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PREFACE

Absolute clarity! That's the aim.

This is everything you need to ace the examined component in this course and beam with pride. Each topic is laid out in a beautifully illustrated format that is clear, approachable and as concise and simple as possible.

Each section of the separate Chemistry and combined science (Trilogy) specifications are clearly indicated to help you cross-reference your revision. The checklist on the contents pages will help you keep track of what you have already worked through and what's left before the big day.

We have included worked exam-style questions with answers for almost every topic. This helps you understand where marks are coming from and to see the theory at work for yourself in an exam situation. There is also a set of exam-style questions at the end of each section for you to practise writing answers for. You can check your answers against those given at the end of the book.

LEVELS OF LEARNING

Based on the degree to which you are able to truly understand a new topic, we recommend that you work in stages. Start by reading a short explanation of something, then try and recall what you've just read. This has limited effect if you stop there but it aids the next stage. Question everything. Write down your own summary and then complete and mark a related exam-style question. Cover up the answers if necessary but learn from them once you've seen them. Lastly, teach someone else. Explain the topic in a way that they can understand. Have a go at the different practice questions – they offer an insight into how and where marks are awarded.

ACKNOWLEDGEMENTS

The questions in the ClearRevise textbook are the sole responsibility of the authors and have neither been provided nor approved by the examination board.

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THE SCIENCE OF REVISION

Illustrations and words

Research has shown that revising with words and pictures doubles the quality of responses by students.[1] This is known as 'dual-coding' because it provides two ways of fetching the information from our brain. The improvement in responses is particularly apparent in students when asked to apply their knowledge to different problems. Recall, application and judgement are all specifically and carefully assessed in public examination questions.

Retrieval of information

Retrieval practice encourages students to come up with answers to questions.[2] The closer the question is to one you might see in a real examination, the better. Also, the closer the environment in which a student revises is to the 'examination environment', the better. Students who had a test 2–7 days away did 30% better using retrieval practice than students who simply read, or repeatedly reread material. Students who were expected to teach the content to someone else after their revision period did better still.[3] What was found to be most interesting in other studies is that students using retrieval methods and testing for revision were also more resilient to the introduction of stress.[4]

Ebbinghaus' forgetting curve and spaced learning

Ebbinghaus' 140-year-old study examined the rate in which we forget things over time. The findings still hold power. However, the act of forgetting things and relearning them is what cements things into the brain.[5] Spacing out revision is more effective than cramming – we know that, but students should also know that the space between revisiting material should vary depending on how far away the examination is. A cyclical approach is required. An examination 12 months away necessitates revisiting covered material about once a month. A test in 30 days should have topics revisited every 3 days – intervals of roughly a tenth of the time available.[6]

Summary

Students: the more tests and past questions you do, in an environment as close to examination conditions as possible, the better you are likely to perform on the day. If you prefer to listen to music while you revise, tunes without lyrics will be far less detrimental to your memory and retention. Silence is most effective.[5] If you choose to study with friends, choose carefully – effort is contagious.[7]

1. Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of dual-coding hypothesis. *Journal of Education Psychology*, (83)4, 484–490.
2. Roediger III, H. L., & Karpicke, J.D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, 17(3), 249–255.
3. Nestojko, J., Bui, D., Kornell, N. & Bjork, E. (2014). Expecting to teach enhances learning and organisation of knowledge in free recall of text passages. *Memory and Cognition*, 42(7), 1038–1048.
4. Smith, A. M., Floerke, V. A., & Thomas, A. K. (2016) Retrieval practice protects memory against acute stress. *Science*, 354(6315), 1046–1048.
5. Perham, N., & Currie, H. (2014). Does listening to preferred music improve comprehension performance? *Applied Cognitive Psychology*, 28(2), 279–284.
6. Cepeda, N. J., Vul, E., Rohrer, D., Wixted, J. T. & Pashler, H. (2008). Spacing effects in learning a temporal ridgeline of optimal retention. *Psychological Science*, 19(11), 1095–1102.
7. Busch, B. & Watson, E. (2019), *The Science of Learning*, 1st ed. Routledge.

CONTENTS

Paper 1

Topic 1 Atomic structure and the periodic table

Topic 2 Bonding, structure, and the properties of matter

Topic 3 Quantitative chemistry

Topic 4 Chemical changes

Topic 8 Chemical analysis

Topic 9 Chemistry of the atmosphere

Topic 10 Using resources

MARK ALLOCATIONS

Green mark allocations[1] on answers to in-text questions throughout this guide help to indicate where marks are gained within the answers. A bracketed '1' e.g.[1] = one valid point worthy of a mark. In longer answer questions, a mark is given based on the whole response. In these answers, a tick mark[✓] indicates that a valid point has been made. There are often many more points to make than there are marks available so you have more opportunity to max out your answers than you may think.

TOPICS FOR PAPER 1

Information about Paper 1:

Separate Chemistry 8462:

Written exam: 1 hour 45 minutes
Foundation and Higher Tier
100 marks
50% of the qualification grade
All questions are mandatory

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from Topics 1–5 (Topics 8–12 Trilogy): Atomic structure and the periodic table; Bonding, structure, and the properties of matter; Quantitative chemistry; Chemical changes; and Energy changes.

Questions

Multiple-choice, structured, closed short answer and open response questions. They may include calculations.

Questions assess skills, knowledge and understanding of Chemistry.

CHEMICAL EQUATIONS

Chemical reactions can be represented using **balanced equations**. These use chemical symbols and formulae rather than words.

> Do not change chemical formulae in order to balance an equation. For example, H_2O is water but H_2O_2 is hydrogen peroxide.

Formulae with brackets

The formula for aluminium hydroxide, $Al(OH)_3$, represents 1 aluminium, (3 × 1) = 3 oxygen and (3 × 1) = 3 hydrogen.

1 Aluminium

3 × 1 Oxygen

3 × 1 Hydrogen

$$Al(OH)_3$$

Ammonium sulfate is commonly used as a soil fertiliser. Its formula $(NH_4)_2SO_4$ represents:

(2 × 1) = 2 nitrogen (2 × 4) = 8 hydrogen 1 sulfur 4 oxygen

Balancing equations

A chemical equation is balanced when the numbers of atoms of each element in the reactants and products are the same. It is important to write the correct symbol or formula for each substance, and to use balancing numbers where necessary.

Methane burns in oxygen to produce carbon dioxide and water:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

The balancing number 2 in front of the formula for water means that there are:

(2 × 2) = 4 hydrogen atoms and (2 × 1) = 2 oxygen atoms

Check: On each side of the arrow: 1 carbon atom, 4 hydrogen atoms, and (2 + 2) = 4 oxygen atoms.

1. Explain why the following chemical equation is balanced: [3]

$$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$$

2. Sodium reacts with oxygen. Complete the equation for this reaction. [2]

$$\_\_\_Na + \_\_\_O_2 \rightarrow \_\_\_Na_2O$$

3. Potassium reacts with water to produce hydrogen and potassium hydroxide:

$$2K(s) + 2H_2O(l) \rightarrow H_2(g) + 2KOH(aq)$$

Describe what the state symbols show about this reaction. [4]

1. The 2 in $Ca(OH)_2$ shows that there are 2 oxygen atoms[1] and 2 hydrogen atoms in the formula[1]. On both sides: 1 calcium atom, 4 hydrogen atoms, and 2 oxygen atoms[1].

