Chemistry

GCSE (9–1) | AQA | 8462

Targeting a Top Grade

in GCSE AQA Chemistry

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Contents

Teacher's Introduction

> **Remember!**
> Always check the exam board website for new information, including changes to the specification and sample assessment material.

The aim of this resource is to provide your students with revision materials, guidance and practice to help them secure a grade 9 in **GCSE (9–1) AQA Chemistry**.

As teachers, we always want our students to attain the highest grades possible. For many of your students entered for the Higher Tier paper, the challenge is to secure a grade 9. It is interesting as professionals to reflect that, on average, around 15% of candidates taking the Higher Tier paper will achieve grade 9, and around 18% will achieve grade 8. Data from AQA suggests that in both Paper 1 and Paper 2 candidates perform relatively poorly on questions associated with practical activities, working scientifically skills, and some mathematical skills such as graph interpretation, and for Paper 2 extended responses can be an area where marks are often lost. As such, these resources focus additional attention on these areas and provide activities for your students to build their confidence in these key areas of assessment. Practice for answering questions based on practical work appears within relevant topic chapters, as well as specific chapters focusing on working scientifically skills and graphical interpretation skills.

Alongside general examination advice, reminders about good exam practice and an overview of the command words, the specification has been divided into 14 units. Each unit consists of the following:

- A student-focused introduction, setting out the key knowledge required to obtain a grade 9.
- Explanations, worked examples, challenges, tips and interesting facts – forming the main content of each unit.
- A set of tasks, questions and have-a-go ideas that help students to test their knowledge, understanding and application.
- Exam-style questions – a chance to practise.
- Answers to the exam-style questions.

All of these photocopiable sections are designed to be used either in class, during a tutorial, during one-to-one sessions or by the students working alone in self-study. They are equally valuable for students currently working at grades 6 and 7 and aiming for grade 8 or 9. Although the primary focus is on securing that 9, any Higher Tier student will find valuable support in these materials.

April 2025

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Chapter 1: Periodic Tr

Introduction

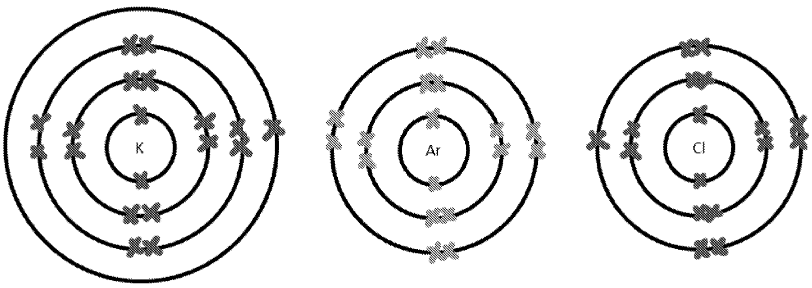
Describing trends in the periodic table, and using your knowledge to explain them
needed for the exam. Clarity is key: how does electron structure link to an eleme
Whilst group 1 metals **lose** electrons, group 7 elements **gain** electrons, and this le
reactivity down the group. Extended-answer questions often focus on these tren
making predictions using your knowledge, so confidence in your understanding is

Required prior knowledge

Before starting this chapter, you should know:

- How to draw dot-and-cross diagrams
- The basic structure of the periodic table
- The reactions of group 1 elements with water
- The appearance and physical properties of group 17 elements

A good way of explaining the difference between the chemical behaviours of groups 1 and 7 elements is by comparing their electron structures to group 0 elements. Let's look at the electron structure of potassium, K (left), and chlorine, Cl (right), comparing them to the electron structure of argon, Ar (middle):



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Use the task below to help you consolidate these ideas.

Task A

1. The shortened electron structure of argon can be written as (2, 8, 8). Write structures of potassium and chlorine.
2. Look at the electron structure of potassium.
   a. How can the electron structure of potassium become like the electron
   b. How does this explain the way group 1 elements form ions?
   c. Give the shortened electron structure of a potassium ion.
3. Look at the electron structure of chlorine.
   a. How can the electron structure of chlorine become like the electron st
   b. How does this explain the way group 7 elements form ions?
   c. Give the shortened electron structure of a chloride ion.

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Trends down the groups

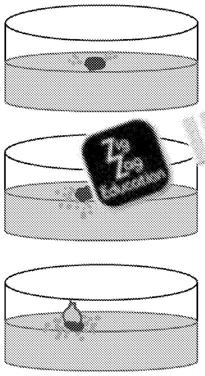
We know that potassium and chlorine react very differently to form ions. Elemen periodic table react in the **same way**, but the *ease* with which they form ions will

Group 1: The alkali metals

These elements **lose <u>one</u> electron** to form **positive ions**. You will have seen this happen on a macroscopic scale when watching the demonstration of group 1 metals in water.

> **Macroscopic scale:** T the naked eye. Expe the macroscopic scale by looking at the **sub** electron structures.

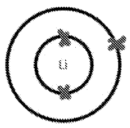
The first three group 1 metals are added to a trough containing water. The obs



Group 1 element	Observations when a
Lithium	Fizzes slowly, moving on the surface
Sodium	Fizzes, moving quickly on the surface The sodium metal melts.
Potassium	Fizzes vigorously, moving quickly on t A lilac flame is seen.

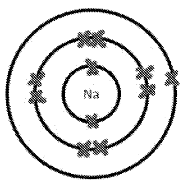
The reactions become **more vigorous** as we descend th

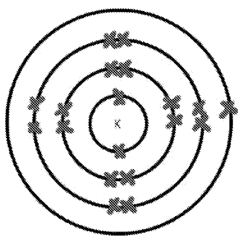
How can this trend be explained?
The electron structures of the first three group 1 metals are shown below.



As we descend the group:

- The atom's radius increases as there are more electron shells
- The valence electrons are further away from the nucle
- The valence electrons experience **less 'pull'** from the positively charged nucleus
- The valence electrons are more **shielded** from the nuc
- Therefore, the electrons become **easier** to lose





Exam tips
When answering questions on reactivity trend down the group, following the 'RASE' mnemonic can help:
- ❑ <u>R</u>adius of atom
- ❑ <u>A</u>ttraction of electron to the nucleus
- ❑ Shielding
- ❑ Ease of losing/gaining electrons

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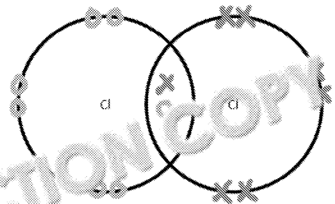
Group 7: The halogens

These elements **gain <u>one</u> electron** to form **negative ions**. The halogens react with metals to form **halide salts**. They will also react with hydrogen to form hydrogen halides.

> **Halogen or halide?**
> When the halogens are in the **elemental form**, their names end in '-ine'. When they have formed their negative ions, we change their name to end in '-ide'.

In their elemental form, the halogens are **diatomic molecules**: two atoms in each molecule are joined by a single covalent bond:

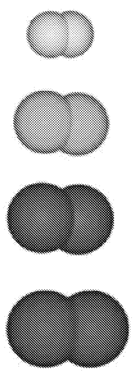


> Group…
> When M… periodic… what to… elements… not yet… meant th… groups at… version, w… the colum… groups, so… group 17… more mod…

As the elements are [illegible] **[illegible]molecular structures**, they have **low meltin[illegible] [illegible]oi[illegible]g points**. The molecules follow a clear trend i[illegible]sical properties:

Halogen	Appearance at room temperature	Melti…
Fluorine	Yellow gas	-
Chlorine	Pale yellow-green gas	-
Bromine	Red-brown liquid which readily vaporises	
Iodine	Black shiny crystals which sublime to a purple vapour	1

As we go down the group:



- The colour **intensifies and darkens**
- The number of electron shells in each atom increases
- This mean that the size of the molecules **increases**
- The strength of the intermolecular forces increases
- It requires more **energy** to overcome these forces to melt or boil the substance
- The melting and boiling points th[illegible] **[illegible]increase**

> Ex… Wl… bo… gr… m… ❑ ❑ ❑

The halogens are slightly soluble i[illegible] soluble in organic solvents such as… know the colour of halog[illegible] for their reactions later. Luckily, you will no… appearance [illegible]

Halogen	Appearance of vapour	Appearance in water	Appear…
Chlorine	Pale yellow-green gas	Colourless	Pa…
Bromine	Red-brown gas	Red-brown	C…
Iodine	Purple gas	Dark brown	

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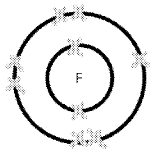
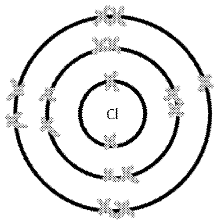
Chemical properties of the halide ions are explained by the electron structures of
The electron structures of fluorine and chlorine atoms are shown below.





As we descend the group:

- The atom's radius increases as there are more electron shells
- The valence electrons are further away from the nucleus
- The valence electrons experience **less 'pull'** from the positively charged nucleus
- The valence electrons are more **shielded** from the nucleus
- Therefore, it is **much harder** to gain an electron to complete the outer shell and form an ion

Reminder: You could only be asked to draw electron structures of the first 20 elements. All the elements in group 17 will have ***7 valence electrons.***

Key halogen reactions:

1. **Reactions of halogens with metals**
   These reactions will form halide salts: $MX_{(s)}$
2. **Reactions of halogens with hydrogen**
   These reactions will form hydrogen halides: $HX_{(g)}$
3. **Reactions of halogen with silver**
   These reactions will form silver halides, $AgX_{(s)}$, important chemicals in identification tests

Key exam skill

Using these trends in properties, you could be asked to **make predictions** of ch
of elements further down the periodic table: rubidium, caesium, astatine an

Task B

1. Copy and complete the word equations:
   a. Sodium + fluorine → sodium _______________
   b. _______________ + chlorine → aluminium chloride
   c. Silver + _______________ → silver bromide
   d. Hydrogen + chlorine → _______________
2. Write the formulae of the following halide compounds:
   a. Iron(III) bromide
   b. Silver chloride
   c. Sodium iodide
   d. Hydrogen fluoride
3. Write balanced equations for the reactions which form the four halide com

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Making predictions

Using the trends you have studied is an essential skill at GCSE. It helps us to make predictions about chemical and physical properties of dangerously reactive elements such as caesium, and synthetic elements such as astatine and tennessine.

Physical properties	Chemical properties
Compare the <u>structure and bonding</u> of the elements	Compare the <u>electron structures</u> of the elements

Astat…
radio…
curre…
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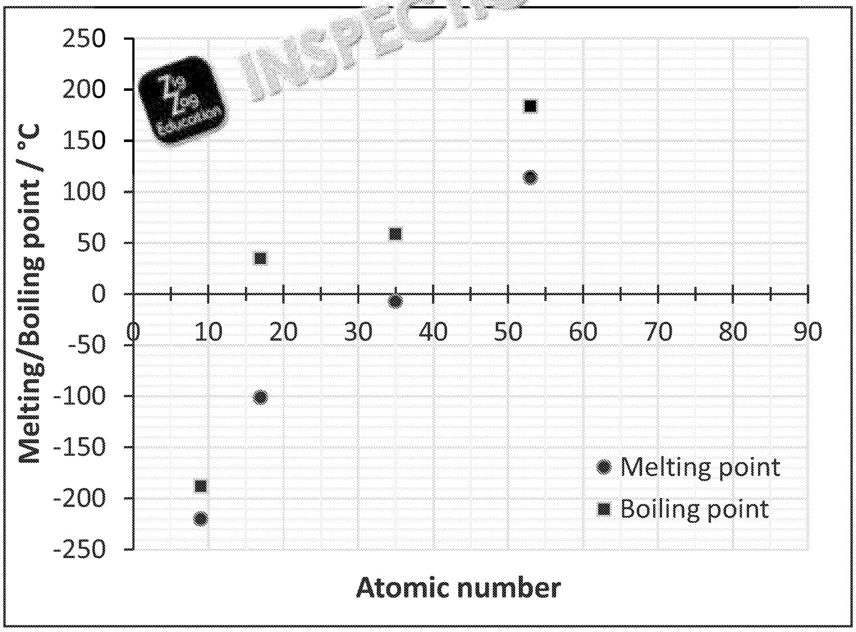
8 hou…
have e…

Consider the graph below, showing the melting and boiling points of the halogens. How could this be used to predict the physical state of astatine?



Steps:
1. Dr… fo…
2. Ex… be… fo…
3. Us… lin… nu… th…
4. W… be… to…
5. Re…
6. Re… bo…

Task C

Tennessine was first identified by a group of scientists in 2010. Only six atoms o… ever been identified, which is not enough to be able to observe the element at t…

1. Give the expected formula of tennessine in its elemental form.
2. How many electrons would be in the outer shell of a tennessine atom?
3. Suggest the appearance of tennessine at room temperature.
4. Give the formula of the ion you would expect tennessine to form.
5. Predict the chemical formulae of the theoretical compounds formed from r… the elements below:
   a. Iron(III)
   b. [illegible]
   c. [illegible]
6. Predict and explain whether tennessine would be more or less reactive tha…

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Exam-style questions: Trends

1. Group 1 elements react in water.
   a. Describe **three** observations that can be seen when potassium is added t
   b. Explain the trend in reactivity as we descend group 1.
   c. Write a balanced symbol equation for the reaction of sodium with water

2. The halogens are found in group 7 of the periodic table.
   a. Describe **two** physical properties of iodine.
   b. Explain the trend in boiling point as we descend group 7.
   c. State which element in group 7 is the most reactive. Explain your answe

3. Caesium is a highly reactive element in group 1 of the periodic table.
   a. Write a balanced equation for the reaction of caesium in water.
   b. Predict one observation you would make when caesium is added to wat caesium is **more** reactive than lithium.
   c. Explain why caesium is more reactive than lithium.

4. A theoretical reaction could occur between caesium and tennessine.
   a. Write a balanced equation for the reaction.
   b. Draw a dot-and-cross diagram to represent the bonding in the product f Draw the outer shell electrons only.

End of questions

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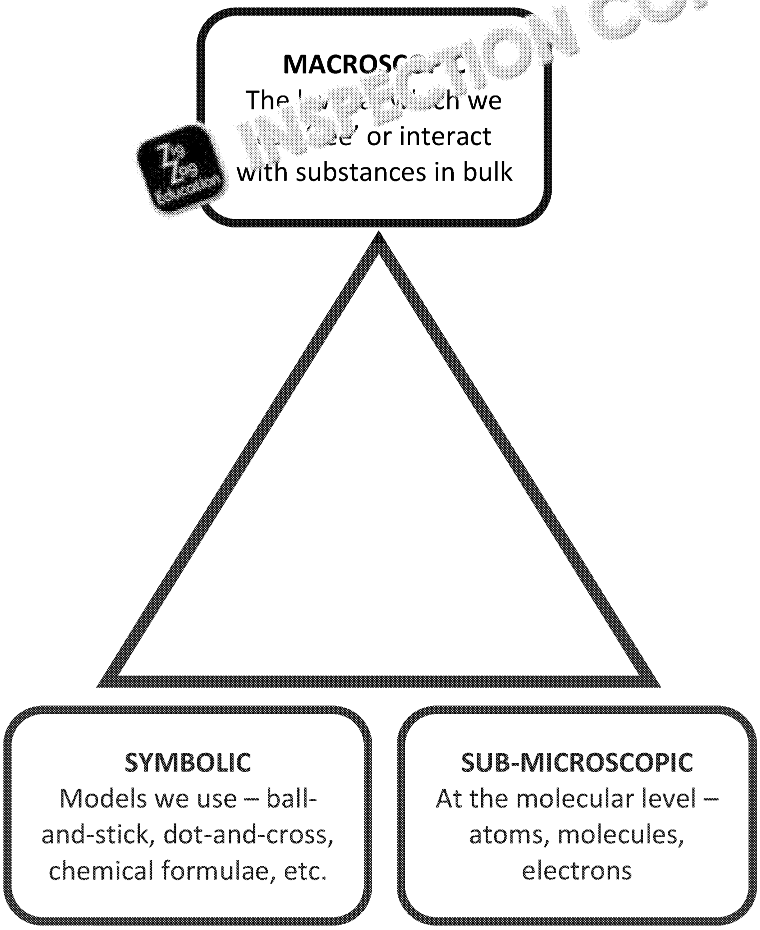
Chapter 2: Structure and

Introduction

A solid understanding of fundamental concepts of chemical bonding is the key to
Bonding is the bedrock of chemistry: it influences the properties and behaviours
daily lives. From simple water molecules to complex organic compounds, the pri
structure underpins their behaviour and our ability to interact with them.

This topic often poses a challenge for students, as it is hard to visualise the abstra
tiny scale, and how this impacts upon its properties and behaviour in bulk. It can
the three different levels upon which we will consider these substances:



Let's take wate

- At the ma it is a clea We could such as m chemical metals.
- At a sub- water is c and an ox bonded to shared be the oxyge
- At the sym the chemi might dra molecule, cross diag

This topic is ch us to continua of working.

Required prior knowledge

- The three types of chemical bonds: covalent, ionic and metallic, and how t
- The types of structures: giant covalent, simple covalent, giant ionic, giant m
- The typical chemical and physical properties of each structure type

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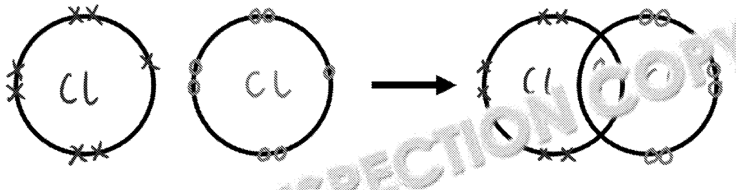
Chemical bonding

There are three types of chemical bonds: covalent, ionic and metallic. Chemical b
what is happening to the **electrons** when an atom bonds to another; are they sha
Remember, atoms bond to **achieve a full outer shell of electrons**. It is just the w

Covalent bonding occurs when two atoms share a pair (or more!) of electrons. Si
electron shells which are more than half-full, these are the atoms which bond cov
An example is the molecule chlorine, Cl_2. Both chlorine atoms have seven electro
achieve a full outer shell, they can share a pair of electrons:



Symbolic diagram to show bonding in chlorine molecules, Cl_2

Key skill: D
for covalent
for the exam
one atom, a
show outer s

Double bonds occur when **two** pairs of electrons are shared, and triple bonds occur when **three** pairs are shared. The hydrocarbons shown each contain just two carbon atoms.

Ethane (C_2H_6) contains a carbon–carbon single bond, shown by the shared pair in the overlap

Ethene (C_2H_4) has a carbon–carbon double bond, shown by the two shared pairs in the overlap

Ethyne (C_2H_2) has a carbon–carbon triple bond, shown by the three shared pairs in the overlap

To work out how many chemical bonds an atom needs to make, simply look at its

Group number	Electrons in outer shell	Electrons needed to complete the outer shell
4	4	4
5	5	3
6	6	2
7	7	1

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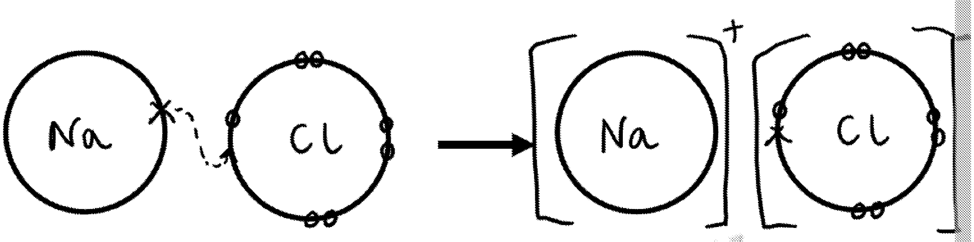
Ionic bonding occurs between metal atoms and non-metal atoms. The metal ato non-metal atom **gains** electrons – the electrons are transferred from the metal to **full outer shell** for both atoms. For example, if we take our chlorine atom again, sodium atom:

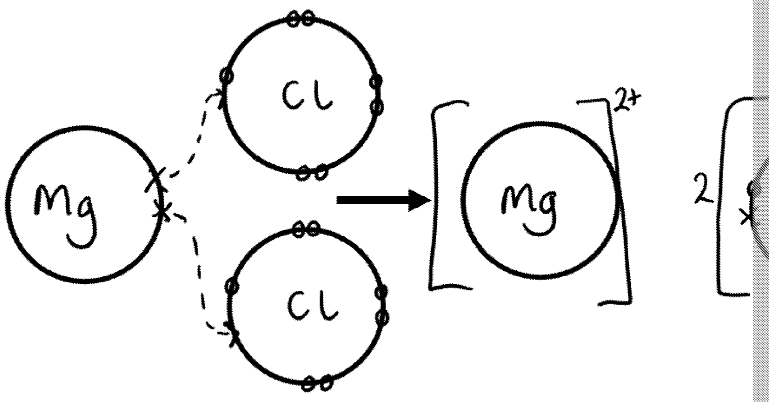


Symbolic representation of the formation of ions from a sodium atom and a chlorine atom

The sodium atom **loses one electron** to form a 1+ ion, whilst the chlorine atom ga a 1- ion. Both atoms have a full outer shell. The **ionic bond** is formed due to the between the positive ions and the negative ions, over many layers in 3D.

Multiple charged ions can occur when more than one electron is lost or gained, e. two electrons) or oxide ions O^{2-} (gained two electrons).

More than one ion may be required if one atom needs to gain/lose more than the magnesium chloride:



Symbolic representation of the formation of ions from a magnesium atom a

To work out the charge on the ion formed for an atom, simply look at its position

Group number	Electrons in outer shell	Electrons needed to be lost or gained for a full outer shell
1	1	Lose 1
2	2	Lose 2
3	3	Lose 3
5	5	Gain 3
6	6	Gain 2
7	7	Gain 1

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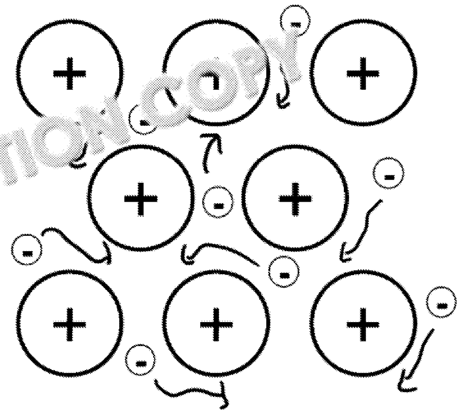
Metallic bonding occurs within a metal in its elemental form. The outer shell elec lost, forming positive metal ions. These are arranged in a regular form. The elect which means they have no fixed position and are free to move around the structu attraction between the positive metal ions and the free-moving delocalised electr holding the structure together.

The diagram shows an example for sodium – each sodium ion has a 1+ charge, an electron to the structure. If magnesium were used instead, the ions would have a double the number of delocalised electrons present.



Symbolic diagram for the bonding in sodium metal

Task A

1. For each substance given below, decide if the bonding is ionic, covalent or r
    a. Al
    b. MgO
    c. Br_2
    d. $BaCl_2$
    e. CH_4
    f. O_2
    g. Na_2O
    h. Ca
2. Copy and complete the table to summarise chemical bonding, placing the exa the 'examples' row.

Type of chemical bond	Ionic	Cova
What happens to the electrons?		
What type of atoms show this bonding?		
Examples		

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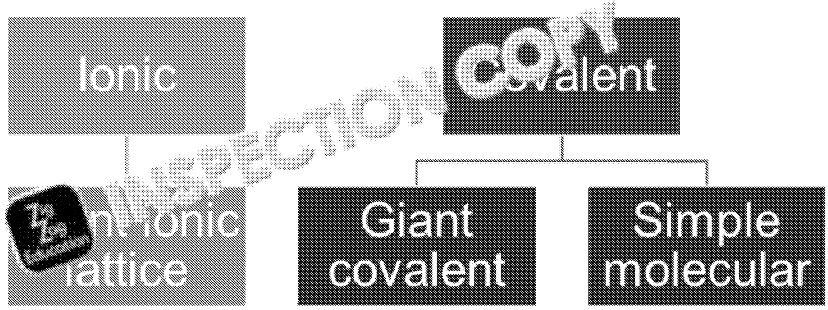
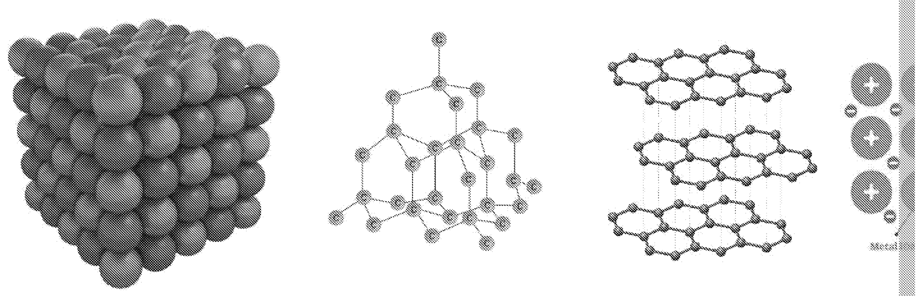
Structure types

Now we have considered the sub-microscopic level of bonding, representing it u
think about how this builds up into macroscopic structures.

Structures can be simple, with fixed, defined numbers, or giant, extending over m
This means that, although there are only three types of bonding, there are four t
from these:

As you can see, ionic substances **always** form giant structures, as do metallic sub
substances which could be simple or giant.





Each structure type is held together by a different **force**:

- Giant ionic lattice – held together by strong electrostatic forces of attraction ions in three dimensions
- Giant covalent network – held together by a strong network of covalent bon
- Simple molecular structures – held together by weak forces between each m
- Metallic lattice – held together by strong electrostatic forces of attraction be delocalised electrons

The stronger the force holding the substance together, the higher the melting po
explains why sodium chloride, held together by many strong electrostatic forces c
melting point than water, which is held together by weak intermolecular forces.

Task B

1. Sodium chloride has the formula NaCl.
   a. What type of bonding does NaCl exhibit?
   b. Describe the structure of sodium chloride.
2. Sodium is a metal. Describe the structure and bonding of sodium.
3. For each substance below, give its **structure type**:

a. Al	b. MgO
c. Br_2	d. $BaCl_2$
e. CH_4	f. O_2
g. Na_2O	h. Ca

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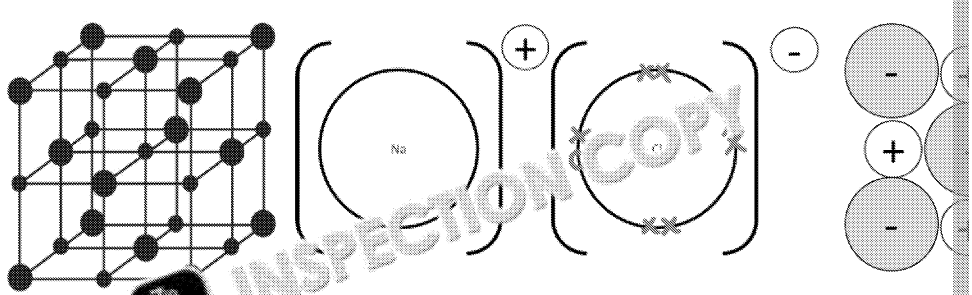
Modelling substances

Models serve as tools for understanding the microscopic world of atoms and mol
representations that aid comprehension. However, it's crucial to recognise that n
benefits and limitations.

Let us take the example of sodium chloride, which can be modelled using four ma
stick model, the dot-and-cross model, the 2D space-filling model, and the 3D spac



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Task C

Look at the models above for sodium chloride. Use the list of statements below
limitation for each model type.

- Could make it look like there are covalent bonds between the ions or that t
from each other
- Clearly represents the electron structure of each ion
- By representing ions as balls and the 'bond' as a stick, it allows us to easily s
relationships in the structure
- Difficult to draw 3D objects in 2D!
- Doesn't show the 3D nature of the structure
- Gives a good representation of how the ions are packed in three dimensio
- Shows the relative sizes of each ion and is easy to draw
- Does not show the true number of ions within the structure (there are billi

Model	Benefit	
Ball-and-stick model		
Dot-and-cross diagram		
3D space-filling diagram		
2D space-filling diagram		

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Exam-style questions

1. This question is about lithium chloride.
   a. Lithium chloride has the formula LiCl. Draw a dot-and-cross diagram to
   lithium chloride.
   b. Explain why lithium chloride is a solid at room temperature.

2. Explain why ammonia, NH_3, is a gas at room temperature, whereas diamond,

3. Magnesium is a metal. Describe the structure of magnesium, and explain wh

End of paper

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Chapter 3: Essential Moles Ca

Introduction

Moles calculations are essential to chemists; they are our bread and butter for un
chemical equations! Calculations **will** crop up in the exam in some form or anoth
topic, we will look at the basic moles calculations you will need for the exam, and
interconverting between quantities in masses, volumes and concentrations.

