses and relative charges of protons, neutrons and electrons	Candidates should know that protons and neutrons have the same mass of 1 atomic mass unit (amu) and that electrons have a negligible mass of approximately 2000 times less. Charges need only be described in terms of positive (+1), neutral (0) and negative (-1).
(d)	atoms having no overall electrical charge	Candidates should be able to build upon this idea to describe how ions form and explain the charges found on simple ions e.g. Na^+, Mg^{2+}, $Cl^–$ and $O^{2–}$.
(e)	the terms atomic number, mass number and isotope	Candidates should be able to describe the difference between the atoms of different isotopes, in terms of the numbers of neutrons present but they are not expected to recall the mass numbers of any particular isotopes of any element. Mass number data will be included in any questions that require it as it is no longer included in the supplied Periodic Table.
(f)	how the numbers of protons, neutrons and electrons present in an atom are related to its atomic number and mass number	Candidates are expected to recall the definitions for both terms and to use them to identify the numbers of protons, neutrons and electrons in any given atom/ion. Question papers in Chemistry will not refer to proton number or nucleon number.
(g)	**how to calculate the relative atomic mass of elements with more than one isotope**	**Candidates are not expected to recall the expression used to calculate the relative atomic mass of elements with more than one isotope.**
(h)	elements being arranged in order of increasing atomic number and in groups and periods in the modern Periodic Table, with elements having similar properties appearing in the same groups	Candidates should be able identify an element given its group and period, and vice versa. They should understand that elements with the same number of electrons in their outer shell undergo similar chemical reactions e.g. as seen in Group 1 and Group 7.

(i)	metals being found to the left and centre of the Periodic Table and non-metals to the right, with elements having intermediate properties appearing between the metals and non-metals in each period	Candidates should know that elements change from being metals to non-metals on going from left to right across the Periodic Table and that many of those in groups 3, 4 and 5 exhibit both metallic and non-metallic properties. The emphasis here should be on trends rather than recall of properties of individual elements.
(j)	the electronic structures of the first 20 elements	
(k)	how the electronic structure of any element is related to its position in the Periodic Table	Candidates should understand that the group number corresponds to the number of electrons in the outer shell and that the period number is the number of occupied electron shells.
(l)	the similarities and trends in physical and chemical properties of elements in the same group as illustrated by Group 1 and Group 7	Candidates are expected to know that elements in the same group undergo the same type of reaction e.g. Group 1 elements react vigorously with water. They should know that Group 1 elements become more reactive down the group and that Group 7 elements become less reactive down the group. They should recall the following trends in melting/boiling points: • Group 1 melting/boiling points decrease down the group (lithium doesn't melt as it reacts with water) • Group 7 melting/boiling points increase down the group (states of chlorine, bromine and iodine at room temperature)
(m)	many reactions, including those of Group 1 elements and many of those of Group 7 elements, involve the loss or gain of electrons and the formation of charged ions	Candidates should understand that elements with atoms containing full outer electron shells (Group 0) are unreactive and that other elements react in order to try to attain the same state. They should understand, for example, that the atoms of Group 1 metals lose one electron to do so, while those of Group 7 elements gain one electron. **Higher tier candidates should also understand that losing or gaining more than one electron is more difficult and that Group 2 elements are therefore less reactive than Group 1 elements (and Group 6 elements are less reactive than Group 7 elements).**
(n)	**the trends in reactivity of Group 1 and Group 7 elements in terms of their readiness to lose or gain an electron**	**Group 1 metals become more reactive down the group. The increasing size of the atom/distance from the positively charged nucleus makes it easier for the outer electron to be lost. Group 7 elements become less reactive down the group. The increasing size of the atom/distance from the positively charged nucleus results in a smaller force attracting the additional electron.**

(o)	the reactions of the alkali metals with air/oxygen, the halogens and water	Candidates are expected to recall observations made during the reactions of lithium, sodium and potassium in each case: • Air/oxygen – tarnishing of freshly cut surface • Burning in air/oxygen – flame colours, white products • Halogens – flame colours, white products • Water – metals floating, movement on the water surface and whether or not a ball is formed, hissing sound, potassium <u>only</u> begins to burn (lilac flame) Observation includes sounds e.g. fizzing/hissing, but 'hydrogen formed' is <u>not</u> an observation. The tarnishing in air and reaction with water can be easily demonstrated in the laboratory but burning and reaction with halogens are best observed through video clips. In common with <u>all</u> specified reactions, candidates should be able to name products and write word and balanced symbol equations describing those reactions. They should know that the metal hydroxides formed during the reaction with water are alkalis.
(p)	the test used to identify hydrogen gas	When a <u>lit splint</u> is placed into a jar/tube containing hydrogen gas, a <u>squeaky pop</u> is observed.
(q)	the reactions of halogens with alkali metals and with iron	Candidates should recall the colours of chlorine, bromine and iodine in their room temperature states. Recall of the observations made during the reactions with iron is <u>not</u> required but candidates should know that it is the iron(III) salt formed in each case. Video clips are a useful resource to observe these reactions.
(r)	**the relative reactivities of chlorine, bromine and iodine as demonstrated by displacement reactions**	**Candidates should appreciate that displacement reactions provide stronger evidence for the decreasing reactivity down Group 7 than that gained from the elements' reactions with iron. Factors such as the halogens' different states at room temperature can make it difficult to make a fair comparison of their reactivities by observation of their reactions with iron but they compete directly against one another in displacement reactions.** **Candidates should know that solutions of halides are colourless and that displacement of bromine and iodine results in the formation of an orange-brown solution.**

(s)	the properties and uses of chlorine and iodine	Candidates should recall the properties of these elements and at least one widespread use of each. Chlorine – poisonous/toxic, kills bacteria; used in treatment of water supplies*, treatment of swimming pool water*, making household cleaners Iodine – poisonous/toxic, kills bacteria; used as antiseptic following hospital procedures * Candidates should understand that the quantities of chlorine used in the treatment of water supplies and in swimming pools is controlled and monitored to ensure that it is sufficient to kill bacteria and sterilise the water, without causing any harm to us.
(t)	the identification of Li^+, Na^+, K^+, Ca^{2+} and Ba^{2+} ions by flame tests and Cl^-, Br^- and I^- ions by their reactions with silver nitrate solution (including ionic equations)	The flame colours expected are as follows: • lithium – red (brick red will not be accepted) • sodium – yellow-orange • potassium – lilac • calcium – brick red • barium – apple green (green will not be accepted) Solutions of the halides produce different coloured precipitates on addition of $Ag^+(aq)$: • chloride – white precipitate • bromide – cream precipitate • iodide – yellow precipitate Candidates should be able to name the insoluble compounds formed and recognise ‘spectator ions’ which take no part in the precipitation reaction. They should be able to write and interpret ionic equations e.g. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ State symbols are an important feature of ionic equations for precipitation reactions but as with any questions on equations, candidates will be told to include them when a specific mark is allocated for this skill.
(u)	the unreactive nature of the Group 0 gases and the uses of helium, neon and argon	Candidates should recall the properties of these gases and at least one use of each. Helium – very low density, very unreactive; used in airships, weather balloons Neon – emits light when electric current passes through it; used in advertising signs Argon – very unreactive; used in light bulbs, as an inert atmosphere for welding

SPECIFIED PRACTICAL WORK

- Identification of unknown ionic compounds using flame tests and chemical tests for ions

Identification of unknown ionic compounds using flame tests and chemical tests for ions

Introduction

Scientists need to identify the compounds that they are working with. To do this we use a series of chemical tests that allow us to identify the different metal or non-metal ions that are present in a compound.
These tests include:

- Flame tests
- Tests for carbonate
- Tests for Group 7 ions

Flame test		Test for a carbonate ion, CO_3^{2-}	Test for Group 7 ions, Cl^-, Br^- and I^-	
Dip a damp wooden splint into the solid sample being tested. Put the sample into the hottest part of a Bunsen flame (air-hole open).		Add dilute hydrochloric acid. Pipette the gas formed into the limewater.	Make a solution by dissolving the sample in water. Add silver nitrate solution.	
Result		**Result**	**Result**	
Ion	**Flame colour**	Fizzes when acid is added Gas formed turns limewater milky	**Ion**	**Precipitate colour**
potassium, K^+	lilac		chloride, Cl^-	white
sodium, Na^+	yellow		bromide, Br^-	cream/pale yellow
calcium, Ca^{2+}	brick red		iodide, I^-	yellow
lithium, Li^+	red			

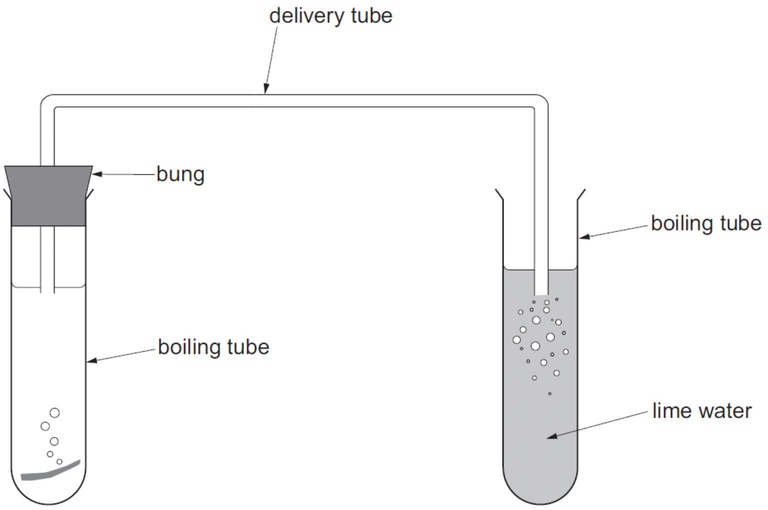
You will be provided with 5 solid compounds, labelled A, B, C, D and E.

You will use these tests to identify the five compounds you have been given.

Apparatus

5 × damp wooden splints
Bunsen burner
heat proof mat
12 × test tubes
1 × dropping pipette
5 × spatulas
silver nitrate solution
dilute hydrochloric acid
limewater

Diagram of Apparatus



Method - Flame test

1. Take a damp wooden splint and dip it into sample A.
2. Hold the splint in the roaring (blue) Bunsen burner flame.
3. Record the flame colour obtained.
4. Repeat for each of the samples with a separate damp splint.

Method – Test for carbonate ions

1. Add one of the samples to a test tube.
2. Half fill a second tube with limewater.
3. Add hydrochloric acid to the sample and quickly attach the bung and side arm tube.
4. Record what happens to the limewater.

Method – Test for Group 7 ions

1. Test each of the samples that did not give a positive result for the carbonate ion for the presence of a Group 7 ion.
2. Add a small amount of the solid to a test tube.
3. Add de-ionised water to each solid to create a solution.
4. Add silver nitrate to the solution using a dropping pipette.
5. Record the colour of the precipitate formed.

Analysis

1. Use the reference tables to identify each of the unknown compounds.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Hydrochloric acid is an irritant	Hydrochloric acid could get onto the skin when adding to test tube	Wash hands immediately if any hydrochloric acid gets onto them / wear laboratory gloves.
	Hydrochloric acid could get transferred from the hands to the eyes	Wear eye protection.
Limewater is corrosive	Limewater could get onto the skin when adding to test tube	Wash hands immediately if any limewater gets onto them / wear laboratory gloves.
	Limewater could get transferred from the hands to the eyes	Wear eye protection.
Silver nitrate is an irritant	Silver nitrate could get onto the skin when adding to test tube	Wash hands immediately if any silver nitrate gets onto them / wear laboratory gloves.
	Silver nitrate could get transferred from the hands to the eyes	Wear eye protection.
Hot apparatus can burn	Burns to skin when moving Bunsen burner	Do not touch Bunsen burner until cool

In this experiment it is important that the splints are soaked in de-ionised water not tap water.

Each splint should be no shorter than 10 cm.

An alternative to the damp splints is to use nichrome wires held in a bung or between tongs.

Reagents for flame tests:
Calcium chloride – Refer to CLEAPSS hazcard 19A
Lithium chloride - Refer to CLEAPSS hazcard 47B
Sodium carbonate – Refer to CLEAPSS hazcard 95A
Potassium iodide – Refer to CLEAPSS hazcard 47B
Potassium bromide – Refer to CLEAPSS hazcard 47B

Other reagents:
Hydrochloric acid – Refer to CLEAPSS hazcard 47A
Limewater – Refer to CLEAPSS hazcard 18
Silver nitrate – Refer to CLEAPSS hazcard 87

Students should design their own table, but a suggested table format is shown below.

Sample	**Flame test observation**	**Carbonate test observation**	**Group 7 test observation**	**Name of Compound**
A				
B				
C				
D				
E				

Working scientifically skills covered

1. **Development of scientific thinking**
   Explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments.

2. **Experimental skills and strategies**
   Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

   Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

   Make and record observations and measurements using a range of apparatus and methods.

3. **Analysis and Evaluation**
   Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

4. **Scientific vocabulary, quantities, units, symbols and nomenclature**
   Use SI units and IUPAC chemical nomenclature unless inappropriate.