*2. **4**Na + O_2[1] → **2**Na_2O[1]*

3. Potassium is in the solid state[1], water is in the liquid state[1], hydrogen is in the gas state[1] and potassium hydroxide is in aqueous solution.[1]

State symbols

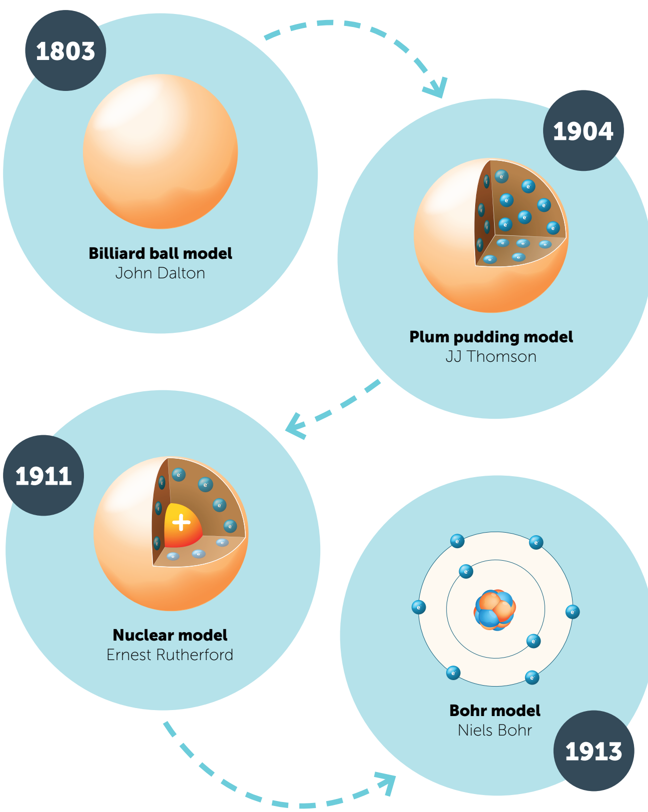
State symbols show the physical state of a substance in a reaction, or whether it is in aqueous solution (dissolved in water).

DEVELOPING THE ATOMIC MODEL

The atomic model has changed over time because of new experimental evidence.

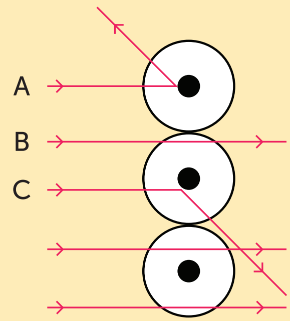
Atomic theories

In the early 19th century, atoms were imagined as tiny, solid spheres. The discovery of the **electron** by J.J. Thomson in 1897 led to his **plum pudding model**. This model was disproved by a series of results from the **alpha particle scattering experiment**.



In this experiment, beams of alpha particles (tiny positively charged particles) were aimed at thin gold foil. The results led to the **nuclear model**. Shortly afterwards, Niels Bohr carried out theoretical calculations showing that electrons orbit the nucleus at set distances. Observations from experiments supported his **electron shell model** and also showed the existence of positively charged **protons**. About 20 years later, James Chadwick demonstrated the existence of **neutrons**.

1. Compare the plum pudding and nuclear models of the atom [3]
2. The diagram shows paths taken by alpha particles through gold foil.



(a) Give a reason why most particles followed the path labelled B. [1]

(b) Explain why some particles followed path C. [2]

(c) Explain why a very small number of particles followed path A. [2]

1. Both models have negatively charged electrons[1]. These are embedded in a sphere of positive charge in the plum pudding model[1] but surround a positively charged nucleus in the nuclear model[1].

2. (a) Atoms are mostly empty space[1] so particles passed straight through.

(b) The nucleus was positively charged[1] so it repelled the positively charged alpha particles[1].

(c) The nucleus was very small[1] but it had a relatively high mass[1] and high charge[1].

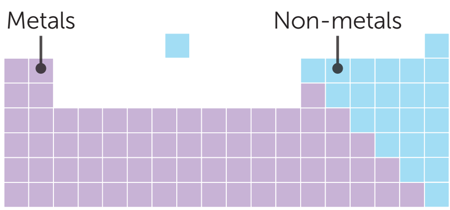
4.1.2.3 5.1.2.3

METALS AND NON-METALS

Most elements are metals rather than non-metals.

Chemical properties

An element is a **metal** if it forms positively charged **ions**, and a **non-metal** if it does **not** form positively charged ions. Metals and non-metals are found in different places on the periodic table.



Chemical bonding

Metals and non-metals form different types of chemical **bonds**:

- metals have metallic bonding
- non-metal elements have covalent bonding
- compounds of metals and non-metals have ionic bonding.

See bonds on **page 26**.

The elements in groups 1 and 2, and between groups 2 and 3, are all metals.

Physical properties

In general, metals and non-metals have opposite physical properties. For example, metals are malleable – they can be hammered into shape without shattering. Non-metals in the solid state are brittle – they shatter when hammered. The table compares some other typical properties.

Property	Metals	Non-metals
Appearance	Shiny	Dull
Melting and boiling points	High	Low
Density	High	Low
Ability to conduct electricity and thermal energy	Good	Poor

1. Describe the positions of the metals and non-metals in the periodic table. [1]
2. The element mercury is in the liquid state at room temperature. Give a reason why this is unusual. [1]
3. Hydrogen is a non-metal. It can form H^+ ions and H^- ions. Explain why this is unusual. [3]

1. Metals are found towards the bottom and left, and non-metals are found towards the top and right[1].

2. Metals are usually in the solid state at room temperature[1].

3. Elements that do not form positive ions are non-metals[1] but hydrogen can form positive ions just like metals do[1].

4.1.2.4 5.1.2.4

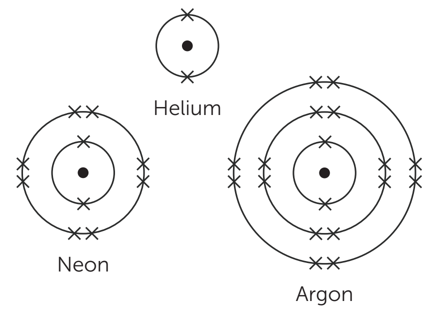
GROUP 0

The Group 0 elements are called the **noble gases**.

Chemical properties

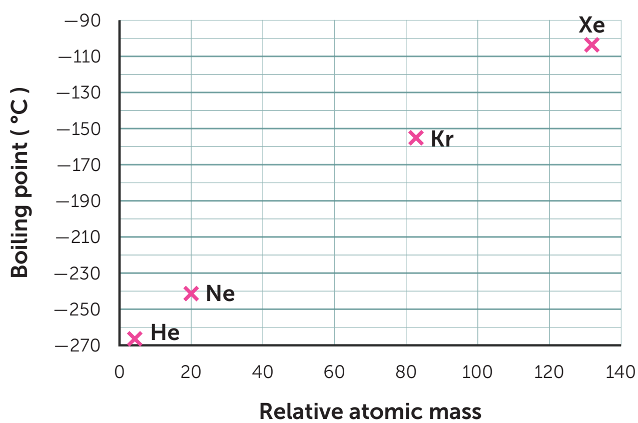
The Group 0 elements are unreactive non-metals. The highest occupied energy levels of their atoms are completely filled. These stable arrangements mean that the noble gases:

- have little tendency to lose or gain electrons in chemical reactions, so they do not easily form **ionic compounds**.
- have little tendency to share electrons, so they do not easily form **molecules**.



Physical properties

The noble gases have very low boiling points, so they are all in the gas state at room temperature. There is a gradual change or **trend** in their boiling points going down the group.



1. Compare the electronic configuration of helium with the electronic configurations of the other elements in Group 0. [1]
2. (a) Describe the relationship in Group 0 between boiling point and relative atomic mass. [1]
   (b) The relative atomic mass of argon is 40. Predict the boiling point of argon. [1]

1. Helium has 2 outer electrons but the other elements have 8 outer electrons[1]*.*

2. (a) Boiling point increases as the relative atomic mass increases[1]*.*

(b) Between −230 °C and −210 °C [1]*.*

Group 0 atoms do lose electrons to form ions when high voltages are applied to them. They give off coloured light when the electrons return to the ions. This is how neon lights work.

IONIC COMPOUNDS

The ions in **ionic compounds** are held together by **ionic bonding**.

Giant ionic lattice

Ionic compounds have a **giant ionic lattice** structure:

- Lattice – A regular structure.
- Ionic – The structure consists of ions with ionic bonding.
- Giant – The regular structure is repeated very many times.

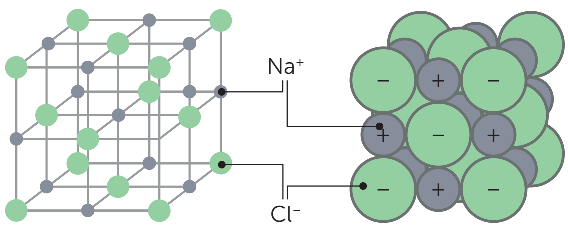
Ionic bonding acts in all directions in the lattice. It is the strong electrostatic force of attraction between oppositely charged ions.