Equations used in this chapter

$n\ (\text{mol}) = \frac{\text{mass (g)}}{M_r}$ $n\ (\text{mol}) = \frac{\text{number of particles}}{\text{Avogadro constant}}$ n (m

concentration (g/dm³) $= \frac{\text{mass (g)}}{\text{vol }(\text{dm}^3)}$ concentration (m

Standard form is used throughout this topic.

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Moles, masses and Avogadro

Imagine you are carrying out a chemical reaction in the lab. It would be complete
on the scale of just *one* molecule. As chemists, we work on the scale of **moles**.

Avogadro constant: The number of particles in one mole of a substance.

Number of moles, $n\ (mol) = \frac{\text{number of particles}}{\text{Avogadro constant}}$
You will be given the Avogadro constant in the exam.
It is equal to 6.02×10^{23}

Worked example: How many particles are contained in 6.0 moles of water (H_2O)

How many significant figures? In this question, the number of moles was given to 2 sf. Therefore, our answer should be given to **no more than 2 sf.**

$6.0\ \text{moles} = \frac{\text{number of particles}}{\text{Avogadro constant}}$
Rearranging the equation gives:
number of particles = 6 × Avogadro constant
$= 6.0 \times (6.02 \times 10^{23})$
$= 3.612 \times 10^{24}$
$= 3.6 \times 10^{24}$ water particles (2

The mass of a mole of a substance will differ depending on which substance we ha
to convert between the two

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Worked example: What mass is the mass of 6.0 moles of water (H_2O)?

$\text{Mass (g)} = \frac{n\ (\text{mol})}{M_r}$

You will always have access to the periodic table in the exam!

Using the periodic table to look up the A_r for hydrogen and oxygen:
M_r of water = (2 × 1.0) + 16.0 = 18.0

So: mass $= \frac{n\ (\text{mol})}{M_r} = \frac{6}{18.0} = 0.3333...$
mass = 0.33 g (2 sf)

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Task A: Moles, mass and Avogadro

You will need your calculator and your AQA GCSE Chemistry periodic table.
Avogadro constant = 6.02×10^{23}

1. How many moles of carbon atoms are in 12 g of carbon?
2. What is the mass of 0.5 moles of water?
3. Calculate the number of molecules in 2 moles of carbon dioxide.
4. How many moles of sodium ions are present in 1.5 g of sodium chloride?
5. If you have 4.82×10^{22} oxygen molecules, what is the mass of oxygen in gra

Concentrations

When working with solutions, we use concentrations rather than masses. There a ways of defining concentration and so two equations you need to learn.

$$\text{Concentration (g dm}^{-3}) = \frac{\text{mass of solution (g)}}{\text{volume (dm}^3)}$$

$$\text{Concentration (mol dm}^{-3}) = \frac{\text{n (mol)}}{\text{volume (dm}^3)}$$

IMPORTANT:
Volumes **must** be in dm^3 for these equations. To convert between cm^3 and dm^3, divide by 1000.

Using our moles equation from earlier, to convert between the different concentration units:

Concentration (g dm^{-3}) → $\div M_r$ → Concentration (mol dm^{-3})
Concentration (mol dm^{-3}) → $\times M_r$ → Concentration (g dm^{-3})

Concentrations c amount of subst solvent they are diagram above. the right would b because there are being placed into We couldn't comp easily if the volum which is why che

Task B: Concentrations

You will need your calculator and your AQA GCSE Chemistry periodic table.

1. What is the concentration, in g dm^{-3}, of a 500 cm^3 solution containing 6 g o
2. Calculate the concentration, in mol dm^{-3}, of a [illegible] cm^3 solution containing (potassium hydroxide.
3. If you dissolve 9 g of glucose ($C_6H_{12}O_6$) in 750 cm^3 of water, what is the con glucose solution in mol dm^{-3}?
4. A 25[illegible] solution contains 5 g of sulfuric acid. What is the concentration i
   a. g dm^{-3}?
   b. mol dm^{-3}?
5. If 3.6 g of calcium chloride is dissolved in 300 cm^3 of water, what is the con chloride solution in:
   a. g dm^{-3}?
   b. mol dm^{-3}?

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Gas volumes

Since particles are **so** tiny, and particles are **extremely** far apart in the gaseous state, the majority of the volume of a gas is actually empty space. We can therefore use the approximation that the volume of 1 mole of any gas occupies 24.0 dm^3.

$$n \text{ (mol) of gas} = \frac{\text{volume of gas } (dm^3)}{24}$$

IMPORTANT:
Volumes **must** be in dm^3 for this equation.

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Task C: Gas volumes

You will need your calculator an[d] [yo]u[r] [A]QA GCSE Chemistry periodic table.

1. Calculate the numb[er of mo]l[e]s in 96 cm^3 of carbon dioxide.
2. Calcul[ate] the [num]b[er] of moles in 36 cm^3 of steam.
3. A co[ntainer] holds 120 dm^3 of gas. How many moles of gas are present?
4. What [is t]he volume of 3 moles of hydrogen?
5. A container holds a 60 cm^3 sample of nitrogen gas.
   a. How many moles of nitrogen are present?
   b. What is the mass of the sample?
   c. How many nitrogen molecules are present in the sample?

Exam-style questions

1. Sulfur hexafluoride has the chemical formula SF_6.
   a. Determine the mass of 0.025 moles of sulfur hexafluoride.
   b. How many molecules of sulfur hexafluoride are contained in the sample
   c. How many sulfur atoms and fluorine atoms are present in the sample?

2. 150 cm^3 of solution contains 4.25 g of ammonium nitrate. Calculate the con
   a. in g dm^{-3}
   b. in mol dm^{-3}

3. A sample of nitrogen gas has a volume of 500 cm^3.
   a. How many moles of gas are present in the sample?
   b. How many grams of nitrogen are present in the sample?
   c. How many atoms of nitrogen are present in the sample?

4. Determine the concentration in mol dm^3 [o]f a 25[0 c]m[3] of solution containing permanganate ($KMnO_4$).

End of questions

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Chapter 4: More moles cal

Introduction

As well as being able to work out moles for quantities of substances we already have, chemists are interested in calculating moles for substances we originally started with or haven't yet formed during a chemical process. We do this by usin **molar ratios** from chemical equations – using the balancing numbers from the symbol equation.

Equations used in this chapter

$n\text{ (mol)} = \frac{\text{mass (g)}}{M_r}$ n (mol) = number of particles / Avogadro constant   n (m

concentration $(\text{g dm}^{-3}) = \frac{\text{mass (g)}}{\text{vol (dm}^3)}$ concentration (m

Standard form is used throughout this topic.

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Reacting substances

In industrial processes, we are interested in how much **product** can be made. The substance required for chemical processes is a core skill of a quantitative chemist. **methodical** in your approach, **showing your working** throughout **with units**: what is a concentration… Numbers can quickly get lost if it is not clear where they cam

Having a step-by-step method to follow in multistep calculations can be really helpful if you find you often don't know where to start.

Steps
1. W th
2. Co su
3. Us ba re
4. Co a r

Worked example: Reacting masses
If 4.0 g of hydrogen gas reacts with an excess of oxygen to form water, what is the mass of water produced?

Step 1: Balanced equation
$2H_2 + O_2 \rightarrow 2H_2O$

Step 2: Convert to moles
$n(H_2) = 4.0 / (2 \times 1.0) = 2$ moles of hydrogen

Step 3: Reacting ratio
In the equation, hydrogen and oxygen ... the **same reacting ratio**, so 2 moles of hydrogen produces 2 moles of water.

$n(H_2O) = 2$

Step 4: Convert back to mass
$\text{mass}(H_2O) = 2 \times 18.0 = 36.0$ g of water produced

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The same method can be used for reactions involving solutions, e.g. titrations.

Worked example: Titration calculation
A 0.125 mol dm^{-3} solution of sulfuric acid is titrated with a sodium hydroxide solution of unknown concentration. If it takes 40.00 cm^3 of sodium hydroxide to neutralise 25.0 cm^3 of the acid, what is the concentration of the sodium hydroxide?

Step 1: Balanced equation
$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

Step 2: Convert to moles
n(HCl) = 0.125 × 25.0 / 1000 = 3.125 × 10^{-3} moles

Step 3: Reacting ratio
In the equation, each mole of sulfuric acid reacts with double the number of moles of sodium hydroxide, so 3.125 × 10^{-3} moles react with 6.25 × 10^{-3} moles.
n(NaOH) = 2 n(H_2SO_4) = 2 × 3.125 × 10^{-3} = 6.25 × 10^{-3} moles

Step 4: Convert back to concentration
$[NaOH] = \frac{6.25 \times 10^{-3}}{40.00 / 1000} = 0.15625 = 0.156 \text{ mol dm}^{-3}$

Steps f
1. W th
2. Co gi
3. Us ba re
4. Co co

Tip: It i answer during end. St when v

At GCSE, we focu there are m throughout the f production, an

Reacting gas calculations are even easier! Since 1 mole of **any gas** occupies 24 dm volumes are **molar volumes**, and can be used as reacting ratios!

Worked example: Reacting gases
Ammonia and oxygen form nitrogen monoxide and water. If you start with 48 cm^3 of ammonia and an excess of oxygen, what volume, in dm^3, of nitrogen monoxide can be produced?

Step 1: Balanced equation
$2NH_3 + 2O_2 \rightarrow NO + 3H_2O$

Step 2: Molar volume ratio
48 cm^3 of ammonia produces half the amount of nitrogen monoxide, so 24 cm^3 is produced

Step 3: Unit conversion
24 cm^3 is equal to 24 / 1000 dm^3, so our final answer is 0.024 dm^3 or 2.4 × 10^{-2} dm^3

Steps
1. W th
2. U fr fi
3. R if

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Task A

Remember to use your AQA GCSE Chemistry periodic table and your calculator wh

1. If 16.0 g of methane (CH_4) burns in oxygen to produce carbon dioxide and w dioxide is formed?
2. If 10.0 g of iron reacts with sulfur to form iron(II) sulfide, what mass of iron
3. When 8.0 g of magnesium reacts with excess hydrochloric acid, what mass of
4. If 5.0 g of calcium carbonate decomposes to produce calcium oxide and car calcium oxide is formed?
5. A 0.1 mol dm^{-3} solution of hydrochloric acid is titrated with sodium hydroxi If 25.0 cm^3 of sodium hydroxide is neutralised by 30.0 cm^3 of hydrochloric a of the sodium hydroxide?
6. A 0.5 mol dm^{-3} solution of sulfuric acid is titrated with a sodium hydroxide s concentration. It takes 35 cm^3 of sodium hydroxide to neutralise 15.0 cm^3 concentration of the sodium hydroxide?
7. When 3.0 dm^3 of hydrogen gas reacts with nitrogen gas, ammonia gas is pr ammonia is produced at room temperature and pressure?

Limiting reagents

In chemical reactions, we rarely have **exactly** the right moles of each substance to exactly react with another amount. One reagent is **in excess**, and the other is **limiting** – it gets used up first.

Limiting is comple reaction. determi **product**

Imagine you are at a barbeque on a summer's day, and you are in charge of making up the burgers. You have 10 patties, but only 8 buns. How many complete burgers can you make?

Although we have 10 patties, **all of the buns have been used up**, so only 8 comple burgers can be made. This is the same for chemical reactions – one reactant **limit** the amount of product we can make.

Worked example: Limiting reagents
In a sealed reaction vessel, 32.0 g of oxygen is added to 2.0 g of hydrogen. The mixture is heated to produce water.

a) Which is the limiting reagent?

Step 1: Balanced equation
$2H_2 + O_2 \rightarrow 2H_2O$

Step 2: Calculate moles
$n(H_2) = 2.0 / 2.0 = 1$ mole
$n(O_2) = 32.0 / 32.0 = 1$ mole

Step 3: Required and actual ratios
Required ratio: 2 : 1
Actual ratio: 1 : 1

Step 4: Limiting reagent
We can see there is **less hydrogen** than would be needed to react with all of the oxygen.

b) How much product can be formed?

Step 5: How much product?

If only 1 mole of **hydrogen** is available, only 1 mole of water can be formed.

Mass (H_2O) = 1 × 18.0 = 18.0 g of water formed

Re ca wh pr **no** mo **rec**

Wh
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2.
3.
4.
5.

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Task B

Remember to use your AQA GCSE Chemistry periodic table and your calculator [cut off] these questions.

1. In a reaction between iron and oxygen, 56.0 g of iron is burned in 48 dm^3 o[cut off]
   a. Balance the equation for the reaction:
      ___Fe + ___O_2 → ___Fe_2O_3
   b. Which reagent is limiting in the reaction?
   c. Calculate the mass of iron oxide which can be formed by the reaction.
2. In the reaction between sulfuric acid and sodium hydroxide, 50.0 cm^3 of 2.[cut off] reacts with 75.0 cm^3 of 4 mol dm^{-3} sodium hydroxide solution.
   a. Write a balanced symbol equation for the reaction between sulfuric a[cut off]
   b. Determine the limiting reagent in this reaction.
   c. Calculate the maximum mass of sodium sulfate which can be formed.
3. In a chemical reaction, ammonia and oxygen react to produce nitrogen mo[cut off] to the equation below. If you started with 15 dm^3 of ammonia and 18 dm^3 [cut off] nitrogen monoxide will be produced?
   $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

Using moles to write balanced equations

If you know the masses of the reactants and products that took part in a reaction, [cut off] symbol equation.

Worked example: Using moles to write balanced equations

8.1 g of zinc oxide reacts completely with 0.60 g of carbon to form 2.2 g of carbon dioxide and 6.5 g of zinc. Use this information to write a balanced symbol equation for the reaction.

n(ZnO) = 8.1 / 71 = 0.10
n(C) = 0.6 / 12 = 0.050
n(CO_2) = 2.2 / 44 = 0.050
n(Zn) = 6.5 / 65 = 0.10

Dividing by the smallest number to get a whole number ratio:
n(ZnO) = 0.10 / 0.050 = 2
n(C) = 0.050 / 0.050 = 1
n(CO_2) = 0.050 / 0.050 = 1
n(Zn) = 0.10 / 0.050 = 2

So the balanced equation becomes:
$2ZnO + C \rightarrow CO_2 + 2Zn$

Task

Remember to use your AQA GCSE Chemistry periodic table and your calculator [cut off] these questions.

1. Copper can form two oxides: copper(I) oxide (Cu_2O) and copper(II) oxide (C[cut off]
   One oxide of copper reacts with hydrogen according to the word equation:
   copper oxide + hydrogen → copper + water
   In the reaction, 2.54 g of copper and 0.72 g of water are produced. Determ[cut off] reacts, and write a balanced equation for the reaction.

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Chapter 5: Metals

Introduction

Metals are frequently the focus of exam questions at GCSE, as they cover a numb
areas: from structure and bonding, reactions of metals and the reactivity series, m
methods of extraction, to alloys and their properties. Questions can be a challen
redox processes.

Required prior knowledge

- Structure and bonding in metals
- Physical properties of metals and alloys
- How metals form ions
- The reactivity series and how it is used
- Definitions of 'oxidation' and 'reduction'
- Alternative methods of metal extraction

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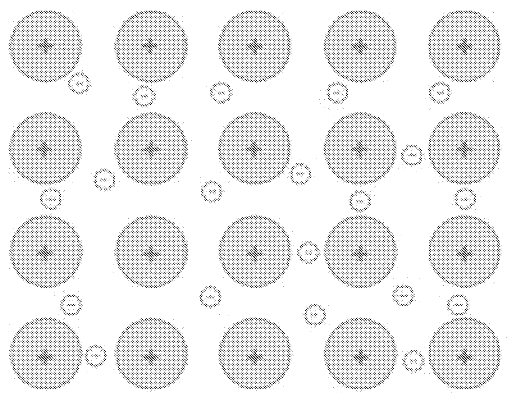
Structure and properties of metals and alloys

Metals are arranged in a regular lattice of positive ions, surrounded by a sea of delocalised electrons. This can be represented by the diagram shown.



Metallic bonds are three-dimensional – every positive ion is attracted to the delocalised electrons which surround it, and in turn, every delocalised electron is attracted to the positive ions surrounding it Metallic bonds are therefore **stro** to overcome. This explains why m **boiling points**.

We can use the structure of meta properties of metals, too.

Malleability and ductility

Metals are highly malleable and ductile – they can be bent and hammered into sh easily. When a force is applied to a metal, the layers of atoms can **move**, shifting changing the shape of the metal overall.

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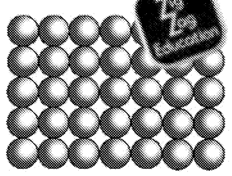
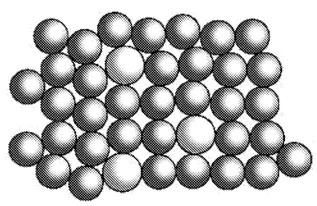
Electrical and thermal conductivity

The delocalised electrons in the structure are free to move. This means they can thermal energy through the structure. This makes metals excellent conductors





Alloys are formed whe element; often carbon see from the diagram, elements **disrupts** the As there are now **diff** much more difficult fo another. Alloys are th stronger than pure me

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Throughout our daily lives, we encounter alloys more often than pure metals (whi
their pure form). Some examples are included in the table below.

Alloy	Elements it is made from	Key properties
Steel	Iron, carbon and other elements	• High carbon steel is strong but brittle • Low carbon steel is soft and easily shaped • Stainless steel is hard and resistant to corrosion
Bronze	Copper and tin	Malleable
Brass	Copper and zinc	Sonorous (rings with a 'bell'-like sound) Malleable Shiny and resistant to corrosion
Aluminium alloys	Aluminium and other elements	Unreactive Very low density
Gold alloys	Gold, copper, zinc	Shiny Malleable (but less malleable than pure gold)

In the exam, you will need to be able to explain how the properties of the alloy re

Task A

1. Compare the structure and bonding in **sodium** with the structure and bond
2. Explain why steel is used in the construction of buildings in place of pure ir
   refer to the structure of iron and steel.
3. The carat number of gold refers to how many gold atoms there are within e
   therefore 'pure' gold. 18 carat white gold is often an alloy of gold and palla
   percentage of gold and palladium atoms in a sample of 18 carat white gold.

Reactions of metals

There are four main metal reactions which help us to determine a metal's reactivity:

1. Metal + acid reactions
2. Metal + oxygen reactions
3. Metal + water reactions
4. Metal displacement reactions

By observing the way in which metals react (or not!), they can be placed into a **reactivity series** from most (at the top) to least (at the bottom) reactive.

General equations

Metal + acid → salt + hydrogen
Metal + oxygen → metal oxide
Metal + water → metal hydroxide + hydrogen

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Metal + acid

A metal will react with an acid if it is **higher** than **hydrogen** on the reactivity serie
A salt solution and hydrogen gas is formed. Fizzing would be observed.

To name the salt formed, we keep the name of the metal and adapt the name of t acid it is formed from. Hydrochloric acid forms **chlorides**, sulfuric acid forms **sulfa** and nitric acid makes **nitrates**.
e.g. magnesium + hydrochloric acid → magnesium chloride + hydrogen

Metal + oxygen

Some metals burn in oxygen to form metal oxides. These reactions are **oxidation reactions**, since oxygen is added.
e.g. sodium + oxygen → sodium oxide

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Metals + water

Some metals react with water, producing a metal hydroxide solution and bubbles of hydrogen. This happens quickly for group 1 metals, but much more slowly for other metals, such as magnesium.
e.g. potassium + water → potassium hydroxide + hydrogen
Iron reacts **very** slowly with water in a process called **rusting**.

Metal displacement reactions

These reactions occur when a **more reactive** metal displaces a **less reactive** metal
A good example of this is when copper wire is dipped into silver nitrate solution. it displaces the silver from the silver nitrate, forming silver and copper nitrate.
e.g. copper + silver nitrate → silver + copper nitrate

Formulae of the products

The products formed have overall neutral charges. To find their formulae, you need to work out how many of each ions are needed to balance out the charges. Some examples are given below.

Important formulae:
POSITIVE IONS

- Group 1 metals form 1+ ions
- Group 2 metals form 2+ ions
- Group 3 metals form 3+ ions
- Transition metals use Roman numerals to show you the charge on the ion

Magnesium hydroxide:
Positive ion: Mg^{2+}
Negative ion: OH^-
Formula of substance: $Mg(OH)_2$

Sodium sulfate:
Positive ion: Na^+
Negative ion: SO_4^{2-}
Formula of substance: Na_2SO_4

Calcium nitrate
Positive ion: Ca^{2+}
Negative ion: NO_3^-
Formula of substance: $Ca(NO_3)_2$

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Aluminium oxide
Positive ion: Al^{3+}
Negative ion: O^{2-}
Formula of substance: Al_2O_3

Once you have worked out the chemical formulae required, balanced equations c

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Task B

1. Write the chemical formulae of the following compounds:
   a. Sodium sulfate b. Barium nitrate c.
2. For each displacement reaction below, explain whether it will occur or not. explain your answer in each case:
   a. Copper + magnesium sulfate b. Lithium + iron(III) nitrate c.
3. Write balanced symbol equations for the reactions:
   a. Sodium is burned in oxygen b. Lithium is reacted with sulfuric a
   c. Calcium reacts with water d. Magnesium is added to zinc nitr

Redox equations

Oxidation and reduction reactions can be defined in the following ways:

Oxidation	Reduction
• Gain of oxygen • Loss of hydrogen • **Loss of electrons**	• Loss of oxygen • Gain of hydrogen • **Gain of electrons**

A useful oxidat Oxid Redu

When oxidation and reduction occur within the same equation, it is called a **redox reaction (red-uction ox-idation)**. As well as balanced symbol equations, **redox equations** (sometimes called ionic equations) can be written to represent these processes more clearly by removing **spectator ions**. These can be further simplified into **half-equations**, which show the electron movement.

Example 1

Magnesium reacts with sulfuric acid according to the equation:

magnesium + sulfuric acid → magnesium sulfate + hydrogen

It is hard to tell what is being oxidised and what is being reduced from this equati equation for the reaction is:

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

By looking carefully at this equation, you may notice that magnesium **atoms** have hydrogen **ions** have formed hydrogen **atoms**. To represent this more clearly, we the steps.

Forming redox equations
- Identify any ionic species
- Split these into their constituent ions
- Remove spectator ions

$Mg + H_2SO_4 \rightarrow MgSO_4$

becomes

$Mg + 2H^+ + SO_4^{2-} \rightarrow Mg^{2+} + SO$

Now we can see that SO_4^{2-} ions are on the left-h side. Removing these forms the ionic equation:

$Mg + 2H^+ + \cancel{SO_4^{2-}} \rightarrow Mg^{2+} + \cancel{SO}$

becomes

$Mg + 2H^+ \rightarrow Mg^{2+}$

We can now look at each species individually to identify the oxidation and reducti

Mg forming Mg^{2+}: for this to occur, one magnesium atom loses two electrons.

This is **oxidation**:
$Mg \rightarrow Mg^{2+} + 2e^-$

$2H^+$ forming H_2: for t ions each gain an ele

This is **reduction**:
$2H^+ + 2e^- \rightarrow H_2$

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Example 2

Displacement reactions are also examples of redox reactions. Let's look at the co

copper + silver nitrate → silver + copper nitrate

$Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$ **balanced symbol equation**

Splitting into constituent ions:

$Cu + 2Ag^+ + 2NO_3^- \rightarrow 2Ag + Cu^{2+} + 2NO_3^-$

Removing spectators (NO_3^-):

$Cu + 2Ag^+ \rightarrow 2Ag + Cu^{2+}$ **redox equation**

Finally, forming the half-equations:

$Cu \rightarrow Cu^{2+} + 2e^-$ **oxidation**

$Ag^+ + e^- \rightarrow Ag$ **reduction**

Task C

1. Identify whic which substa following pro
   a. Calcium
   b. Sodium
   c. Zinc rea
2. Write the re equations fo
   a. Lithium
   b. Zinc rea
   c. Magnesi

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Metal extraction processes

Most metals are found as metal ores, unless they are inert such as gold and platin

'Traditional' extraction methods

Metal ores are rocks found within Earth's crust which contain enough metal-containing compounds to make it profitable to extract.

First, the rocks are quarried or mined and broken up in smaller pieces. The reactivity series can then be used t how the metal compound should be processed to extr metal:

- Metals **above** carbon on the reactivity series are extracted by electrolysis.
- Metals **below** carbon on the reactivity series are extracted by reduction with carbon – a displacem reaction.

As supplies of metal ores run low, it is becoming more and more economically vi extract metals from **low-grade ores**. Biological methods are favoured over quarr mining for metal extraction in these cases:

- **Phytomining** – using **plants** to extract metals from low-grade ores. As the plants grow, they absorb minerals from the ground in which they are growing. The metal compounds are taken up into the plants through the roots, and stored within the plants. The plants are harvested and burned, and the ash left behind contains a relatively high concentration of metal compound, which can then be extracted.
- **Bioleaching** – using bacteria to extract metal ions from low-grade ores. Bacteria convert the metal compounds within the ores into a solution called a leachate. The metal can then be extracted from the leachate.

Task D

1. State on over tra
2. State on method
3. Explain separat
4. Explain from its

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Exam-style questions

1. This question is about calcium.
   a. Calcium reacts with hydrochloric acid. Name the salt formed, and state this reaction.
   b. Calcium reacts with copper nitrate solution in a displacement reaction. and state which substance is oxidised and reduced.
   c. Explain how calcium should be extracted from its ore.
2. Evaluate the use of phytomining compared with quarrying.

End of paper

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Chapter 6: Acids, Alkalis a

Introduction

Acids and bases are important chemical compounds in the world around us. Bein
substances will react, how they will react, and what products will form is critical i
processes in our bodies, in industry, and in the environment work.

Key definitions

An **acid** is a substance with a pH < 7. Acids react with bases and neutralise ther
sources of **H^+ ions**. Acids also react with metals.

A **base** is a substance with a pH > 7. Bases react with acids and neutralise them
amount of bases are soluble in water and these are called **alkalis**. Alkalis are u

Strong and weak acids

Strong acids are acids which **fully dissociate in solution** to release their H^+ ions. There are **three** strong acids which you need to know the formula for at GCSE. These are:

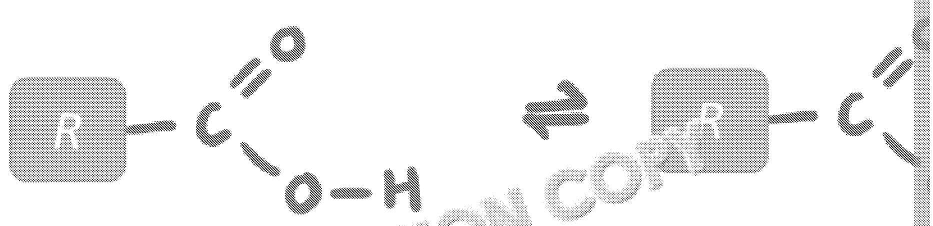
1. Hydrochloric acid, HCl, which dissociates into H^+ and Cl^- ions.
2. Sulfuric acid, H_2SO_4, which dissociates into **2**H^+ and SO_4^{2-} ions.
3. Nitric acid, HNO_3, which dissociates into H^+ and NO_3^- ions.

If we consider the dissociation of hydrochloric acid as an equilibrium:

$$HCl \rightleftharpoons H^+ + Cl^-$$

Since hydrochloric acid **fully dissociates**, the position of this equilibrium lies almo
almost all of the acid molecules dissociate.

Weak acids, however, do **not** fully dissociate in solution. In fact, they barely diss
sometimes known as 'organic acids', are examples of weak acids. They have gene
as shown below, where 'R' represents the rest of the carbon chain (the *residual g*
dissociate in the same way:



Notice how this is very similar to strong acids – releasing H^+ ions and a negative io
the position of equilibrium lies almost 100 % to the **left-hand side** – very few acid

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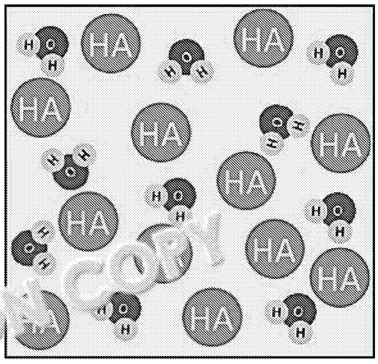
Concentrated and dilute acids

All acids can be either concentrated or dilute, regardless of the type (and strength) a measure of **how many acid molecules are present in a set volume of solution**. Th has the units mol dm^{-3} or *moles per decimetre cubed*; how many moles of acid are i

Consider the diagrams to the right. Here, the acid is represented by the general formula 'HA'. On the left, there are many more HA molecules than there are on the right. Note that the overall volume is the same in both cases. This means that the left is **more concentrated**, and the right is **dilute**.