1.3 WATER

Spec Statement		Comment
(a)	the composition of water in 'natural' water supplies, including dissolved gases, ions, microorganisms and pollutants	Candidates should be aware that rainwater contains dissolved CO_2 (which lowers the pH) and O_2. Groundwater contains ions such as Mg^{2+}, Ca^{2+}, Na^+ and K^+ from minerals dissolved as it permeates through rocks. Candidates will not be expected to name any microorganisms present in water. Candidates should be aware that man-made pollutants include fertilisers, pesticides and household and industrial waste. Natural pollutants include bacteria and viruses.
(b)	the need for a sustainable water supply to include reducing our water consumption, reducing the environmental impacts of abstracting, distributing and treating water	Candidates should show an understanding that water is a resource ever more in demand as a result of increasing population and industrialisation, and that climate change could potentially cause water shortages all over the world, including the UK. They should appreciate that as demand outstrips supply, the cost of water will increase and that measures to conserve water have economic benefits for domestic, commercial and industrial consumers.
(c)	the treatment of the public water supply using sedimentation, filtration and chlorination	Sedimentation – in reservoirs/tanks, larger solid particles settle under gravity Filtration – through layers of sand and gravel, removes smaller insoluble particles Chlorination – chlorine added to kill bacteria, prevents disease/makes it safe to drink Candidates are not expected to recall details of substances added to water at sedimentation and filtration stages.

(d)	the arguments for and against the fluoridation of the water supply in order to prevent tooth decay	Candidates are expected to know that fluoridation of water supplies is a controversial issue. They should be able to present the arguments for and against the process. Candidates should be aware that there is strong evidence to suggest that fluoride ions prevent tooth decay in young children. Significant amounts of fluoride ions are found naturally in the water in some areas but fluoride can also be ingested from toothpastes and mouthwashes. Candidates should be aware that the link between fluoride ions and a reduction in incidence of tooth decay has been established by surveying school children of various ages, and that the data is reliable because all school children are surveyed and only absentees on the day are excluded. They should also understand that comparing data from one fluoridated area with that from one non-fluoridated area does not provide sufficient evidence to draw a valid conclusion, since other factors, such as social and economic backgrounds, also have an effect. Many people object to proposals to fluoridate water supplies for a number of reasons. Fluoride can be harmful in high concentrations, e.g. causing discolouring or decay of teeth (fluorosis). High fluoride intake has also been linked to stomach and bone cancers and to infertility. Some argue against fluoridation on the grounds that it is ‘mass medication’ and that no one should be forced to consume fluoride. It is important for candidates to realise that science cannot address ethical issues and therefore cannot answer the question as to whether or not it is correct to fluoridate water supplies. Science can only provide the facts and evidence required for people to form their own opinions. They should also be aware that information relating to the fluoridation of water supplies comes from many different sources and that some of these may be biased and may try to influence opinions.
(e)	desalination of sea water to supply drinking water including the sustainability of this process on a large scale	Candidates should know that the simplest method for desalination of sea water is distillation. This involves boiling sea water which uses large amounts of costly energy, preventing it from being a viable process in many parts of the world. Candidates should be aware that other methods are also used, e.g. the use of membrane systems, but they are not required to know any details of such methods. They should be able to discuss the potential of desalination as a source of drinking water in different parts of the world in terms of proximity to the sea, availability of ‘cheap’ energy and a country’s wealth.

(f)	the separation of water and other miscible liquids by distillation	Candidates should know that pure liquids have distinct boiling points and recall that water boils at 100°C. Distillation allows a mixture of liquids to be separated as a result of their different boiling points. They should be able to name the important parts of a distillation apparatus and explain the separation process in terms of boiling and condensation. **Higher tier candidates should appreciate that it is not possible, for example, to obtain 'pure' ethanol (bp 78°C) from a mixture with water because some water evaporates at temperatures below its boiling point.**
(g)	simple methods to determine solubility and produce solubility curves	Candidates should be familiar with the following methods: • Add known mass of solute (e.g. ammonium chloride) to a measured volume of water which will only dissolve a portion of the solute; filter, dry and weigh excess solute; determine solubility • Add slightly more weighed solute (e.g. potassium chlorate) than will dissolve to a measured volume of water at room temperature; heat solution until all solute dissolves; allow to cool and record temperature at which crystals first appear; repeat several times with increasing volumes of water; determine solubility at each temperature; plot solubility curve
(h)	the interpretation of solubility curves	
(i)	the causes of hardness in water and how to distinguish between hard and soft waters by their action with soap	Candidates should know that hardness in water is caused by the presence of Ca^{2+} and Mg^{2+} ions from dissolved calcium and magnesium compounds and that hard water forms a 'scum' and poor lather when shaken with soap solution. They should be able to describe in detail how the relative amount of hardness in different water samples can be determined, e.g. by measuring the volume of soap solution required to produce a given lather or by measuring the lather produced by a given volume of soap solution.
(j)	the difference between temporary and permanent hardness	Candidates should know that temporary hardness can be removed by boiling and that this leads to 'furring' of kettle elements as a result of formation of insoluble calcium carbonate. **Higher tier candidates should be able to explain this in terms of the removal of hydrogencarbonate ions.**

(k)	the processes used to soften water to include boiling, adding sodium carbonate and ion exchange; the advantages and disadvantages of different methods of water softening **and the explanation of how these methods work**	Boiling – no need for expensive equipment; only useful for small volumes and does not remove permanent hardness Adding sodium carbonate (washing soda) – removes both temporary and permanent hardness; limescale is formed which can block washing machine pipes Ion exchange – removes temporary and permanent hardness and is a continuous process, uses concentrated sodium chloride which is cheap and widely available; exchange columns are expensive **Boiling causes hydrogencarbonate ions to decompose forming calcium carbonate on the heating element. Adding sodium carbonate (washing soda) removes hardness by precipitating calcium carbonate. Candidates should be able to write appropriate equations for these reactions.** **Ion exchange removes hardness because calcium (and magnesium) ions are exchanged for sodium ions on passing hard water through an ion exchange resin (two sodium ions needed for every calcium ion). Water coming from the resin contains sodium ions. All the sodium ions attached to an ion exchange resin are eventually 'used up' so no more hardness can be removed, but the resin can be 'regenerated' by being rinsed in a concentrated solution of sodium chloride.**
(l)	the health benefits of hard water and its negative effects, e.g. on boiler elements	Candidates are expected to recall that calcium compounds dissolved in water have benefits for teeth and bones and also help reduce heart disease. Boilers and hot water pipes become 'furred up' as calcium carbonate precipitates – boilers become less efficient and pipes can become completely blocked.

SPECIFIED PRACTICAL WORK

- Determination of the amount of hardness in water using soap solution

Determination of the amount of hardness in water using soap solution

Introduction

Soft water readily forms **lather** with soap, but it is more difficult to form lather with hard water. Hard water contains dissolved calcium or magnesium compounds. This can 'fur up' kettles, boilers and pipes, which wastes energy and can be dangerous if the flow of water is impeded. The calcium ions and magnesium ions in hard water react with the soap to form scum, so more soap is needed to form a lather.

Temporary hard water contains calcium and magnesium hydrogen carbonate. Temporary hard water becomes soft on boiling (limescale). Permanent hard water does not become soft when it is boiled.

Apparatus

100 cm^3 conical flask and stopper
dropping pipette
50 cm^3 measuring cylinder
water samples - A, B, C, D, boiled A, boiled B, boiled C, boiled D
stopwatch
soap solution

Method

1 Measure 50 cm^3 of water sample **A** into a conical flask.
2. Add 1 cm^3 of soap solution, insert the stopper and shake vigorously for 5 seconds.
3. Repeat step 2 until a lather forms that lasts for 30 seconds. Record the total volume of soap solution added.
4. Repeat steps 1-3 with 50 cm^3 samples of all other types of water.

Analysis

1. Draw a bar chart of volume of soap solution against water sample.
2. Use your results to identify which samples are: soft water, temporary hard water and permanent hard water.

Teacher / Technician notes

Wanklyn's or Clarke's soap solution can be used.

Suggested hard water concentration (and approximate volume of soap solution required)

- **A - Soft Water**

Unboiled	de-ionised water (1 cm^3)
Boiled	de-ionised water (1 cm^3)

- **B - Permanent Hard Water**

Unboiled	60% magnesium hard water, 40% calcium hard water (8 cm^3)
Boiled	60% magnesium hard water, 40% calcium hard water (8 cm^3)

- **C - Temporary Hard Water**

Unboiled	50% magnesium hard water, 50% calcium hard water (12 cm^3)
Boiled	de-ionised water (1 cm^3)

- **D - Permanent hard water**

Unboiled	calcium hard water (15 cm^3)
Boiled	calcium hard water (15 cm^3)

- Hard water solutions
  - Magnesium hard water – 0.45 g/dm^3 magnesium sulphate
  - Calcium hard water – 0.45 g/dm^3 calcium sulphate

Sample C is used to represent boiled temporary hard water to demonstrate that hardness has been removed. Teachers may want to create a further sample that contains a mixture of permanent hard water and temporary hard water to extend the experiment for more able students.

- **E - Permanent hard water**

Unboiled	calcium hard water (15 cm^3)
Boiled	50% calcium hard water, de-ionised water (8 cm^3)

Results are best recorded in a tally chart to enable students to record each time 1 cm^3 of soap is added to the solution.

Water sample	Tally chart of volume of soap solution added (cm^3)	Total volume of soap solution added (cm^3)

Working scientifically skills covered

1. **Development of scientific thinking**
   Explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments.

2. **Experimental skills and strategies**
   Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

3. **Analysis and Evaluation**
   Translate data from one form to another.

   Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

   Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

1.4 THE EVER-CHANGING EARTH

Spec Statement		Comment
(a)	the large scale structure of the Earth in terms of solid iron core, molten iron outer core, mantle and crust	
(b)	the theory of plate tectonics and how it developed from Alfred Wegener's earlier theory of continental drift	Candidates should know that the Earth's outer layer, called the lithosphere (the crust and the rigid upper part of the mantle), is broken into 7 or 8 major and many minor plates. These plates continuously move at a rate of a few centimetres per year in relation to one another. Candidates should know that Wegener suggested that all of the continents were once joined together in one supercontinent, called Pangaea, and that they have since drifted apart. This idea of 'continental drift' is based on the following observations: • Jigsaw-like fit of the edges of continents e.g. the west coast of Africa and the east coast of South America; • Similar rocks of the same age found on different continents; • Similar plant and animal fossils found on opposite sides of huge oceans. Wegener's theory did not include any attempt to explain how the continents moved and it was dismissed by more renowned scientists of the time. Convection currents in the mantle were proposed by some scientists as an explanation for plate movement as far back as the 1930s and this was generally accepted as being correct by the 1960s, but the exact mechanism remains a widely researched and much debated question. This is a very good example of how scientific ideas continually develop as new evidence is accumulated over time. Wegener's theory of continental drift was refined and became known as 'plate tectonics'.

(c)	the processes occurring at conservative, destructive and constructive plate boundaries where plates slide past one another, move towards one another and move apart respectively	Candidates should know that plotting the epicentres of major earthquakes and the sites of active volcanoes indicates the location of plate boundaries – regions where the edges of different plates are in contact. Plates move apart at a mid-ocean ridge; this is called a constructive plate boundary because volcanic activity produces new igneous rock. At a destructive plate boundary, one plate is pushed down into the mantle and melts to form magma, causing explosive volcanoes. Both of these boundary types are linked to earthquakes and volcanic activity. At a conservative plate boundary, where plates slide past each other, powerful earthquakes are generated but there are no volcanoes because melting does not occur. Candidates are not expected to recall the detailed structures of these boundary types.
(d)	the formation of the original atmosphere by gases, including carbon dioxide and water vapour, being expelled from volcanoes	Candidates should know that there are several theories that have been used to account for the formation of the Earth's early atmosphere, but many scientists agree that it is most likely to have formed from gases expelled by volcanoes. Carbon dioxide, water vapour and ammonia make up the greatest proportion of volcanic gases.
(e)	the present composition of the atmosphere and how the composition of the atmosphere has changed over geological time	Candidates should know that the surface of the Earth cooled over time and that water vapour present in the early atmosphere condensed forming the oceans. They should appreciate that this happened quickly, in geological terms, and that other changes took far longer. The percentage of carbon dioxide has decreased to a fraction of one percent as a result of a number of processes, the most important being photosynthesis. Photosynthesis began as green plants evolved, using up carbon dioxide and releasing oxygen into the atmosphere for the first time. The evolution of marine animals followed over hundreds of millions of years and much carbon dioxide was locked into limestone and chalk formed from their shells. More still was locked into fossil fuels formed many millions of years ago from the remains of simple marine organisms (crude oil and natural gas) and larger land plants (coal). Ammonia decomposed on reaction with oxygen forming nitrogen, which became the most abundant gas in the atmosphere. These changes occurred over billions of years and eventually led to the composition with which we are familiar: nitrogen 78% oxygen 21% argon (+ other noble gases) 0.9% carbon dioxide 0.04%

(f)	the roles of respiration, combustion and photosynthesis in the maintenance of the levels of oxygen and carbon dioxide in the atmosphere	Candidates are expected to know that the composition of the atmosphere has remained stable for many millions of years. Photosynthesis uses carbon dioxide and produces oxygen, while respiration (animals & plants) and combustion use oxygen and produce carbon dioxide. The burning of ever more fossil fuels releases more and more of the 'locked-in' carbon dioxide into the atmosphere, disturbing the equilibrium that has existed for so long.
(g)	the environmental effects and consequences of the emission of carbon dioxide and sulfur dioxide into the atmosphere through the combustion of fossil fuels	Candidates should know that enhanced global warming due to the increasing amounts of carbon dioxide produced by burning fossil fuels could cause: • Climate change e.g. hotter summers in some parts of the world (leading to droughts) and increased rainfall in others (flooding) • Higher rate of melting of ice caps, polar sea ice, glaciers • Rising sea levels They should know that fossil fuels contain many impurities, including many sulfur-containing compounds and that these produce sulfur dioxide on burning. Sulfur dioxide forms a solution of sulfuric acid on contact with water in the atmosphere and this falls as acid rain. Candidates should understand that ‘clean’ rain is weakly acidic (pH ~5.5) and that acid rain has a pH in the range of about 2-4. They should know that acid rain lowers the pH of lakes etc., damaging aquatic life and damaging forests and vegetation. They should know that it damages buildings (particularly those made of limestone [calcium carbonate]) and increases the rate of corrosion of metal structures such as bridges and statues.
(h)	the measures used to address the problems of global warming and acid rain	Candidates should appreciate that there are no simple solutions to the environmental problems associated with burning fossil fuels. They should be able to suggest ways in which we can be more ‘responsible consumers’ of energy and describe alternative energy sources. They should be able to explain the use of weak alkalis to neutralise soil and lakes affected by acid rain. **Higher tier candidates should be familiar with the basic principles of ‘carbon capture and storage’ and ‘sulfur scrubbing’. No detailed recall of these processes is expected.**
(i)	the air as a source of nitrogen, oxygen, neon and argon	Candidates should know that gases can be separated because they have different boiling points but they are not required to know the details of fractional distillation in this unit.