You should know the structure of sodium chloride, but not the structures of other ionic compounds

Representing ionic structures

Ionic structures extend in three dimensions. You can represent these structures using plastic molecular modelling kits. Each ball represents an ion and each stick represents the bonding.

You can also show ionic structures in two dimensions.



Ball and stick

Space-filling

A third representation of bonding in ionic compounds is through dot and cross diagrams. (See **page 27**.)

The different diagrams have limitations.

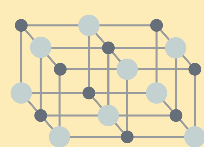
	Dot and cross	Ball and stick	Space-filling
Shows bonding	In detail	As lines	×
Shows relative sizes of atoms	×	Inaccurately	✓
Shows shape of lattice	×	✓	✓

The diagram shows the structure of silver bromide.

(a) Explain why the diagram shows that silver bromide is an ionic compound. [2]

(b) Define the term **empirical formula**. [2]

(c) Determine the empirical formula of silver bromide. [2]



(a) It shows oppositely charged ions[1] from more than one element[1].

(b) The simplest whole number ratio[1] of ions or atoms in a substance[1].

(c) The diagram shows 9 Ag^+ ions and 9 Br^- ions[1], the simplest whole number ratio is 1 : 1 so the empirical formula is $AgBr$[1].

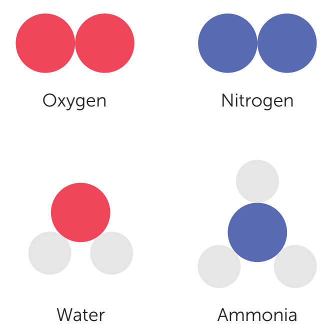
4.2.2.4–5 5.2.2.4–5

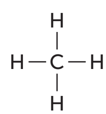
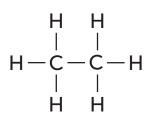
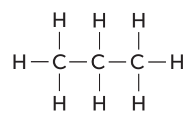
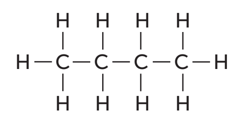
PROPERTIES OF SMALL MOLECULES

Small molecules

The size of molecules varies between substances. This affects the physical properties of substances. Substances that consist of small molecules have relatively low melting and boiling points. These substances may be elements or compounds, and their molecules contain few atoms.

The atoms in a small molecule are held together by strong covalent bonds. These bonds are not broken during melting or boiling. Instead, the much weaker intermolecular forces between molecules are overcome. In general, as the size of the molecule increases, intermolecular forces increase and therefore, melting and boiling points increase.



Substance				
Boiling point in °C	−161	−89	−42	−1

4.2.2.5

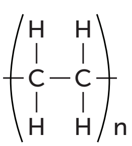
POLYMERS

Chemistry only: Addition polymerisation is covered on **page 117**.

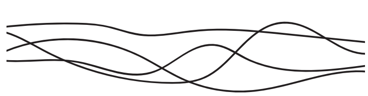
Chemistry Higher only: Condensation polymerisation is covered on **page 118**.

Polymers consist of large molecules, formed from many small molecules called **monomers**. The atoms in each individual polymer molecule are joined together by strong covalent bonds. Polymer molecules are attracted to each other by intermolecular forces. These forces are relatively strong because polymer molecules are so large.

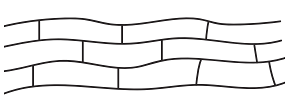
You should be able to recognise polymers from diagrams like these.



Repeating unit



Tangled polymer chains



Chains with cross-links

Explain why poly(propene) is in the solid state at room temperature. [4]

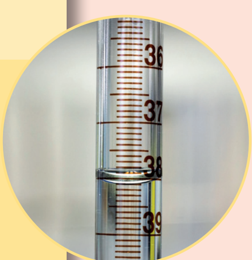
Poly(propene) consists of large molecules[1]. Intermolecular forces between polymer molecules are overcome during melting[1]. These are relatively strong because the molecules are so large[1] so a lot of energy is needed to overcome them[1].

REQUIRED PRACTICAL 2

Titration

This activity helps you develop your ability to accurately make and record measurements, and to analyse unknown substances.

1. Describe **two** precautions needed to read a burette accurately. [2]
2. Describe how to record a burette reading. [3]
3. Determine the burette reading shown in the photo. [1]



1. Read at eye level to avoid parallax errors.[1] *Read to the bottom of the meniscus.*[1] *Place a piece of paper behind the burette to make it easier to see the meniscus.*[1]

2. Give the reading to 2 decimal places[1]*, ending in 0 if the meniscus is on a line and 5 if it is part-way between two lines*[1]*.*

3. 38.10 cm^3[1]

Outline of the practical

The aims of this practical are slightly different, depending on your tier of entry in the exam:

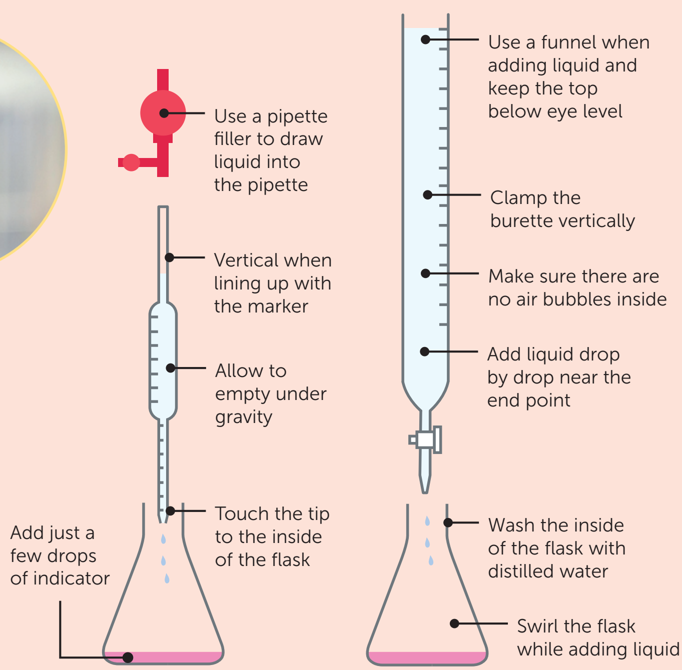
- Foundation – to find the volume of acid needed to neutralise a known volume of alkali
- Higher – to find the concentration of an acid solution using a known concentration of alkali.

You can revise the outline method on **page 69** and the calculations needed on **page 71**.

Precautions for accurate results and safe working

Phenolphthalein is often used as the indicator in acid-alkali titrations. It is pink in alkalis and colourless in acids.

The colour change is easier to see if the conical flask is placed on a white tile.



EXAMINATION PRACTICE

01 Describe what is meant by an exothermic reaction. [2]

02 A student added some water to a polystyrene cup, then recorded its temperature. The student dissolved some ammonium nitrate in the water, then recorded the temperature of the solution formed. The table shows the results.

Temperature at start °C	Temperature at end °C
19.4	16.7

02.1 Explain what the results show about the process of dissolving ammonium nitrate. [2]

02.2 Suggest **one** practical use of the observed changes. [1]

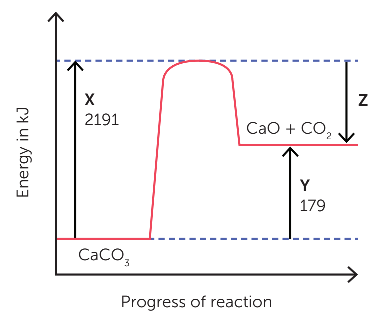
03 The diagram is a reaction profile for the reaction:

$$CaCO_3 \rightarrow CaO + CO_2.$$

It is not drawn to scale.

Explain what this reaction profile represents.

In your answer, you should refer to energy transfers and chemical bonds. [6]



Higher Tier only

04 Hydrogen reacts with iodine to form hydrogen iodide:

$$H–H + I–I \rightarrow 2(H–I)$$

Bond energies in kJ/mol: I–I = 151, H–I = 298. The overall energy change is –9 kJ/mol.