Strength AND concentration

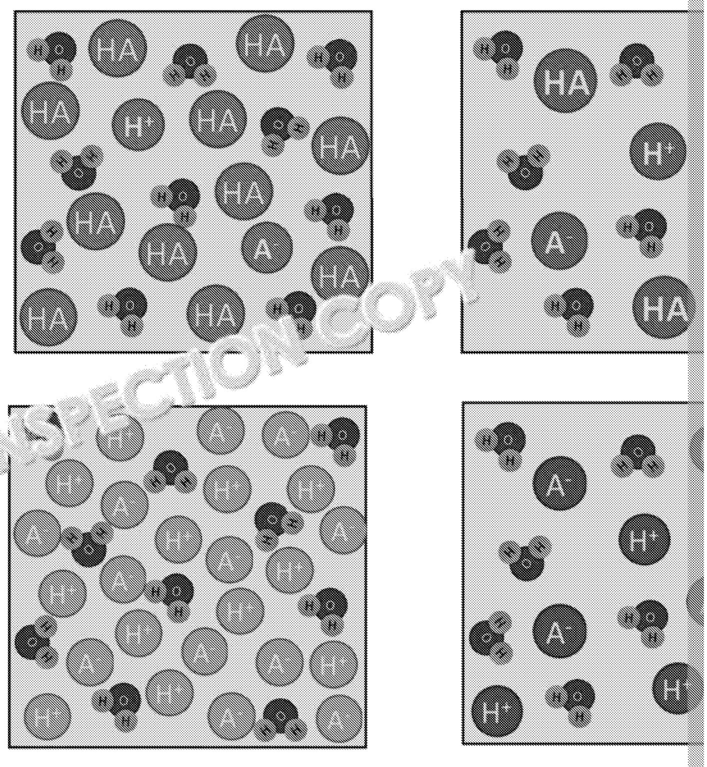
Combining these ideas together, you will need to be able to describe acids as strong or weak **and** concentrated or dilute.

- When considering acid strength, we **only** consider the type of acid present – it doesn't matter how much.
- When considering concentration, we **only** consider how many acid molecules are present per unit volume – it doesn't matter which type.

This means we could have any combination of strong, weak, concentrated and dil strength and its concentration will have an impact on the pH: the stronger the aci more concentrated the acid, the lower the pH.

Task A

1. Label each acid below as **strong or weak**, <u>and</u> as **concentrated or dilute**.



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Reactions of acids

Acids react in a variety of ways, and you will need to be confident in:

Key skills:

1. Naming salts and writing word equations
2. Deducing chemical formulae of salts
3. Completing balanced symbol equations for reactions
4. HT: Writing ionic equations for reactions
5. HT: Writing redox half-equations for reactions

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Naming salts and writing word equations

When acids react, they produce **salts** – the H^+ ion in the acid is replaced by a meta… substance. Salts are named after the metal and the acid which produced them.

Hydrochloric acid produces **chloride salts**
Sulfuric acid produces **sulfate salts**
Nitric acid produces **nitrate salts**
Ethanoic acid produces **ethanoate salts**

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Depending on which metal-containing substance is reacted with the acid, differen… You will need to know the following general equations to help you:

acid + metal → salt + hydrogen
acid + metal hydroxide → salt + water
acid + metal oxide → salt + water
acid + metal carbonate → salt + water + carbon diox…

Example:
sodium hydroxide + hydrochloric acid →

- The metal part of the salt will be **sodium**
- Hydrochloric acid produces **chloride**
- The salt is therefore sodium chloride
- Acid + metal hydroxide, so water is produced

Task B

Copy and complete the word equations for the reactions of hydrochloric acid (H… nitric acid (HNO_3) and ethanoic acid (CH_3COOH):

1. Hydrochloric acid + __________ → zinc chloride + hydrogen
2. ____________________ + sodium hydroxide → sodium sulfate + water
3. Sulfuric acid + magnesium carbonate → ____________________ + water + …
4. Nitric … + ____________________ → potassium nitrate + water
5. ____________________ + calcium hydroxide → calcium ethanoate + water
6. Nitric acid + iron → ____________________ + ____________________

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Deducing chemical formulae of salts

To deduce the formula of the salts formed, we need to know the formula of the i

Let's first consider our previous example:

sodium hydroxide + hydrochloric acid →

We now know that the salt formed is **sodium chloride**.

Sodium is a group 1 metal, so the formula of its ion is Na^{+}

Chloride has the formula Cl^{-}

Both of these ions have **equal but opposite charges**, so only one of each ion is needed to produce a neutral salt:

Na^{+} Cl^{-}

NaCl

The same would be true for Mg^{2+} and SO_4^{2-} which have equal but opposite charges, so the salt is simply $MgSO_4$ – only one of each ion is required to produce a neutral salt.

Let's look at a harder example:

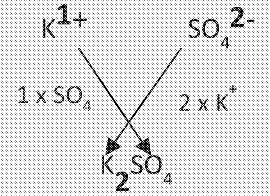
potassium + sulfuric acid → ?

The salt formed here would be **potassium sulfate**.

Potassium is a group 1 metal, so the formula of its ion is K^{+}

Sulfate has the formula SO_4^{2-}

These ions do not have equally sized charges, so we need to 'swap and drop'.



Take each ion charge and swap it over to the other species.
Drop it to a $_{subscript}$ *in the formula*
Note that we don't include '1', just like you don't write 1× in maths!

The salt formed is now neutrally charged: the 2 positive ions 'cancel out' the 2- ion. This can look confusing at first; it takes practice!

Final example:

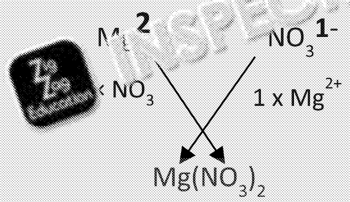
magnesium carbonate + nitric acid → ?

The salt formed here would be **magnesium nitrate**.

Magnesium is a group 2 metal, so the formula of its ion is Mg^{2+}

Nitrate has the formula NO_3^{-}

These ions do not have equally sized charges, so we need to 'swap and drop'.



Take each ion charge and swap it over to the other species.
Drop it to a $_{subscript}$ *in the formula*
Note that we don't include '1', just like you don't write 1× in maths!

The salt formed is now neutrally charged: the 2+ positive ion 'cancels out' the 2 negative ions. Here, a bracket is needed around the nitrate ion. Without this, we would have a very bizarre formula:

~~$MgNO_{32}$~~

This makes it appear as though 32 oxygens are present, and only 1 nitrogen. In reality, magnesium nitrate has 2 nitrogens and 6 oxygens.

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Completing balanced equations

Balancing a chemical equation is an essential skill in chemistry that ensures that there are the same number of atoms within the products and the reactants.

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How to balance a chemical equation

1. Write down the chemical equation for the reaction including the formulae of the reactants on the left side of the arrow, and the formulae of products on the right side of the arrow.
2. Count the number of atoms of each element on both sides. This can be done as a tally.
3. Identify the elements that are unbalanced.
4. Choose a *coefficient* to balance an element so that the number of atoms of that element is the same on both sides. It is often easiest to start with an element that only appears once on each side of the equation.
5. Repeat the process for other unbalanced elements.
6. Check the equation again to ensure the equation is balanced.

Let's write balanced equations for our three worked examples.

sodium hydroxide + hydrochloric acid → sodium chloride + wa

First, we will write the formulae of all of the substances.
Underneath, we can tally how many atoms of each element the

	NaOH	+	HCl	→	NaCl
Na:	I				I
O:	I				
H:	I		I		
Cl:			I		I

In this example, we can see that there are the same number of a element on the left side and the right side. The equation is alre

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potassium + sulfuric acid → potassium sulfate + hydrogen

First, we will write the formulae of all of the substances.
Underneath, we can tally how many atoms of each element there are:

	K	+	H_2SO_4	→	K_2SO_4	+	H_2
K:	|						
H:			||				||
S:					|		
O:			||||		||||		

From this, we can see that potassium is unbalanced – there are two on the right side, but only one on the left side.
To balance this, we can add a coefficient to the left and recount.

	2K	+	H_2SO_4	→	K_2SO_4	+	H_2
K:	||				||		
H:			||				||
S:			|		|		
O:			||||		||||		

The equation is now balanced.

magnesium carb

First, we will writ
Underneath, we

	$MgCO_3$
Mg:	|
C:	|
O:	|||
H:	
N:	

Complicated! He
hydrogen and nit
best to leave unt
Since there are t
need to place a c

	$MgCO_3$
Mg:	|
C:	|
O:	|||
H:	
N:	

Thankfully, this o
the equation is b

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Task D

Balance the chemical equations:

1. $HCl + Mg \rightarrow MgCl_2 + H_2$
2. $H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$
3. $HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$
4. $HCl + Zn \rightarrow ZnCl_2 + H_2$
5. $H_2SO_4 + Fe(OH)_2 \rightarrow FeSO_4 + H_2O$
6. $HNO_3 + CuCO_3 \rightarrow$ Cu
7. $H_2SO_4 + KOH \rightarrow K_2S$
8. $HCl + CaO \rightarrow CaCl_2$
9. $HNO_3 + MgCO_3 \rightarrow$ M
10. $HCl + Al \rightarrow AlCl_3 +$ H

HT: Ionic equations and redox equations

This area of the specification is designed to stretch and challenge. It is crucial to n how to form word equations, find formulae of substances, use these to construct balance them. Only when you have mastered these skills should you move on to equations and redox.

Let's consider a simple neutralisation reaction:

$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

Following the steps to form an ionic equation:

$$\underline{NaOH_{(aq)}} + \underline{HCl_{(aq)}} \rightarrow \underline{NaCl_{(aq)}} + H_2O_{(l)}$$

The dissolved substances are underlined. Splitting these into the ions they are made up of gives:

$$Na^+ + OH^- + H^+ + Cl^- \rightarrow Na^+ + Cl^- + H_2O$$

We can now see that Na^+ and Cl^- are on both the left and the right sides of the equation – they are **spectator ions**. Removing these leaves us with:

$$OH^- + H^+ \rightarrow H_2O$$

This is the ionic equation for all neutralisation reactions.

Forming an

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2. For any **substan** constitu
3. Conside side of t spectat from th
4. You sho **ionic e**

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To form a redox reaction, we will consider our metal + acid equation.

First, we will form an ionic equation in the same way.

$$2K_{(s)} + \underline{H_2SO_{4\,(aq)}} \rightarrow \underline{K_2SO_{4\,(aq)}} + H_{2\,(g)}$$

The dissolved substances are underlined. Splitting these into the ions they are made up of gives:

$$2K + 2H^+ + SO_4^{2-} \rightarrow 2K^+ + SO_4^{2-} + H_2$$

We can now see that SO_4^{2-} is on both the left and the right sides of the equation – it is a **spectator ion**. Removing this leaves us with:

$2K \quad + \quad 2H^+ \quad \rightarrow \quad 2K^+ \quad + \quad H_2$ *ionic equation*

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Redox equations consider the oxidation and reduction processes occurring durin redox half-equations, we need to consider what is happening to each element.

$$2K + 2H^+ \rightarrow 2K^+ + H_2 \quad \textit{ionic equation}$$

Potassium is going from its elemental form to a positive ion. This means it is **losing an electron**; it is **oxidised**:

$$K \rightarrow K^+ + e^- \quad \textit{oxidation half-equation}$$

Hydrogen, on the other hand, is going from hydrogen ions to elemental form. This means each ion is **gaining an electron**: it is reduced:

$$2H^+ + 2e^- \rightarrow H_2 \quad \textit{reduction half-equation}$$

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Task

1. Prove that the ionic equation for the neutralisation of sulfuric acid by sodiu $H^+ + OH^- \rightarrow H_2O$.
2. Construct ionic equations for the following reactions:
   a. $HCl + Mg \rightarrow MgCl_2 + H_2$
   b. $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$
   c. $2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$
3. For reaction 2a, explain with the aid of equations which species is being oxi being reduced. Why is this reaction called a redox reaction?

Exam-style questions

1. Sulfuric acid reacts with calcium.
   a. Write a balanced symbol equation for the reaction.
   b. Convert the symbol equation into an ionic equation.
   c. Identify and explain which species has been oxidised, using a half-equati
   d. Explain, in terms of electron transfer, why this is a redox equation.

2. A student reacts sodium hydroxide with hydrochloric acid in a titration.
   a. Name the type of reaction which occurs.
   b. The student adds sodium hydroxide until the substances have *complete* What chemical could be added to ensure this?
   c. State the ionic equation for this reaction.

End of paper

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Chapter 7: Energy to an our surroundings

Introduction

Energy transfers are all around us; from the moment you wake up, you interact w food, you are interacting with energy transfers as the chemicals react. By studyin we can calculate the energy transferred by a chemical reaction.

Equation used in this chapter

Energy transferred by a reaction (in kJ) = Energy required to break reactant bonds –

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Exothermic and endothermic reactions

During chemical reactions, bonds are broken within the reactant molecules, and n the product.

Three key ideas:

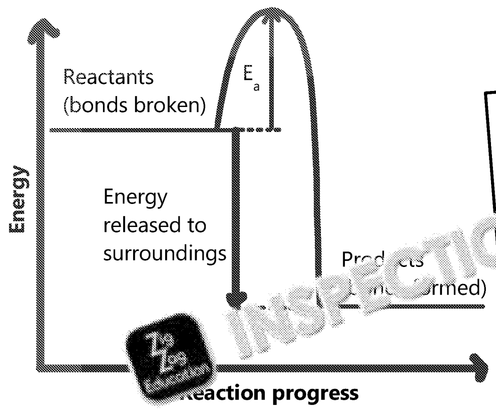
Activation energy (E_a) is the minimum energy required for a reaction to occur

Bond breaking is **endothermic** – it requires energy input from surroundings

Bond forming is **exothermic** – it releases energy to the surroundings

Key skill: Explaining why a reaction is exothermic or endothermic overall due to the balance of energy input and output

The **balance** between the energy required to break reactant bonds compared wit product is formed tells us if an overall reaction is exothermic or endothermic. Thi represented on a **reaction profile diagram**.



Common pitfall:
Remember, activation energy ... to the top of the curve!

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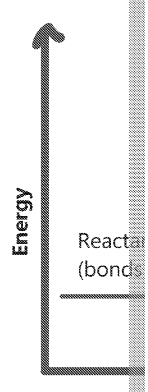

This reaction is **exothermic** – more energy is released when the product bonds are formed than was required to break reactant bonds.

Key skill: Drawing a labelled reaction profile diagram

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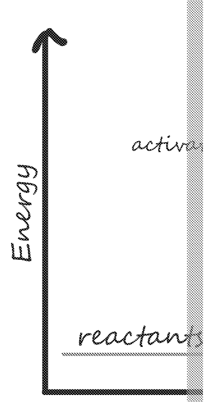
Task A

1. Define 'activation energy'.
2. A reaction releases energy to the surroundings. State whether the reaction is exothermic or endothermic and explain why in terms of the balance of bond-breaking and bond-forming.
3. A student has drawn the reaction profile for the reaction described in Q2. Is the student's diagram correct? Explain why.



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Bond energy calculations

We can calculate the overall energy transfer for a reaction using average bond energies.

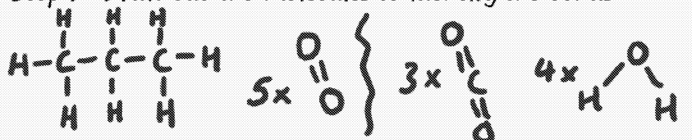
Energy transferred by a reaction (kJ/mol)	=	Energy required to break reactant bonds	-	Energy released when product bonds form

Worked example 1: Use the average bond energies given to calculate the energ propane is burned

Step 1: Write a balanced equation for the reaction

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

Step 2: Draw out the molecules to identify the bonds



Step 3: Work out how many of each bond type you need

8(C−H) + 2(C−C) + 5(O=O) } 6×(C=O) + 8(O−H)

Step 4: Calculate the energy transfer

Bonds broken = (8×413) + (2×347) + (5×498) = 64[illegible] } Bonds formed = ([illegible]) + (8×464) = 8542

Energy transferred = 6488 − 8542 = −2054 kJ/m

The **negative** value indicates that the reaction is <u>exothermic</u>.

Bond
C-C
C-H
C=O
O-H
O=O

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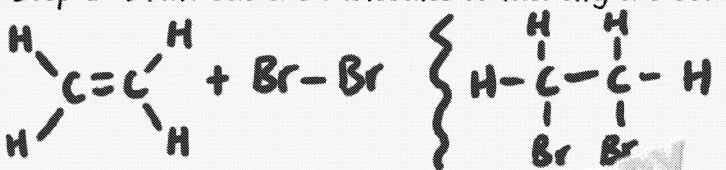
Worked example 2: Ethene reacts with bromine as shown by the equation:

$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

The overall energy transfer for the reaction is -122 kJ/mol. Calculate the bond e

Step 1: Draw out the molecules to identify the bonds



Bo
C
C-
C
Br

Step 2: Work out how many of each bond type you need

1 × (C=C) 1 × (Br–Br) 1 × (C–C) 2 × (C–Br)
4 × (C–H) 4 × (C–H)

Step 3: Work out the bonds broken and bonds formed

Bonds broken
612 + (4 × 413) + 464
= 805

Bonds formed
348 + (4 × 413)
+ 2 (C–Br)
= 348 + 2 (C–Br)

Step 4: Rearrange the equation to find the unknown bond energy

Energy transferred = Bonds broken – Bonds

-122 = 805 – [348 + 2(C–Br)

2(C–Br) = 805 – 348 + 122 = 579

(C–Br) = 290 kJ/mol

Task B

Use the mean bond energy in the table to carry out the calculations:

1. Calculate the energy transfer when water is formed from hydrogen and oxygen.
   $2\ H_{2\ (g)} + O_{2\ (g)} \rightarrow 2H_2O$
2. Calculate the energy transfer when methanol, CH_3OH, is burned completely in oxygen.
3. Methane reacts with chlorine according to the equation:
   $CH_{4\ (g)} + Cl_{2\ (g)} \rightarrow CH_3Cl + HCl$
   The overall energy transferred during this reaction is -122 kJ mol^{-1}.
   Calculate the mean bond energy of the C–Cl bond.
4. How much energy is required to break the bonds within water molecules? How much energy is released when water is formed? Compare these value

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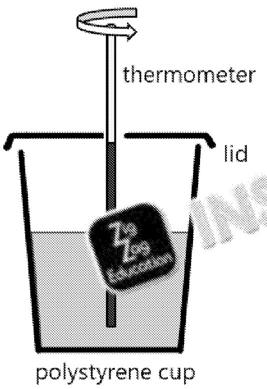
Investigating temperature changes

The **Required Practical** in this topic investigates variables affecting temperature c

- Metal + acid
- Metal carbonate + acid
- Neutralisation
- Displacement of metals

Independent variable: the va
Dependent variable: the vari
Control variables: variables v

Calorimetry is the technique used to investigate temperature changes.



- A polystyrene cup and lid are used to **insulate** the reaction, preventing heat transfer to/from the surroundings
- A thermometer is used to monitor the temperature change
- Volumes of solution and masses of solids must be carefully measured
- The **initial** temperature is measured
- The substances are mixed and stirred
- The **maximum** or **minimum** temperature is measured
- The temperature change is determined.

Task C

1. A student carried out an experiment to investigate the temperature change reacts with sodium hydroxide. The student added 25 cm^3 of hydrochloric a measured the initial temperature. The student then quickly added 25 cm^3 and stirred. The highest temperature was recorded. The student's results
   Starting temperature = 21 °C
   Highest temperature = 32 °C
   a. Calculate the change in temperature.
   b. How can you tell from the student's results whether the reaction is ex
   c. Identify an error in the student's experimental set-up.
2. A student investigated the reaction of magnesium with hydrochloric acid. dropped into the hydrochloric acid. The student repeated the experiment, of hydrochloric acid.
   a. Identify the independent variable in the student's experiment.
   b. Suggest **two** control variables in this investigation.
   c. Predict the trend the student will see as the concentration is increase

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Chemical cells

As well as measuring **temperature** change, we can measure the energy carried by two substances in solution react by recording the voltage produced. This is achie electrochemical cells.

Two different metal electrodes are placed into an electrolyte. The electrodes are connected by a wire, allowing electrons to flow. A voltmeter can be added to measure the voltage.

A reaction occurs between the electrodes and the electrolyte, causing **oxidation** and **reduction**. The chemical reactions cause the flow of electrons – producing electricity. The bigger the difference in reactivity between the two electrodes, the larger the voltage.

You could be asked to write re equations.

Electrode: a substance which can conduct electricity
Electrolyte: a conducting liquid containing ions
Oxidation: loss of electrons
Reduction: gain of electrons

Worked example: Interpreting cell voltages
A student investigated the reactivity series of some metals. The student set up an electrochemical cell as shown in the diagram. Electrode A is copper. Electrode B is changed each time, and the voltage of the cell is measured. The results are shown in the table. Place the metals in order of reactivity, from least reactive to most reactive.

Key points

- *Cells which have produced a positive voltage are more reactive than copper.*
- *Cells which have produced a negative voltage are less reactive than copper.*
- *Electrode A is copper, so if Electrode B is also copper, no voltage can be produced.*

Placing the metals in order:
Zinc – most reactive
Iron
Cobalt
Nickel
Copper
Silver – least reactive

Factors which could affect the cell voltage

1. The metal used for the electrode – the bigger the difference in reactivity, the
2. The **concentration** of the electrolyte solution – more concentrated solutions

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Batteries

Connecting multiple cells together **in series** creates a battery. The voltage of the
voltage of the chemical cells combined.

- Non-rechargeable batteries have **irreversible** reactions, and the electrodes c
down over time. Once one of the reactants is used up, the battery 'goes flat'
- Rechargeable batteries have reactions which can be **reversed** by applying an
electrical supply – a 'charger'. This reverses the reactions, allowing the react
be reformed.

Fuel cells

Fuel cells work in a different way to chemical cells, but are still based on redox react **continuously** when supplied with fuel and oxygen. The fuel becomes oxidised elect through combustion which requires a much higher temperature), and the energy is

Hydrogen–oxygen fuel cell

At the negative electrode:
Hydrogen gas is supplied as a fuel, where it releases electrons to produce H^+ ions:
$2\ H_2 + 4\ OH^- \rightarrow 4\ H_2O + 4\ e^-$

At the positive electrode:
Oxygen gains electrons, becoming reduced to OH^- ions
$O_2 + 2\ H_2O + 4e^- \rightarrow 4\ OH^-$

Adding these two half-equations together forms the overall equation: $\mathbf{2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O}$

A key example of fu
fuel cell. Water is t
fuel cells are **very** e
Additionally, the hy
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Task D

1. Describe how to make a 12 V battery using 1.5 V cells.
2. Why do non-rechargeable batteries stop producing electricity?
3. The following chemical cells are set up, and voltage read. Using your know which cell (a, b or c) would produce the highest voltage?
   a. Copper and iron
   b. Iron and zinc
   c. Zinc and copper
4. The voltage produced by chemical cells depends on the type of electrodes Suggest **one** other factor that could affect the cell voltage.
5. Suggest why batteries should not be put into household waste.
6. Hydrogen fuel cells or rechargeable cells can be used to power electric vehi and one advantage of using a hydrogen fuel cell compared with a rechar

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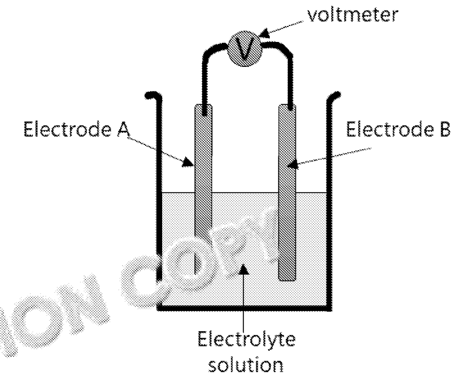
Exam-style questions

1. This question is about electrochemical cells.
   a. A student investigated the voltage produced by different chemical cells apparatus shown.



   Electrode A is made from copper. The student connected a metal to ele voltage and repeated with a different metal.

   Suggest **two** control variables for this investigation.

   b. The table shows the student's results.

Metal of Electrode B	Voltage (V)
Cobalt	+0.62
Copper	+0.00
Magnesium	+2.71
Nickel	+0.59
Silver	-0.46
Tin	+0.48

   Place the six metals used for electrode B in order of reactivity. Justify y

   c. Hydrogen fuel cells and rechargeable lithium-ion batteries can be used t Copy and complete the balanced equation for the overall reaction in a h

   __________ H_2 + __________ $\rightarrow$ __________ H_2O

   d. Why can a rechargeable cell be recharged?

   e. Another type of fuel cell uses methanol instead of hydrogen.
   $2\ CH_3OH + 3\ O_2 \rightarrow 2\ CO_2 + 4\ H_2O$

   The table shows the bond energies for the reaction.

   Calculate the overall energy change for the reaction.

Bond	Mean bond energy (kJ mol^{-1})
C–C	[illegible]
C–H	413
C–O	358
C=O	805
O–H	464
O=O	498

End of paper

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Chapter 8: Graphical Ski

Introduction

If you have ever looked at the GCSE specification in detail (you should!), you may mathematical skills. This chapter focuses specifically on MS 4: Graphing skills, as t different topics, and it is highly likely you will encounter a graph in one or more o

Maths Skill 4: Graphs

a) Translate information between graphical and numerical form
b) Understand that y = mx + c represents a linear relationship
c) Plot two variables from experimental or other data
d) Determine the slope and intercept of a linear graph
e) Draw and use the slope of a tangent to a curve as a measure of rate of cha

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At first glance this can look confusing, and a little overwhelming. Reviewing this uses of graphs throughout the GCSE specification, and demystify what could be e

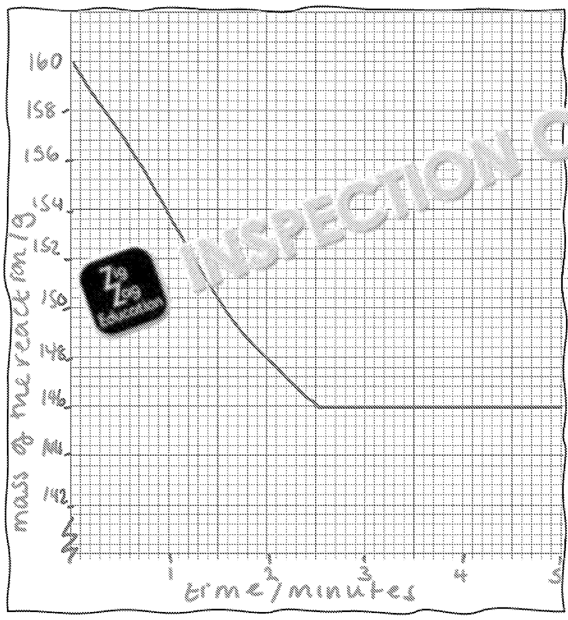
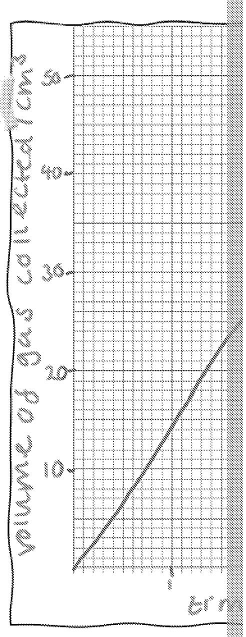
Rates of reaction graphs

Rate of reaction is a measure of how quickly a chemical reaction occu

$$\frac{\text{quantity (g } or\ cm^3\text{)}}{\text{time (seconds / minutes)}}$$

A relative rate of reaction can also be used, calculated by: $\frac{}{\text{time taken for reactio}}$

Depending on the method used to measure the rate of reaction, the graphs will lo

'Mass loss method' graph	'Volum
If you placed all of the reactants on a mass balance, and measured the mass of the reaction as it proceeds, this type of graph would be obtained. Notice that the mass ***decreases*** *with time, as the gas produced is allowed to escape.* 	*Instead of allowing the collected using a gas sy cylinder in a trough of w of graph.* 

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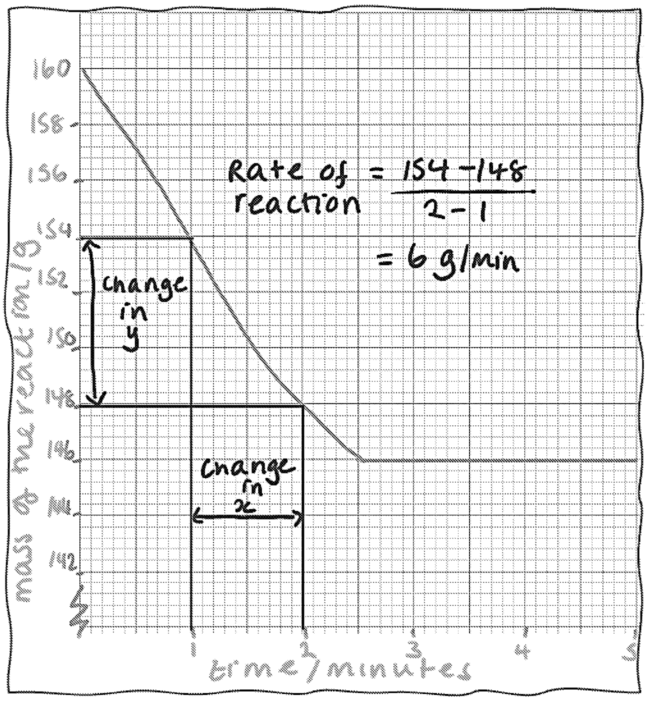
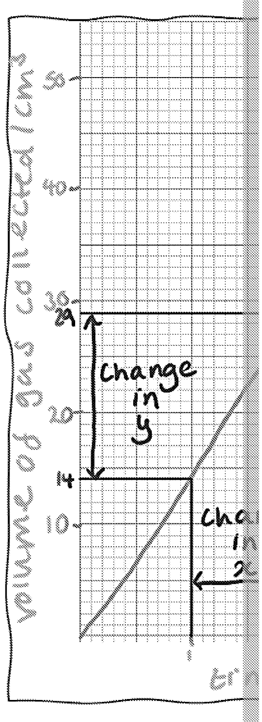
'At what time is the reaction complete? Explain your answer.'
This is a common exam question. To find the time that the reaction has finished, we look for where the variable on the y-axis is **no longer changing** – in other words, where the graph plateaus (becomes flat). For both of our rates graphs, the reaction is finished at 2½ minutes.