(j)	the tests used to identify oxygen gas and carbon dioxide gas	When a glowing splint is placed into a jar/tube containing oxygen gas, it re-lights. (Please note that reference to a flame glowing more brightly is not acceptable as a test for oxygen gas.) When carbon dioxide gas is passed through limewater the solution turns milky. (Please note that reference to extinguishing a lit splint or flame is not acceptable as a test for carbon dioxide gas.)

1.5 RATE OF CHEMICAL CHANGE

Spec Statement		Comment
(a)	practical methods used to determine the rate of reaction – gas collection, loss of mass and precipitation (including using data-logging apparatus)	Candidates should recognise that a rate measures a change over a given time. They should be familiar with gas collection and mass loss methods of studying the rates of reactions such as acids and metals/carbonates, as well as the precipitation reaction of dilute hydrochloric acid and sodium thiosulfate.
(b)	the effect of changes in temperature, concentration (pressure) and surface area on rate of reaction	Candidates should know that the rate of reaction is increased by increasing temperature, concentration (pressure) and surface area. They should appreciate that decreasing solid particle size increases surface area.
(c)	the particle theory in explaining changes of rate as a result of changes in temperature, concentration (pressure) and surface area	Candidates should understand that particles of reactants must collide in order for a reaction to occur and that the greater the number of collisions in a given time, the faster the reaction/higher the rate. They should explain how changing concentration, temperature and surface area/particle size affect the collision rate. **Higher tier candidates should be familiar with the idea of a minimum energy required for 'successful collisions' where products are formed.**
(d)	catalysts as substances that increase the rate of a reaction while remaining chemically unchanged **and that they work by lowering the energy required for a collision to be successful (details of energy profiles are not required)**	Candidates are not expected to recall the names of any specific catalysts. They should know that the same catalyst does not work for all reactions and that although the catalyst used in any industrial process is not used up, it does need to be replaced regularly as it is affected by impurities and loses its activity over time. **Higher tier candidates should understand that catalysts increase the rate of a reaction by lowering the minimum energy required for 'successful collisions'.**
(e)	enzymes as biological catalysts which catalyse particular reactions under particular conditions	Candidates should understand what is meant by an enzyme's optimum temperature and that enzymes are denatured at high temperature e.g. over about 60°C. No explanation of how enzymes work, i.e. the lock and key idea, is expected.
(f)	the wide-ranging uses of enzymes	Candidates should be familiar with a range of uses of enzymes but no detailed recall is required.

SPECIFIED PRACTICAL WORK

- Investigation of the factors that affect the rate of a reaction using a gas collection method
- Investigation of the factors that affect the rate of the reaction between dilute hydrochloric acid and sodium thiosulfate

Investigation of the factors that affect the rate of reaction using a gas collection method

Introduction

Magnesium reacts with dilute hydrochloric acid to produce hydrogen. The equation for the reaction is as follows:

$$\text{Magnesium} + \text{Hydrochloric acid} \longrightarrow \text{Magnesium chloride} + \text{Hydrogen}$$

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

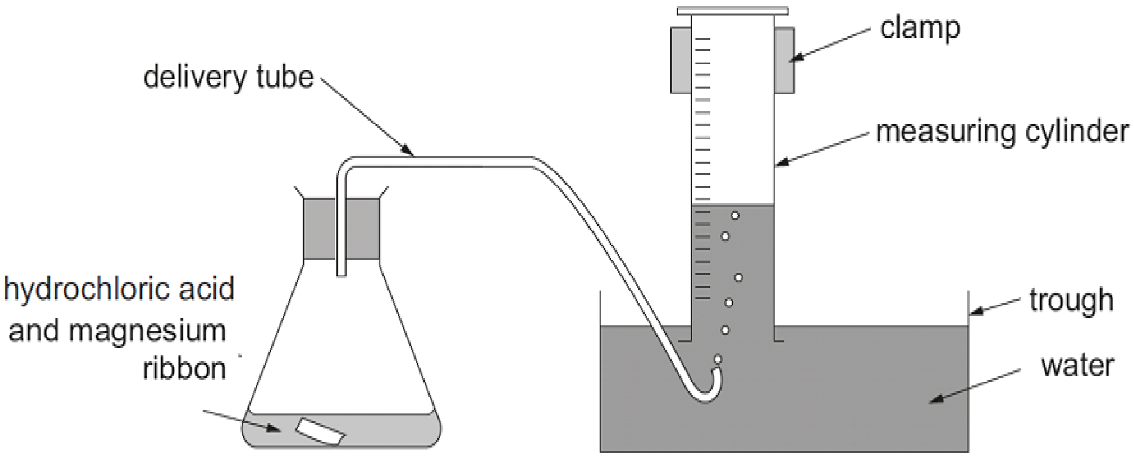
The rate at which the hydrogen gas is produced can be used to determine the rate of the reaction.

In this experiment you will study the effect of changing the concentration of the hydrochloric acid on the rate of the reaction.

Apparatus

250 cm^3 conical flask
single-holed rubber bung
delivery tube to fit conical flask
trough or plastic washing-up bowl
100 cm^3 measuring cylinder
250 cm^3 measuring cylinder
clamp stand, boss and clamp
stopwatch
magnesium ribbon in 3 cm lengths
1 mol/dm^3 hydrochloric acid

Diagram of Apparatus



Method

1. Set up the apparatus as shown in the diagram.
2. Measure 20 cm^3 of 1 mol/dm^3 hydrochloric acid using the 25 cm^3 measuring cylinder. Pour the acid into the 250 cm^3 conical flask.
3. Fill the other measuring cylinder with water, make sure that it stays filled with water when you turn it upside down and clamp above the trough.
4. Add a 3 cm strip of magnesium ribbon to the flask, put the bung into the flask and start the stopwatch.
5. Record the volume of hydrogen gas given off every ten seconds. Continue timing until no more gas appears to be given off.
6. Repeat steps 2-5 using 10 cm^3 of the hydrochloric acid and 10 cm^3 of water to make the total volume used 20 cm^3.

Analysis

1. Plot a graph of volume of hydrogen gas (y-axis) against time (x- axis),for both concentrations of hydrochloric acid and label the lines appropriately.

Teacher / Technician notes

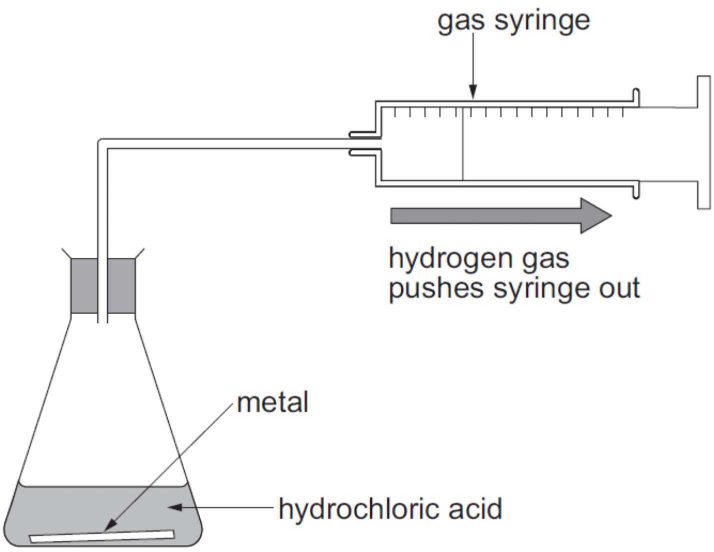
Risk Assessment

Hazard	Risk	Control measure
Hydrochloric acid is an irritant	Hydrochloric acid could get onto the skin when adding to measuring cylinder	Wash hands immediately if any hydrochloric acid gets onto them / wear laboratory gloves.
	Hydrochloric acid could get transferred from the hands to the eyes when pouring	Wear eye protection.

The magnesium ribbon should be clean and free from obvious corrosion or oxidation. Clean if necessary by rubbing lengths of the ribbon with an emery board to remove the layer of oxidation. To ensure that most of the magnesium surface is under the surface of the acid, it should be folded into a zigzag shape.

The bungs in the flasks need to be rubber. Corks are too porous and will leak. The tube through the bung should be a short section of glass, and then a flexible rubber tube can be connected. These can be pre-prepared before the reaction so all the student has to do is push the bung into the flask.

Gas syringes can be used instead of troughs of water and measuring cylinders. Syringes should not be allowed to become wet, or the plungers will stick inside the barrels. The apparatus set up for this procedure is shown in the diagram below:



Reagents:

- Hydrochloric acid – Refer to CLEAPSS hazcard 47A
- Magnesium ribbon – Refer to CLEAPSS hazcard 59A

A 3 cm length of magnesium ribbon has a mass of 0.04 g and should yield 40 cm^3 of hydrogen gas when reacted with this excess of acid.

If a graph of volume (y-axis) against time (x-axis) is drawn, the slope of the graph is steepest at the beginning. This shows that the reaction is fastest at the start. As the magnesium is used up, the rate falls. This can be seen on the graph, as the slope becomes less steep and then levels out when the reaction has stopped (when no more gas is produced).

No repeats have been included in the method, but students can compare results with other groups to make judgements on reproducibility.

Working scientifically skills covered

2. **Experimental skills and strategies**
   Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

   Make and record observations and measurements using a range of apparatus and methods.

3. **Analysis and Evaluation**
   Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

4. **Scientific vocabulary, quantities, units, symbols and nomenclature**
   Use scientific vocabulary, terminology and definitions.

Investigation of the factors affecting the rate of reaction between dilute hydrochloric acid and sodium thiosulfate

Introduction

Sodium thiosulfate reacts with hydrochloric acid to form a solid precipitate of sulfur. The formation of this precipitate makes the solution become cloudy, and so the rate at which this cloudiness appears can be used as a way to measure the rate of the reaction. The equation for this reaction is as follows:

$$\text{sodium thiosulfate} + \text{hydrochloric acid} \longrightarrow \text{sodium chloride} + \text{water} + \text{sulfur dioxide} + \text{sulfur}$$

$$Na_2S_2O_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$$

The rate at which this precipitate forms can be changed by changing the conditions under which the reaction is carried out.

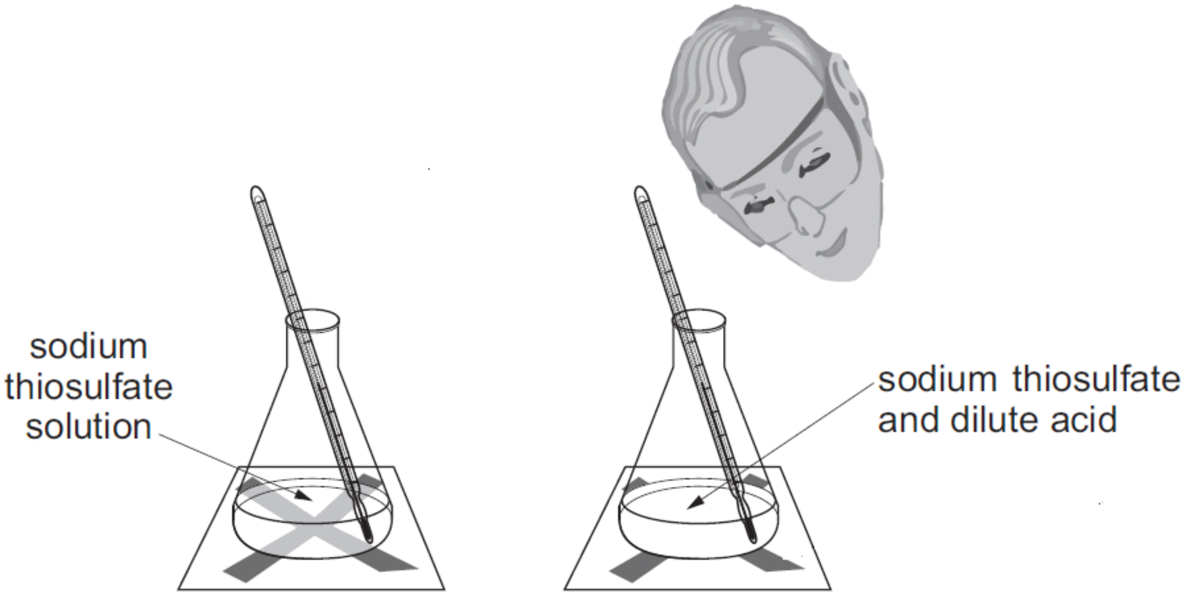
In this experiment you will study the effect of changing the temperature of the sodium thiosulfate solution.