Calculate the bond energy for the H–H bond. [4]

Chemistry only

05 Lithium-ion batteries are rechargeable but alkaline batteries are non-rechargeable.

05.1 Explain this difference between the two types of battery. [2]

05.2 Give **one** reason why both types of battery eventually stop working. [1]

05.3 A student makes a cell using a piece of zinc, a piece of copper, and copper sulfate solution.

The potential difference between the two metals is 1.10 V.

Explain **one** change needed to obtain a higher voltage. [2]

Chemistry Higher Tier only

06 Methanol fuel cells use methanol as a fuel instead of hydrogen.

06.1 Explain why air must be supplied to a methanol fuel cell. [2]

06.2 Balance the half equation for the anode reaction in the methanol fuel cell. [1]

$$CH_3OH + H_2O \rightarrow ...... H^+ + ... e^- + CO_2$$

TOPICS FOR PAPER 2

Information about Paper 2:

Separate Chemistry 8462:

Written exam: 1 hour 45 minutes
Foundation and Higher Tier
100 marks
50% of the qualification grade
All questions are mandatory

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from Topics 6–10 (Topics 13–17 Trilogy): The rate and extent of chemical change; Organic chemistry; Chemical analysis; Chemistry of the atmosphere; and Using resources.

It may also draw on fundamental concepts and principles from Topics 1–3 (Sections 5.1–5.3 Trilogy): Atomic structure and the periodic table; Bonding, structure, and the properties of matter; and Quantitative chemistry.

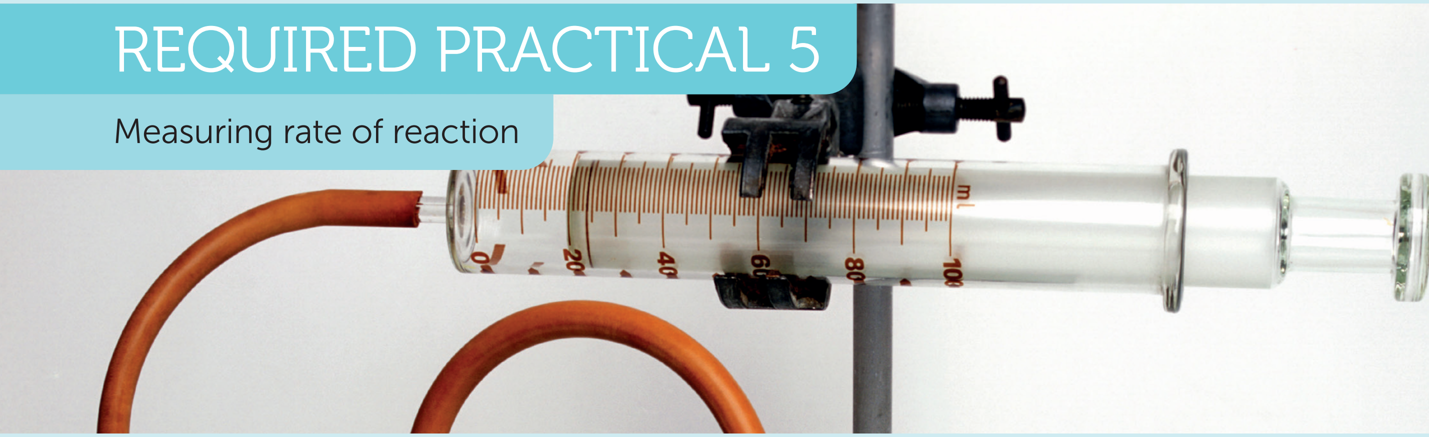
Questions

A mix of multiple-choice, structured, closed short answer and open response questions. They may include calculations.

Questions assess knowledge, understanding and skills.

REQUIRED PRACTICAL 5

Measuring rate of reaction



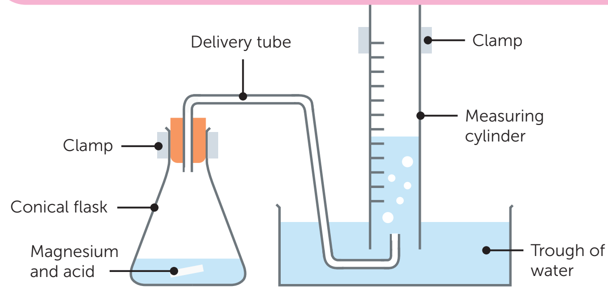
This required practical activity helps you develop your ability to accurately make and record observations and measurements, to carry out and monitor chemical reactions, and to use substances carefully and safely.

Measuring volumes of gases

Fill the measuring cylinder with water, then turn it upside down under water in a trough.

As bubbles of gas go into the measuring cylinder, the water it contains is pushed downwards before you read the new volume.

You can use a **gas syringe** to measure the volume of any gas more accurately. They are made of glass and are expensive, so you may be given a measuring cylinder instead.



An example experiment

Magnesium reacts with dilute hydrochloric acid to produce magnesium chloride and hydrogen. You can use the rate of production of hydrogen to compare the rate of reaction at different concentrations of acid. The faster the gas syringe or measuring cylinder fills with gas, the greater the rate of reaction. You should control variables such as:

- the mass of magnesium – the greater the mass, the more gas is produced
- the size of the piece of magnesium – powders react more quickly than ribbon.

A table is the best way to record the results. For example:

Time in s	0	10	20	30	40	50	60	70	80	90
0.5 mol/dm^3 acid										
1.0 mol/dm^3 acid										

1. Explain why the temperature of the acid is a variable that should be controlled. [2]

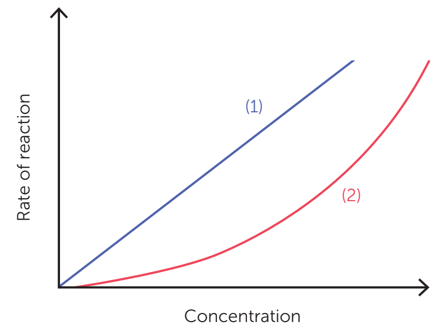
1. The rate of reaction depends upon the temperature of the reaction mixture.[1] If this was not kept the same each time, the rate of reaction would not only depend upon the concentration of the hydrochloric acid.[1]

ACTIVATION ENERGY AND CATALYSTS

Effects of concentration

You might see two different effects of concentration on the rate of reaction:

- **Line 1** if the rate depends on the concentration of one of the reactants
- **Line 2** if the rate depends on the concentrations of two or more reactants



Effect of temperature

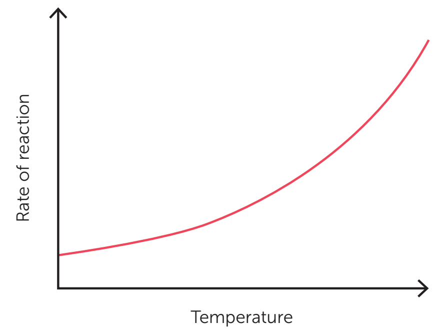
As the temperature of a reactant increases, the average energy of its particles increases. The percentage of particles that have the **activation energy** or more is much greater at high temperatures than it is at low temperatures.

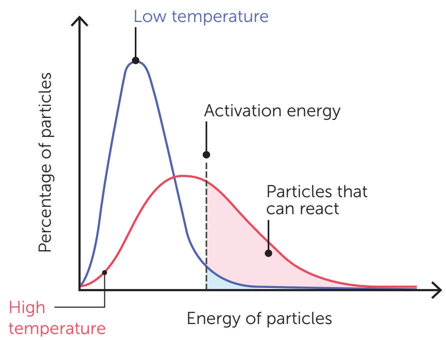
Unlike increases in concentration, pressure or surface area, an increase in temperature causes:

- an increase in the frequency of collisions, **and**
- an increase in the energy of reactant particles.

These two factors combine to produce very large increases in the frequency of successful collisions, and in the rates of reactions. You are likely to observe reactions starting, or happening much faster, when the reaction mixture is warmed up.

This graph is here just to help you understand what is happening. You do not need to remember it.