'Find the rate of reaction between 1 and 2 minutes.'
The key word here is 'between'. To find this, we need to draw two lines on the graph: one vertical line at 1 minute, and another vertical line at 2 minutes. Where these intersect our line of best fit, we then draw horizontal lines to the y-axis, and read off the values.

To calculate the rate, we need to do $\frac{\text{change in y}}{\text{change in x}}$

where the change in y is the change in mass or volume, and the change in x is the change in time – 1 minute in this case.





'Find the rate of reaction at 1½ minutes.'
The key word here is 'at', which signals that this question requires the use of a **tangent**. A tangent is a line which touches the curve at a single point. The tangent line has the same gradient as the curve at this point, so we can use it to find the rate of reaction.

Key skill: Drawing and using the slope of a tangent to a curve as a measure of rate is **MS 4e**

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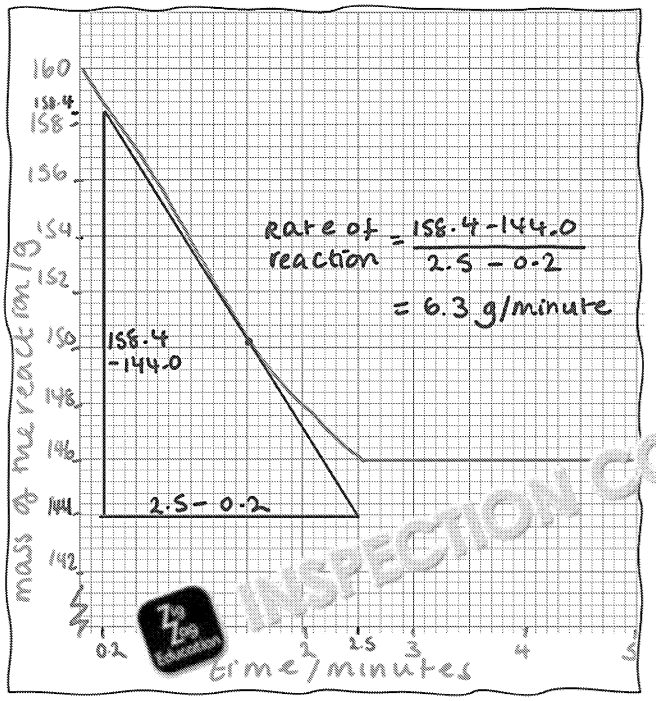
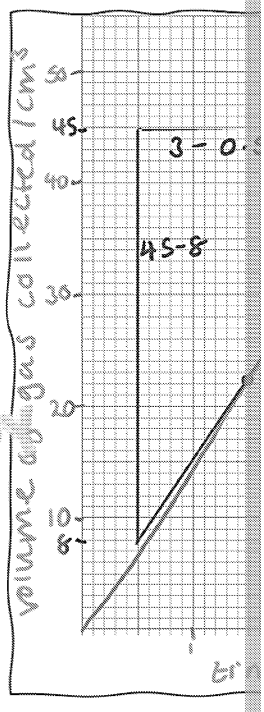




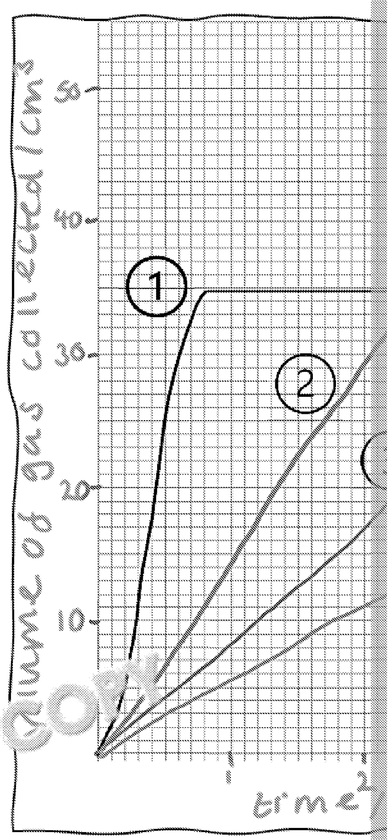
'Which reaction has the highest rate of reaction?'

The final interpretation you may need to do on rates graphs focuses on factors which speed up or slow down the rate of reaction. Multiple lines of best fit can be plotted on the same graph, and you need to be able to match the reaction conditions with each line.

Consider the 'Volume of gas' graph shown. The reaction was completed four times under different conditions. Which is fastest?

Line 1 has the steepest gradient, and produces the 35 cm^3 of gas after around 45 seconds, whereas line 3 takes 4 minutes to produce the same volume. Therefore, line 1 has the highest rate of reaction.

A common misconceptio [illegible] that line 4 m[illegible]t b[illegible]ckest. Howeve[illegible]thing different is going on [illegible]. The amount of reactants used is smaller – and therefore a much lower volume of gas has been produced.



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Task A

A student reacted magnesium with hydrochloric acid, measuring the volume of
every 30 seconds over 5 minutes, at 20 °C. The experiment was repeated twice
heated to 30 °C, then 50 °C. The data is shown in the table below. Plot a graph
answer the questions which follow. ***Graph paper is available to photocopy in t***

Time (seconds)	Volume of gas produced at 20 °C / cm^3	Volume of gas produced at 30 °C / cm^3
0	0	0
30	6	10
60	12	18
90	18	27
120	[illegible]	30
150	30	40
[illegible]	36	45
[illegible]	40	50
[illegible]	44	50
270	48	50
300	50	50

1. At what time does each reaction finish? Explain how you used your graph t
2. Use your answer to Q1 to find the *relative rate* at each temperature.
3. Find the rate of reaction at 90 seconds at each temperature.
4. Find the rate of reaction during the first 30 seconds at each temperature.
5. Explain which temperature had the highest rate of reaction. Use collision the

Flame emission spectra and calibration curves

We know from the Chemical Analysis topic that metal ions produce characteristic flame colours. This is because each type of metal ion absorbs and releases unique wavelengths of light. These can be analysed in a **spectrometer**, producing a line spectrum unique to each metal ion. This can be used to identify the metal ion by comparison to a computer database.

A flame spectrum of a metal ion is like a 'barcode' for that element. It is so precise that it even enables us to pick out component parts of a mixture! The emission spectra of some group 1 metal ions, and a mixture, are given in the spectra below.

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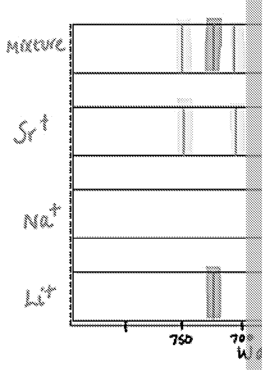
Making identifications from spectra

a) Use the spectra to identify the two metal ions in the mixture.

To answer the question, it is a good idea to grab a highlighter and a ruler. Line up your ruler with each line in the barcode of the mixture, and see if these lines correspond to any lines in the known spectra. When we do this, we can clearly see that the spectrum overlaps for ***strontium ions and lithium ions****. It is just as important to note the* ***absence*** *of any lines corresponding to* ***sodium ions****, too.*

b) Why would a flame test not identify these ions in the mixture?

Think carefully. Lithium ions produce a crimson flame, and strontium also produces a red flame. This test alone would ***not*** *be able to distinguish between the two.*



Many metal
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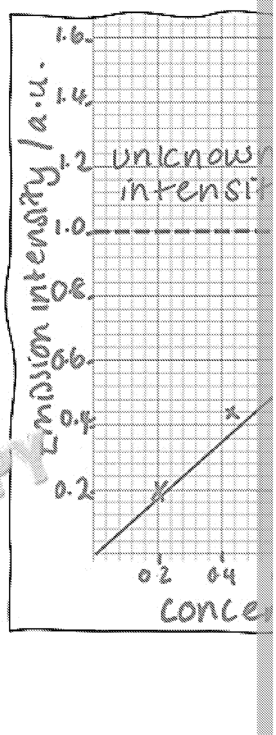
between usi

Flame emission spectra can also be used to determine **concentrations** of ions pre
unknown, a calibration graph is plotted:

Sodium ions of unknown concentration produced an emission intensity of 1.0.
Find the unknown concentration.

1. Solutions of **known concentration** of sodium ions are made.
2. The emission intensity is measured for each known concentration.
3. A graph of the results is plotted, and a line of best fit drawn.
4. The emission intensity of the **unknown concentration** is read.
5. The graph is used to find the unknown concentration.

From the graph, we can see that the unknown concentration is 1.12 m[illegible]



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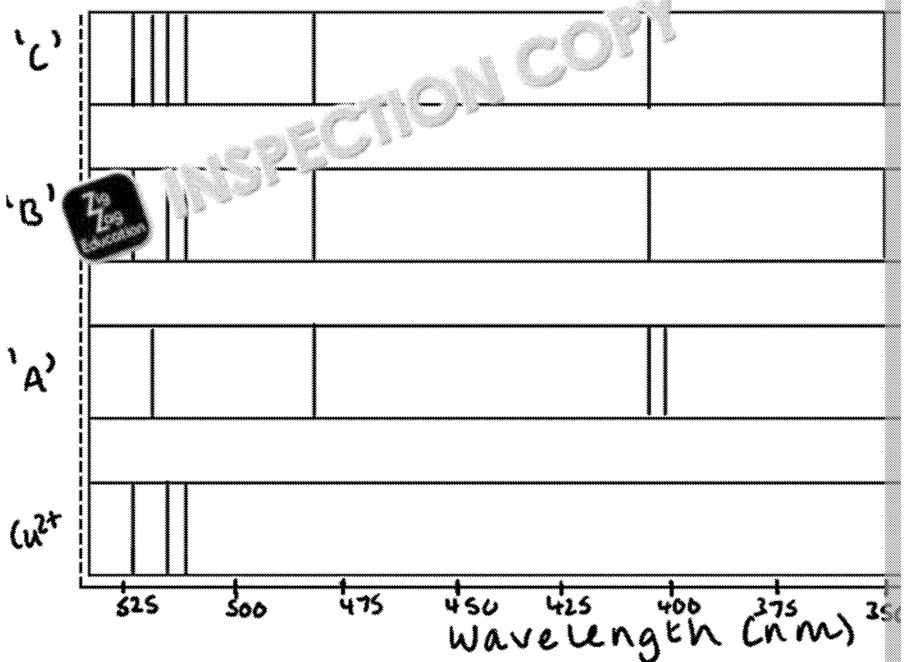
Task B

Copper ions play an important role in our body as enzyme cofactors, and are re
such as mitochondrial respiration. It is estimated that around 25 % of people m
Copper is often added to multivitamins as a result.

The presence of copper ions in the blood, and within multivitamins, could be m
spectroscopy. Copper ions typically show emission at wavelengths of 325, 327,

1. Three multivitamins, A, B and C, were tested for the presence of copper io
produced are shown below.



a. Which multivitamins contain copper ions?
b. What deductions can be made about the contents of multivitamins A,

2. These spectra alone do not tell us the **concentration** of copper ions presen
were used to produce a calibration curve of the emission intensity of **know**
ions. This was compared with the emission intensity of the two multivitam
The data is given in the table below.

Concentration / mol dm^{-3}	0	0.1	0.2	0.3	0.4	0.5
Emission intensity / au	0.0	0.25	0.32	0.44	0.58	0.81

a. Plot the calibration curve on squared paper. ***Graph paper is available***
b. Multivitamin B produces an emission intensity of 0.6, and multivitami
intensity of 0.4. Use your graph to determine which has the highest c

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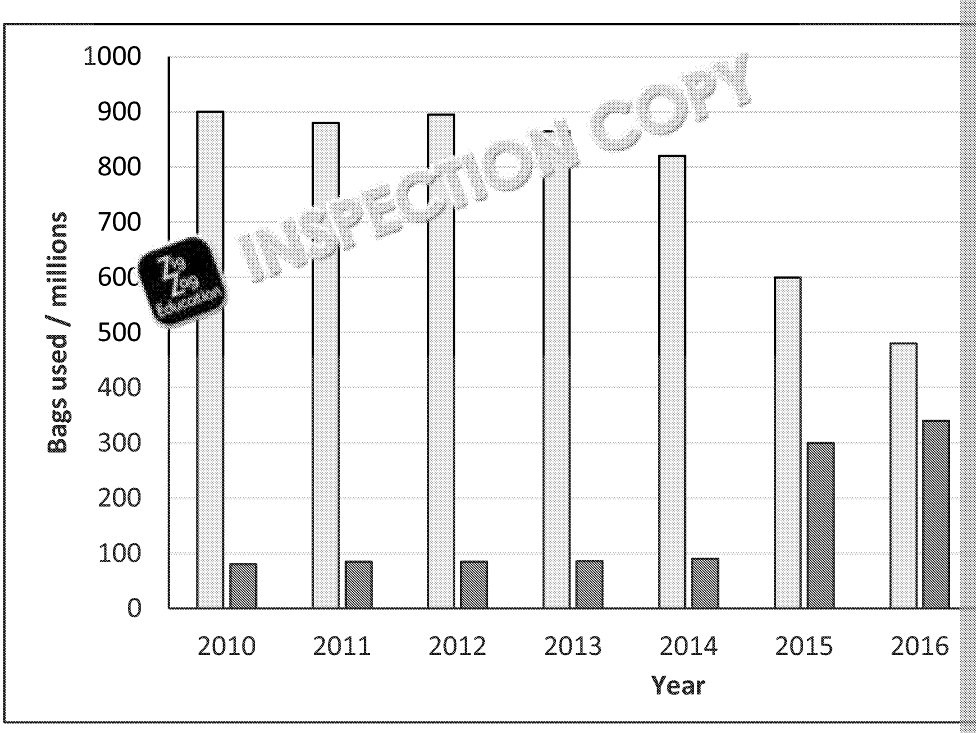
Describing and evaluating data from graphs

The examples we have looked at so far have been fairly familiar examples. It is als
encounter unfamiliar graphs and data. This is particularly true of the topics 'Chem
'Using Resources', where data plays a big role in understanding the chemistry of th
questions focus on your analysis skills, and your ability to use data, linking in your k

Let's look at an example.

In the UK, a 5p charge on single-use plastic carrier bags was introduced in 2015. T
paper and plastic bag use has varied from 2010 to 2019.



Describing trends

Describe how the use of plastic and paper bags has changed in the years 2010 to 2019.

There are a number of key points we could pick out here:

- Generally, the use of plastic bags has more than halved between 2010 and 2019.
- The use of paper bags remained relatively constant until 2015.
- After 2015, the use of paper bags increased.
- From 2010 to 2017, more plastic bags were used than paper bags. From 2018–2019, more paper bags were used.

*Notice that, since this question is a **describe question**, we do not need to bring in our own knowledge. We simply say what we see, using key data to support it. Things to consider:*

- ✓ *What is the **general** trend?*
- ✓ *How much has the variable increased/decreased by?*
- ✓ *Is the **rate of change** consistent throughout, or are there rises and falls?*
- ✓ *Are there any anomalies to the trend? Where are they?*

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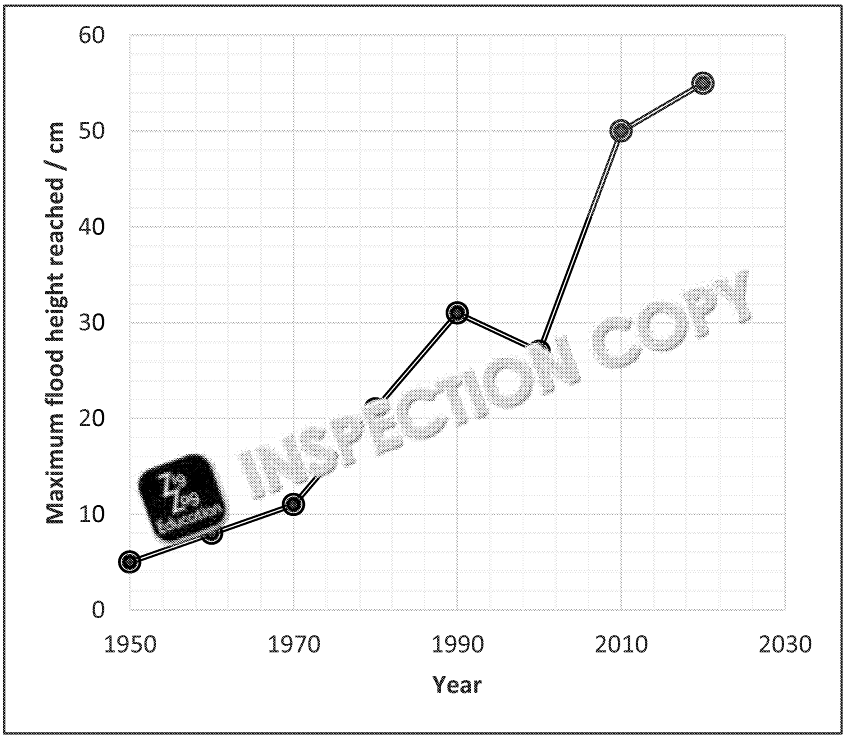
Here's another example.
A small town in Cornwall began recording the height of flooding each year. The m
every 10 years is shown in the graph below. Describe the trend.



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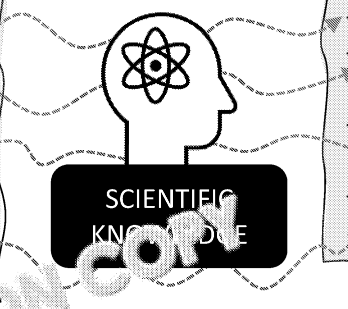
Explaining and evaluating trends

When drawing a reasoned conclusion from a graph, we need to bring in our own k
the changes we are observing in the data.

Looking at our flooding example above, instead of being asked to describe the tre
ask us to explain the trend.

Describing trends
- ✓ *What is the **general** trend?*
- ✓ *How much has the variable increased/decreased by?*
- ✓ *Is the **rate of change** consistent throughout, or are there rises and falls?*
- ✓ *Are there any anomalies to the trend? Where are they?*



Explaining
- ✓ *What*
- ✓ *Expla trend*
- ✓ *What varia*
- ✓ *What in the*

Atmospheric carbon dioxide levels have increased. Carbon dioxide is a gre contributor to global warming. Global warming causes melting of polar ic levels and flooding of low-lying areas. This has caused the general increas from 1950–2020.

Between 1990 and 2000, the maximum flood height decreased. It may temperature for that year was not as high an increase as previous years. Between 2000 and 2010, the maximum flood height rose sharply. It ma average temperature rise has accelerated. This could be due to an increas contributing to greater CO_2 emissions.

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Many examples of these questions focus on manufacture and **optimum conditio**
reasoned conclusion of suggested conditions for chemical processes. The graphs
especially important to analyse them slowly!

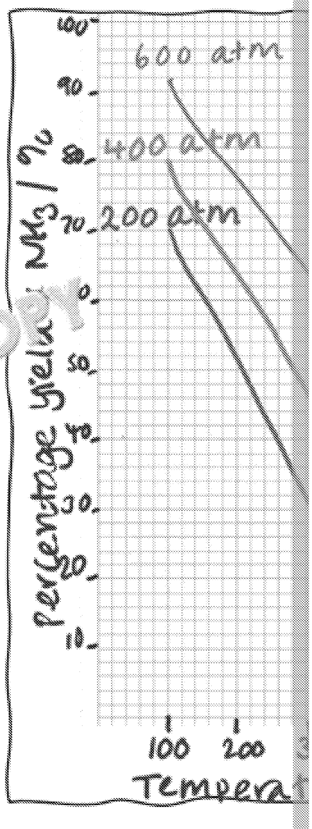
The Haber process is used to produce ammonia:

$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}$$

A temperature of 450 °C, a pressure of 200 atm and an iron catalyst are used in the Haber process.

The figure shows how the equilibrium yield of ammonia changes with temperature at different pressures.

a) How does the graph show that the forwards reaction is exothermic?
b) Explain the trends shown in the graph.
c) A student suggests that a temperature of 400 °C and a pressure of 600 atm could be used instead of those used in the Haber process. Determine how much greater the percentage yield of ammonia obtained would be. Use the graph.
d) Suggest why, despite your answer to c), the **optimum** reaction conditions of the Haber process are **not** 400 °C and 600 atm.



There is a **lot** of information to process and unpack here.

Key skill: Describing and explaining two different trends shown on the same graph

From the graph, we can see:

- As the temperature increases, the percentage yield of ammonia decreases.
- As the pressure increases, the percentage yield of ammonia increases.

It is sensible to mark on the graph where the **actual reaction conditions** are, so that we can refer to them later. Question c) also looks at some specific conditions, so again it is sensible to annotate the graph with these.

Using this information, and bringing in our own knowledge of equilibria, we can n
the questions.

a) How does the graph show that the forwards reaction is exothermic?
As the temperature increases, the percentage yield decreases.

b) Explain the trends shown in the graph.
The forwards reaction is exothermic. Increasing the temperature ca
equilibrium to shift to the left, lowering the yield of ammonia. There
increases, the yield decreases.

Increasing the pressure causes the position of equilibrium to shift to t
gas. The reactant side has 4 moles, whereas the product side has 2,
increases as pressure increases.

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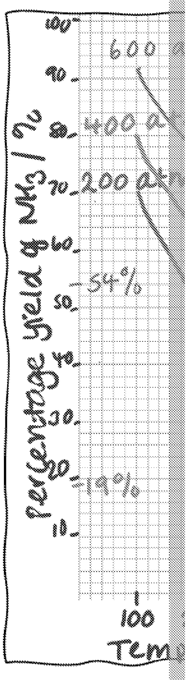
c) A student suggested that a temperature of 400 °C and a pressure of 600 atm could be used instead of those used in the Haber process. Determine how much greater the percentage yield of ammonia obtained would be. Use the graph.

Yield using suggested conditions = 54 %

Yield using actual conditions = 19 %

Yield would be 35 % larger



The final question is a common 6-mark question on the Haber process and optimum conditions. Breaking up the answer into three short paragraphs is the best approach.

- ✓ Temperature: rate, equilibrium, energy and cost
- ✓ Pressure: rate, equilibrium, energy and cost
- ✓ Catalyst: rate, equilibrium and cost

d) Suggest why, despite your answer to c), the **optimum** reaction conditions c 400 °C and 600 atm.

A higher temperature would increase the rate of reaction, but would shi to the left, decreasing the yield. Higher temperatures require large amo expensive. 450 °C is used to balance the rate and the cost.

High pressure increases the rate of reaction and would shift the position o fewer gas moles – the right-hand side, increasing the yield. However, hi amounts of energy and specialist equipment, and so is expensive. Therefo

An iron catalyst is used to speed up the rate of reaction, but has no imp equilibrium. Unreacted nitrogen and hydrogen are recycled over the hot

Now you are prepared to approach any style of graph questio

- ✓ Take the time to process what information the graph is tellin
- ✓ Make sure you read the question (and command words!) ca
- ✓ Annotate the graph so that you have key information clearl
- ✓ Be methodical in your approach.
- ✓ Be aware you may need to bring in your own knowledge.

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Chapter 9: Organic Che

Introduction

Organic chemistry is an important aspect of chemistry; it is chemistry of life and a behind it. This area of chemistry will feel quite different from what you are used t like a minefield of new content, representations and language. Once you learn to patterns and links to topics you have covered previously.

Required prior knowledge

This topic will assume some understanding of the following topics:

- Chemical bonding
- The structure and bonding of carbon allotropes
- The structure and properties of small molecules vs giant networks
- Alkanes and alkenes

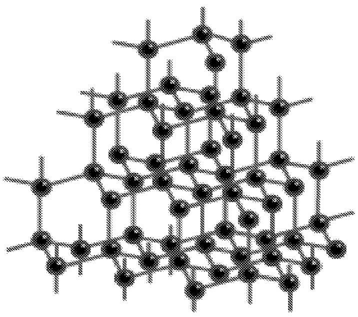
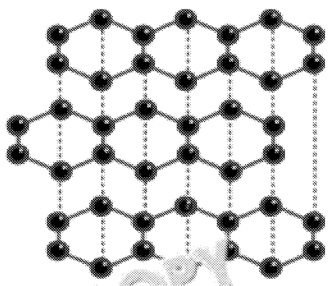
Organic chemistry primarily focuses on the chemistry of carbon-containing struct Carbon is in **group 4** of the periodic table. It has the electron structure 2, 4; it has electrons in its valence shell. It can form **four** covalent bonds with other atoms.

Allotropes of carbon

In its element form, carbon exists as a number of **allotropes**.

Key term: Allotropes
Different forms of the same element, in the same physical state, but with different bonding of atoms.

- In **diamond** (left, below) each carbon atom is bonded to 4 other carbon atoms. There are no electrons left over.
- In **graphite** (right, below) each carbon atom is only bonded to 3 other carbon atoms. This leaves one electron per atom left over. These electrons are **delocalised** and can move through the layers.

Task A

Sort the statements below into two categories: properties of diamond and prop the properties that apply to **both** diamond and graphite.

High melting point	Electrical conductor	4 covalent bonds between a
Very hard substance	Soft and slippery substance	
3 covalent bonds between atoms	Large network of atoms	

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Alkanes

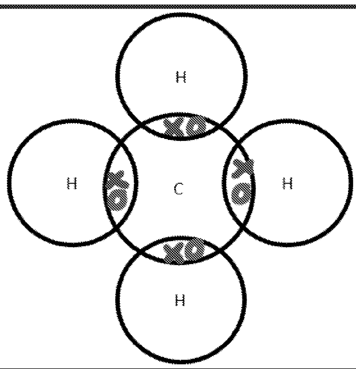
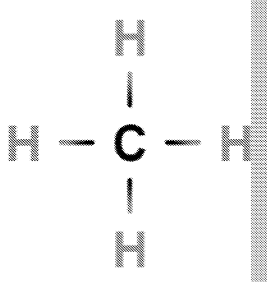
Compounds containing carbon and hydrogen **only** are known as the hydrocarbon (which are giant covalent networks), hydrocarbons form **small molecules** with we between each molecule.

The first **homologous series** of hydrocarbons are alkanes, which have the general formula C_nH_{2n+2}. All alkane names end in '-ane'.
In alkanes, each carbon atom is bonded by a **single** covalent bond – one electron pair is shared between the carbon atom and its neighbour.

Different representations of compounds
You need to be able to represent the alkanes using different representations, and evaluate the benefits and shortcomings of each.

- **Dot-and-cross diagrams** represent the valence electrons of each atom and how they are bonded together.
- **Displayed formulae** represent each covalent bond with a single line. Double bonds are shown by two lines, and triple bonds with three.
- **Ball-and-stick diagrams** represent each atom as a ball, and covalent bonds with sticks. They show the 3D structure of the molecule.
- **Chemical formulae** only show the chemical symbol of each atom and how many of each is contained in the molecule.

This means that the same compound, methane, can be represented in four different ways, shown below.

Alkane	Chemical formula	Dot-and-cross diagram	Displayed formula
Methane	CH_4		

Task B

As chemists, we use different representations to talk about molecules, dependi strengths and limitations of each model type.

Below are five scenarios. Suggest which of the four representations would be scenario. Give a brief explanation for your answer.