Apparatus

10 cm^3 measuring cylinder
25 cm^3 measuring cylinder
250 cm^3 conical flask
white paper with cross marked on it
stopwatch
1 mol/dm^3 hydrochloric acid
thermometer

Access to:
40 g/dm^3 sodium thiosulfate solution at 5 °C
40 g/dm^3 sodium thiosulfate solution in a waterbath at 60 °C

Diagram of Apparatus



Method

1. Draw a cross on a square of white paper.
2. Measure 25 cm^3 of hot sodium thiosulfate using the 25 cm^3 measuring cylinder and pour into the conical flask. Record the temperature of the solution.
3. Using the 10 cm^3 measuring cylinder, measure out 5 cm^3 of the hydrochloric acid.
4. Place the conical flask onto the cross and add the hydrochloric acid. Swirl the flask to mix the contents and at the same time start the stopwatch.
5. Look down at the cross from above the mixture.
6. Stop the stopwatch as soon as the cross disappears.
7. Record the time taken for the cross to disappear.
9. Repeat steps 2 to 7 for different temperatures of sodium thiosulfate, made according to the table below.

Volume of sodium thiosulfate solution at 60 °C (cm^3)	Volume of sodium thiosulfate solution at 5 °C (cm^3)
25	0
20	5
15	10
10	15
5	20
0	25

Analysis

1. Plot a graph of the temperature of sodium thiosulfate against the time taken for the cross to disappear.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Hydrochloric acid is an irritant.	Splashing onto hand/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Sodium thiosulfate is an irritant	Splashing onto hand/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Sulphur dioxide gas produced is an irritant	Inhalation of gas produced in reaction may cause damage/irritation to the lungs	Carry out in a well ventilated space/fume cupboard
Hot liquid can scald Hot apparatus can burn	Burns or scalds if the hot sodium thiosulphate is touched.	Keep maximum temperature to 60 ^{o}C. Leave to cool before moving

The crosses on the paper can be pre-prepared and laminated.

An alternative method can also be followed using the method set out on CLEAPSS card C195. It reduces the volume of reactants used so enabling more sets of equipment to be created.

Reagents

- Hydrochloric acid – Refer to CLEAPSS hazcard 47A
- Sodium thiosulfate – Refer to CLEAPSS hazcard 95A

No repeats have been included in the method, but reproducibility can be checked by comparing results with other groups. As temperatures will vary across groups, the whole class data could be plotted onto one graph.

More able candidates could calculate and plot the rate of the reaction using $\frac{1}{\text{time (s)}}$.

Students should design their own table, but a suggested table format is shown below.

Recorded temperature (°C)	Time taken for cross to disappear (s)

Working scientifically skills covered

2. **Experimental skills and strategies**
   Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

3. **Analysis and Evaluation**
   Represent distributions of results and make estimations of uncertainty.

   Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

   Evaluate data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

1.6 LIMESTONE

Spec Statement		Comment
(a)	the trend in stabilities of metal carbonates and their thermal decomposition to produce oxides and carbon dioxide	Candidates should be able to describe the practical details of an experiment to demonstrate that the gas given off during the thermal decomposition of carbonates is carbon dioxide. They should recall that green copper(II) carbonate turns black on gentle heating and that calcium carbonate (limestone/marble) glows when heated strongly for several minutes. They should understand that the more reactive the metal, the more stable the carbonate and that sodium carbonate (and therefore the carbonates of the more reactive Group 1 metals below it in the Periodic Table) does not decompose at the highest temperature attainable using a Bunsen burner flame.
(b)	calcium carbonate, calcium oxide and calcium hydroxide as the chemical names for limestone, quicklime and slaked lime respectively	Candidates are required to recall these names.
(c)	the cycle of reactions involving limestone and products made from it, including the exothermic reaction of quicklime with water and the reaction of limewater with carbon dioxide	Candidates should be able to describe the observations made during all of these reactions.
(d)	the uses of limestone in the production of iron and steel, in road-building, to neutralise soil acidity and to make cement	Candidates should know that powdered limestone, quicklime and slaked lime are used to neutralise acidity in soil and/or water. They should know that limestone is used in the blast furnace (iron and steel production) and in making cement but no details of either process are required.
(e)	the social, economic and environmental benefits and drawbacks of limestone quarrying	Candidates should be able to give their own opinion and argue a case for or against quarrying limestone i a particular location, based on how the associated benefits/drawbacks affect themselves and other individuals/groups.

SPECIFIED PRACTICAL WORK

- Investigation of thermal stabilities of calcium carbonate, copper(II) carbonate and sodium carbonate

Investigation of thermal stabilities of calcium carbonate, copper (II) carbonate and sodium carbonate

Introduction

Metal carbonates can be made to break down (decompose) when they are heated. The harder it is to break them down, the more stable they are. In this experiment, three carbonates are heated strongly to see how easily they decompose. By carrying out this experiment you will be able to place the carbonates in order of their thermal stability.

$$\text{metal carbonate} \longrightarrow \text{metal oxide} + \text{carbon dioxide}$$

$$XCO_3(s) \longrightarrow XO(s) + CO_2(g)$$

Apparatus

3 × boiling tubes
test tube holder
Bunsen burner
heat proof mat
rack for boiling tubes
calcium carbonate
copper(II) carbonate
sodium carbonate
spatula
Access to:
electronic balance ± 0.01 g

Method

1. Record the mass of an empty boiling tube.
2. Add approximately 2 g of calcium carbonate.
3. Record the mass of the boiling tube and the calcium carbonate.
4. Heat in a roaring (blue) Bunsen burner flame for approximately 5 minutes.
5. Allow the boiling tube to cool.
6. Record the mass of the boiling tube and the calcium carbonate.
7. Repeat steps 1-6 with copper(II) carbonate and sodium carbonate.

Analysis

1. Calculate the loss of mass for each carbonate. Use this to place the carbonates in order of thermal stability.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Copper(II) carbonate is an irritant	Transfer onto skin when using Transfer from hand into eye	Wash off/wear gloves Wear eye protection
Sodium carbonate is an irritant	Transfer onto skin when using Transfer from hand into eye	Wash off/wear gloves Wear eye protection
Hot apparatus/chemicals can burn	Burning skin when moving hot apparatus	Do not move apparatus until cool

Copper(II) carbonate - Refer to CLEAPSS hazcard 26B.

Sodium carbonate - Refer to CLEAPSS hazcard 95A.

Powders can be roughly pre-weighed (2 g) into weighing bottles or similar to save time. Alternatively, teacher can show that 2 g is roughly half a spatula.

Knowledge of the science behind thermal stability of carbonates is not required. Cement production can be used as a link to an every day application of this.

No repeats are given in the method, but can be done if time allows. Alternatively, students can compare results to discuss reproducibility.

Students should design their own table, but a suggested table format is shown below.

	Calcium carbonate	Copper(II) carbonate	Sodium carbonate
Mass of boiling tube (g)			
Mass of boiling tube + carbonate (g)			
Mass of carbonate (g)			
Mass of tube + contents after heating			
Mass of boiling tube (g)			
Mass of contents after heating (g)			
Loss of mass (g)			

Working scientifically skills covered

1. **Development of scientific thinking**
   Explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments.

2. **Experimental skills and strategies**
   Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

3. **Analysis and Evaluation**
   Carry out and representing mathematical analysis.

UNIT 2 – CHEMICAL BONDING, APPLICATION OF CHEMICAL REACTIONS and ORGANIC CHEMISTRY

2.1 BONDING, STRUCTURE AND PROPERTIES

Spec Statement		Comment
(a)	the properties of metals, ionic compounds, simple molecular covalent substances and giant covalent substances	Candidates should know the general properties of each of these substance types including, for example, qualitative descriptions of melting/boiling points, conductivity and solubility in water.
(b)	the 'sea' of electrons/lattice of positive ions structural model for metals in explaining their physical properties	Candidates should use this model to explain why, in general, metals have high melting/boiling points, are good conductors of heat and electricity and are malleable and ductile. **Higher tier candidates would also be expected to explain the trend in melting points of sodium, magnesium and aluminium, for example.**
(c)	electronic structure in explaining how ionic bonding takes place (and how this is represented using dot and cross diagrams)	Questions involving dot and cross diagrams are familiar to all and nothing new is expected here. It should be emphasised to candidates that the dot/cross notation should be used to ensure that it is completely clear which electrons have been transferred in forming ions and that no electrons should appear to be in two places at once.
(d)	the accepted structural model for giant ionic structures in explaining the physical properties of ionic compounds	Candidates should use this model to explain why ionic compounds have high melting/boiling points, are soluble in water and conduct electricity when dissolved or in molten form. **Higher tier candidates would also be expected to explain the difference in melting/boiling points of sodium chloride and magnesium oxide, for example, in terms of the greater charges giving rise to greater attraction/stronger ionic bonds.**
(e)	electronic structure in explaining how covalent bonds are formed (and how this is represented using dot and cross diagrams)	These too are familiar diagrams and the point regarding use of the dot/cross notation to show from which atom a given electron has come should again be emphasised. **Higher tier candidates would also be expected to draw diagrams for molecules that contain double or triple bonds.**
(f)	the intermolecular bonding structural model for simple molecular structures in explaining the physical properties of simple molecular substances	Candidates should use this model to explain why simple molecular substances have low melting/boiling points and do not conduct electricity, even in molten form.

(g)	the properties of diamond, graphite, fullerenes, carbon nano-tubes and graphene and how these are explained in terms of structure and bonding	Candidates should recognise each of these as giant structures containing covalent bonds. Candidates should recognise that the very high melting points of diamond and graphite are a result of the strong covalent bonding present. Their differing hardness, brittleness, lubricating and conducting properties are a result of each carbon atom in diamond being strongly bonded to four others whilst each one in graphite forms only three strong bonds. Candidates should explain these differences in terms of the graphite carbon atoms' fourth 'delocalised' or 'free' electron. Candidates should also know that fullerenes are cage structures made entirely of carbon atoms. Buckminsterfullerene is the most widely-known fullerene. Its molecules are spherical and contain 60 carbon atoms. Research into the use of fullerenes as drug delivery systems in the body, in lubricants and as catalysts is on-going. Candidates should know that carbon nano-tubes have important properties – conductors/semi-conductors, high strength but very low density – and explain these in terms of free electrons, bond strength. Carbon nano-tubes are made from single layers from a graphite structure, known as graphene layers, rolled into tubes. It should be noted that carbon nano-tubes have a much smaller scale structure than carbon fibres and are <u>not</u> what is used in the manufacture of bikes and tennis rackets. Graphene has been shown to be the strongest material ever tested and also the best electrical conductor but although claims have been made that it will transform technology in the future, there are as yet no commercially available 'graphene products'.
(h)	individual atoms not having the same properties as bulk materials as demonstrated by diamond, graphite, fullerenes, carbon nano-tubes and graphene having different properties despite all containing only carbon atoms, and by nano-scale silver particles exhibiting properties not seen in bulk silver	

(i)	the properties and uses of nano-scale particles of silver and titanium dioxide	Candidates should know that nano-sized silver particles are antibacterial, antiviral and antifungal and that they are used in plasters, antiseptic sprays, refrigerator linings, socks, deodorant sprays and so on. Nano-sized titanium dioxide particles are used in some sun screens as they absorb and reflect UV light but are also transparent so more appealing to consumers. Self-cleaning glass is coated with nano-scale titanium dioxide particles. These catalyse the breakdown of dirt in the presence of UV light and also cause water to spread out in a thin film, rather than forming droplets on the surface. The combined effort of sunshine and rainwater cleans the windows!
(j)	**the possible risks associated with the use of nano-scale particles of silver and titanium dioxide, and of potential future developments in nanoscience**	**Candidates should appreciate that nanomaterials currently used have been tested to ensure that they cause no damage to individuals or the environment, but that their long-term effects are as yet unknown. Some people have expressed concern that nano-scale silver (deodorants) and titanium dioxide (sun screens) are applied to the skin and can therefore be easily absorbed into the body. While it has been shown that these uses are safe in the short term, there is no certainty that exposure over many years will not result in problems.**
(k)	the properties and uses of smart materials including thermochromic pigments, photochromic pigments, polymer gels, shape memory alloys and shape memory polymers	Candidates must show an understanding that these materials have *properties that change* when a *change occurs in their environment* <u>and</u> that this change is *reversible*. They should know that the following smart materials change as follows. • Thermochromic pigments – change colour with changing temperature • Photochromic pigments – change colour with changing light intensity • Polymer gels e.g. hydrogels – absorb/expel water and swell/shrink (up to 1000 times their volume) due to changes in pH or temperature • Shape memory alloys – regain original shape when heated • Shape memory polymers – regain original shape when heated In relating the use of a smart material to its properties, the emphasis here should be the ability to identify situations where the properties of particular smart materials may be desirable, rather than the recall of a specific number of uses.