1. Explain what line 1 on the first graph shows. [3]
2. Predict how the rate of a reaction will depend on the surface area of a solid reactant. Give a reason for your answer. [2]

1. The graph shows that the rate of reaction is directly proportional to the concentration of a reactant.[1] This is because the line is straight, has a positive gradient[1] and passes through the origin[1].

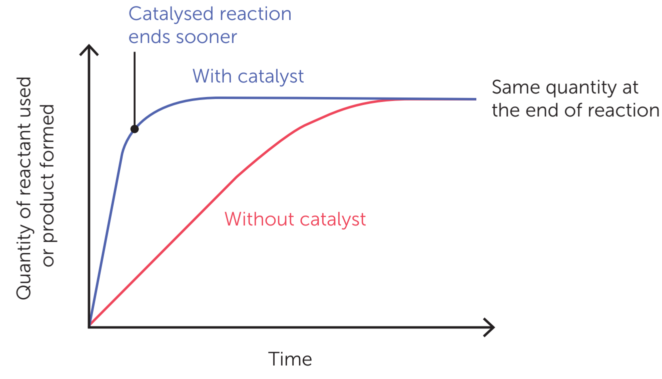
2. The rate of reaction will be directly proportional to surface area.[1] This is because the number of reactant particles exposed at the surface increases as the surface area increases.[1]

Catalysts

A catalyst changes the rate of a chemical reaction without being used up in the reaction. Different reactions are catalysed by different catalysts.

You can tell if a substance in a reaction mixture acts as a catalyst because:

- it increases the rate of reaction
- it is **not** shown in the chemical equation for the reaction.

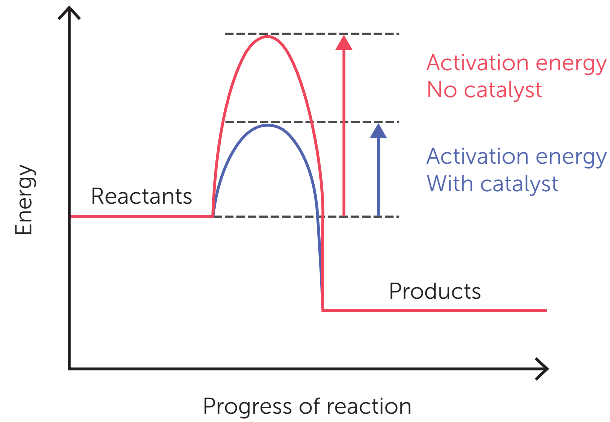


Activation energy

A catalyst provides a pathway that has a **lower activation energy** than the uncatalysed reaction. This can be shown on a **reaction profile** (you can revise these diagrams on **page 82**).

At a given temperature, a greater percentage of reactant particles will have the activation energy or more. The frequency of collisions will be the same as in the uncatalysed reaction, but a greater percentage of these collisions will be successful.

In the middle diagram on the opposite page, the effect is as if the activation energy line is moved to the left, letting more particles react.



Cars are fitted with catalytic convertors which contain precious metals. Hot exhaust gases heat these up and increase the rate of reaction to change harmful gases into CO_2 and water vapour.

1. A mixture of hydrogen peroxide solution and manganese(IV) oxide powder forms water and oxygen:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Identify the catalyst in this reaction. Give a reason for your answer. [2]

2. (a) Describe what is meant by an enzyme. [2]

(b) Give **one** example of the use of an enzyme in chemistry. [2]

1. Manganese(IV) oxide is the catalyst[1] *because it does not appear in the balanced equation as a reactant or as a product*[1]*.*

2. (a) A protein that acts as a catalyst[1] *in living things and other biological systems*[1]*.*

(b) Fermentation to make ethanol[1] *using enzymes in yeast*[1]*.*

4.7.1.1 5.7.1.1

CRUDE OIL, HYDROCARBONS AND ALKANES

Crude oil consists of many compounds, most of which are **hydrocarbons**.

Crude oil

Crude oil and **natural gas** formed over millions of years from once-living plants and animals (mainly plankton). They are **finite resources** because they take so long to form or may not be being formed anymore. They are being used faster than they are being replaced.

Millions of years

Plankton and algae die and are buried in mud

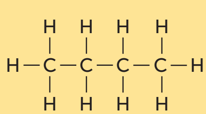
Ancient remains are exposed to high pressures and temperatures

Crude oil and natural gas in rocks

1. Butane is an alkane. Its molecules contain four carbon atoms.
   1. (a) Determine the molecular formula of butane. [1]
   (b) Draw the displayed structural formula of butane. [1]

1. (a) Number of hydrogen atoms = (2 × 4) + 2 = 10, so the formula is C_4H_{10} [1]

(b) [1]



Hydrocarbons and alkanes

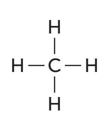
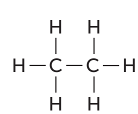
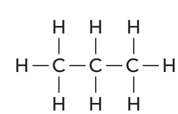
Hydrocarbons are compounds of hydrogen and carbon only. There are several types of hydrocarbon, but the ones in crude oil are mostly **alkanes**.

The alkanes are a **homologous** series, a 'family' of compounds with similar chemical properties and the same general formula:

$$C_nH_{2n+2}$$

(where n stands for the number of carbon atoms in the molecule)

The table shows the first three alkanes.

Name of alkane	Methane	Ethane	Propane
Molecular formula	CH_4	C_2H_6	C_3H_8
Displayed structural formula			

FRACTIONAL DISTILLATION AND PETROCHEMICALS

The different hydrocarbons in crude oil are separated by **fractional distillation**.

Fractional distillation

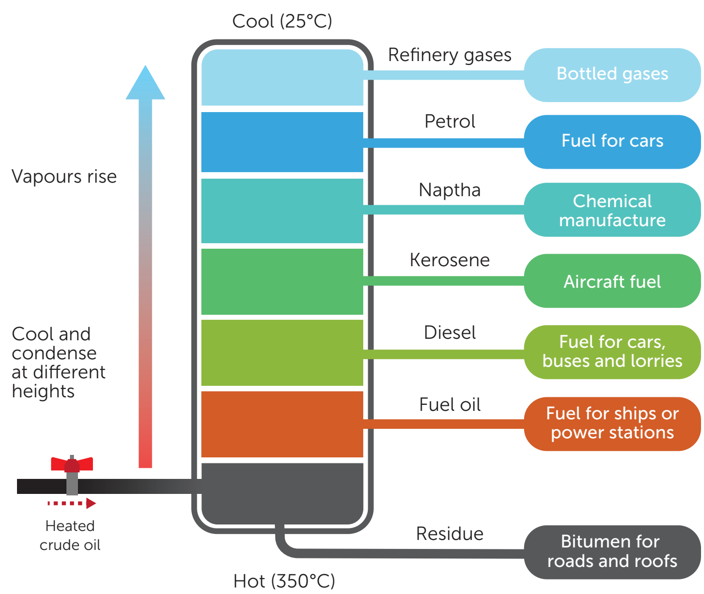
Fractional distillation relies on the different **boiling points** of the different components in a mixture. You can revise fractional distillation of mixtures on **page 9**.

It involves:

- heating the mixture to **evaporate** its components
- cooling the vaporised components so they **condense** at different temperatures.

The fractional distillation of crude oil happens in a metal tower called a fractionating column.

The column gets cooler towards the top, so it has a **temperature gradient**. Different **fractions** have different ranges of boiling points, so they condense at different heights in the column.



A substance occupies less volume when it is in the liquid state than when it is in the gas state. This makes LPG more suitable for transporting petroleum gases.

Fuels and petrochemicals

Crude oil provides many of the **fuels** that we use in everyday life. It also provides **feedstock** (starting materials) for the petrochemical industry. **Petrochemicals** are useful substances and materials produced from crude oil. They include detergents, lubricants, polymers (plastics) and solvents.

2. Place the following fractions in decreasing order of boiling point: diesel oil, heavy fuel oil, kerosene, LPG (liquefied petroleum gases), petrol. [1]
3. Give a reason why a huge number of different natural and synthetic carbon compounds are possible. [1]

2. Correct order: heavy fuel oil, diesel oil, kerosene, petrol, LPG.[1]

3. Carbon atoms can form homologous series or families of similar compounds.[1]

FLAME TESTS

A **cation** is a positive ion. Some metal cations give distinctive colours to flames.