1. Jameel wants to compare alkanes and alkenes using their electron structur
2. Ada wants to show the three-dimensional structure of the alkanes.
3. Thanusha wants to draw diagrams to compare the relative size of ethane w
4. Michael is separating a mix of alkanes using fractional distillation. He needs
5. Maymuna wants to compare the number of carbon atoms in butane and oc

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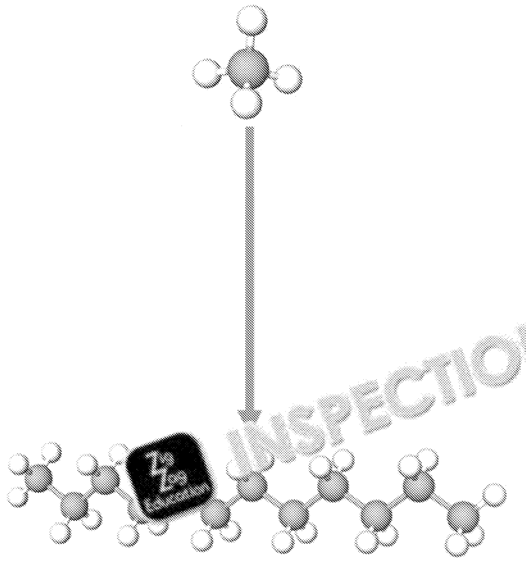
Properties of alkanes

The alkanes are small molecules, and so have **weak intermolecular forces**. They g
properties. However, as the size of the molecule increases, there are **more** intern
there is a **trend in properties** as the **size of the molecule increases**:



Smaller molecules:

- Lower melting and boiling po
- Tend to be **volatile** (vaporise
- More flammable (burn with a
- Viscous (the liquid form flows

Larger molecules:

- Higher melting and boiling po
- Less volatile
- Less flammable (burn with a s
- Low viscosity (thick and sticky

Reactions of alkanes

The main use of alkanes is as **fuels**. Alkanes release large amounts of energy when burnt, forming carbon dioxide and water.

Tip for balancing:
Balancing combustion equations can get very confusing: oxygen appears in **both** products. The easiest order to balance is: carbon, then hydrogen, then oxygen **last**.

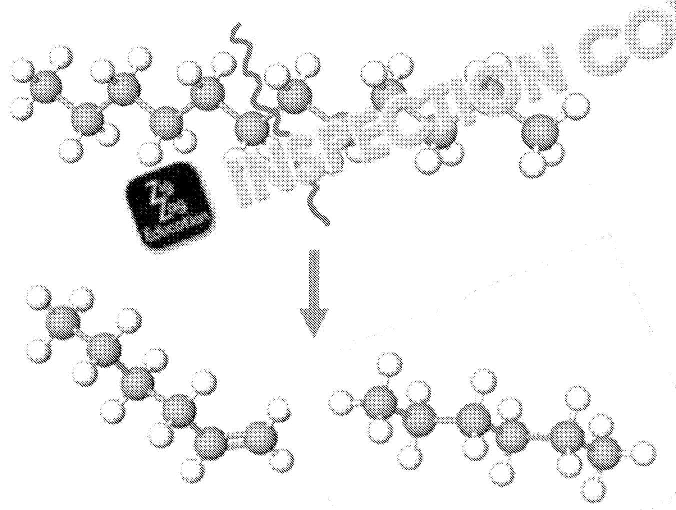
e.g. the combustion of octane, the main component of petrol:

$C_8H_{18} + 12\frac{1}{2} O_2 \rightarrow 8 CO_2 + 9 H_2O$

This process releases around 5470 kJ of energy per mole of fuel burned.
There is a **high demand** for shorter-chained alka

However, a large component of crude oil consists of **longer-chain** alkanes. These
These large molecules are broken down in a process known as **cracking**.

Cracking is exactly as it sounds – we take a larger molecule, 'crack' one of the bonds
products. Importantly, we still have the **same** number of each atom before and aft
smaller alkane, but also an **alkene**. The diagram shows an example of how dodecan



The equation for th

$C_{12}H_{26} \rightarrow C_6H_{12} + C$

However, we have
cracking occurs in t
form:

$C_{12}H_{26} \rightarrow C_4H_8 + C_8$

or even:

$C_{12}H_{26} \rightarrow C_2H_4 + C_4$

The process is **ran**
alkene are always t

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Cracking can be done by various methods, including **catalytic cracking** and **steam**

Catalytic cracking	Steam cracking
• 550 °C • Zeolite catalyst • Reactants passed over hot catalyst	• 800 °C • No catalyst • Reactants mixed with steam under high pressure

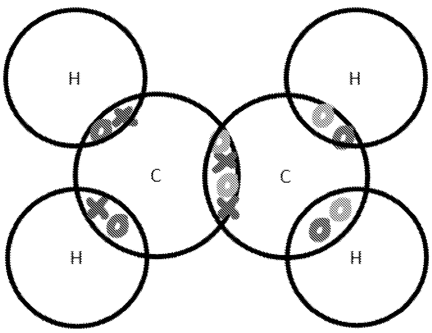
Cracking
process
short-ch
are also
feedsto
petroche

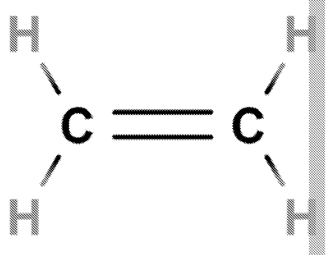
Task C

1. State the general formula for an alkane.
2. What would the name and chemical formu a alkane with three carbo
3. Give the displayed formula of but
4. Describe and explain the ing points of the alkanes as the length
5. Petrol often cont C_7H_{16}. Write an equation for the complete
6. An al or 20 carbon atoms is cracked via catalytic cracking, for
   Desc process of catalytic cracking and write a balanced equation fo

Alkenes

Alkenes contain *at least* one **carbon–carbon double** bond (C=C). For your GCSE, y only need to consider alkenes containing **one** C=C, but it is possible to have multi double bonds within the same molecule. The simplest alkenes have the general formula C_nH_{2n}. All alkene names end in -ene, and they are named in the same wa alkanes. Note that the first alkene is **eth**ene – 'methene' is impossible!





Since there are **four** electrons within the carbon–carbon double bond, alkenes ar **more reactive** than alkanes.

Reactions of alkenes

Alkenes combust in oxygen, forming carbon water:

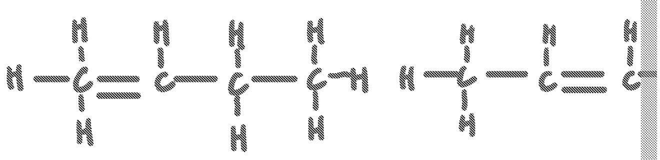
$C_2H_4 + 3\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$

They releas rgy per mole than their alkane counterparts, and usua Alkenes are more useful as a feedstock for other reactions.

Beyond GCSE: Naming alkenes

Take the alkene butene. The double bond could be in two possible places, f

This alkene has the double bond between the first and second carbons, so is called but-1-ene



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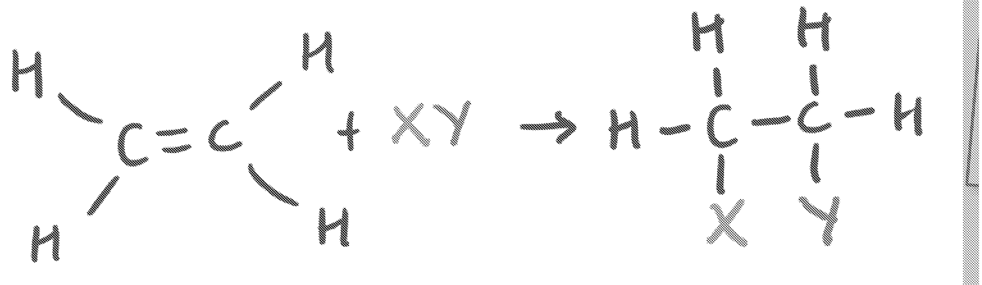
All the reactions of alkenes are the same process:



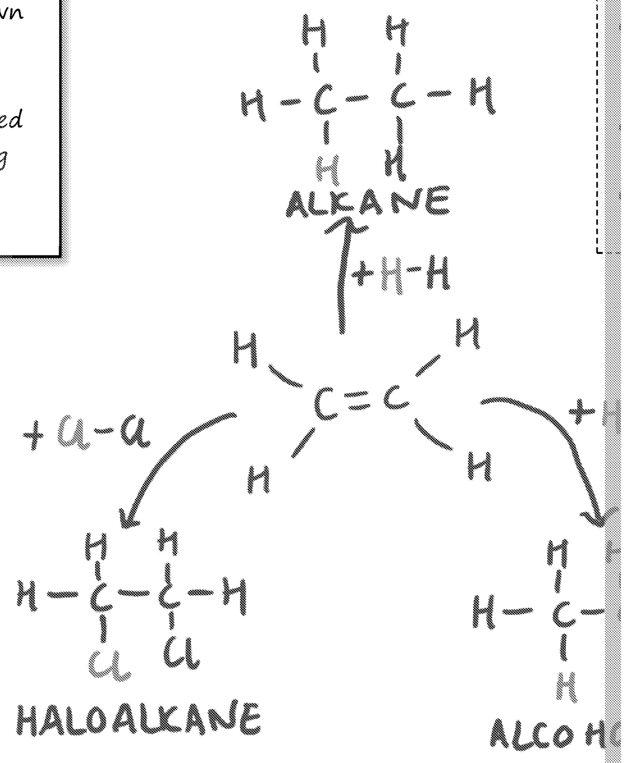
All that varies each time is what X-Y is!

1. Reaction with **hydrogen**, where X-Y is H_2. The reaction conditions are 60 °C a
2. Reaction with **halogens**, where X-Y is Cl_2, Br_2 or I_2. The reaction takes place at
3. Reaction with **steam**, where X is H and Y is OH. The reaction conditions are 3 acid catalyst.

We can form a variety of different products from these reactions.

Addition of hydrogen is known as ***hydrogenation****. Saturated molecules are formed. This reaction is used in unsaturated oils – it increases the melting point of the oil, e.g. in the manufacture of margarine.*

This is an ***important chemical test*** *to confirm the presence of a carbon–carbon double bond. Only alkenes react with bromine water, decolourising the brown solution. Alkanes do not react with bromine water, and do not decolourise the solution.*



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Task D

1. Ethene is used as a starting material in the petrochemical industry. It is pr are cracked.
   a. Ethene can be produced by the steam cracking of $C_{28}H_{58}$:
      $\rightarrow C_{11}H_{24} + C_{11}H_{22} + C_4H_8 + C_2H_4$
      One of the products is a different type of hydrocarbon to the other pr the product that is different, and explain how the structure is differen
   b. Ethene is used in the manufacture of ethanol. Write a balanced symb and draw the displayed formula of the product.
   c. Describe a chemical test which could be used to distinguish ethene fr
2. An alkane with 13 carbons is cracked. One product is pentane. Give the fo
3. Give the formulae of the product(s) formed when:
   a. butene reacts with chlorine   b. propene reacts with hydrogen   c.

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Alcohols

Alcohols have the functional group –OH. Alcohols are named in the same way as other organic molecules, ending in '–ol'.

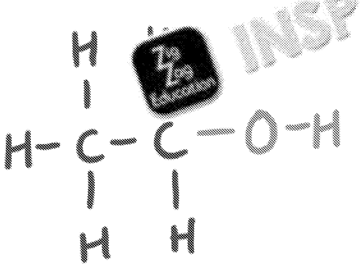
The first four alcohols have important uses:

- **Meth**anol is used extensively in the chemical industry. It is **toxic**, so is added **methylated spirit** to prevent people from drinking it.
- **Eth**anol is present in alcoholic drinks. It is a useful fuel and solvent.
- **Prop**anol and **but**anol are used as solvents and fuels.

Reactions of alcohols

Alcohols burn readily in oxygen to form carbon dioxide and water:

$C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$



Unlike other organic solvents, alcohols can react sodium metal:

sodium + ethanol → sodium ethoxide + hydroge

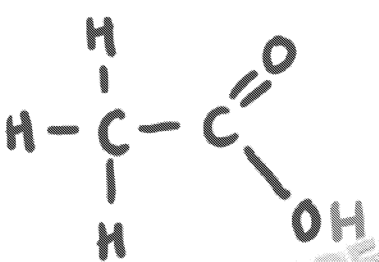
Short-chained alcohols also dissolve in water – another unusual property for organic substances! The solubility does decrease as the chain length increases.

Alcohols can be **oxidised** using an **oxidising agent** to produce carboxylic acids. For example, ethanol can be oxidised to form ethanoic acid and water.

Carboxylic acids and esters

Carboxylic acids have the **functional group** –COOH. They are named in the same ending in '-oic acid'.

Ethanoic acid is a common carboxylic acid found in vinegar. It has the displayed formula shown.



The carboxylic acids partially dissociate in water, releasing the H^+ ion. They are **weak acids**. They still behave as normal acids do, reacting with metals, bases and carbonates, but the rate of reaction will be **slower** and the energy released will be much **less**.

Carboxylic acid reactions

Like other acids you have seen, carboxylic acids react with metal carbonates:

> carboxylic acid + metal carbonate → salt + water + carbon dioxide
> *e.g.*
> *ethanoic acid + sodium carbonate* → sodium ethanoate + water + c

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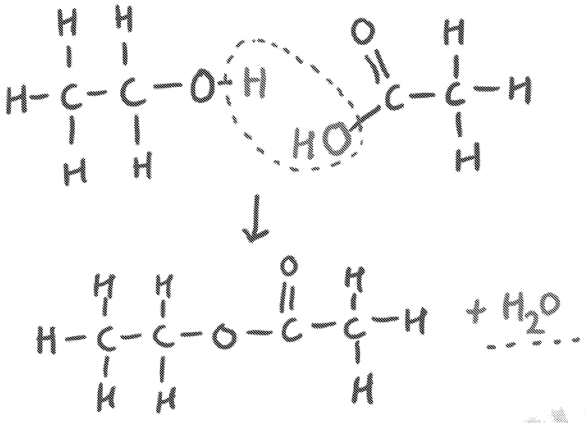
Carboxylic acids react with alcohols, in the presence of concentrated sulfuric acid,



carboxylic acid + alcohol → es

For example, the reaction sho reacting to form the ester **eth** the water is released in this pr

Esters have the functional g

Esters are fruity-smelling, vola flavouring, perfumes and adh re ... is are used to make po

Key point: The reaction between **ethanol** and **ethanoic acid** to f **ethyl** ... and **water** is the only esterification reaction you

Task E

1. State one use of butanol.
2. Write a balanced equation for the combustion of propanol.
3. Name the carboxylic acid formed from butanol.
4. State an observation you would make when ethanol reacts with sodium.
5. Write the word equation for the reaction of ethanol with ethanoic acid.

Exam-style questions

1. Alkanes and alkenes are examples of hydrocarbons.
   a. Define the term 'hydrocarbon'.
   b. Describe the difference in chemical structure between an alkane and an bromine water can be used to identify between an alkane and an alkene
   c. Alkanes are saturated hydrocarbons. Explain what is meant by the term and state whether alkenes are saturated or unsaturated.

2. Propene is an alkene containing three carbon atoms.
   a. Draw the displayed structure of propene.
   b. Propene reacts with bromine. Draw the displayed structure of the prod
   c. Propene can undergo a hydration reaction when reacted with steam. G required, and write a balanced symbol equation for the reaction.

3. Diamond and graphite are allotropes of carbon.
   a. Describe the structure and bonding of diamond.
   b. Explain why diamond is hard but graphite is soft and slippery.
   c. Explain why diamond has a high melting point.

End of paper

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Chapter 10: Chemical Iden

Introduction

Chemical analysis techniques are key skills for a chemist to help us understand th analysing our medicines, to testing for traces of explosives at airports, and even d our foods, these techniques play a crucial role in our everyday lives. At A Level, y further, so it is important to have a good understanding at GCSE level.

Since the nature of these techniques involves multiple steps (collecting samples, r examining the results), this area of the specification is tricky. As well as understa experiment and analyse results, **evaluating** procedures is important, too; you wil step is important, and be able to **identify mistakes** in procedures and **explain ho**

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Equation used in this chapter

R_f (retention factor) = $\frac{\textit{distance travelled by spot}}{\textit{distance travelled by solvent}}$

Chromatography

Paper chromatography and thin-layer chromatography are techniques for separating dissolved substances from one another. This is especially useful when the substances are **coloured**, e.g. inks, food colourings and plant dyes, but it can also be used when substances are colourless by viewing the chromatogram under UV light.

Baseline: drawn in pencil, the samples are placed on this line.
Chromatography: the technique which separates dissolved substances from one another.
Chromatogram: the paper strip produced which contains the separated mixture. This is analysed to allow conclusions to be made.
Mobile phase: the phase in chromatography which travels up the chromatography paper – the solvent.
R_f (retention factor): a measurement from chromatography: it is the distance a spot of substance has been carried above the baseline divided by the distance of the solvent front.
Solvent front: the highest distance travelled by the solvent.
Stationary phase: the phase in chromatography which does not move – the paper.

L i w sc w ar pr oc an bec sur posi

Note that, although water is often used as the solvent, other solvents can be use ethanol are used, **a lid** will need to be used to prevent **solvent evaporation**.

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Chromatography works due to substances having different **solubility in the solve** **stationary** phase. This means that different components will travel different dist paper and have different R_f values:

- Substances with **high solubility** in the solvent and **low attraction** to the stati **distances**. These substances will have **high R_f values**.
- Substances with **low solubility** in the solvent and **high attraction** to the stati **distances**. These substances will have **low R_f values**.

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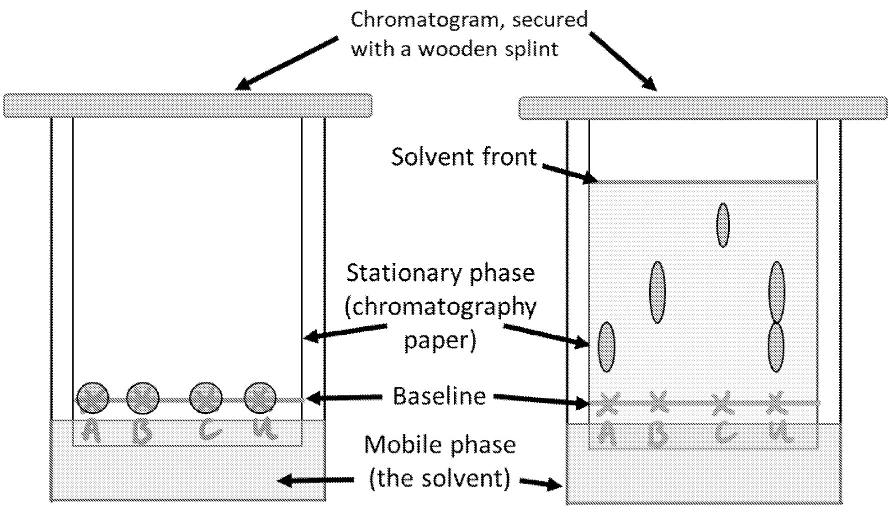
A student is trying to identify which of three water-soluble food colourings, A, B and C, are contained in some cupcake icing.

Method:

1. Draw a baseline in pencil around 2 cm from the bottom of the chromatography paper.
2. Using a capillary tube, place a small spot of each food colouring, and a small sample from the unknown, at evenly spaced intervals along the baseline. Label each sample in pencil.
3. Fill a beaker with water so that the water level is below the baseline.
4. Place the chromatogram in the beaker, securing it with a wooden splint.
5. Leave the chromatogram in the beaker until the water has travelled ¾ of the way up the paper. Remove the chromatogram, immediately marking the solvent front in pencil.
6. Using a ruler, measure the distance travelled by each component of the food colourings. Measure the solvent front. Use the values to calculate R_f values for each component part.



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Task A

Look at the experiment above, and the chromatogram produced.

1. State the stationary and mobile phases in this experiment.
2. Which substance is the most soluble? Explain why this substance is the mo
3. Is the unknown a pure substance or a mixture? Explain your answer.
4. The student measured the distances travelled by each substance. The solv baseline. Use this to calculate the R_f values.

Substance	Distance travelled / cm	
A	2.0	
B	3.5	
C	5.5	
U: Spot 1	2.0	
Spot 2	3.5	

5. What can the student conclude about the unknown substance?

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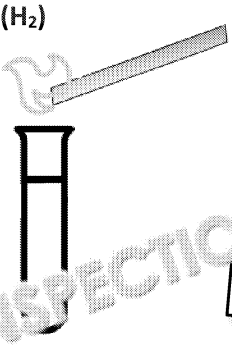
Testing for common gases

Many of the chemical reactions you have studied produce gases, but how can we tell which gas is being produced? There are four common gases you need to be able to identify: hydrogen (H_2), oxygen (O_2), carbon dioxide (CO_2) and chlorine (Cl_2).

Key skill
1. Desc
2. Give

Testing for hydrogen (H_2)

Hold a lit splint to the neck of the test tube



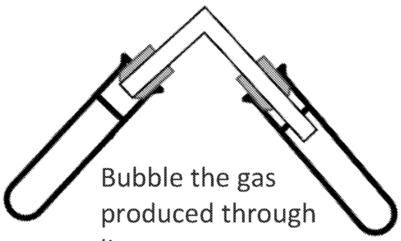
IMPORTANT!
Note here the difference between testing for hydrogen and oxygen – one uses a lit splint, and the other a glowing splint. Easy to mix up!

Positive result: A squeaky pop sound

Testing for oxygen (O_2

Positive resu

Testing for carbon dioxide (CO_2)



Bubble the gas produced through limewater

Positive result: Limewater turns cloudy

Testing for chlorine (C

Hold a piece of damp litmus paper in the neck of the tube

Positive result: Th

Task B

1. Name the gas produced when hydrochloric acid reacts with calcium carbon confirm the presence of this gas.
2. Describe a safe method for distinguishing between oxygen and hydrogen g
3. Carbon dioxide gas is produced. Would the gas have any effect on a lit spli
4. Magnesium carbonate reacts with sulfuric acid. Write a balanced equation a method to test for the gas produced.

Identifying positive ions

There are two methods for identifying metal ions:

1. Flame tests involve **placing a sample of the ions into a flame**, and observing **colour** produced.
2. The metal hydroxide test involves adding **hydroxide (OH^-)** ions into a solutio observing the **precipitate colour** formed. You should be able to write the **io** of the precipitate:
   $M^{X+}{}_{(aq)} + X\,OH^-{}_{(aq)} \rightarrow M(OH)_X{}_{(s)}$

Note the state symbols for the equation – they are **essential**.

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Metal ion	Flame colour	Hydroxide p
Li^{+}	Crimson	
Na^{+}	Yellow	
K^{+}	Lilac	
Ca^{2+}	Orange-red	White
Cu^{2+}	Green	Blue
Al^{3+}		White precipitate, red
Mg^{2+}		White
Fe^{2+}		Green
Fe^{3+}		Brown

Task C

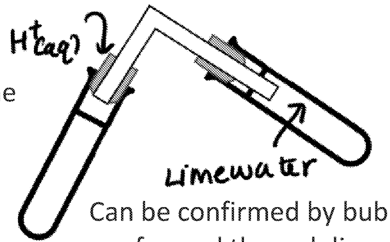
1. Copper(II) ions produce characteristic flame colours and hydroxide precipit
   a. Explain how the flame test could be used to identify copper(II) ions.
   b. Describe how to carry out the hydroxide test to confirm this identity.
   c. Write a balanced ionic equation for the reaction in part b.
2. Suggest why flame tests are not useful for identifying components in mixtu
3. Explain how you would identify between aluminium and calcium using met

Identifying negative ions

You must be able to describe test tube reactions to identify **carbonate (CO_3^{2-}), su** **chloride (Cl^-), bromide (Br^-) and iodide (I^-)**.

Testing for carbonate:

Add some drops of acid



Can be confirmed by bubbling any gas formed through limewater

Positive result: Fizzing, the limewater turns cloudy

Testing for sulfate:

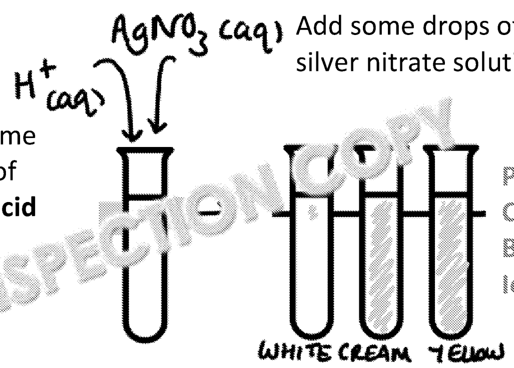
Add some drops of acid (nitric or sulfuric acid <u>only</u>)

Positive result: W

Testing for halides:

Add some drops of **nitric acid**

Add some drops of silver nitrate solution



Positive result
Chloride ions f
Bromide ions f
Iodide ions for

Task D

1. Give the observations you would expect to see if the following chemical te
   a) Acidified barium chloride is added to sodium sulfate
   b) Hydrochloric acid is added to calcium carbonate
   c) Acidified silver nitrate solution is added to sodium iodide
2. Give the ionic equations for the formation of the precipitates.

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Exam-style questions

1. a) A lab technician finds a bottle containing an unknown chemical. They su calcium chloride solution. The technician uses chemical analysis tests to ions present in the solution. Suggest why the technician would require t identify whether the positive ions are calcium ions.
   b) The technician adds a few drops of **nitric acid** to test for the negative ior acid is appropriate for the chemical test.
   c) The technician adds silver nitrate to the solution in b), and identifies chlo ionic equation, including state symbols, for the reaction which occurs wh chloride ions.

2. When testing for halides and sulfate ions, it is necessary to acidify the solutio with analysis tests.
   a) Why should hydrochloric acid not be used to acidify solutions before car for halides? Construct an ionic equation, including state symbols, to exp
   b) Construct a balanced ionic equation to show how barium chloride can be sulfate ions.
   c) State the observation made when the reaction in b) is carried out.

3. Seawater contains a mixture of ions, including lithium chloride.
   a) One way of identifying lithium chloride is using a flame test. State the o be made.
   b) State the reagents needed to identify chloride ions, and give the positive

4. Calcium chloride is a salt made up of two ions.
   a) Give the formulae of the ions present in calcium chloride.
   b) Explain how to identify calcium ions. In your answer, you should include with state symbols.

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Chapter 11: Chemistry
Evolving Atmosphe

Introduction

This topic provides the insights into the composition and behaviour of the air we b delving into the chemistry of our early atmosphere and its evolution over time. B its origins, we can appreciate how Earth's environment has shaped and been char how gradual changes in atmospheric composition due to natural phenomena and delicate balance that sustains life on our planet. The issue of global warming high understand the intricacy between atmospheric chemistry and climate change, an rounded, informed discussions about the future. Many synoptic questions focus o you to understand not only the chemistry behind the processes, but also the abili conclusions from data.

Composition of the atmosphere: past and present

Earth's atmosphere is dynamic, and its composition can be influenced by a number of factors. The composition over the past 200 million years has remained relatively constant, at *approximately*:

- 80 % nitrogen
- 20 % oxygen
- Small proportions of other gases (carbon dioxide, water vapour and noble ga

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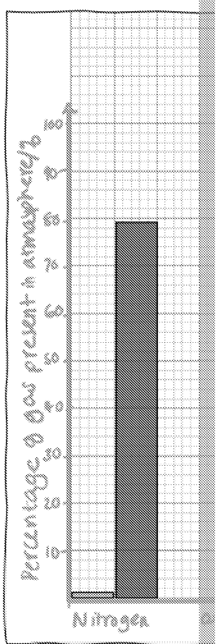
However, over the past 4.5 billion years, Earth's atmosphere has changed dramatically, and there are theories about how this has developed, utilising some **limited** evidence. The early atmospheric composition was likely to be *approximately*:

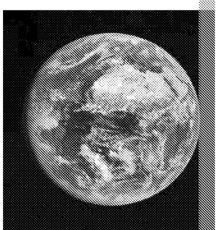
- 80 % water vapour
- 12 % carbon dioxide
- Small proportions of other gases (sulfur dioxide, methane, ammonia)

Consider the graph. You can see that the composition has changed dramatically. You will need to be able to state which gases have changed, and **compare** different atmospheric compositions.



Venus and Mars
The composition of Earth's early atmosphere is thought to have been comparable to that of **Venus** and **Mars** today. Many exam questions focus on this idea.