2.2 ACIDS, BASES AND SALTS

Spec Statement		Comment
(a)	substances as acidic, alkaline or neutral in terms of the pH scale, including acid/alkali strength	Candidates should understand that acids and alkalis can be classified as being either strong or weak and how universal indicator and the pH scale are used to for this purpose. They should recall the colours, approximate pH values and associated acid/alkali strength e.g. orange > pH ~3/4 > weak acid.
(b)	solutions of acids containing hydrogen ions and alkalis containing hydroxide ions	Candidates should know that acids are a source of H^+ ions whereas alkalis are a source of OH^- ions.
(c)	the reactions of dilute acids with metals and how these relate to the metals' position in the reactivity series	Candidates should know that when an acid reacts with a metal, a solution of the metal salt and hydrogen gas are produced. They should explain the reactions of metals with acids in terms of their position in the reactivity series, in relation to hydrogen. This section can be linked to topic 2.3(b) in which the reactivity series is used in relation to displacement reactions and metal extraction. Candidates should be able to describe in detail how crystals of soluble salts, such as zinc sulfate, can be prepared by the reaction of metals and acids. In common with all specified reactions, candidates should be able to name products and write word and balanced symbol equations describing those reactions.
(d)	the neutralisation of dilute acids with bases (including alkalis) and carbonates	Candidates should know that metal oxides and metal hydroxides are known as bases and that an alkali is a soluble base. They should know that the reactions of acids with bases always produce a metal salt and water and that acids and carbonates produce carbon dioxide gas in addition to a salt and water. They should know that neutralisation reactions are exothermic and that effervescence (fizzing) is observed when an acid reacts with a carbonate.
(e)	**neutralisation as the reaction of hydrogen ions with hydroxide ions to form water** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$	**Candidates should understand that neutralisation reactions can be summarised by this ionic equation.**

(f)	the acid/carbonate reaction as a test for acidic substances and CO_3^{2-} ions	Effervescence (fizzing) is observed when an acid reacts with a carbonate. Note that 'carbon dioxide formed' is <u>not</u> an observation.
(g)	the preparation of crystals of soluble salts, such as copper(II) sulfate, from insoluble bases and carbonates	Candidates should know the method used to prepare crystals of soluble salts from the reaction of acids with insoluble bases and carbonates: • excess base/carbonate to use up all acid; • filtration to remove excess base; • evaporation of water to form crystals. They should know that small crystals can be formed quickly by heating to evaporate until about ⅓ of the solution remains and leaving to cool. Allowing the filtered solution to evaporate slowly over a period of days results in the formation of larger crystals.
(h)	the names of the salts formed by hydrochloric acid, nitric acid and sulfuric acid	
(i)	the test used to identify SO_4^{2-} ions	White precipitate forms when barium chloride solution is added to a solution containing sulfate ions. The ionic equation is also required.
(j)	titration as a method to prepare solutions of soluble salts and to determine relative **and actual** concentrations of solutions of acids/alkalis	Candidates should know the method used to prepare crystals of soluble salts from the reaction of acids with alkalis: • indicator and fixed volume of acid/alkali in flask; • exact volume of alkali/acid needed for neutralisation is measured and recorded; • same fixed volume of acid/alkali in clean flask and exact volume of alkali/acid needed for neutralisation is added but with <u>no</u> indicator; • evaporation of water to form crystals. All candidates should be able to compare relative concentrations of acid/alkali on the basis that if, for example, 25cm^3 of NaOH requires 30cm^3 of HCl to neutralise it, the alkali must be of higher concentration than the acid. **Higher tier candidates should be able to use this method to determine actual concentrations of acids/alkalis from calculations. They should appreciate that titrations are repeated in order to establish accurate volumes required for neutralisation, when the data is used to calculate the concentration of one of the solutions.**

(k)	**the concentration of a solution in mol/dm^3**	**Candidates are required to recall the relationship between concentration, number of moles and volume and be able to use it appropriately.** **Following on from Unit 1, they should be able to interconvert number of moles and mass in grams and therefore express concentrations in g/dm^3 as well as mol/dm^3.**
(l)	**calculations involving neutralisation reactions in solution, using a balanced chemical equation**	**Candidates should be familiar with calculations relating to reactions with both 1:1 and 2:1 mole ratios.**
(m)	the distinction between the description of acids as dilute or concentrated (amount of substance) and strong or weak (degree of ionisation)	Candidates should know that any acid (or any solution) can be dilute or concentrated whilst any given acid is either strong or weak, e.g. hydrochloric acid is a strong acid (pH 1) and ethanoic acid is a weak acid (pH 3). They are not required to explain acid strength.
(n)	the similarities and differences in the reactions of strong and weak acids e.g. hydrochloric acid and ethanoic acid	Candidates should know that weak acids, such as ethanoic acid, react with metals, bases (including alkalis) and carbonates in the same way as strong acids but that the reactions occur more slowly and are less exothermic. They should know that ethanoic acid forms salts called ethanoates, e.g. sodium ethanoate is formed when it reacts with sodium hydroxide.
(o)	the preparation of insoluble salts by precipitation reactions	Candidates should be able to use given information to select appropriate soluble salts to form an insoluble salt. They should be able to describe the steps taken to prepare a clean, dry sample of that salt. Candidates should link this with their knowledge of ion tests and are expected to know that the silver halides and barium sulfate are insoluble. They are not required to recall general rules on the solubility of salts.

SPECIFIED PRACTICAL WORK

- Preparation of crystals of a soluble salt from an insoluble base or carbonate
- Titration of a strong acid against a strong base using an indicator

Preparation of crystals of a soluble salt from an insoluble base or carbonate

Introduction

In this experiment you will make crystals of copper sulfate. This can be done using either copper carbonate or copper oxide.

copper carbonate + sulfuric acid → copper sulfate + water + carbon dioxide

$$CuCO_3(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$$

copper oxide + sulfuric acid → copper sulfate + water

$$CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$$

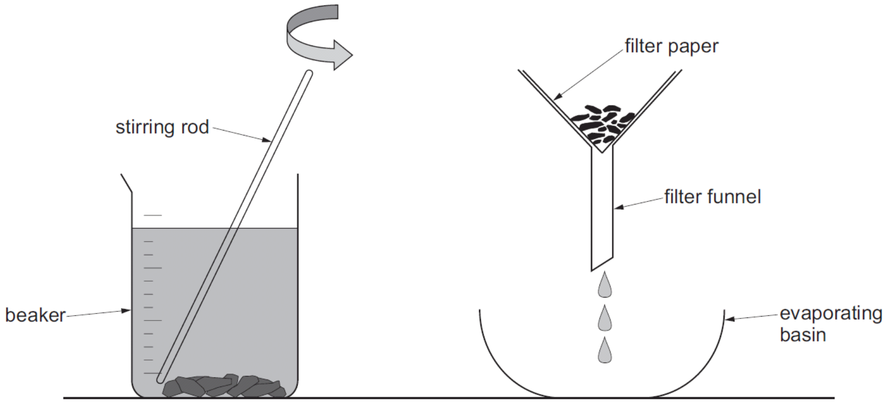
Apparatus

100 cm^3 beaker
stirring rod
filter funnel and paper
evaporating basin
50 cm^3 measuring cylinder
0.5 mol/dm^3 H_2SO_4
copper(II) oxide or copper carbonate
spatula
indicator paper

Access to:

electronic balance ± 0.1 g

Diagram of Apparatus



Method

1. Measure 50 cm^3 of sulfuric acid and pour into the beaker.
2. Measure approximately 4 g copper (II) oxide **or** 5 g copper(II) carbonate. (This does not need to be precise as the solid will be in excess.)
3. Add the solid to the acid and stir thoroughly.
4. To ensure all the acid has reacted, touch the glass rod onto a piece of indicator paper. If it is acidic continue stirring.
5. If the solution is neutral, pour the mixture into the filtration apparatus above the evaporating basin.
6. Allow to evaporate for several days until dry.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Sulfuric acid is an irritant	Splashing onto hand/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Copper sulfate is an irritant	Splashing onto hand/skin/you whilst pouring Transfer from hand into eye when pouring	Wash off/wear gloves Wear eye protection
Hot apparatus can burn	Contact with skin will cause burns when handling/touching/moving apparatus	Leave apparatus to cool before moving.

Reagents:

- Copper(II) oxide - Refer to CLEAPSS hazcard 26
- Copper(II) carbonate - Refer to CLEAPSS hazcard 26
- Sulfuric acid [0.5 mol/dm^3] - Refer to CLEAPSS hazcard 98A
- Copper sulfate solution - Refer to CLEAPSS hazcard 26

50 cm^3 of copper sulfate solution requires medium to large evaporating basins. Quantities can be reduced to suit available equipment. However it is vital that the solid is always in excess.

It can be emphasised that the reason for adding the insoluble base in excess is to ensure all of the acid has reacted and that a pure sample of the salt can thus be obtained.

At method point 6, it is possible to heat the evaporating basin to reduce the volume of copper sulfate solution by approximately a third using a Bunsen burner. This will reduce the time needed to reach dryness.

There is also scope for extension work – the mass of the base added could be weighed accurately and recorded. The mass of excess could then be obtained and thus the number of moles of copper sulfate produced could be calculated.

Working scientifically skills covered

2. **Experimental skills and strategies**
   Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.

   Apply a knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to the experiment.

   Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Titration of a strong acid against a strong base using an indicator

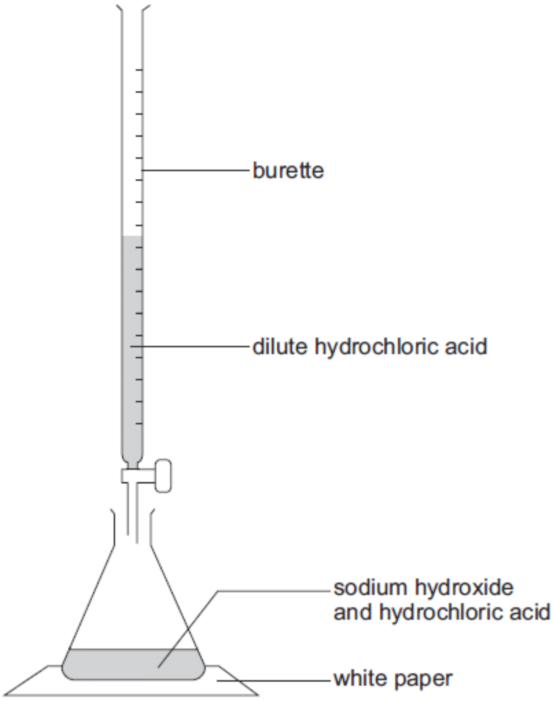
Introduction

In this experiment sodium hydroxide is neutralised with hydrochloric acid to produce the soluble salt, sodium chloride in solution. An indicator is used to show when neutralisation has occurred. The solution could then be concentrated and crystallised to produce sodium chloride crystals.

Apparatus

burette
measuring cylinder
100 cm^3 conical flask
small filter funnel
white paper
dilute sodium hydroxide
dilute hydrochloric acid
indicator
clamp stand, boss and clamp or burette stand

Diagram of Apparatus



Method

1. Use the small funnel to fill the burette with acid. Run a little acid out into a waste beaker to fill the part of the burette that is below the tap. Record the starting volume of acid in the burette.
2. Accurately measure 25 cm^3 of sodium hydroxide solution into a conical flask.
3. Add 2 drops of indicator.
4. Add 0.1 cm^3 of acid at a time, swirl the flask after each acid addition. Keep adding acid until the indicator changes colour. Record the final volume of acid in the burette.
5. Repeat steps 1-4 twice more.

Analysis

1. Calculate the volume of acid that was needed to neutralise the alkali in each repeat.
2. Calculate the mean volume of dilute hydrochloric acid needed to neutralise 25 cm^3 sodium hydroxide solution.
3. What do your results tell you about the concentration of the alkali?

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Dilute sodium hydroxide is an irritant	Sodium hydroxide spilling onto hands when filling burette or measuring volume of liquids	Wear gloves Wash hands immediately after contact with solutions
	Sodium hydroxide splashing into eyes when filling burette	Wear eye protection

Reagents:

- Hydrochloric acid – Refer to CLEAPSS hazcard 47A
- Sodium hydroxide – Refer to CLEAPSS hazcard 31

Sodium hydroxide and hydrochloric acid solutions do not need to be made up to a high degree of accuracy, but should be reasonably close to the same concentration and less than 0.5 mol/dm^3.

Burette stands and clamps are designed to prevent crushing of the burette by over-tightening, which may happen if standard jaw clamps are used.

A white tile can be used to go under the titration flask, instead of white paper.