Carrying out a flame test

You can carry out a flame test on a solid sample or a sample in aqueous solution:

- Use a damp wooden splint (as in this test for calcium shown)
- Use a nichrome wire loop.

It is more difficult to use nichrome wire because the loop must be cleaned before the first test, then between each test:

1. Dip the loop in dilute hydrochloric acid.
2. Hold the loop in the hot part of a blue Bunsen burner flame.
3. Repeat steps 1 and 2 until there is little or no extra colour to the flame.

Test a sample using the cleaned nichrome wire loop:

4. Dip the loop in dilute hydrochloric acid, then in the sample.
5. Hold the loop in the edge of a blue Bunsen burner flame.
6. Observe and record the flame colour obtained.

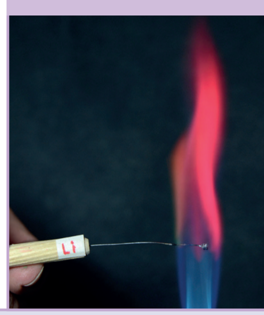
Calcium flame test

Flame test colours

The table summarises the flame colours that you need to know. The photos show three flame tests carried out using a nichrome wire loop.

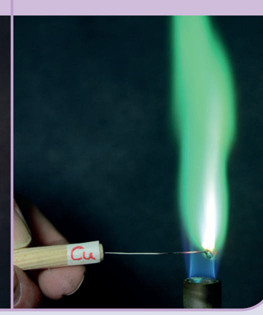
Cation	Flame colour
Li^+	Crimson
Na^+	Yellow
K^+	Lilac
Ca^{2+}	Orange-red
Cu^{2+}	Green

Lithium



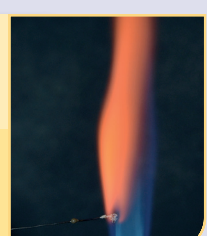
Sodium

Copper(II)



A student carried out a flame test using potassium chloride.
The photo shows the results.
Suggest an explanation for why the flame colour differs from the expected colour. [3]

The flame colour should be lilac[1] *but the colour is masked by another flame colour*[1]*. This may be because the nichrome wire was not cleaned properly first, or because the student used a mixture of ions.*[1]



HUMAN ACTIVITIES AND GREENHOUSE GASES

Human activities release additional quantities of greenhouse gases into the atmosphere.

Carbon dioxide

Carbon dioxide accounts for most of the greenhouse gas emissions because of human activities, such as:

- burning fossil fuels, for example for transport and generating electricity
- cement manufacture.

Methane

Methane is a much more powerful greenhouse gas than carbon dioxide. Human activities that release methane include:

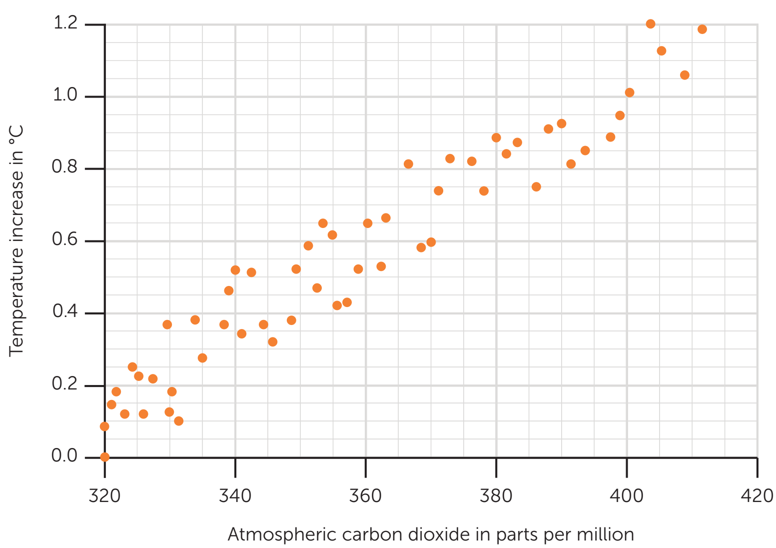
- cattle farming
- coal mining, and oil and gas production.

Methane is also released from decaying animal and plant waste on farms and in landfill sites.

Linking greenhouse emissions to global warming

As carbon dioxide levels in the atmosphere have increased, the average global temperature has increased.

The Intergovernmental Panel on Climate Change (IPCC) makes scientific conclusions based on large amounts of scientific research. It believes that it is highly likely that human activities are the main cause of global warming.



1. Describe the relationship shown in the graph. [2]
2. The IPCC uses 'peer reviewed' scientific evidence. Describe what this means. [2]

1. There is a positive correlation[1] between the increase in temperature and the atmospheric carbon dioxide concentration[1].

2. Peer reviewed evidence is evaluated by other scientists.[1] This means that findings reported by a scientist or research group are checked before being accepted or rejected.[1]

WASTE WATER TREATMENT

Waste water must be treated before it can be released back into rivers.

Waste water

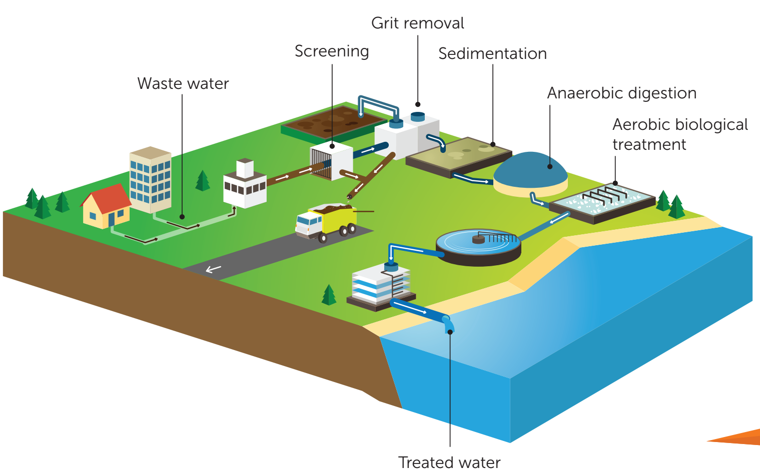
Large volumes of waste water come from sources such as farms, homes and factories.

Depending on the source, this water may contain harmful substances, solids containing **organic compounds**, and harmful **microbes**. These will damage the environment and may cause disease unless the waste water is treated to remove them.

Treatment

Waste water goes through several stages before it is released into the environment.

Solid materials such as toilet paper and grit are removed. Sewage **sludge** and liquid **effluent** are produced by sedimentation, then digested by bacteria. Further biological treatment removes excess nitrates and phosphates that can cause excessive, harmful growth of algae in rivers.



1. Describe what is meant by:
   (a) anaerobic digestion [2]
   (b) aerobic biological treatment. [2]
2. Suggest why it is easier to obtain potable water from fresh water rather than from waste water. [1]

1. (a) Breaking down substances[1] in the absence of air or oxygen[1].

(b) Treatment that uses living things such as bacteria[1] in the presence of air or oxygen[1].

2. Many more stages are needed to treat waste water to make it safe to drink.[1]

Methane produced by anaerobic digestion can be used as a fuel. You can revise hydrocarbon fuels on **pages 104** and **105**.

CORROSION AND ITS PREVENTION

Chemical reactions with substances in the environment can damage materials.

Corrosion

Corrosion involves metals reacting with substances in the environment. These are usually air or water, but they can be substances such as sulfur dioxide. Corrosion starts on the surface, but eventually it can destroy the metal.

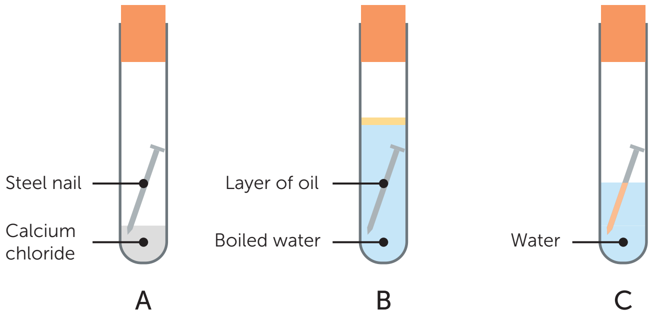
Corrosion of steel

Corrosion of copper

Corrosion of silver

Corrosion of iron and steel

Rusting is the corrosion of iron and steel. It needs both air (oxygen) and water to happen. You can show this using a suitable experiment, such as the one below.