Approximate atmospheric composition of Venus	**Approximate atmospheric composition of Mars**
96 % carbon dioxide	96 % carbon dioxide
3.5 % nitrogen	2 % argon
Small proportions of other gases (carbon monoxide, argon, sulfur dioxide, water vapour)	<1 % oxygen
	Small proportions of other gases (nitrous oxides, noble gases, water vapour)



As you can see, a c composition of th You will need to b and **differences** i atmosphere: mod comparisons to ot

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Worked example

Titan, a moon of Saturn, has an atmosphere composed of mainly nitrogen (95 %) and methane (<5 %), with the rest of the atmosphere composed of other gases such as hydrogen, carbon dioxide and argon.

a) Compare the composition of the atmospheres of Earth and Titan.

*To answer this question, we need to consider the **similarities** and the **differences** – the command word is 'compare'. It is important to think about the gases mentioned AND ones that may be missing…*

Similarities	Differences
• ***Both*** *atmospheres contain mostly nitrogen* • ***Both*** *atmospheres contain trace amounts of the noble gases such as argon* • ***Both*** *atmospheres contain carbon dioxide in small amounts*	• *Titan's atmosphere has a* ***higher*** *composition of nitrogen than Earth's atmosphere* • *Titan's atmosphere contains* ***more*** *methane than Earth's atmosphere* • *Titan's atmosphere contains* ***no oxygen*** *whereas Earth's atmosphere has around 20 %*

*Notice the use of **comparative language** such as 'both', 'more', 'higher'.*

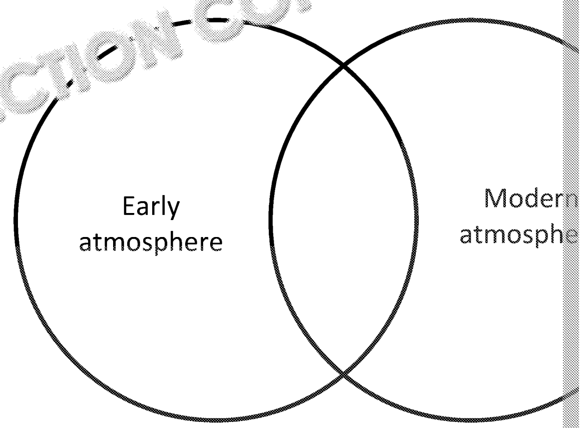
b) Earth's **early** atmosphere is estimated to have been very different from how it is today. Explain why scientists cannot be sure of the **exact** composition of the early atmosphere.

This question is much simpler than it seems!
*Humans had not yet evolved… it was **billions** of years ago. Note that you cannot simply say it was a 'long time ago'; it is crucial you explain that it is an **extremely** long time ago!*

Task A

1. Add the gases to the **Venn diagram** to show which gases were present in t modern atmosphere only, or both.

nitrogen, ammonia, oxygen, carbon dioxide, water vapo



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Task A

2. It is suggested that Earth's early atmosphere may have been similar to the
The table below shows the compositions of the atmospheres on Earth and

Gas	Percentage composition on **Earth today** / %
Nitrogen	80
Oxygen	20
Carbon dioxide	<1 (traces)
Argon	<1 (traces)
Water vapour	<1 (traces)

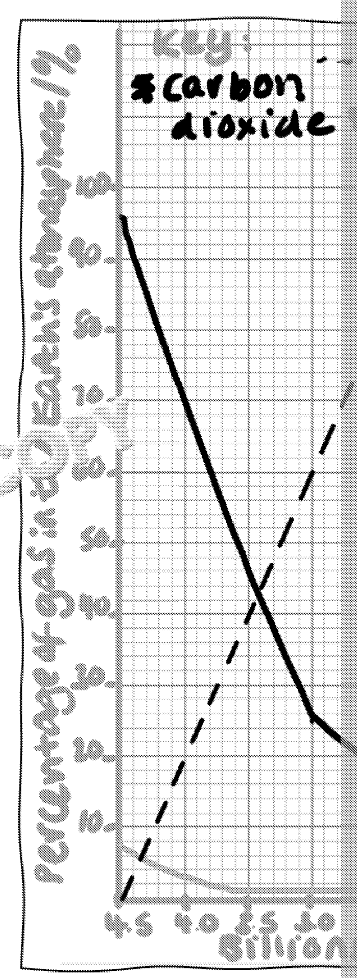
The average surface temperatures on Earth and Venus today are 20 °C and

a. State the name of a gas which is present in higher amounts in Earth's early atmosphere.
b. State the name of a gas present in Earth's atmosphere in a higher amo of Venus.
c. Explain why there is unlikely to be life as we know it on Venus.
d. Both the atmospheres of Earth and Venus contain water vapour. Muc covered by water. Explain why the surface of Venus does **not** have wa

The evolution of Earth's atmosphere

The graph shows how the composition of the atmosphere has changed over the l four key gases which have changed significantly. You will need to be able to desc **oxygen, water vapour** and **carbon dioxide**.

> **Evidence?**
> It is important to remember that these are **theories** based on **scientific evidence**. It is difficult to know **exactly** which changes occurred **when** and **how**, because it was an **exceptionally** long time ago!



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Task B

Look at the table below and decide whether the event causes the four main gas
or stay the same (=).

Event	Effect on N_2	E o
During Earth's first billion years, there was **intense volcanic activity**, releasing CO_2, CH_4, NH_3* and H_2O. * Which later formed nitrogen through chemical processes		
As Earth cooled, water vapour **condensed** to form ocean. Carbon dioxide dissolved in the water, and carbon ... precipitated to produce sediments. Sedimentary rock formed.		
Around 2.7 billion years ago, plants and algae formed, undergoing photosynthesis: $6CO_2 + 6H_2O \rightarrow$ ... $+ 6O_2$		
When plants and animals died and decayed, **fossil fuels** such as coal (from land biomass) and crude oil (from marine biomass) formed.		

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Task C

1. The bar chart (right) shows the composition of gases in Earth's early atmosphere.
   a. Complete the graph to show the approximate percentage of carbon dioxide in the early atmosphere.
   b. The pie chart shows the composition of the atmosphere on Planet X.
      i. Calculate the percentage composition for each gas.
      ii. Compare Earth's early atmosphere with the atmosphere on Planet X.
2. The table below shows the composition of gases in the Earth's atmosphere.

Gas	Percentage / %
Nitrogen	
Oxygen	21
Argon	0.93
Carbon dioxide	0.04
Other gases	0.03

   a. The proportion of nitrogen in the atmosphere is approximately 39 parts in 50. Calculate the percentage of nitrogen in the atmosphere.
   b. If the total mass of the atmosphere is approximately 5×10^{18} kg, calculate the approximate mass of oxygen in the atmosphere.

Continued overleaf

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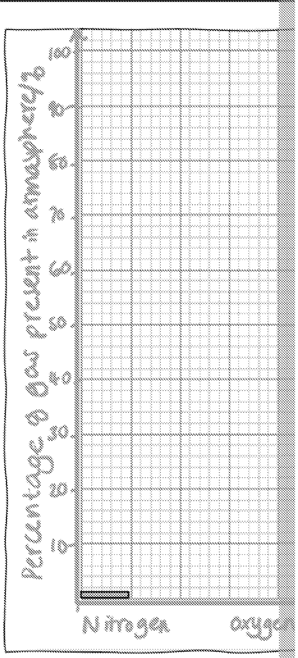

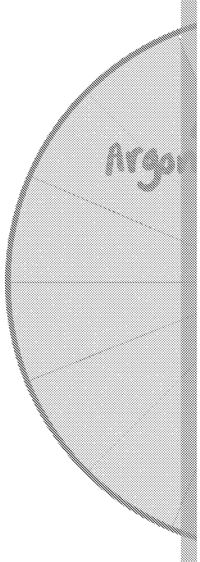

Composition of t

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c. The role of plants and algae has caused the proportion of two gases to
   i. Name the chemical process by which plants and algae altered the whether their amounts increased or decreased.
   ii. Write a balanced chemical equation for the process.
   iii. Explain how this process allows scientists to pinpoint the date wh on Earth.

d. Other gases make up small proportions of the modern atmosphere.
   i. Name a gas included in the 'other gases' and state its origin.
   ii. Describe and explain how the proportion of this gas has changed
   iii. Explain how this process impacted the proportion of carbon dioxi

Greenhouse gases

Greenhouse gases in our atmosphere are essential to keep our planet warm enough for life – they help maintain **habitable** temperatures on Earth. The three main greenhouse gases in our atmosphere are:

1. Methane
2. Carbon dioxide, CO_2
3. Water vapour, H_2O

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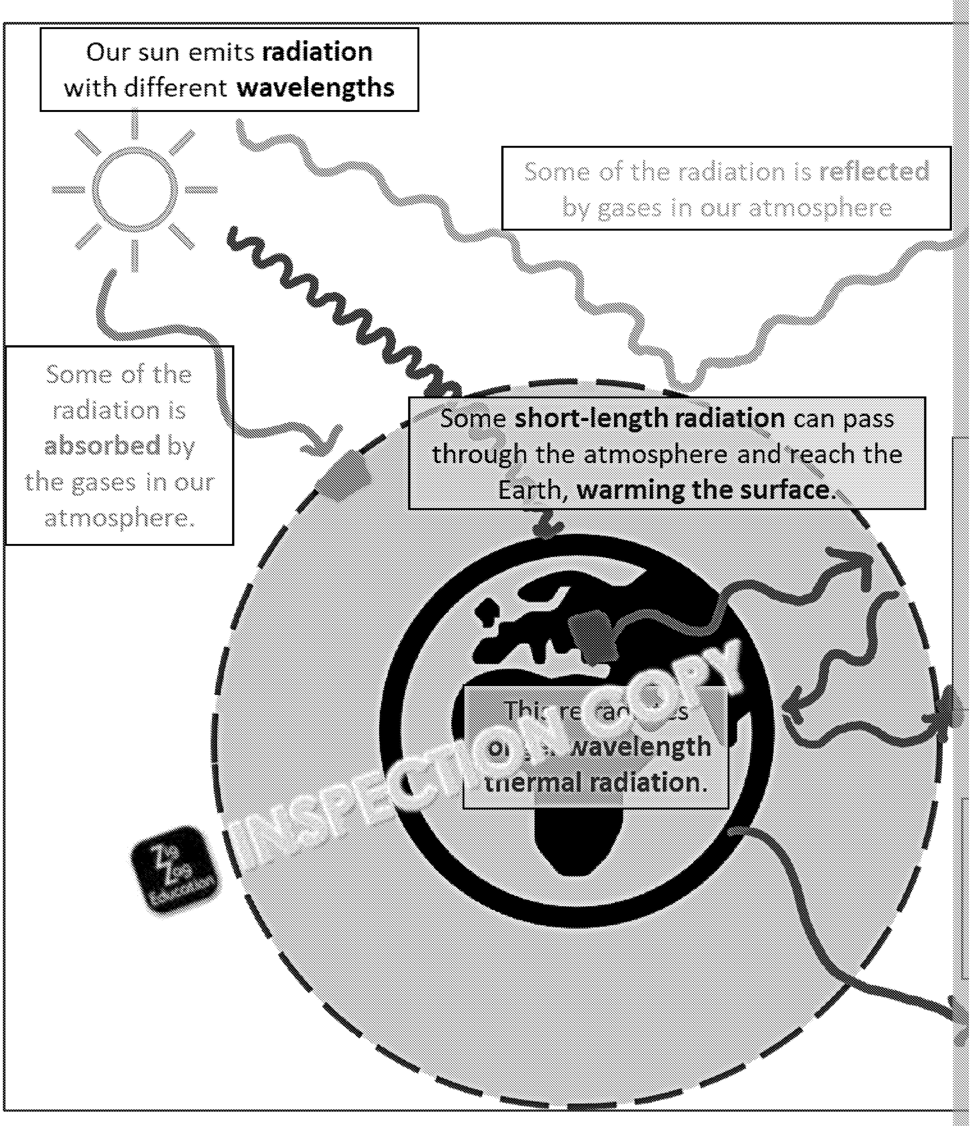
The natural greenhouse effect is summarised below.



It is important to note that this is a **natural** and **essential** effect. However, huma in greenhouse gas emissions, which **enhances the effect**, leading to increased wa

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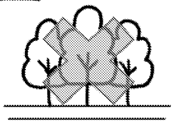
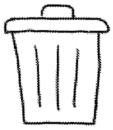
Human activity

There are some key processes leading to the increase in greenhouse gas emission

Rice fields are a big source of **methane** emiss cattle and their decomposing waste also pro amounts of **methane**.

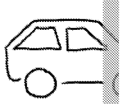


Deforestation to clear space for crops and anima in **reducing carbon dioxide uptake** by plants.

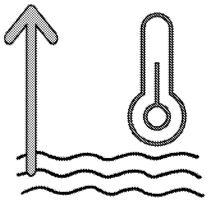


A larger population means a larger amount of wa **landfill**. When it breaks down, this releases **meth**

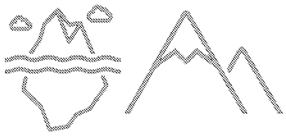
Fossil fuels are used to produce electricity, heat our homes and power our cars. All of these act to release **carbon dioxide** into our atmosphere.



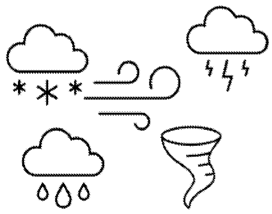
Evidence for climate change



Our oceans are getting **warmer**, and sea levels are **rising**



Our ice sheets are **shrinking,** glaciers are **retreating**, and snow cover is **decreasing**



Extreme weather events are **increasing in frequency.**

The Eart **complex** understa impacted **variable** very diff and mod **simplify** predict w certainty of climat

When analysing the evidence for the impact of climate change, you wi

- Evaluate the **quality of evidence** in a report about global climate
- Describe why there are uncertainties over the evidence for climat
- Recognise the importance of **peer-review** of results

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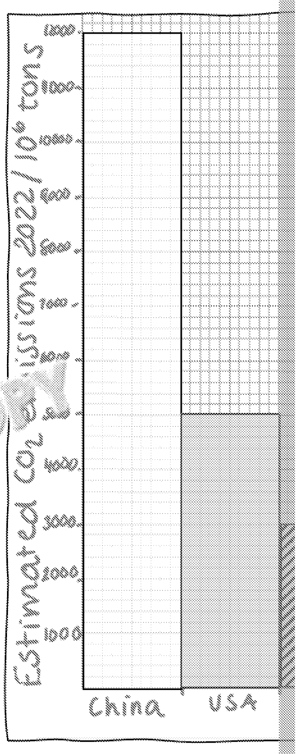
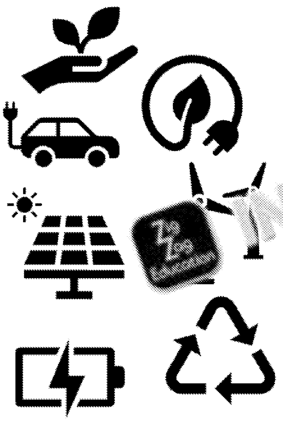
Task D

The graphs show the estimated CO_2 emissions by country, and their approximate percentage share of the world population in 2022. Use the graphs to answer the questions.

1. Identify which country had the highest estimated CO_2 emissions in 2022, and state the approximate amount in tons.
2. This question relates to the USA and India.
   a. Compare the estimated CO_2 emissions of the USA and India.
   b. Evaluate the CO_2 emissions of the USA and India, referring to their relative population sizes and other factors that may impact CO_2 emissions.
3. Consider the data on China and India. Describe the relationship between the country's population size and its CO_2 emissions.
4. This question relates to the USA, Russia, Germany and South Korea.
   a. Calculate the combined percentage of the world population for the USA, Russia, Germany and South Korea.
   b. Given this combined population percentage, discuss whether these countries' CO_2 emissions are proportional to their sizes, referring to the bar chart.
5. From the bar chart, estimate the total CO_2 emissions from all six countries in 2022.
6. Suggest two ways in which countries could reduce their CO_2 emissions.



Reducing our carbon footprint



A carbon footprint measures the total greenhouse gas e
indirectly by a person, an organisation, an event or a pr

There are a number of steps which can be taken at an i
to reduce their footprints.

Task E

1. A school-aged student wants to limit their carb
   meant by this concept, and suggest actions whi
2. A clothing company wants to become more car
   meaning of 'carbon-neutral' and suggest some a
   take. Explain why some actions might be challe

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Atmospheric pollutants

We know that human activity can contribute to the release of **greenhouse gases** into our environment. When a pure fuel burns, carbon dioxide and water vapour are produced:

An **atmospheric pollutant** is
in the air and can be harmfu
damage to our climate and
pollutants are **contaminants**
human activities.

Worked example: Write a balanced equation for the combustion of butane:

When a hydrocarbon such as butane (an alkane) is burned, the carbon and hydr ***oxidised*** *to form their oxides – carbon dioxide and 'hydrogen oxide' or water:*

butane + oxygen → carbon dioxide + water

Converting this into a symbol equation:

$$C_4H_{10} + \_O_2 \rightarrow \_CO_2 + \_H_2O$$

The equation is ***unbalanced****. Counting the number of each atom type, we can se*

$C_4H_{10} + \_O_2$	$\_CO_2 + \_H_2O$
C: 4 H: 10 O: 2	C: 1 H: 2 O: 3

Ti
co
Th
ba
for
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the

We can see we need to multiply the carbon dioxide on the RHS by 4:

$C_4H_{10} + \_O_2 \rightarrow \mathbf{4}CO_2 + \_H_2O$

Checking the number of each atom type again:

$C_4H_{10} + \_O_2$	$\mathbf{4}CO_2 + \_H_2O$
C: 4 H: 10 O: 2	C: 4 H: 2 O: 9

Note that we have impacted the number of oxygen atoms, too, but we will addre Now, we need to address the hydrogen. To get the same number on both sides, water by 5:

$C_4H_{10} + \_O_2 \rightarrow 4CO_2 + \mathbf{5}H_2O$

Checking the number of each atom type again:

$C_4H_{10} + \_O_2$	$\mathbf{4}CO_2 + \mathbf{5}H_2O$
C: 4 H: 10 O[illegible]	[illegible] [illegible]: 10 O: 13

Tip for balanci
There are two
equation with
You can either
half, or multipl
2. Either is fine
numbers repres

All that remains is to balance the oxygen. If there is an ***odd number****, don't forge as a balancing number! To balance 13 oxygen atoms on the RHS, we need 7 ½ ×*

$C_4H_{10} + \mathbf{7\frac{1}{2}}\,O_2 \rightarrow 4CO_2 + \mathbf{5}H_2O$

The equation is now balanced.

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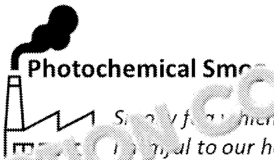
However, the fuels we burn are very rarely pure, and many contain **contaminants** oxidise when burned to form their oxides. We also **rarely burn fuels in pure oxyg** gases present in the air could react to form their oxides, too. **Incomplete combus** supplies of oxygen. All of these lead to the formation of **pollutants** when a fuel is to describe how each pollutant is formed and explain its effect on living organism

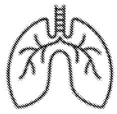
Task F

1. Match the pollutant to its effect on living organisms and the environment.

Nitrous oxides, NO_x



ful to our health



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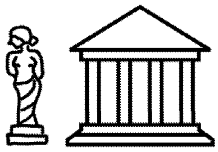
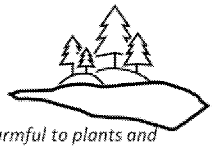
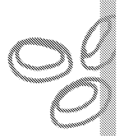
Sulfur dioxide, SO_2



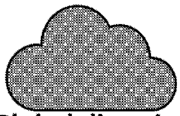
Can cause damage to statues and buildings



Harmful to plants and animals, especially those which inhabit water



Carbon monoxide, CO



*Small particles in atmosphere redu of **radiation ene** Earth's surface fr*

Carbon particulates, C

2. For each pollutant above, describe how it is formed.
3. Incomplete combustion occurs when there is a poor supply of oxygen. Give incomplete combustion of octane. State an environmental impact of the p
4. Fossil fuel power stations release sulfur dioxide.
   a. State the source of the sulfur.
   b. Explain the environmental impact of the release of sulfur dioxide.
   c. Name the other cause of acid rain, explaining how it arises.

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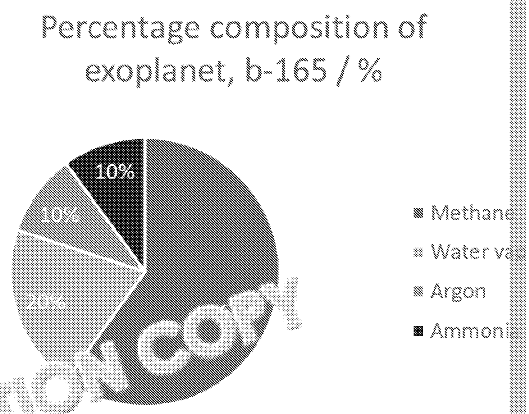
Exam-style questions

1. An exoplanet, b-165, has an atmospheric composition shown below.



   a. Some scientists believe that living organisms could not have evolved on organisms could not evolve in the same way that life is thought to have
   b. b-165 has an average surface temperature of 450 °C. Explain how the g b-165 keep the surface temperature high.

2. Our world population has increased considerably over the past 50 years. Ov of the atmosphere has also changed, and the average temperature of Earth's
   a. The increase in world population may have contributed to the changes i Explain why.
   b. The increase in world population may have contributed to the changes i Explain why.
   c. Describe two impacts of global warming.
   d. Some scientists dispute that global warming is due to the increase in gre Give one reason why some scientists dispute the theory.

3. Michelangelo's Statue of David originally stood outside the Piazza della Signo place. Soot has made the statue appear blackened, and it has become erode with atmospheric pollutants.
   a. What causes the blackened surface? Explain how this pollutant is forme are burned.
   b. Car engines run on petrol or diesel. Explain how desulfurisation of these on statues such as Michelangelo's David.
   c. Nitrous oxides are pollutants formed inside car engines. Explain how th and give an environmental impact.

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Chapter 12: Water (Required

Introduction

It is impossible to understate how vital water is to our everyday lives. It is, howev and forget about the myriad of processes required to get **clean, potable** water flo what potable water is, how it is obtained from different sources, and how to test for its purity.

Potable water is water which is safe for human consumption.
Pure water contains only H_2O molecules, with nothing else added to it.

We get our water from a variety of sourc... it ... important to understand wh may be contained in the water, what ... may be required to make the wat potable, and why some ... over others.

... of water	**Sources** of this type
Pure water is sometimes referred to as 'deionised' or 'distilled' water. It contains no dissolved substances.	This water is made by distillation, which inv condensation, removing any dissolved subst that it contains only H_2O molecules.
Fresh water describes water with a low concentration of dissolved substances in it.	Groundwater is water found in undergroun rocks ('aquifers').
	Reservoirs are large natural or artificial lakes used as a source of water supply. They can be used to store fresh water for drier seasons.
	Rainwater, rivers, streams, lakes, ice caps a glaciers are also sources of fresh water.
Seawater contains high levels of dissolved salts and minerals	These natural saltwater supplies are found i seas and oceans.
Waste water may contain chemicals, organic matter, and dissolved substances, as well as insoluble solids.	Waste water is ... from home ... and ... 

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Analys... st 1: pH testing water sources

1. Take a sample of the water to be tested and place it in a test tube.
2. Add a few drops of **universal indicator** to the sample.
3. Compare the colour of the solution to an indicator chart and decide on an a

Pure water should have a neutral pH of around 7.
Saltwater has a slightly more alkaline pH of around
Rainwater has a slightly more acidic pH, which can be as l

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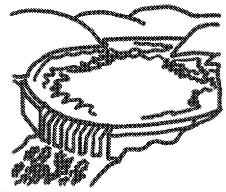
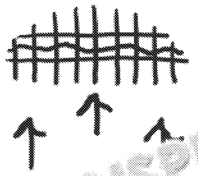
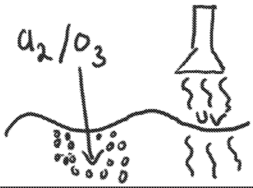
Treating groundwater

In the UK, the silver lining of our often wet and rainy climate is that much of our t
groundwater. This is pumped to a water treatment works, where it goes through
make it safe to drink.

	Water may be stored in reservoirs b treatment process. This ensures we the drier months.
	**Screening** involves passing the wate remove large solids such as leaves a
	**Settlement** allows the water to pass which removes any further insolubl
	The water now needs to be made sa **chlorine or ozone** are added to kill a within the water. **UV light** can also

Analysis test 2: Testing the boiling point

Pure substances have **fixed boiling points**, whereas impure substances will have
whether the water is 100 % pure, we check whether it boils at exactly 100 °C – t
This is a **definitive test** as it tells us if the water is pure or impure, not just if the

Task A

1. A sample of water is tested with universal indicator, and is found to have a
   a. Suggest the source of the water.
   b. Would you expect this water to have high or low concentrations of dis
2. Describe the process of screening, stating what is removed in this process.
3. Explain how water is sterilised and what is achieved by this process.
4. A student suggests that we should only drink **pure water**. Is this student co stating the difference between pure water and potable water.
5. State the sources of waste water. What may be contained in waste water?

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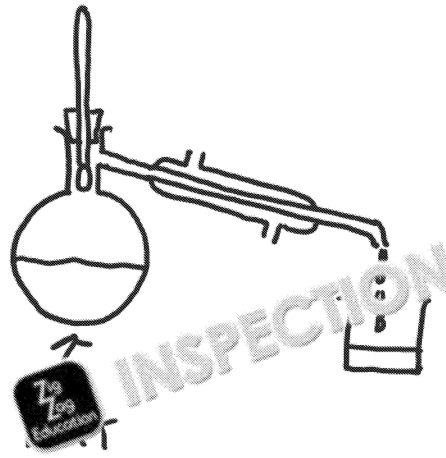
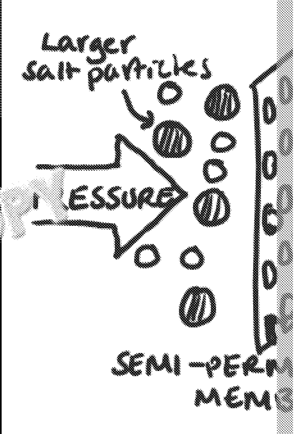
Treating seawater

In countries with a much drier climate than the UK, desalination is used to obtain
done in two main ways: distillation and reverse osmosis.

Distillation	Reve
	
The water is heated to above 100 °C (the boiling point of water) which requires a large amount of energy. The steam produced passes into a condenser, where it cools and condenses to give pure water.	Under high pressure, w permeable membrane. molecules through, but salt from passing throu
• **Expensive** – high amounts of heat energy required to heat the water. • **Harmful waste** – since the waste produced is highly concentrated in salt, it is difficult to dispose of in a way which does not harm marine life.	• **Expensive** – both t obtaining the high expensive. • **Inefficient** – a larg produced from thi

Clearly, both processes have a large energy cost associated with them when comp
treatment, and so these methods are much more suited to drier climates such as
are very low reserves of groundwater.

Analysis test 3: Identifying salt in a water sample

To check whether common salt, sodium chloride, is present in a water sample, we can carry out identification tests.

1. Dip a clean nichrome wire into a sample of the water to be tested.
2. Place the nichrome wire into a Bunsen flame and observe any changes to the flame colour. An orange flame indicates the presence of sodium ions, Na^+.
3. To a different sample of the water, add a few drops of nitric acid, followed by a few drops of silver nitrate solution. Observe any changes. A white precipitate indicates that chloride ions, Cl^-, are present.

This technique tells us **if** there is salt present in the sample, but not **how much**.

Analysis test dissolved sal

Different water sou
of dissolved salts.

1. Weigh an empty its mass.
2. Take a 1 cm^3 sa and place it on t
3. Place the watch heat it until all o has evaporated.
4. Allow the watch bottom of the w mass again.
5. By comparing re which water has contained in it, i

This technique can a
water purification p

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Task B

1. A country with a hot climate produces drinking water in a different way to t
   do countries such as the UK not use this method routinely?
2. Explain in detail how seawater is purified by distillation in a laboratory.
3. Describe the differences between distillation and reverse osmosis.
4. Three students are testing an unknown liquid to determine if the water is li
   suggests using cobalt chloride paper. Student B suggests testing the pH of t
   carrying out flame tests and the silver nitrate test. Which student, if any, wi
   water is potable?