Students need training in using burettes correctly, including how to clamp them securely and fill them safely. You should consider demonstrating burette technique, and give students the opportunity to practise this. Students do not need the acid volume to start on 0 in the burette, but must ensure that the reading is not above zero.

In this experiment a pipette is not essential and measuring cylinder is acceptable. However, a pipette and filler could be used to increase accuracy if desired.
There is an opportunity here with more able students to do quantitative measurements leading to calculations but the primary aim is to introduce students to the titration technique to produce a neutral solution.

Indicators you can use include screened methyl orange (green in alkali, violet in acid) and phenolphthalein (pink in alkali, colourless in acid).

At the end of the experiment the solution can be left to crystallise slowly in a warm room to produce large crystals or heated to half the volume of solution with a Bunsen burner and allowed to cool.

Students should design their own table, but a suggested table format is shown below.

	Trial			
	1	**2**	**3**	**Mean**
Final volume of acid in burette (cm^3)				
Initial volume of acid in burette (cm^3)				
Titre (volume added) (cm^3)				

Working scientifically skills covered

2. **Experimental skills and strategies**
   Apply a knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to the experiment.

   Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

   Make and record observations and measurements using a range of apparatus and methods.

3. **Analysis and Evaluation**
   Translate data from one form to another.

   Carry out and representing mathematical analysis.

4. **Scientific vocabulary, quantities, units, symbols and nomenclature**
   Use an appropriate number of significant figures in calculation.

2.3 METALS AND THEIR EXTRACTION

Spec Statement		Comment
(a)	ores found in the Earth's crust as the source of most metals and that these metals can be extracted using chemical reactions	Candidates should know that ores are minerals found in the Earth's crust and that they contain metal compounds, from which these metals can be extracted. They should be able to identify metals present in given ores from their chemical formulae.
(b)	some unreactive metals (e.g. gold) being found in their native form and that the difficulty involved in extracting metals increases as their reactivity increases	Gold and silver are examples of metals that are found native. Candidates should know that the most reactive metals are extracted by electrolysis while those towards the middle of the reactivity series can be chemically reduced. They may be required to use information such as, "X is more/less reactive than carbon…" to suggest a method of extraction for any metal. There is a link here with topic 2.2(c) where candidates may have to use information such as, "X is more/less reactive than hydrogen…" to suggest whether or not a metal will react with dilute acid. Candidates should have an awareness of the approximate position of common metals (and carbon and hydrogen) in the reactivity series but detailed recall is not required.
(c)	the relative reactivities of metals as demonstrated by displacement (e.g. iron nail in copper(II) chloride solution) and competition reactions (e.g. thermit reaction)	The emphasis is on the understanding of the processes and not on recall of colours of elements, compounds or solutions, although information of this nature these may be given in a question.
(d)	reduction and oxidation in terms of removal or gain of oxygen	Candidates should be able to recognise loss or gain of oxygen in any given reaction. They should be precise in their descriptions e.g. iron(III) oxide – not iron – is reduced in the blast furnace.

(e)	the industrial extraction of iron in the blast furnace, including the combustion, reduction, decomposition and neutralisation reactions	Candidates are expected to name each of the raw materials are added to the furnace and to explain why they are needed: • Iron ore – source of iron • Coke – as a fuel and to produce carbon monoxide for the reduction • Limestone – to remove impurities (slag formation when limestone breaks down and reacts with sand from the rocks) • Hot air – provides oxygen so that coke can burn Candidates should be able to write word and balanced symbol equations for the combustion of carbon, reduction of iron(III) oxide by carbon monoxide, decomposition of calcium carbonate and the neutralisation reaction between calcium oxide and silicon dioxide. Candidates should have an understanding that the process is continuous with new raw materials added and products removed all the time due to the time and cost associated with getting the furnace up to temperature.
(f)	electrolysis of molten ionic compounds e.g. lead(II) bromide (including electrode equations)	Candidates should know that for electrolysis to proceed, compounds must be melted to release their ions. They should explain electrolysis in terms of positive ions moving towards the cathode where they gain electrons (are reduced) and negative ions moving towards the anode where they lose electrons (are oxidised). Candidates should be able to write balanced equations for the processes taking place at the electrodes.
(g)	reduction and oxidation in terms of gain or loss of electrons	Candidates should be able to recognise gain or loss of electrons in any given reaction e.g. Pb^{2+} ions are reduced during the electrolysis of lead(II) bromide because they gain electrons to form Pb atoms; Br^- ions are oxidised because they lose electrons. Defining reduction and oxidation in terms of electrons is useful when reactions do not involve oxygen.

(h)	the industrial extraction of aluminium using electrolysis, including the use of cryolite to dissolve alumina	Candidates should know that alumina (aluminium oxide) dissolves in molten cryolite at a temperature much lower than its melting point, therefore saving energy. They should be able to write balanced equations for the processes occurring at the cathode and the anode. $Al^{3+} + 3e^- \rightarrow Al$ $2O^{2-} \rightarrow O_2 + 4e^-$ They should also understand that the oxygen formed reacts with the carbon anodes, forming carbon dioxide gas and requiring these to be replaced frequently.
(i)	the properties and uses of iron (steel), aluminium, copper and titanium	Candidates are expected to recall some common uses of steel, aluminium, copper and titanium and explain these uses in terms of the following properties: • steel – hard, strong • aluminium – strong, low density, good conductor of heat and electricity, resistant to corrosion • copper – very good conductor of heat and electricity, malleable and ductile, attractive colour and lustre • titanium – hard, strong, low density, resistant to corrosion, high melting point.
(j)	the general properties of transition metals, including their ability to form ions with different charges	Candidates should know that the transition metals are found in the centre of the Periodic Table and that they display the typical metallic properties of high melting and boiling points, malleability, high density, good electrical and thermal conductivity. They have a number of other properties. Many transition metals are useful catalysts (e.g. iron in the manufacture of ammonia, platinum in catalytic converters). They can form more than one type of ion e.g. Fe^{2+}/Fe^{3+} and their compounds are often coloured. **Higher tier candidates should know the characteristic colours of compounds/solutions containing the following ions:** **Fe^{2+} – pale green** **Fe^{3+} – brown** **Cu^{2+} – blue**

(k)	**the identification of Cu^{2+}, Fe^{2+} and Fe^{3+} ions by their precipitation reactions with aqueous OH^-**	**Candidates should know the colours of each of these hydroxide precipitates. They should recognise 'spectator ions' and be able to write ionic equations e.g.** **$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$** **Candidates will only be expected to include state symbols when specifically asked to do so.**
(l)	an alloy being a mixture made by mixing molten metals, whose properties can be modified by changing its composition	Candidates should know that steel is much harder and stronger than iron and is therefore more useful. Different types of steel are made by varying the carbon content and by adding other metals but candidates are not required to recall the names, compositions or properties of any other alloys.
(m)	the electrolysis of water (including electrode equations)	Candidates should know that hydrogen gas is collected at the cathode while oxygen gas is collected at the anode and be able to explain why the volume of hydrogen formed is twice that of oxygen. Candidates should be able to write a balanced equation to show the reaction taking place at the cathode **and higher tier candidates should be able to balance the equation (atoms and charges) for the reaction taking place at the anode. They are not required to recall this equation.** $2H^+ + 2e^- \rightarrow H_2$ **$2OH^- \rightarrow O_2 + 2H^+ + 4e^-$**
(n)	electrolysis of aqueous solutions such as copper(II) chloride (including electrode equations)	Candidates should know that there are H^+ and OH^- ions present in an aqueous solution as well as the ions from the dissolved salt. They should know that metals lower in the reactivity series than hydrogen are formed at the cathode. In the case of copper(II) chloride solution, the products are copper metal and chlorine gas. Candidates should be able to write balanced equations for the processes occurring at the cathode and the anode e.g. $Cu^{2+} + 2e^- \rightarrow Cu$ $2Cl^- \rightarrow Cl_2 + 2e^-$

(o)	**electrolysis of aqueous solutions involving competing ions such as sodium chloride (including electrode equations)**	**Candidates should know that when the dissolved salt contains ions of metals higher in the reactivity series than hydrogen, it is hydrogen gas rather than the metal that forms at the cathode.** **Candidates should be able to write balanced equations for the processes occurring at the cathode and the anode e.g. in the case of sodium chloride solution** $2H^+ + 2e^- \rightarrow H_2$ $2Cl^- \rightarrow Cl_2 + 2e^-$ **Candidates are not required to consider the products formed at the anode on electrolysis of sulfate or nitrate solutions.**
(p)	the use of electrolysis in electroplating, **purification of copper and the manufacture of sodium hydroxide (and hydrogen gas and chlorine gas)**	Candidates should be able to describe the use of electrolysis in electroplating and explain using electrode equations. **Higher tier candidates should be able to describe and explain the purification of copper (using an active electrode) and the manufacture of sodium hydroxide, hydrogen and chlorine. They should be able to write all relevant electrode equations. Details of membrane cells are not required.**

(q)	factors affecting economic viability and sustainability of extraction processes e.g. siting of plants, fuel and energy costs, greenhouse emissions and recycling	Candidates should be aware that the primary reason for siting plants near to the coast is for the importing of raw materials and <u>not</u> the export of products. Other factors that affect the siting of plants include: • A site away from built up areas; • A town or city within commuting distance to accommodate the workforce; • Good transport links for transporting the product to buyers; • A direct electricity supply (a power station close by) in the case of aluminium. The energy costs associated with aluminium production are very high and when Wylfa Power Station was decommissioned, Anglesey Aluminium closed. When it was running the plant accounted for around 10-15% of all the electricity used in Wales. Without a power station close by, guaranteeing the direct supply of electricity, this became unsustainable and the plant closed. Candidates should be aware that although all the raw materials for iron extraction can be found in Wales and that Wales has a long history of iron and steel production, the plant at Port Talbot imports iron ore, coal to make coke and limestone from other countries. Using raw materials from Wales is not sustainable on an economic (cost) or environmental (quarrying) basis. Candidates should appreciate that recycling metals is more sustainable as it conserves the raw materials and uses much less energy. Recycling aluminium requires approximately 5% of the energy used to extract the metal from bauxite. The reduction in energy for recycling means that less electricity is needed and so there are smaller associated greenhouse emissions.

SPECIFIED PRACTICAL WORK

- Determination of relative reactivities of metals through displacement reactions
- Investigation into electrolysis of aqueous solutions and electroplating

Determination of relative reactivities of metals through displacement reactions

Introduction

Some metals are more reactive than others. In this experiment, a piece of metal is added to a solution of a compound of another metal. A more reactive metal displaces a less reactive metal from its compound. By carrying out this experiment, you will be investigating the competition reactions of metals and produce a reactivity series of the metals.

Apparatus

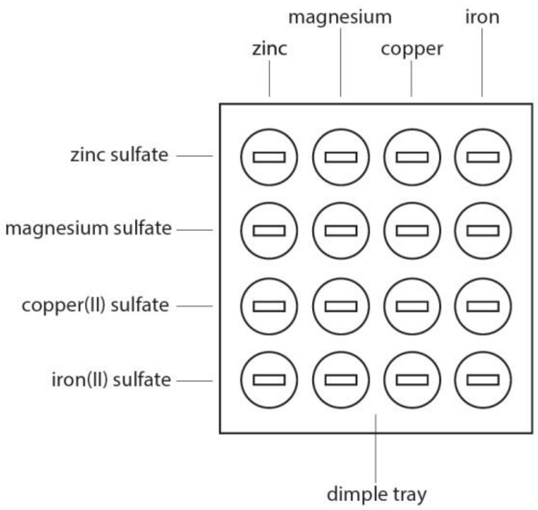
dimple tray
100 cm^3 beaker
4 × dropping pipettes
5 cm^3 of each of the following at 0.1 mol/dm^3

- zinc sulfate
- magnesium sulfate
- copper(II) sulfate
- iron(II) sulfate

Approximately 1 cm length/square sample of the following metals.

- zinc
- magnesium
- copper
- iron

Diagram of Apparatus



Method

1. Using a dropping pipette, put a little zinc sulfate in four of the depressions of the dropping tile. Do this for each solution in turn. Do not overfill dimples.
2. Put a piece of metal in each of the solutions, using the apparatus diagram as a guide.
3. Observe and record the changes in the solutions or metal samples.

Analysis

1. Use your results to construct a reactivity series for the metals used. Write equations for any reactions that occurred.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Zinc and copper sulfate are irritants	Splashing onto hands/skin/you whilst pouring Transfer from hands into eye	Wear eye protection Wash hands when solutions spilt on to hands

Reagents

- Zinc sulfate - Refer to CLEAPSS hazcard 108
- Magnesium sulfate - Refer to CLEAPSS hazcard 59B
- Copper(II) sulfate - Refer to CLEAPSS hazcard 27B
- Iron(II) sulfate - Refer to CLEAPSS hazcard 38
- Zinc foil - Refer to CLEAPSS hazcard 107
- Magnesium ribbon - Refer to CLEAPSS hazcard 59A
- Copper foil - Refer to CLEAPSS hazcard 26
- Iron(II) sulfate - Refer to CLEAPSS hazcard 38

Solutions may be dispensed in small beakers to each group of students or in small dropper bottles.

Students may need two dimple trays per group, if trays do not contain 16 dimples.

Metals should be approximately 1cm lengths/squares of ribbon or foil cleaned with an emery cloth and as similar in size as possible.