The table shows the results of this experiment after a few days.

Tube	A	B	C
Air	✓	×	✓
Water	×	✓	✓
Nail rusts?	×	×	✓

1. (a) Explain why calcium chloride is added to Tube A. [2]

(b) Explain the conditions in Tube B. [2]

1. (a) Calcium chloride absorbs water[1], so the air in Tube A is dry[1].

(b) Air leaves water when the water is boiled[1]. The layer of oil stops air getting back into the water during the experiment[1].

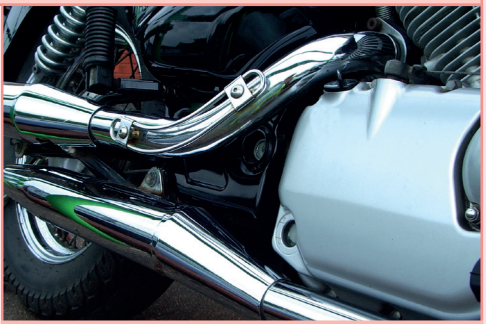
Preventing corrosion

Corrosion can be prevented in different ways.

Barriers

A metal will not corrode if it has a coating that acts as a barrier. An iron or steel object will not rust if air, water, or both air and water are kept away from its surface. This is why bike chains do not rust if they are oiled regularly, and steel bike frames do not rust if they are painted.

Metal objects can be protected by **electroplating** them. This process uses **electrolysis** to apply a very thin metal coating on the surface of another metal. The inside of steel food cans can be electroplated with a thin layer of tin, which keeps air and water away from the steel.



Steel parts are electroplated with chromium to stop them rusting and to improve their appearance

Sacrificial protection

The **reactivity series** shows the relative reactivity of metals (See **page 60**).

A more reactive metal reacts with air and water more readily than a less reactive metal does. This means that a suitable metal can 'sacrifice itself' to protect iron and steel from rusting.

Magnesium and zinc are suitable **sacrificial metals**. As long as they are in contact with an iron or steel object, they corrode instead of the object. The sacrificial metal is replaced before it completely corrodes away.

Most reactive

Potassium
Sodium
Lithium
Calcium
Magnesium
Zinc
Iron
Copper

Least reactive

Sacrificial protection of a pipeline

Sacrificial protection of a ship's hull

2. Aluminium is more reactive than zinc. Explain why it does not corrode in air or water. [2]
3. A farmer's steel gate is galvanised with zinc to stop it rusting. Explain how this works. [2]

2. Aluminium has a natural, thin coating of aluminium oxide[1] which stops air and water reaching the metal below[1].

3. The zinc acts as a barrier[1] and it also acts as a sacrificial metal[1].

Food cans are commonly lined with a polymer coating to provide a further barrier against rusting.

EXAMINATION PRACTICE ANSWERS

Topic 1

01 Any two from: [2]

- Compounds formed in chemical reactions, but mixtures not formed in chemical reactions.
- Compounds contain two or more elements chemically combined together, but substances in a mixture are not chemically combined together.
- Elements in compounds are present in fixed proportions, but substances in mixtures are in variable proportions.
- Chemical properties of elements in a compound are changed, but chemical properties of substances in mixtures are unchanged.
- Compounds are only separated into their elements by chemical reactions, mixtures can be separated by physical methods.

02 $\mathbf{2}Fe_2O_3 + \mathbf{3}C \rightarrow \mathbf{4}Fe + \mathbf{3}CO_2$ Correctly balanced. [1]

03.1 It showed that atoms could be divided [1] leading to the plum pudding model [1] in which atoms are positive balls with negative electron inside [1]. [2]

03.2 1 mark for each correct row to 3 marks: [3]

Name of subatomic particle	Relative charge	Relative mass
Neutron	0	1
Electron	–1	very small
Proton	+1	1

03.3 7 protons [1] 8 neutrons [1] 10 electrons [1]. [3]

03.4 2.8×10^{-10} m. [1]

04.1 relative atomic mass= $\frac{(69 \times 63) + (31 \times 65)}{(69 + 31)}$ [1] = $\frac{4347 + 2015}{100}$ [1] = 63.6 [1] 3 marks for correct answer without working. [3]

04.2 The chemical properties of an element are determined by the number of electrons [1]; the two isotopes have the same number of electrons / 29 electrons [1]. [2]

05.1 He left gaps for undiscovered elements [1]; he changed the order of some elements [1]. [2]

05.2 Group 5 [1] period 3 [1] (Allow top right for 1 mark only.) [2]

05.3 (Positively charged ions because) metals / transition metals are placed between groups 2 and 3 [1] and metals are elements that react to form positive ions / non-metal elements do not form positive ions [1]. [2]

06 Indicative content: [6]

Filtration

- to separate carbon particles from the ink
- as a residue

Fractional distillation

- of the filtrate
- to separate the propanol from the water

Chromatography

- of the filtrate / ink
- to separate the coloured substances from one another

Safety precautions relevant to the experiment with reasons

- eye protection because of solvent / hot liquid
- care with hot apparatus to avoid burns
- heat flask with an electrical heater / care with naked flames because ethanol is flammable

07.1 The atoms of Group 0 elements have full outer shells / stable arrangements of electrons [1], so they have little tendency to share electrons [1]. [2]

07.2 The boiling point increases going down the group / increases as the relative atomic mass increases. [1]

07.3 Answer in the range 3.65–3.90 g/m^3 [1] because the relative atomic mass of krypton is about half-way between those of argon and xenon [1] and its density should be about half-way between their densities [1]. [3]

07.4 Oganesson is predicted to be a solid / a metal rather than a non-metal. [1]

08.1 $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ 1 mark for correct formulae, 1 mark for correct balancing, 1 mark for state symbols. [3]

08.2 The outer electron of potassium is further from the nucleus [1] so the potassium nucleus has a weaker force of attraction for the outer electron [1] and the outer electron is lost more easily [1]. [3]

INDEX

LEVELS BASED MARK SCHEME FOR EXTENDED RESPONSE QUESTIONS

What are extended response questions?

Extended response questions are worth 4, 5 or 6 marks. These questions are likely to have command words such as 'compare', 'explain' or 'evaluate'. You need to write in continuous **prose** when you answer one of these questions. This means you must write in full sentences (rather than in bullet points), organised into paragraphs as necessary.

You may need to bring together skills, knowledge and understanding from two or more areas of the specification. To gain full marks, your answer needs to be logically organised, with ideas linked to give a sustained line of reasoning.

Some of extended response questions may involve calculations. These need two or more steps that must be done in the right order. These questions are likely to include the command work 'calculate'.

Marking

Calculations are **not** marked using 'levels of response' mark schemes, but written answers are marked this way. Examiners look for relevant points (indicative content) but they also use a best fit approach. This is based on your answer's overall quality and its fit to descriptors for each level.

Example level descriptors

Level descriptors vary, depending on the question being asked. Level 3 is the highest level and Level 1 is the lowest level. No marks are awarded for an answer with no relevant content. The table gives examples of the typical features that examiners are asked to look for.

Level	Marks	Descriptors for a method	Descriptors for an evaluation
3	5–6	The method would lead to a valid outcome. All the key steps are given, and they are ordered in a logical way.	The answer is detailed and clear. It includes a range of relevant points that are linked logically. The answer uses relevant data that may be given in the question. A conclusion is made that matches the reasoning in the answer.
2	3–4	The method might not lead to a valid outcome. Most of the key steps are given, but the order is not completely logical.	The answer is mostly detailed but not always clear. It includes some relevant points with an attempt at linking them logically. Data may not be used fully. A conclusion is given that may not fully match the reasoning given.
1	1–2	The method would not lead to a valid outcome. Some key steps are given, but they are not linked in a clear way.	The answer gives separate, relevant points. Uses little or no data that may be given in the question. The points made may be unclear. If a conclusion is given, it may not match the reasoning given in the answer.

COMMAND WORDS

A **command word** in a question tells you what you are expected to do.