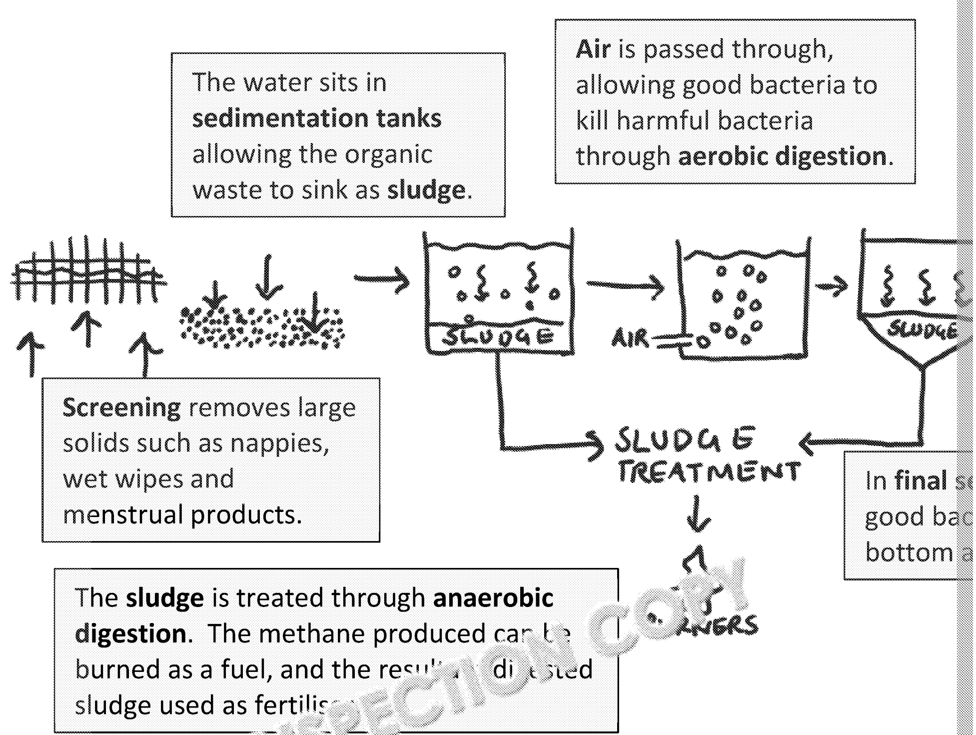
Treating waste water

To maintain a balanced water cycle, waste water from homes, industry and agricu
released into the environment.

Waste water can contain a number of contaminants, including:

- Human and animal waste, which contains harmful bacteria
- Hazardous chemicals including toxic metal compounds
- Medicines and other drugs
- Fertilisers and pesticides

This means that the water requires more processing to make it potable.



Task

Sort the following statements into a Venn diagram of groundwater, waste wate

- Contains dissolved solids
- Contains organic waste
- Contains chemicals
- Sourced from rivers and lakes
- Low levels of bacteria
- Undergoes scre
- Produces slud
- Requires aerat
- Requires steril
- Produces pota

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Exam-style questions

1. Potable water is crucial to our everyday lives.
   a. Define the term 'potable water'.
   b. Seawater can be changed into potable water by desalination. Name the seawater by desalination, and explain why desalination is only used whe of potable water.
   c. Two students investigated different water samples. The table below sho

Water	pH	Mass of dissolved
A	6.8	0.5
B	8.2	42
C	7.0	

   i. Copy and complete the table above to suggest the mass of dissolve
   ii. Which sample is most likely to be tap water? Explain your answer.
   iii. Identify two other sources of water.

2. Waste water treatment involves four key processes: screening, sedimentatio
   a. Give an example of a substance removed during screening.
   b. Describe the process of aeration. Give a reason for this step.
   c. What could be used to carry out the process of sterilisation? Give **two** e
   d. The water produced through this process is **not** pure water. What is pu
   e. How could water be tested to make sure that it is pure? Give the expect pure water.

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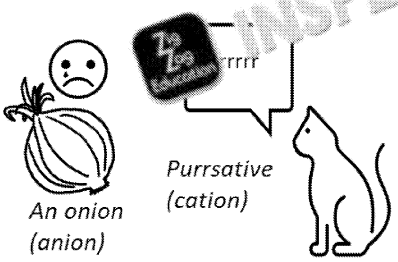
Chapter 13: Electrol

Introduction

Electrolysis is a fundamental topic in GCSE, as it bridges several key concepts, incl properties of ionic substances, reactivity series, extraction of metals, redox reacti many practical applications that are crucial for understanding modern chemical p extracting aluminium, and the production of chemicals from brine.

Electrolysis is using **electricity** to **split / break up** the flow of electrical current through an electrolyte, which causes **chemical changes** to occur.

Two **electrodes** (conducting materials, usually graphite) are dipped into the electrolyte solution and connected to a power supply, causing the flow of electro

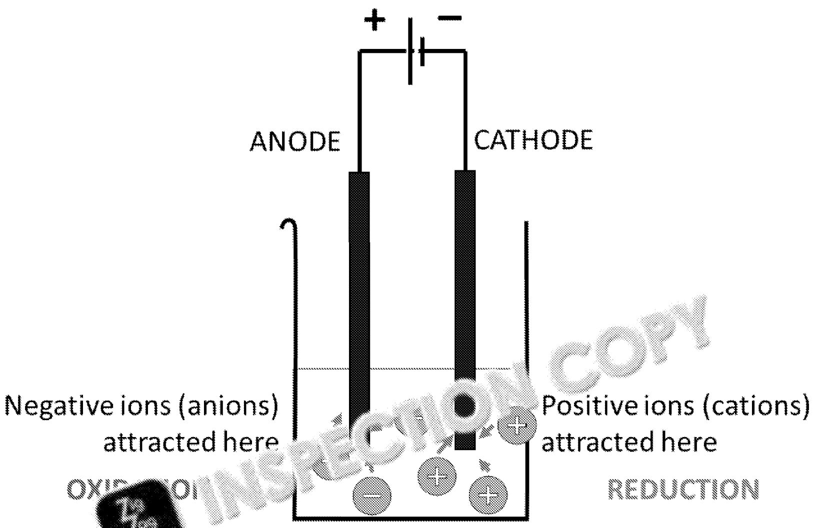


The **positive ions**, **cations**, are attracted tow (since opposites attract). **Negative ions**, ani **positive** electrode. An easy way to rememb onions and cats. Cutting on(an)ions can mak whilst cat(ion)s purr – they are **purrsative**!

Importantly, the ions have to be **free to mov** happen – the substance must be **molten or**

Once at the electrodes, **redox reactions** occur. One species will **lose electrons** an become **oxidised**, whilst the other will **gain electrons**, becoming **reduced**. A great way to remember the reactions occurring at each electrode is to think about an o and a red cat. Yes, really!

ANode → **OX**idation, **RED**uction → **CAT**hode. Pulling these ideas together:



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You will need to be able to:

- Describe the process of electrolysis
- Predict the products of electrolysis of molten ionic compounds and solutions
- Explain how electrolysis is used to extract metals such as aluminium
- Write half-equations for the reactions occurring at each electrode during ele

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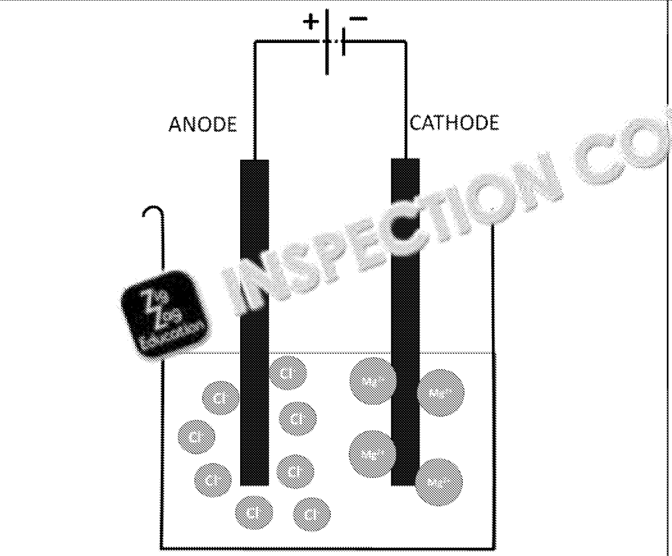
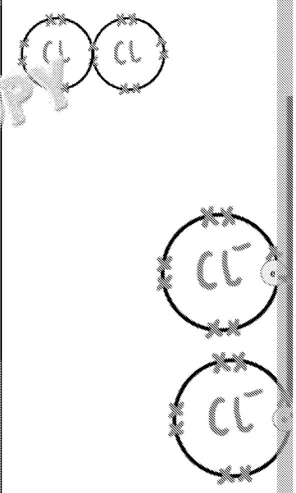
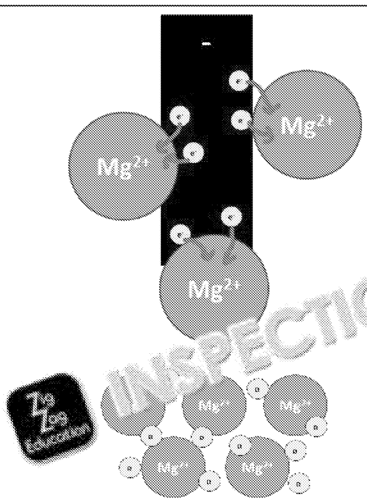
Electrolysis of molten ionic compounds

One way of producing an electrolyte solution is by melting an ionic compound.
This enables the ions to be able to move towards the oppositely charged electrod
When the ionic compound is electrolysed:

- the metal is produced at the cathode
- the non-metal is produced at the anode

For example, if magnesium bromide is heated above its melting point and electrol

	
Magnesium chloride has a high melting point – 714 °C. The ions in **molten** magnesium bromide can *slide over one another* – they are **liquid**. • *Magnesium ions are attracted to the -ve electrode (cathode) and move towards it.* • *Chloride ions are attracted to the +ve electrode (anode) and move towards it.* This is because they are **oppositely charged**. When the electrodes are connected to an external power supply, electrons can begin to flow.	At the **positive electro** • Each chloride ion l outer shell to refo • Two chlorine atom chlorine **molecule** shell of electrons. • Since chlorine is a gas rises and we w electrode.
	Mg^{2+} + OXI $2Cl^-$ → RED
At the **negative electrode**: • Magnesium ions **each gain two electrons**. Magnesium reforms its **metallic lattice** structure, and the electrons become **delocalised** within the structure. • We would see shiny metallic magnesium coating the outside of the electrode.	We can represent the c each electrode using h electron transfer. The magnesium ions a The chloride ions are o

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Task A

The following questions relate to the electrolysis of **molten ionic compounds**.

1. Copy and complete the table by filling in the gaps.

Formula of ionic compound	Product at **positive** electrode	Product at **negative** electrode	**Oxidat** half-equ
NaBr	Br_2 – bromine		
	O_2 – oxygen	Fe – Iron	
Na_2O		Na – sodium	
		Al – aluminium	$2Cl^-_{(l)} \rightarrow Cl_2$
	Br_2 – bromine	Pb – lead	

2. This question relates to the molten electrolysis of barium chloride.
   a. [illegible] why barium chloride cannot be electrolysed in its solid state.
   b. [illegible] the name and formula of the product formed at the **positive** electr
   State an observation seen at this electrode.
   c. Construct a half-equation to show the **oxidation** process occurring. Exp

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Extracting aluminium by molten electrolysis

Some metals can be extracted by **reduction with carbon**. This only works if the metal is **less reactive** than carbon. For **more reactive** metals such as aluminium, electrolysis must be used.

Aluminium is the ***most abundant metal on Earth****, but it is very expensive. This is due to the high energy costs associated with its extraction.*

The weight of aluminium is around one-third the weight of steel. It has a high strength : density ratio, making it ideal for many uses.

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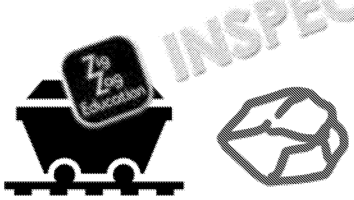
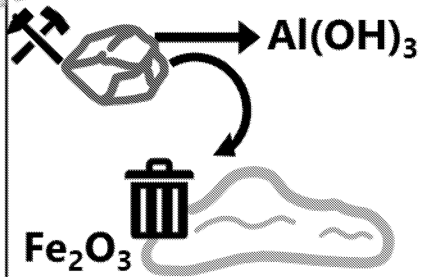
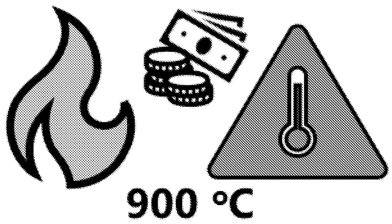
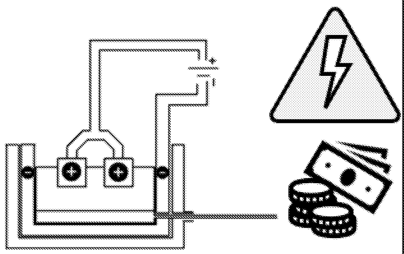
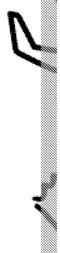
- Gr but **rep**
- Liq wh

		Al(
Bauxite, an ore containing aluminium oxide, is **mined** by open-cast mining. An ore is a rock containing enough mineral to make it profitable to extract.	The ore is separated from rocky impurities, forming aluminium hydroxide. **Waste material** rich in iron(III) oxide must be stored in lagoons.	The heat oxide The extr
		
The aluminium oxide is mixed with molten **cryolite**. This **reduces the melting point** to 900 °C. There is a **high energy cost** to heat the mixture.	The mixture is placed inside the electrolysis cell. Graphite electrodes are used, and the cell has a steel case. There is a **high energy cost** to produce the electrical current needed.	Alum meta **costs** It is li stron uses.

The electrolysis cell looks a little different as this is an **industrial process**, rather t scale within the lab. The principles of how it works are the same, though.

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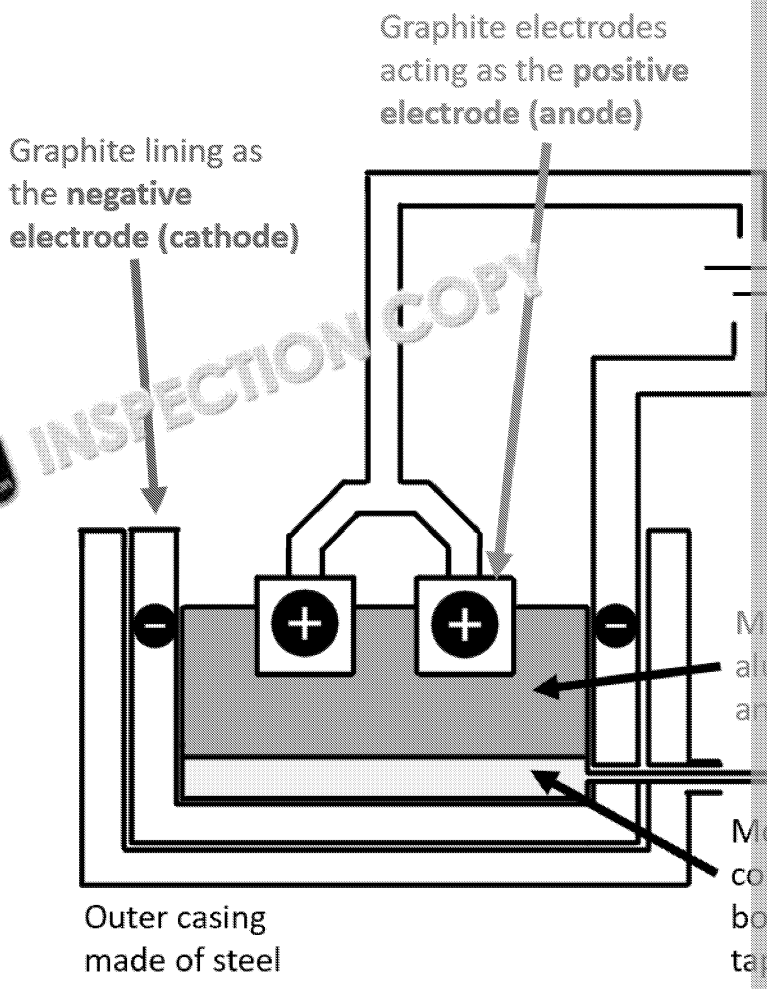
Molten aluminium is produced at the **negative electrode** (cathode); it is **reduced** $Al^{3+} + 3e^- \rightarrow Al$	Oxygen is produce[d] (anode[)] $2O^{2-}$



The problem: the electrodes are made out of **carbon (graphite)**. When oxygen is
temperatures required, the electrodes **combust**:

$$C + O_2 \rightarrow CO_2$$

This means that over time the electrodes get **worn down** and **need to be regularl**
high cost of the process.

Task B

The process of metal extraction using molten electrolysis can be used to extract

1. Write the equations for the reduction of lithium ions.
2. Explain why a mixture is often used as the molten electrolyte.
3. Explain which electrode the lithium ions move towards during the process.
4. Explain why the process has a high energy cost.
5. Lithium is one of the key components in electrical vehicle batteries. Lithium scarce. Explain why recycled lithium batteries should be used in place of lit
6. The positive electrode in a lithium ion battery consists of $LiCoO_2$. Calculate lithium in this compound to the nearest whole number.
7. Reports of lithium ion cell fires have raised concerns about the safety of th Explain why lithium shows this chemical behaviour.

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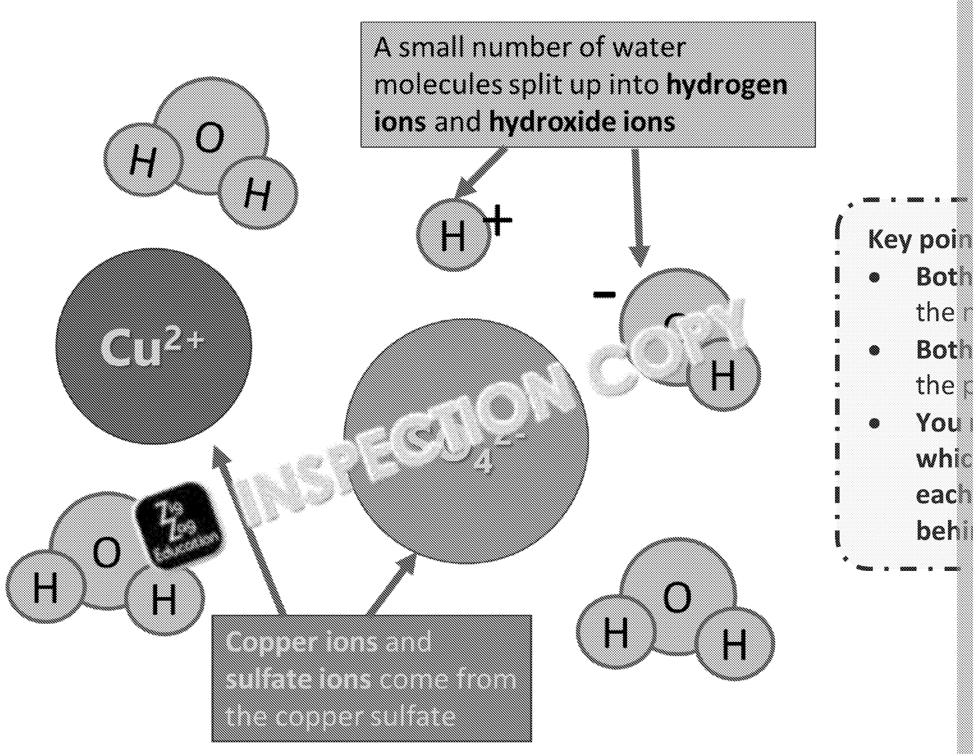
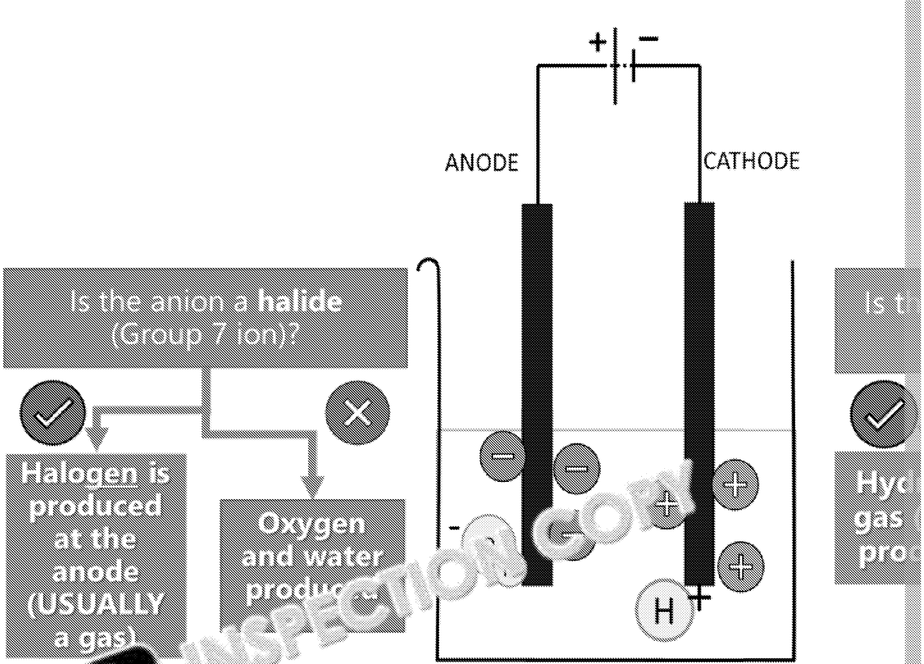
Electrolysis of aqueous solutions

Consider a solution of copper sulfate. There are **four** ions present in the solution:



What happens next depends on which ions are present. There are two rules; one



In our copper sulfate example:

- Copper is **less reactive** than hydrogen, so **copper** will be produced at the pos
  $Cu^{2+} + 2e^- \rightarrow Cu$
- There are **no halide ions** present in the solution, so **oxygen and water** will be
  $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

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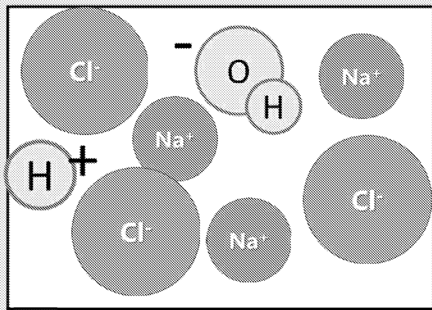
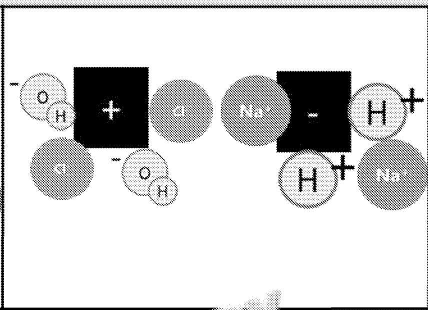
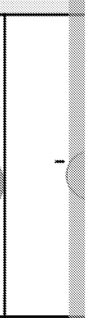
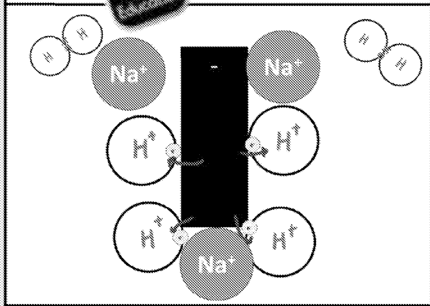
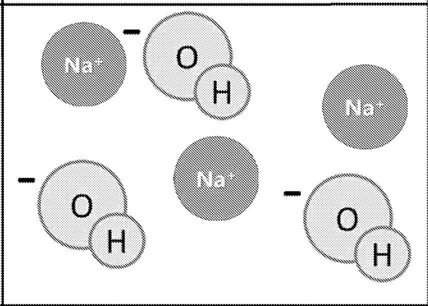
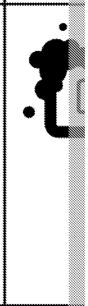
Application: The electrolysis of brine (concentrated sodium chloride so

Brine from seawater can be electrolysed to form three very useful products.

		
Brine is a **concentrated** sodium chloride solution. When electrolysed, three useful products are produced. There are four ions present in the solution	When an external voltage is applied, the ions move to the oppositely charged electrode.	At th (ano since chlor The h the s
		
At the negative electrode (cathode), **hydrogen** is reduced, since sodium is **more reactive**. Fizzing of hydrogen gas would be seen. The **sodium ions** remain in solution.	Once the solution is electrolysed, all that is left behind in the solution is **sodium hydroxide**. The solution would be **highly alkaline**.	Sodi prod Hydr hydr prod Chlor bleac

Task C

1. For each of the substances below:
   a. State which product is produced at each electrode
   b. Write half-equations to represent the oxidation and reduction process

$CaBr_2$ (l) $CuCl_2$ (aq) $FeCl_3$ (l)

[illegible]$_4$ (aq) PtI_2 (l) $Ca(NO_3)_2$ (aq)

2. During electrolysis of an aqueous solution of calcium chloride:
   a. Describe the observations you would make at each electrode.
   b. Explain how you would confirm the identity of any gases produced.
   c. Construct a half-equation representing the reduction reaction.

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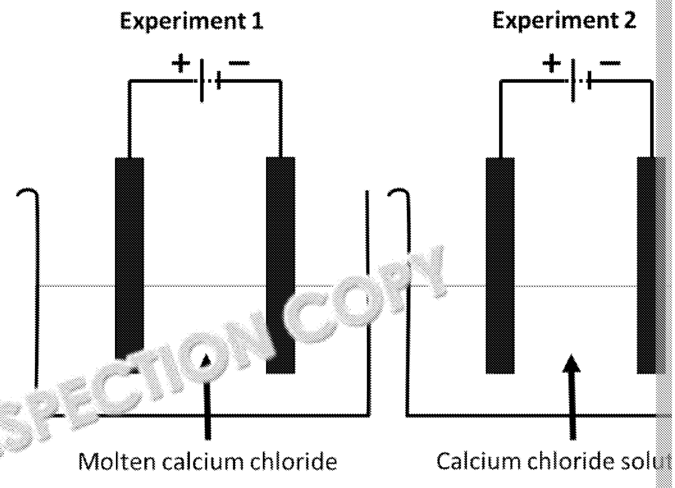
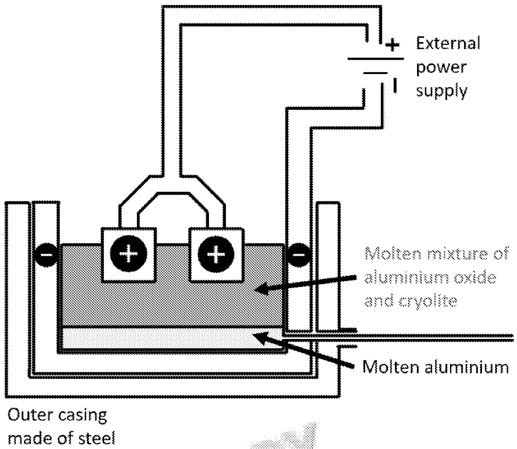
Exam-style questions

1. The ionic compound copper chloride is electrolysed in two experiments usin[g] shown below.



   a. The calcium chloride used in **Experiment 1** is molten, and in **Experiment** Explain why this is necessary before carrying out electrolysis.
   b. Explain how calcium is produced in **Experiment 1**.
   c. Name the gas produced at the positive electrode in **both** experiments.
   d. Construct a balanced half-equation for the reaction at the **negative elec**
   e. Is the product produced at the **negative electrode** the same in both exp and identify the product(s).

2. Aluminium is a very useful metal. It is not found in its elemental form, and m by electrolysis.



   a. Explain why aluminium **cannot** be extracted by reduction with carbon.
   b. At which electrode does aluminium form? Explain why, and construct a reaction occurring at that electrode.
   c. Explain why the positive electrode needs to be regularly replaced.

End of paper

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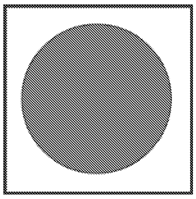
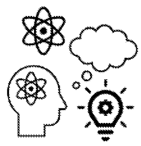
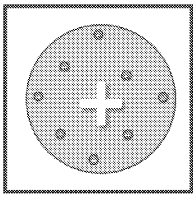
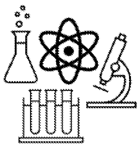
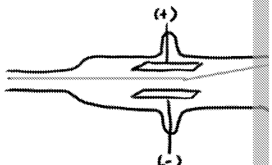
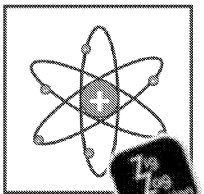
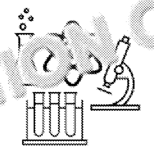
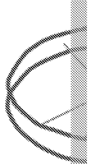
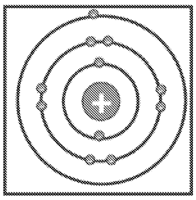
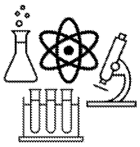
Chapter 14: How Scientific
and Theories Develop Ov

Introduction

As well as key content knowledge, the AQA specification focuses on 'Working Scie
particularly emphasises the **development of scientific thinking**: how methods an
why, limitations of science, and the importance of peer review in the scientific pr
reaching implications for a number of topics; this section will focus on the develo
atomic model, the periodic table, and the evolution of the atmosphere.