Students will need to record which metals react with the solutions. A table may be useful. Use a ✓ to show reactivity and a ✗ to show no reaction. The metals with the most ticks are the most reactive.

Students should design their own table, but a suggested table format is shown below.

	Zinc	**Magnesium**	**Copper**	**Iron**
Zinc sulfate				
Magnesium sulfate				
Copper(II) sulfate				
Iron(II) sulfate				

You can point out to students that there is no need to carry out the zinc/zinc sulfate, magnesium/magnesium sulfate reactions, etc or allow them to decide for themselves if these reactions are likely to lead to a positive result.

Remind students that they are looking for metal displacement, some solutions are slightly acidic so bubbles of hydrogen can be seen. Explain that this doesn't count as displacement. Students may need to be given guidance of the sort of observations they may expect to see.

It may be best to get the class to tell you what they think the order of reactivity is while they still have the evidence in front of them, so that discrepancies can be resolved.

There are many ways of carrying out this series of reactions. The one described here uses a dimple tray, but it can be adapted with test tubes. The advantages of the dimple tray are the small amounts of chemical involved and the way the results are displayed.

Working scientifically skills covered

2. **Experimental skills and strategies**
   Make and record observations and measurements using a range of apparatus and methods.

3. **Analysis and Evaluation**
   Present observations and other data using appropriate methods.

   Interpret observations and other data including identifying patterns and trends, making inferences and drawing conclusions.

Investigation into electrolysis of aqueous solutions and electroplating

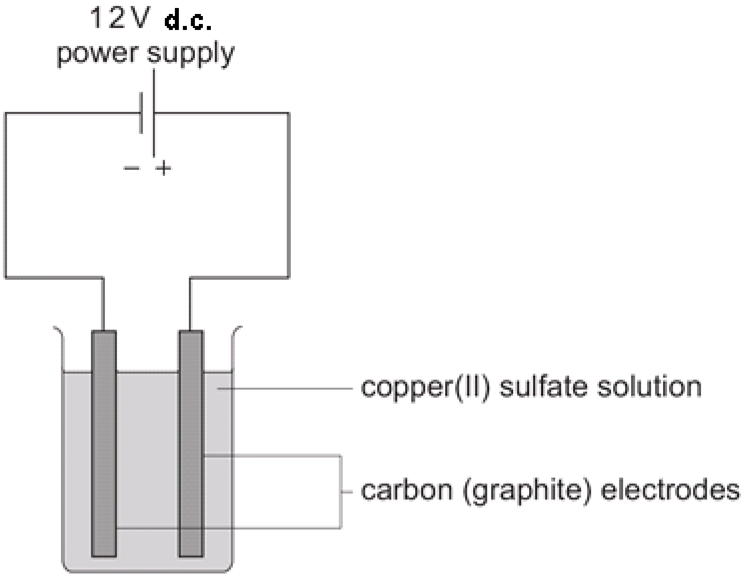
Introduction

In this experiment you will carry out the electrolysis of copper(II) sulfate solution and link your findings to industrial copper purification and copper plating.

Apparatus

250 cm^3 beaker
2 × graphite electrodes (about 5 mm diameter)
clamp stand, boss and clamp
12 V d.c. power supply
leads and crocodile clips
200 cm^3 copper(II) sulfate, about 0.5 mol/dm^3

Diagram of Apparatus



Method

1. Measure 200 cm^3 of copper(II) sulfate into the beaker.
2. Set up the apparatus as in the diagram.
3. Switch on the power supply.
4. After 2 minutes record any observations seen at the electrodes.

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Copper(II) sulfate is an irritant	Splashing onto hand/skin/you whilst pouring Transfer from hands into eye	Wash hands if copper(II) sulfate spilt on them Wear eye protection

- Copper sulfate solution - Refer to CLEAPSS hazcard 26

There are several ways of securing the graphite electrodes. Using a clamp stand and clamp is probably the most convenient. They can also be fixed on to a small strip of wood or cardboard resting on the top of the beaker.

A lamp can be included in the circuit to indicate that there is a flow of current.

As an extension to the basic experiment, strips of copper can be used in place of the graphite rods.

After setting up the cell as shown students can observe changes to each of the electrodes. They should see a deposit of copper forming on the cathode. This will often be powdery and uneven. It can be explained that, if the current used is much lower, then the solid coating is shiny, impermeable and very difficult to rub off; this process forms the basis of electroplating.

Bubbles of gas (oxygen) are formed at the anode.

Cathode $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

Anode $2H_2O(l) \longrightarrow O_2(g) + 4H^+(aq) + 4e^-$

With copper electrodes, the copper anode dissolves. The reaction is the reverse of the cathode reactions.

With graphite electrodes, the oxygen usually reacts with the anode to form CO_2.

The results can lead to a discussion about electroplating and the electrolytic purification of copper. It is useful to allow students to copperplate metal objects supplied by the school and previously tested for their suitability. Personal items should not be used. In many cases, an alternative redox reaction often takes place before any current is actually passed.

After doing the electrolysis as described above, the electrodes can be interchanged. Students can then see the copper disappearing from the surface of the copper-coated anode

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

This leads to a discussion as to why, during electrolysis the:

- anode consists of an unrefined sample of the metal.
- cathode is made of pure copper or a support metal such as stainless steel.

Working scientifically skills covered

1. **Development of scientific thinking**
   Explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments.

2. **Experimental skills and strategies**
   Make and record observations and measurements using a range of apparatus and methods.

2.4 CHEMICAL REACTIONS AND ENERGY

Spec Statement		Comment
(a)	exothermic and endothermic reactions in terms of temperature change and energy transfer to or from the surroundings	Candidates should know that in an exothermic reaction energy is transferred to the surroundings, resulting in a temperature increase. Similarly, they should know that in an endothermic reaction energy is taken in from the surroundings, resulting in a temperature decrease. The emphasis here should be on interpretation of experimental data to identify exothermic and endothermic reactions. There is no requirement for candidates to recall examples of endothermic reactions but they do need to know that combustion and neutralisation reactions are exothermic.
(b)	energy profiles for exothermic and endothermic reactions	Candidates should be able to sketch energy profile diagrams for exothermic and endothermic reactions, labelling the reactants, products, activation energy and the overall energy change.
(c)	the activation energy as the energy needed for a reaction to occur	Candidates should know that this is the minimum amount of energy required to start a reaction.
(d)	the use of bond energy data to calculate overall energy change for a reaction and to identify whether it is exothermic or endothermic	Candidates should be able to calculate the total amount of energy required to break bonds and the total amount released in forming bonds during a given reaction, and use those values to find the overall energy change for the reaction. They should explain that a reaction is exothermic because more energy is released in forming bonds than is required to break bonds, rather than by stating simply that the overall energy change has a negative value. **Higher tier candidates should also be able to apply their understanding to more complex questions, e.g. where the given data is used to calculate a bond energy value.**

2.5 CRUDE OIL, FUELS AND ORGANIC CHEMISTRY

Spec Statement		Comment
(a)	crude oil as a complex mixture of hydrocarbons that was formed over millions of years from the remains of simple marine organisms	Candidates should know that hydrocarbons are compounds that contain carbon and hydrogen only. They should understand that carbon atoms have the ability to form bonds with other carbon atoms resulting in the formation of chains of carbon. Crude oil consists of dozens of hydrocarbons with carbon chains of varying lengths.
(b)	the fractional distillation of crude oil	Candidates should know that crude oil is boiled/vaporised before it enters the fractionating column and that the hydrocarbons present condense at different heights in the column. The lower the boiling point, the higher in the column a compound is collected.
(c)	fractions as containing mixtures of hydrocarbons (alkanes) with similar boiling points	Candidates should know that fractions are mixtures containing hydrocarbon compounds that have similar boiling points and that these have similar chain lengths. They are not expected to recall details such as the range of chain lengths present in the constituent hydrocarbons of different fractions but they should know the uses of the following fractions: petroleum gases; gasoline/petrol; naphtha; kerosene; diesel; lubricating oil; fuel oil; bitumen.
(d)	the trends in properties of fractions with increasing chain length and the effect on their usefulness as fuels	Candidates should know that the longer the chain lengths of the hydrocarbons present in a fraction, the higher its boiling point. They should also recall the effect of chain length on different fractions' colour (colourless – yellow – brown), viscosity, ease of ignition and cleanliness of burn.

(e)	the global economic and political importance and social and environmental impact of the oil industry	Candidates should know that decisions made about the use of crude oil impact on all aspects of life, and all over the world. They should know that burning fuels causes global warming and acid rain, which of course don't only affect the countries using the energy. Rapidly growing economies in China and India will consume greater amounts of energy year on year and supplying that energy using crude oil is not sustainable in the long term. Growing demand drives prices upwards, affecting individuals' heating and travel costs but also indirectly causing inflation e.g. in food prices. Candidates should also consider that many important products (e.g. plastics, medicines) are made using components of crude oil and that people will eventually have to decide between burning the remaining reserves of oil and using it for other purposes.
(f)	the combustion reactions of hydrocarbons and other fuels	Candidates should know that the combustion of any fuel requires oxygen (from the air) and that burning hydrocarbons produces carbon dioxide and water. All combustion reactions are exothermic.
(g)	how to determine experimentally the energy per gram released by a burning fuel	Candidates should be able to describe the steps of a simple experiment to determine the amount of energy released by a fuel. They are not required to recall the equation used in the subsequent calculations but they should be able to calculate values from given data.
(h)	the combustion reaction of hydrogen and its use as an energy source including its advantages and disadvantages as a fuel	Candidates should know that when hydrogen burns, it forms water only. Candidates should know that hydrogen is used as a rocket fuel and in hydrogen fuel cells that are now being utilised to power cars. It is expected that candidates are able to discuss the advantages and disadvantages of its use as a fuel. • Advantages – produced from water therefore renewable and water is the only product of its combustion so burning hydrogen does not contribute towards global warming or acid rain. • Disadvantages – requires large amounts of electricity to produce hydrogen from water by electrolysis (how is this generated?), storage requires bulky and heavy pressurised containers and is potentially hazardous as it forms an explosive mixture with air.

(i)	the fire triangle in fire-fighting and fire prevention	Candidates should understand the fire triangle and how it is used in fire prevention and fire-fighting. They should be able to suggest methods to prevent and extinguish fires in a range of situations and explain their reasoning.
(j)	the cracking of some fractions to produce smaller and more useful hydrocarbon molecules, including monomers (alkenes) which can be used to make plastics	Candidates should know that the cracking process involves heating fractions obtained from crude oil to a high temperature in the presence of a catalyst. This causes the hydrocarbon molecules present to decompose forming smaller molecules, including an alkene. There is greater demand for the smaller hydrocarbons, and alkenes such as ethene, are the starting material for the production of many plastics.
(k)	the general formula C_nH_{2n+2} for alkanes and C_nH_{2n} for alkenes	Candidates should be able to apply their understanding of these formulae to identify unfamiliar formulae as those of alkanes or alkenes and to write molecular formulae for compounds containing any given number of carbon atoms
(l)	the names and molecular and structural formulae for simple alkanes and alkenes	Candidates should know that carbon atoms must always have four bonds. Alkanes contain single bonds between the carbon atoms only and are said to be <u>saturated</u>. The alkenes contain a double covalent bond between two carbon atoms and are said to be <u>unsaturated</u>. Candidates are expected to recall the names and molecular and structural formulae of the alkanes methane, ethane, propane, butane and pentane, and the alkenes ethene and propene.
(m)	**isomerism in more complex alkanes and alkenes**	**Candidates should be able to identify isomers from the structural formulae of given hydrocarbons and draw true isomers of a given molecular formula. They should be able to draw structural formulae for all isomers of C_4H_{10} and C_5H_{12}. They should know how carbon atoms in the longest chain are numbered and therefore draw structural formulae for but-1-ene and but-2-ene (names required). They do not need to know about E-Z isomers of but-2-ene but they should know that propene with a methyl group attached to the second carbon atom is a third isomer with the molecular formula C_4H_8.** **Candidates will not be required to use or interpret skeletal formulae.**

(n)	**the names of more complex alkanes and alkenes**	**Candidates should be able to name isomers with a maximum of one alkyl side-chain (methyl or ethyl) on the longest chain of carbon atoms. This includes alkenes e.g. 2-methylbut-1-ene. They should also be able to draw the structural formula of any such isomer from a given name.**
(o)	the addition reactions of alkenes with hydrogen and bromine and the use of bromine water in testing for alkenes	Candidates should know that these reactions involve addition of two atoms across the C=C bond in an unsaturated compound thus forming a saturated compound. They should know that one atom is added to each of the carbon atoms involved. Candidates should know that addition of hydrogen forms an alkane and that addition of bromine forms a colourless 'bromoalkane'. They will not be required to name the bromoalkane. Bromine water is used in the test for alkenes as it is safer and easier to handle than bromine. It turns from orange/brown to colourless when added to an alkene. Candidates should be able to represent these reactions using structural formulae in balanced equations.
(p)	the addition polymerisation of ethene and other monomers to produce polythene, poly(propene), poly(vinylchloride) and poly(tetrafluoroethene)	Candidates should know that monomers are small, reactive molecules that can be joined together to make a polymer. They should know that this process is called polymerisation. They should understand that the reactivity of a monomer arises from the presence of its double bond, and that as polymerisation happens one of the bonds breaks to allow the molecule to join to another. Candidates should be able to draw the structural formulae of the ethene, propene, vinylchloride and tetrafluoroethene monomers and describe the reactions forming their respective polymers in the form of an equation using ‘n’ monomer molecules.