The structure of a question

You should see one command word per sentence, with the command word coming at the start. A command word might not be used, however, if a question is easier to follow without one. In these cases, you are likely to see:

- What ...?
- Why ...?
- How ...?

Command word	What you need to do
Balance	Add correct balancing numbers to a chemical equation.
Calculate	Use the numbers given to work out an answer.
Choose	Select from a range of options.
Compare	Write about the similarities and/or differences between things. You must write about all the things, not just one of them.
Define	Give the meaning of something.
Describe	Recall a fact, event or process accurately.
Design	Describe how something will be done, such as a practical method.
Determine	Use the data or information given to you to obtain an answer.
Draw	Produce a diagram, or complete an existing diagram.
Estimate	Work out an approximate value.
Evaluate	Use your knowledge and understanding, and the information supplied, to consider evidence for and against something. You must include a reasoned judgement in your answer.
Explain	Give the reasons why something happens, or make something clear.
Give, name, write	Only write a short answer, not a description or explanation. Your answer might be a single word, phrase or sentence.
Identify	Name or point out something.
Justify	Support your answer using evidence from the information given to you.
Label	Add the correct words or names to a diagram.
Measure	Use a ruler or protractor to obtain information from a photo or diagram.
Plan	Write a method.
Plot	Mark data points on a graph.
Predict	Write a likely outcome of something.
Show	Give structured evidence to come to a conclusion.
Sketch	Make an approximate drawing, such as a graph without axis units.
Suggest	Apply your knowledge and understanding to a new situation.
Use	You **must** base your answer on information given to you, otherwise you will not get any marks for the question. You might also need to use your own knowledge and understanding.

KEY TERMS IN PRACTICAL WORK

Experimental design

Key term	Meaning
Evidence	Measurements or observations collected using a valid method
Fair test	When the dependent variable is only affected by the independent variable
Hypothesis	A suggested explanation for observations or facts
Prediction	A reasoned statement that suggests what will happen in the future
Valid	A valid method involves fair testing and is suitable for an investigation
Valid conclusion	A discussion of a valid experiment and what it shows

Variables

A variable is a characteristic that can be measured or observed.

Type of variable	Meaning
Categoric	It has names or labels rather than values
Continuous	It has values rather than names or labels
Control	It affects the dependent variable, so it must be kept the same or monitored
Dependent	It is measured or observed each time the independent variable is changed
Independent	It is deliberately changed by the experimenter

Measurements and measuring

Key term	Meaning
Accurate	Close to the true value
Calibrated	A device is calibrated when its scale is checked against a known value
Data	Measurements or observations that have been gathered
Interval	The measured gap between readings
Precise	Very little spread about the mean value
Range	The values between the measured maximum and minimum values
Repeatable	When the same results are obtained using the same method and apparatus
Reproducible	Someone else gets the same results, or when different apparatus and methods are used
Resolution	The smallest change a measuring device can show
True value	The value you would get in an ideal measurement
Uncertainty	An interval in which the true value will be found

Errors

Type of error	Meaning
Anomaly	Anomalous results lie outside the range explained by random errors
Measurement	The difference between the true value and a measured value
Random	Unpredictably different readings – their effects are reduced by repeats
Systematic	Readings that differ from true values by the same amount each time
Zero	A type of systematic error where a device does not read 0 when it should

USEFUL EQUATIONS

Mathematical skills account for at least 30% of the marks in the exams. Foundation Tier students may be given equations like the ones below. All students may be given an unfamiliar equation if a question needs one.

Shown in the specification

$$\text{mean rate of reaction} = \frac{\text{quantity of reactant used}}{\text{time taken}}$$

$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

$$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$$

Chemistry only

$$\%\ \text{yield} = \frac{\text{mass of product actually made}}{\text{maximum theoretical mass of product}} \times 100$$

$$\%\ \text{atom economy} = \frac{\text{relative formula mass of desired product from equation}}{\text{sum of relative formula masses of all reactants from equation}} \times 100$$

Not shown in the specification

relative formula mass (M_r) = sum of relative atomic masses (A_r) of atoms shown in the formula

relative atomic mass (A_r) using abundances of two isotopes, A and B =

$$\frac{(\text{mass number} \times \text{percentage})\text{ of A} + (\text{mass number} \times \text{percentage})\text{ of B}}{100}$$

mass of solute (g) = concentration of solution (g/dm^3) × volume of solution (dm^3)

Higher Tier only

mass (g) = amount (mol) × M_r

$$\text{concentration of solution (mol/dm}^3) = \frac{\text{amount of solute (mol)}}{\text{volume of solution (dm}^3)}$$

volume of gas at room temperature and pressure (dm^3) = amount of gas (mol) × 24

overall energy change of a reaction =

(energy in to break bonds in reactants) – (energy out when bonds form in products)

$$\text{gradient of a graph} = \frac{\text{change in vertical axis}}{\text{change in horizontal axis}}$$

THE PERIODIC TABLE

1	2											3	4	5	6	7	0
							1 **H** Hydrogen 1										4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	63.5 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	[98] **Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	[209] **Po** Polonium 84	[210] **At** Astatine 85	[222] **Rn** Radon 86
[223] **Fr** Francium 87	[226] **Ra** Radium 88	[227] **Ac** Actinium 89	[261] **Rf** Rutherfordium 104	[262] **Db** Dubnium 105	[266] **Sg** Seaborgium 106	[264] **Bh** Bohrium 107	[277] **Hs** Hassium 108	[268] **Mt** Meitnerium 109	[271] **Ds** Darmstadtium 110	[272] **Rg** Roentgenium 111	[285] **Cn** Copernicium 112	[286] **Nh** Nihonium 113	[289] **Fl** Flerovium 114	[289] **Mc** Moscovium 115	[293] **Lv** Livermorium 116	[294] **Ts** Tennessine 117	[294] **Og** Oganesson 118

Key

Relative atomic mass
Atomic symbol
Name
Atomic (proton) number

Notes

The Lanthanides (atomic numbers 59–71) and the Actinides (atomic numbers 90–103) are omitted.

Relative atomic masses for Cu and Cl have not been rounded to the nearest whole number.

EXAMINATION TIPS

When you practice examination questions, work out your approximate grade using the following table. This table has been produced using a rounded average of past examination series for this GCSE. Be aware that boundaries vary by a few percentage points either side of those shown.

GCSE Chemistry

Grade	9	8	7	6	5	4	3	2	1	U
F Tier (%)					67	61	48	33	18	6
H Tier (%)	74	64	55	43	35	26	18			

Combined Science: Trilogy

Grade	5–5	5–4	4–4	4–3	3–3	3–2	2–2	2–1	1–1	U
F Tier (%)	59	54	50	44	37	31	25	19	13	0

Grade	9–9	9–8	8–8	8–7	7–6	6–6	6–5	5–5	5–4	4–4	4–3	3–3
H Tier (%)	66	62	58	53	49	44	40	35	31	26	22	19

1. Read questions carefully. This includes any information such as tables, diagrams and graphs.
2. Remember to cross out any work that you do not want to be marked.
3. Answer the question that is there, rather than the one you think should be there. In particular, make sure that your answer matches the command word in the question. For example, you need to recall something accurately in a describe question but not say why it happens. However, you do need to say why something happens in an explain question.
4. All the examination papers will include multiple-choice questions (MCQs). Make sure you tick the correct number of boxes, or link boxes with straight lines. When completing sentences, use words from the word list if one is given.
5. Show all the relevant working out in calculations. If you go wrong somewhere, you may still be awarded some marks if the working out is there. It is also much easier to check your answers if you can see your working out. Remember to give units when asked to do so.
6. Plot the points on graphs to within half a small square. Lines of best fit can be curved or straight, but must ignore anomalous points. If the command word is sketch rather than plot, you only need to draw an approximate graph, not an accurate one.
7. Make sure you do not mix words and symbols in chemical equations. You will be given full marks if you are asked to write a word equation, but you give the correct balanced equation instead. This does not work the other way round! Check that all the numbers of atoms, ions and charges balance in symbol equations. Remember to include state symbols when asked.
8. Remember that you may be asked to label a diagram or to complete a diagram. Sometimes you may be given the words to use. Make sure you can recall experiments you have done.

Good luck!