(q)	the general properties of plastics and the uses of polythene, poly(propene), poly(vinylchloride) and poly(tetrafluoroethene)	Candidates should know that plastics are generally flexible, strong, good thermal and electrical insulators, resistant to corrosion, have low density and do not rot. They should be able to select suitable plastics for specific uses, given their properties, and to evaluate their usefulness when compared with traditional materials. Candidates are required to recall the following uses of the named plastics and to link them to their properties: • polythene – bags, plastic bottles • poly(propene) – ropes, crates • poly(vinylchloride) – drain pipes, window frames • poly(tetrafluoroethene) – non-stick pans
(r)	the environmental issues relating to the disposal of plastics, in terms of their non-biodegradability, increasing pressure on landfill for waste disposal, and how recycling addresses these issues as well as the need to carefully manage the use of finite natural resources such as crude oil	Candidates should understand that disposing of plastics in landfill is not desirable because these sites are rapidly being filled and any plastic items will not decompose for hundreds of years. They should also be able to explain that burning plastics is not a particularly good solution to the problem because of the carbon dioxide gas and various toxic fumes they release when they burn. Candidates should appreciate that recycling waste plastic reduces the amount of waste either ending up in landfill or being burned. Equally important are the benefits of conserving crude oil reserves and, because recycling uses less energy than production, reducing fossil fuel use.
(s)	how ethanol (an alcohol) is made from sugars by fermentation using yeast	Candidates should know that yeast contains an enzyme which breaks down sugar, making ethanol and carbon dioxide. They should be able to represent the fermentation reaction using word and balanced symbol equations. They should know the conditions used in the process and that fermentation products are distilled in the alcoholic drinks industry to produce spirits, such as whisky. Candidates should know that more efficient methods have been developed to produce ethanol for industrial uses.
(t)	the use of potassium dichromate(VI) in testing for alcohols	Candidates should know that acidified potassium dichromate(VI) solution changes from orange to green in the presence of an alcohol. This is an unpleasant reagent to use and it is suggested that this test should be demonstrated by the teacher. Candidates should know that this reaction was the basis of a previously-used breathalyser test.

(u)	the use of ethanol in alcoholic drinks and the social and economic impact of these drinks	Candidates should show an awareness of the social and health problems associated with ‘binge drinking’ and misuse of alcohol over a long period. They should know that advice regarding 'healthy' limits has recently changed and that the recommended maximum number of units of alcohol that should be consumed per week was reduced to 14 for men and women. They should recognise that tax raised from the sale of alcoholic drinks generates significant revenue for the government. On the other hand a significant amount of public money is spent each year in treating alcohol-related illnesses and in dealing with various other issues resulting from alcohol abuse.
(v)	the uses of ethanol as a solvent and as a fuel and the social, economic and environmental factors that affect the development of bioethanol fuel	Candidates should know that ethanol is a solvent which dissolves many substances, including some that are insoluble in water. Candidates should know that bioethanol is produced from plants such as sugar cane in some countries. They should be know the benefits of bioethanol as an alternative fuel, e.g. renewability and carbon-neutrality, but also recognise drawbacks such as decreasing the amount of land available to grow food crops and dependency on climate for sugar growth.
(w)	the names and molecular and structural formulae for alcohols, **including positional isomers**	Candidates should know that alcohols have the general formula $C_nH_{(2n+1)}OH$ and that the names of methanol, ethanol, propanol, butanol and pentanol are derived from the names of the corresponding alkanes. They should recognise the —OH group as a functional group. They should be able to draw structural formulae for alcohols but foundation tier candidates are not required to consider the position of the —OH group on the carbon chain. **Higher tier candidates must be familiar with the concept of positional isomerism and therefore differentiate, for example, between butan-1-ol and butan-2-ol. They should be able to name the various isomers, including examples with a maximum of one alkyl side-chain (methyl or ethyl) on the longest chain of carbon atoms e.g.** **2-methylbutan-1-ol.**

(x)	the microbial oxidation of ethanol to ethanoic acid (a carboxylic acid)	Candidates should understand that this reaction occurs slowly and leads to beer and wine ‘going off’ once left exposed to the air for a period of a few days. They should know that ethanoic acid belongs to an homologous series called carboxylic acids. Candidates should understand that other alcohols can also be oxidised, e.g. propanol to propanoic acid. **Candidates should know that oxidation results in a formula containing a greater proportion of oxygen and a lower proportion of hydrogen as demonstrated by ethanol, C_2H_5OH, and ethanoic acid, CH_3COOH.**
(y)	**the use of infrared spectroscopy to identify the presence of certain bonds in organic molecules thereby indicating whether they may be alkanes, alkenes, alcohols or carboxylic acids**	**Candidates are <u>not</u> expected to know the theory of infrared spectroscopy.**

SPECIFIED PRACTICAL WORK

- Determination of the amount of energy released by a fuel

Determination of the amount of energy released by a fuel

Introduction

Fuels react with oxygen when they burn, releasing energy. You will burn four different alcohols and compare the energy they give off.

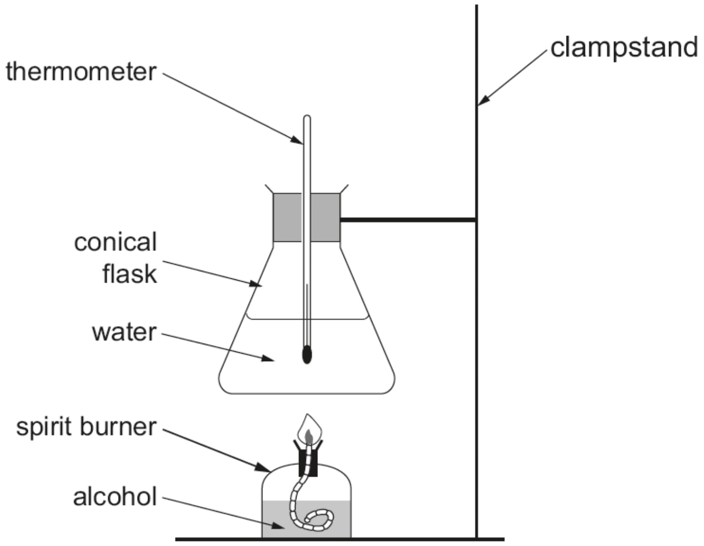
Alcohol + oxygen $\longrightarrow$ carbon dioxide + water

Apparatus

clamp stand, clamp and boss
250 cm^3 conical flask
100 cm^3 measuring cylinder
thermometer

Access to:
electronic balance ± 0.01 g
4 × spirit burners containing methanol, ethanol, propanol, butanol

Diagram of Apparatus



Method

1. Measure 100 cm^3 of water into the conical flask.
2. Clamp the flask at a suitable height so the spirit burner can be placed below it (as shown in the diagram - make sure that the thermometer does not touch the bottom of the flask).
3. Record the temperature of the water.
4. Record the mass of the spirit burner (including the lid and alcohol).
5. Place the spirit burner under the conical flask and light it.
6. Allow the burner to heat the water until the temperature rises by about 40 °C. Record the temperature of the water.
7. Extinguish the flame carefully and record the mass of the burner.
8. Repeat steps 1-7 with each of the other alcohols.

Analysis

1. Calculate the temperature rise for each fuel.
2. Calculate the mass of each alcohol burnt.
3. Calculate the energy released for each alcohol using the following equation.

4. Calculate the energy released for each alcohol using the following equation:

$$\text{Energy released from alcohol per gram (J)} = \frac{\text{mass of water (g)} \times \text{temperature increase (°C)} \times 4.2}{\text{mass of alcohol (g)}}$$

Teacher / Technician notes

Risk Assessment

Hazard	Risk	Control measure
Alcohols are highly flammable	Alcohol could ignite if left near a naked flame	Ensure spirit burners are kept away from lit Bunsen burners
The hot flask could burn/hot water could scald	Burning could result if hot beaker handled Scalding could result if hot water spilled on skin	Allow hot beaker to cool before disassembling the apparatus.

Methanol - Refer to CLEAPSS hazcard 40B

Ethanol - Refer to CLEAPSS hazcard 40A

Propanol - Refer to CLEAPSS hazcard 84A

Butanol - Refer to CLEAPSS hazcard 84B

Pentanol should not be used as a fume cupboard is needed - Refer to CLEAPSS hazcard 84C.

Spirit burners should not be used for more than one alcohol. Make sure that the wick fits tightly in the holder and the holder sits tightly in the container.

Students should not fill or refill spirit burners.

An extension activity could be to plot a graph of the number of carbon atoms in the alcohol against the energy released per gram.

No repeats are planned in this experiment, but can be carried out if time allows. Alternatively, groups can compare results to discuss reproducibility.

Students should design their own table, but a suggested table format is shown below.

Alcohol	Initial mass of burner (g)	Final mass of burner (g)	Change in mass of burner (g)	Initial temperature (ºC)	Final temperature (ºC)	Temperature increase (ºC)	Energy released per gram (J)

Working scientifically skills covered

1. **Development of scientific thinking**
   Explain every day and technological applications of science: evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments.

2. **Experimental skills and strategies**
   Carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

   Evaluate methods and suggest possible improvements and further investigations.

3. **Analysis and Evaluation**
   Carrying out and representing mathematical analysis

   Evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.

4. **Scientific vocabulary, quantities, units, symbols and nomenclature**

   Use SI units and IUOAC chemical nomenclature unless inappropriate

2.6 REVERSIBLE REACTIONS, INDUSTRIAL PROCESSES AND IMPORTANT CHEMICALS

	Spec Statement	Comment
(a)	what is meant by a reversible reaction	Candidates should know that a reversible reaction is a reaction that can go in either direction. They should use the ⇌ symbol in an equation representing a reversible reaction. Candidates should know that the reaction conditions determine whether a reversible reaction goes in the forward or the backward direction. They should understand that if the forward reaction is exothermic, the backward reaction is endothermic and that the same amount of heat is transferred in both directions.
(b)	the production of ammonia by the reversible reaction of nitrogen and hydrogen in the Haber process	Candidates should know that nitrogen gas for the process is obtained from the air and that hydrogen is usually made from methane. Candidates should recall the basic reaction conditions used in the Haber process – temperature in the range 350-450°C, pressure in the range 150-200 atmospheres and iron catalyst. They should be able to write word and balanced symbol equations for the reaction taking place.
(c)	**the factors involved in choosing conditions to ensure the most economical production of ammonia (Le Chatelier's principle not required)**	**Candiates are not required to be familiar with Le Chatelier's principle. They should know that a higher yield of ammonia would be achieved at a lower temperature and be able to explain why a moderately high temperature is chosen. They should also explain why a higher pressure is not chosen although that would give a higher yield. The conditions chosen are those that allow the production of the greatest amount of ammonia per day/week/month, which is subtly different to what we understand by 'yield'.** **Candidates should also know that the iron catalyst, like all catalysts, is poisoned over time and needs replacing. They should appreciate that a low yield (in the range 15-40%) can be tolerated because the unreacted nitrogen and hydrogen gases are recycled through the system.**
(d)	the test used to identify ammonia gas	Candidates should know that damp red litmus paper turns blue in the presence of ammonia gas. They are <u>not</u> required to know the hydrogen chloride gas test. (Please note that the pungent smell of ammonia gas is <u>not</u> a chemical test.)

(e)	the production of sulfuric acid by the contact process; a three-stage process including the reversible formation of sulfur trioxide	Candidates should recall the basic details of the three-stage process to form sulfuric acid, including the conditions chosen for the reversible second stage and the reason for the absorption of sulfur trioxide in concentrated sulfuric acid. They should be able to write word and balanced symbol equations for each stage of the process. **Higher tier candidates should be able to explain the choice of temperature and pressure for the reversible second stage.**
(f)	the broad range of uses of sulfuric acid, including in the production of fertilisers, paints, dyes, fibres, plastics and detergents	
(g)	concentrated sulfuric acid as a dehydrating agent in its reaction with sugar and hydrated copper(II) sulfate	Candidates should know that dehydration involves the removal of water of crystallisation (from hydrated copper(II) sulfate) or the 'elements of water' (from sugar). Candidates should recall the observations made during these reactions but equations are not required.
(h)	the production of nitrogenous fertilisers such as ammonium sulfate and ammonium nitrate by neutralisation of ammonia solution	Candidates should know that ammonia is an alkali and that it will therefore neutralise acids to form ammonium salts. This section links with salt formation in topic 2.2(j).
(i)	the identification of NH_4^+ ions by addition of aqueous OH^-	Candidates should know that ammonium ions can be identified by adding sodium hydroxide solution and warming gently to release ammonia gas (which turns damp red litmus paper turns blue).
(j)	the benefits of nitrogenous fertilisers for crop growth and the problems that arise when they are washed into waterways	Candidates should know that healthy plant growth requires nitrogen to make protein, and that this is why farmers spread nitrogenous fertilisers on their land. Candidates should recall the problems associated with fertilisers being washed into waterways and be able to give a basic explanation of eutrophication.