Development of the atomic model

Now that you are approaching the end of your GCSE, it is easy to take the fundam
granted. Our concept of the atom has evolved over many years as **scientific under**
technology has improved, as has our **mathematical understanding**. This has ena
and **draw conclusions**, as well as carry out **calculations** about the atom. Rather t
events, this topic focuses more on key comparisons between the models, and the
one model to the next.

Model	Scientist and year	What led to the change?	Ke
	Dalton 1803	 THEORY	• Atoms are **solid sphe** • Each element has its o
	Thomson 1904	 EXPERIMENT	• Deflection experiment both positive and nega  • Atoms are a sphere of **electrons** studded in t
	Rutherford (with Geiger and Marsden) 1911	 EXPERIMENT	• Atoms are **mostly emp** **positively charged** co • Electrons orbit in **shell** • This was discovered by experiment. Most α-p through, but some we 
	Bohr 1913	 EXPERIMENT	• **Emission spectra** led t **shells** • These are **not** all at the fixed distances around orbit the Sun (hence p

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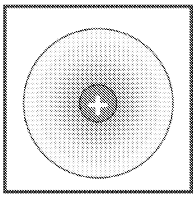
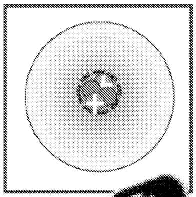
Model	Scientist and year	What led to the change?	Ke
	Schrodinger 1926	MATHEMATICAL EQUATIONS (QUANTUM MECHANICS)	• Mathematical equatio electrons move • Instead of a strict elect more of a 'cloud'
	Chadwick 1932	EXPERIMENT	• ...er more-accurate m Chadwick noticed that **often double** what it w its charge • This proved the existe **particles within the nu**

Task A

1. State the correct order of the discovery of each subatomic particle.
2. Describe the key features of Dalton's atomic model. Compare this model with the modern atomic model.
3. Explain how the gold foil experiment led to the development of the nuclear model of the atom.
4. Outline the contributions of **Niels Bohr** to the atomic model.
5. Compare the plum pudding model of the atom with the nuclear model.
6. Discuss, in detail, how advances in technology and a better understanding of mathematics have contributed to the development of the atomic model from Dalton's theory in 1803 to the modern model proposed by Chadwick in 1932.

The f
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Development of the periodic table

Similarly for the periodic table, you need to know the key changes which led to th table we use today. A broad overview of the early steps is given below, but the k relate to **Mendeleev** and the changes he made, and comparisons to the version i

Lavoisier	Dalton	Doebereiner	Meyer
• Defined the concept of an element • Made a list of the known elements at the time and tried to classify them	• Arranged the elements according to their **atomic mass**	• Grouped elements into threes, 'triads', of similar properties • This didn't work for all elements	• Used atomi masses to a elements • Grouped el into six 'fa according t their **valen**

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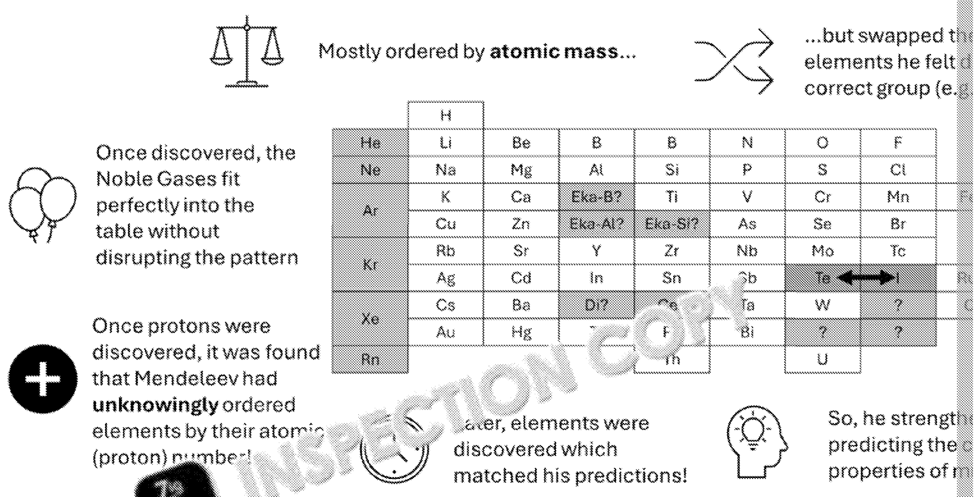
Mendeleev's periodic table

Mendeleev took some very important steps when developing his periodic table. I
of the modern-day version still in use today.



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Task B

1. Describe how Mendeleev arranged elements in his periodic table. (3 marks)
2. Explain why Mendeleev's periodic table was **not** initially accepted by the scientific community. (2 marks)
3. Compare Mendeleev's periodic table with Newland's octaves. (4 marks)
4. Compare Mendeleev's periodic table with the modern-day version. (4 marks)
5. Describe and explain how the discovery of new elements and advancements in technology have contributed to the development of the modern periodic table, building on Mendeleev's version. (6 marks)

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The power and limitations of science

It is crucial to understand that science can be robust and founded on evidence, bu
Science allows us to understand many aspects of the world around us through ob
enables the advancement of technology to find solutions to complex problems. S
continuously evolving, which means that data may be incomplete due to limitatio
methods. Additionally, scientific conclusions can change with new evidence. It is
data is **reliable** to allow us to draw reasonable conclusions and make informed deci
scientific claims lack credibility, and it is crucial that any scientific claims are **peer-**

There are also ethical considerations to take into account. New technologies are
such as artificial intelligence, and new materials developed, such as nanoparticles
questions about the impact on society and our environment. Balancing the benef
technologies involves considering factors like safety, fairness, and the well-being

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Task C

1. Explain why scientific data may sometimes be uncertain, incomplete or un examples in support of your explanation.
2. Discuss the ethical considerations that should be taken into account when alternative. Include both potential benefits and harms in your discussion.
3. Evaluate the use of nanoparticles in consumer products.
4. Explain why life cycle assessments are beneficial, and why they can be flaw
5. Explain why an individual and industry should reduce their carbon footprin considerations in your arguments.
6. Explain why it can be difficult for an individual to reduce their carbon footp used to measure carbon footprints can sometimes be flawed.

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Exam-style questions

1. This question is about the development of the atomic model.
   a. Describe the model of the atom presented by Dalton, giving the key feat
   b. Describe the plum pudding model of the atom.
   c. State the unexpected observation from the alpha particle scattering exp the changes made to the atomic model as a result.
   d. Compare the planetary model of the atom with the nuclear model of th

2. This question is about the periodic table and its development.
   a. Describe the key features of the modern periodic table.
   b. Döbereiner arranged elements in triads. Describe the benefit and limita
   c. Describe **two** things Mendeleev did which meant his periodic table was scientific community.
   d. Explain why there are differences between Mendeleev's periodic table

3. This question is about scientific evidence.
   a. Explain why scientists cannot be certain how the modern atmosphere e
   b. Explain why scientists cannot be sure about the long-term impacts of cli
   c. Evaluate the role of life cycle assessments (LCAs) in reducing the carbon Explain why it can be challenging to conduct accurate LCAs.

End of paper

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Challenges –
A Level AQA Chemis

Introduction

It is important to understand **that nothing in this section is required for the GCS**
a set of challenges for students considering studying Chemistry at GCE Advanced

There are no exam questions in this section; each part contains some informatio
some challenges. In each case it is the thinking and the effort to come up with yo

These are not tasks for the search engines of the Internet; they are tasks for your

You don't have to be right all the time; there really is the effort that counts. At t
this publication you will find some suggestions and possible answers and solution
remember, they are not the only answers. Like real science, not all the answers a
valid and worthy of exploration and experimentation.

1. Molar volumes

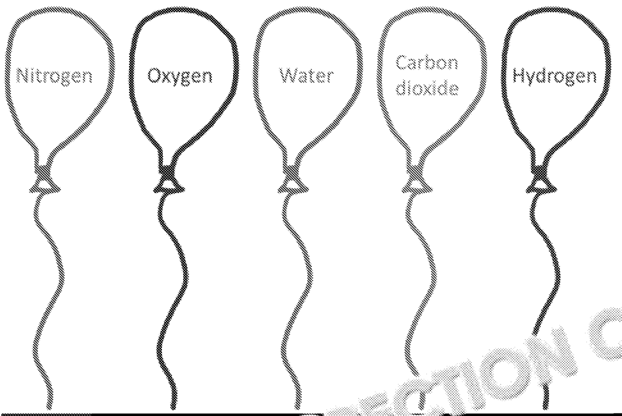
Avogadro's hypothesis on molar gas volume was based on previous laws by Boyle
liquids, which are packed tightly together, gas particles have vast distances betw
actual size of the particles themselves is almost negligible; the majority of the vol
particles, not the particles themselves.

This means that a given volume of Gas A would contain the same number of part
the particles themselves are very different.

Challenge 1.1 – Moles of gas

Questions

Five 15 dm^3 balloons were filled with five different gases, as shown below.



Have a go at completing th
information about each ga
- → What do you notice ab
- → What do you notice ab each sample?
- → Which factors might n molar gas volume law t

Name of substance in balloon	Chemical formula of substance in balloon	M_r of substance in balloon	Number of moles of gas in balloon / mol	Mass of balloon / g
Nitrogen				
Oxygen				
Water				
Carbon dioxide				
Hydrogen				

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2. Ideal gases

When using the molar gas volume law, we have made a number of assumptions a
We have also not considered two very important factors: temperature and pressu

→ What impact would increasing the temperature of the balloons have on their volume? Would this have changed the number of particles present?

→ What impact would increasing the pressure of the balloons have on their vol Would this have changed the number of particles present?

To take these important factors into account, Benoit Paul Emile Clapeyron combi **ideal gas law**.

$$PV = nRT$$

P is the pressure of the gas in Pa
V is the volume of gas in m^3
n is the number of moles of the gas
R is the **gas constant**
T is the temperature in kelvin

Convers
1 kPa =
1 cm^3 =
R = 8.31
°C + 27

Challenge 1.2 – Ideal gases

Let's look at our five balloons again. Assuming that the balloons are all kept at ro pressure (101 kPa).

Questions

Calculate the moles of each gas again, and hence the mass of the balloon, the nu number of atoms. The gas constant, R, is equal to 8.31 J K^{-1} mol^{-1}.

Name of substance	Pressure / Pa	Volume of balloon / m^3	Temperature / K	Moles in balloon / mol	Mass o balloo / g
Nitrogen					
Oxygen					
Water					
Carbon dioxide					
Hydrogen					

Further reading
Van der Waals equation, Redlich-Kwong equations, and if you really fancy a challenge, Benedict-Webb-Rub[illegible] Robi[illegible] primarily foc[illegible] non-ideal gases!

What do you notice about these valu calculations? [illegible]ough it may seem l the magnitude. The difference betw number of molecules! Even this valu number of different assumptions hav more approximations which consider gases... Luckily, we only assume 'idea

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Answers

Chapter 1

Task A

1. Potassium: (2, 8, 8, 1)
   Chlorine: (2, 8, 7)
2. a. Potassium atoms need to **lose 1 electron** to achieve the electron structure of ar
   b. Group 1 elements **lose 1 electron**, forming 1+ ions
   c. $(2, 8, 8)^+$
3. a. Chlorine atoms need to **gain 1 electron** to achieve the electron structure of arg
   b. Group 7 elements **gain 1 electron**, forming 1- ions
   c. $(2, 8, 8)^-$

Task B

1. a. Sodium + fluorine → **sodium fluoride**
   b. **Aluminium** + chlorine → aluminium chloride
   c. Silver + **bromine** → silver bromide
   d. Hydrogen + chlorine → **hydrogen chloride**
2. a. Iron(III) bromide: $FeBr_3$
   b. Silver chloride: AgCl
   c. Sodium iodide: NaI
   d. Hydrogen fluoride: HF
3. a. $2Fe + 3Br_2 \rightarrow 2FeBr_3$
   b. $2Ag + Cl_2 \rightarrow 2AgCl$
   c. $2Na + I_2 \rightarrow 2NaI$
   d. $H_2 + F_2 \rightarrow 2HF$

Task C

1. Ts_2
2. 7
3. Solid, dark in colour
4. Ts^-
5. a. $FeTs_3$
   b. HTs
   c. NaTs
6. **Less** reactive, more electron shells, less attraction between the incoming electron an
   therefore harder to gain an electron to form an ion

Exam-style questions

1. a. Any three from the following (max. 3 marks):
   - Lilac flame (1)
   - Fizzes / gas produced / effervescence (1)
   - Moves on the surface of the water (1)
   - Floats (1)

   b. Atoms get larger (1) **OR** shielding increases (1)
   Attraction between nucleus and outer electrons decreases (1)
   Therefore reactivity increases / easier to lose an electron (1)

   c. $2Na + 2H_2O \rightarrow 2NaOH + H_2$
   1 mark for correct species, 1 mark for balancing. Ignore state symbols.
2. a. Any two from the following (max. 2 marks):
   - Shiny (1)
   - Black (1)
   - Solid/Crystalline (1)

   b. Molecules increase in size / more electron shells (1)
   Forces between molecules / intermolecular forces increase / become stronger (
   Therefore more energy is required to overcome the forces (and boil the substar

   c. Fluorine (1)
   Small<u>est</u> atoms / <u>least</u> electron shells (1)
   Least shielding (1)
   So strong<u>est</u> attraction between incoming/gained electron and the nucleus (1)

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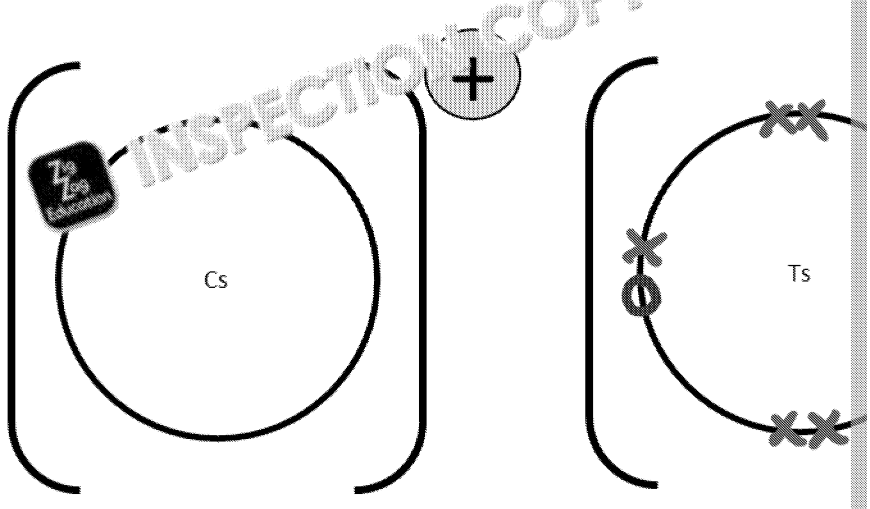
3. a. $2Cs + 2H_2O \rightarrow 2CsOH + H_2$
1 mark for correct species, 1 mark for balancing. Ignore state symbols.
b. Any one from (max. 1 mark):
- Flame produced (1)
- <u>More</u> gas produced / <u>more</u> fizzing (1)
- Explosion (1)

c. Any three from:
Caesium is the larg<u>est</u> atom (1)
Least attraction between valence/outer electrons and the nucleus (1)
More shielding (1)
Therefore easier to lose its outer electron (1)

4. a. $2Cs + Ts_2 \rightarrow 2CsTs$ 1 mark for correct formulae, 1 mark for correct bal
b.



Cs showing empty electron shell (1)
Ts showing full shell (note: dots or crosses accepted, but it is **good practice** to s
different symbol) (1)
Square brackets showing the ion charges in the top right corner (1)

Chapter 2

Task A

1. a. Al – metallic
b. MgO – ionic
c. Br_2 – covalent
d. $BaCl_2$ – ionic
e. CH_4 – covalent
f. O_2 – covalent
g. Na_2O – ionic
h. Ca - metallic

2.

Type of chemical bond	[illegible]	**Covalent**
What happens to th[illegible] electro[illegible]	[illegible]lect[illegible]s are transferred from the metal to the non-metal	Electrons are shared between the atoms
What [illegible] atoms show this bonding?	Metal + non-metal	Non-metals
Examples	MgO, Na_2O	Br_2, CH_4, O_2

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Task B

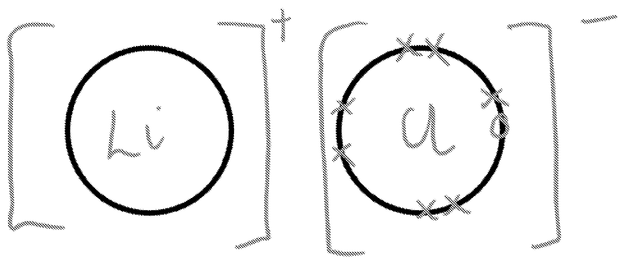
1. a. Ionic bonding
   b. Giant ionic lattice: regular arrangement of 1+ and 1- ions (*must be specific to N
   in 3D
2. Sodium is a metal. Sodium 1+ ions arranged in regular arrangement, surrounded by
3. a. Al – metallic
   b. MgO – giant ionic lattice
   c. Br_2 – simple molecular
   d. $BaCl_2$ – giant ionic lattice
   e. CH_4 – simple molecular
   f. O_2 – simple molecular
   g. Na_2O – giant ionic lattice
   h. Ca – metallic

Task C

Model	Benefit	
Ball-and-stick model	By representing ions as balls and the 'bond' as a stick, it allows us to easily see the geometric relationships in the structure	Coul cova that each
Dot-and-cross diagram	Clearly represents the electron structure of each ion	Does ions billi
3D space-filling diagram	Gives a good representation of how the ions are packed in three dimensions	Diffi
2D space-filling diagram	Shows the relative sizes of each ion and is easy to draw	Does struc

Exam-style questions

1. a.



   Correct electron structures (note: can be dots or crosses shown) (1)
   Square brackets and correct charges (1)

   b. Lithium chloride has a **giant ionic lattice** (1)
   Held together by **strong electrostatic forces** (1)
   Over 3D/many layers (1)
   Which require lots of energy to overcome (1)

2. **MUST BE A COMPARISON**
   Ammonia is simple molecular WHEREAS diamond is giant covalent network (1)
   Ammonia held together by intermolecular forces (1)
   Which are weak (1)
   WHEREAS diamond held together by strong covalent network (1)
   With many strong bonds (1)
   Which take more energy to overcome (1)
3. Positive ions arranged in a regular lattice (1)
   Surrounded by a sea of electrons (1)
   Which are delocalised (1)
   And can move to carry charge/current (1)

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Chapter 3

Task A: Moles, mass and Avogadro

1. A_r of carbon = 12.0   So 12 g of carbon = 1 mole
2. M_r of $H_2O = (2 \times 1.0) + 16.0 = 18.0$
   mass = $n \times M_r$
   $= 0.5 \times 18.0$
   $= 9.0$ g (2 sf)
3. Number of particles $= n \times 6.02 \times 10^{23}$
   $= 2 \times 6.02 \times 10^{23}$
   $= 1.20 \times 10^{24}$ molecules (2 sf)
4. M_r of NaCl = 23.0 + 35.5 = 58.5
   n = mass / M_r = 1.5 / 58.5
   = 0.026 moles (2 sf)
5. $n = 4.82 \times 10^{22} / 6.02 \times 10^{23}$
   = 0.08007 moles
   M_r of oxygen (O_2) = 2 × 16.0 = 32.0   mass = n × M_r = 0.08007 × 32.0 = 2.56 g

Note: There is no need to round your answer during working, just the final answer.

Task B: Concentration

1. 500 cm^3 = 0.5 dm^3 concentration = 6 / 0.5 = 12 g dm^{-3}
2. 250 cm^3 = 0.25 dm^3 concentration = 0.025 / 0.25 = 0.1 mol dm^3
3. M_r of glucose = (6 × 12.0) + (12 × 1.0) + (6 × 16.0) = 180.0
   n = 9 / 180 = 0.05 mol
   750 cm^3 = 0.75 dm^3
   concentration = 0.05 / 0.75 = 0.666666… = 0.67 mol dm^{-3}
4. 250 cm^3 = 0.25 dm^3
   a. concentration = 5 / 0.25 = 20 g dm^{-3}
   b. M_r of sulfuric acid (H_2SO_4) = (2 × 1.0) + 32.0 + (4 × 16.0) = 98.0
      concentration = 20 / 98 = 0.20 mol dm^{-3}
5. 300 cm^3 = 0.3 dm^3
   a. concentration = 3.6 / 0.3 = 12 g dm^{-3}
   b. M_r calcium chloride ($CaCl_2$) = 40 + (2 × 35.5) = 111
      concentration = 12 / 111 = 0.11 mol dm^{-3}

Note: It is n… important t… chemical fo… in these qu…

Task C: Gas volumes

1. 96 cm^3 = 0.096 dm^3 n = 0.096 / 24 = 0.004 moles
2. 36 cm^3 = 0.036 dm^3 n = 0.036 / 24 = 0.0015 moles
3. n = 120 / 24 = 5 moles
4. volume = 3 × 24 = 72 dm^3
5. 60 cm^3 = 0.06 dm^3
   a. n = 0.06 / 24 = 0.0025 moles
   b. M_r of N_2 = (2 × 14.0) = 28.0   mass = 0.0025 × 28.0 = 0.07 g
   c. Number of molecules = 0.0025 × 6.02 × 10^{23} = 1.51 × 10^{21} molecules

Exam-style questions

1. a. M_r of SF_6 = 32 + (6 × 19) = 146 (1)   mass = 0.025 × 146 = 3.65 g (1)
   b. Number of molecules = 0.025 × (6.02 × 10^{23}) = 1.51 × 10^{22} (1)
   c. For every 1 molecule, there is 1 sulfur atom
      So number of sulfur atoms = 1.51 × 10^{22} (1)
      For every 1 molecule, there are 6× fluorine atoms
      So number of fluorine atoms = 9.06 × 10^{22} (1)
2. 150 cm^3 = 0.15 dm^3
   a. Concentration = 4.25 / 0.15 = 28.3 g dm^{-3} (1)
   b. M_r of ammonium nitrate NH_4NO_3 = (14 × 2) + (1 × 4) + (3 × 16) = 80 (1)
      Concentration = 28.3 / 80 = 0.354 mol dm^{-3} (1)
3. 500 cm^3 = 0.5 dm^3
   a. Number of moles = 0.5 / 24 = 0.021 mol (1 mark for answer, 1 mark for 2 sf)
   b. M_r of N_2 = (14 × 2) = 28 (1)
      Mass = 28 × 0.021 = 0.59 g (1) *Accept 0.58 if 0.0208333… is used as number o*
   c. Number of molecules = 0.021 × 6.02 × 10^{23} = 1.26 × 10^{22} (1)
      Each molecule contains 2× nitrogen atoms, so number of atoms = 2.53 × 10^{22} at
4. 250 cm^3 = 0.25 dm^3
   M_r of $KMnO_4$ = 39 + 55 + (4 × 16) = 158 (1)
   Number of moles of $KMnO_4$ = 0.65 / 158 = 0.0041 mol (1)
   Concentration = 0.0041 / 0.25 = 0.016 mol dm^{-3} (1)

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Chapter 4

Task A

1. 44 g of carbon dioxide
2. 15.7 g of iron(II) sulfide
3. 31.7 g of magnesium chloride
4. 2.8 g of calcium oxide
5. 0.12 mol dm^{-3} sodium hydroxide
6. 0.43 mol dm^{-3} sodium hydroxide
7. 2.0 dm^3 ammonia

Task B

1. a. **4**Fe + **3**O_2 → **2**Fe_2O_3
   b. n(Fe) = 1 mol
      n(O_2) = 2 mol
      Required ratio = 4 : 3
      So 1 mol of iron would ne[illegible] mol of oxygen – oxygen is in excess and i
   c. If only 1 mol of ir[illegible]e, only 0.5 mol of iron oxide can be produced, so
      Ma[illegible]
2. a. H[illegible]NaOH → Na_2SO_4 + $2H_2O$
   b. n(H[illegible]) = 2 × 50 / 1000 = 0.1 mol
      n(NaOH) = 4 × 75 / 1000 = 0.3
      Required ratio: 1 : 2
      0.1 mol of H_2SO_4 would require only 0.2 mol of NaOH, so NaOH is in excess and
   c. If only 0.1 mol of H_2SO_4, only 0.1 mol of Na_2SO_4 produced
      Mass(Na_2SO_4) = 0.1 × 142.0 = 14.2 g
3. n(NH_3) = 15 / 24 = 0.625 mol
   n(O_2) = 18 / 32 = 0.563 mol
   Required ratio: 4 : 5
   So 0.625 mol of NH_3 would require 0.781 mol of O_2 – but we have only 0.563, so O_2 i
   0.563 mol of O_2 would produce 0.45 mol of NO
   v(NO) = 0.45 × 24 = 10.8 dm^3

Task C

1. 2.54 g of copper = 0.04 mol   0.72 g of water = 0.04 mol
   If copper and water are in a 1 : 1 ratio of moles, they are in a 1 : 1 ratio in the equati
   Copper oxide + H_2 → Cu + H_2O
   If copper and water are in a 1 : 1 ratio, copper and oxygen must also be in a 1 : 1 ratio,
   CuO + H_2 → Cu + H_2O

Chapter 5

Task A

1. Similarities: both are pure metals, both have positive ions arranged in regular lattice, electrons. Differences: sodium has 1+ ions whereas magnesium has 2+ ions. For eve delocalised electron, whereas for every one magnesium io[illegible]ere are two delocalise
2. Iron in its elemental form has atoms all the same [illegible] means that layers of ator another. Steel is an alloy, with atoms of dif[illegible], disrupting the layers. Layers another. Steel is therefore much [illegible]er [illegible] iron.
3. 18 carat white gold conta[illegible]% [illegible] (18 / 24 × 100) and 25 % (6 / 24 × 100) pallad

Task B

1. a. Na
   b. $Ba(NO_3)_2$
   c. $Cu(OH)_2$
2. a. Will not occur – copper is less reactive than magnesium, so cannot displace ma
   b. Will occur – lithium is more reactive than iron so displaces iron from iron nitrat
   c. Will not occur – zinc is less reactive than aluminium, so cannot displace alumini
3. a. $4Na + O_2 \rightarrow 2Na_2O$
   b. $2Li + H_2SO_4 \rightarrow Li_2SO_4 + H_2$
   c. $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$
   d. $Mg + Zn(NO_3)_2 \rightarrow Zn + Mg(NO_3)_2$

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Task C

1. a. Calcium is oxidised, hydrogen ions are reduced
   b. Sodium is oxidised, oxygen is reduced
   c. Zinc is oxidised, copper ions are reduced
2. a. $2Li + 2H^+ \rightarrow 2Li^+ + H_2$
   $Li \rightarrow Li^+ + e^-$ $2H^+ + 2e^- \rightarrow H_2$ *Accept multiple for the Li equation*
   b. $3Zn + 2Fe^{3+} \rightarrow 3Zn^{2+} + 2Fe$
   $Zn \rightarrow Zn^{2+} + 2e^-$ $Fe^{3+} + 3e^- \rightarrow Fe$
   c. $Mg + 2H^+ \rightarrow Mg^{2+} + H_2$
   $Mg \rightarrow Mg^{2+} + 2e^-$ $2H^+ + 2e^- \rightarrow H_2$

Task D

1. Any one from: reduced carbon emissions, reduced environmental destruction, make
2. Biological methods are much slower
3. Aluminium is more reactive than carbon so should be extracted by electrolysis
4. Iron is less reactive than carbon so can be displaced by reduction with carbon

Exam-style questions

1. a. Calcium chloride (1), any one from: fizzing, calcium moves on the surface of the
   smaller, heat evolved (1)
   b. $Ca + Cu^{2+} \rightarrow Ca^{2+} + Cu$
   $Ca \rightarrow Ca^{2+} + 2e^-$ (1) oxidation (1)
   $Cu^{2+} + 2e^- \rightarrow Cu$ (1) reduction (1)
   c. Calcium should be extracted by electrolysis (1) because it is more reactive than
2. Must be a comparison. Any four from:
   Phytomining is less damaging to the environment than quarrying (1)
   Phytomining requires less energy usage than quarrying (1)
   Phytomining produces less wastage than quarrying (1)
   Phytomining results in smaller carbon dioxide emissions / carbon dioxide emissions a
   Phytomining is slower than quarrying (1)
   Both involve destroying natural environments (1)

Chapter 6

Task A

Top left: concentrated weak acid   Top right: dilute weak acid
Bottom left: concentrated strong acid   Bottom right: dilute strong acid

Task B

1. Hydrochloric acid + **zinc** → zinc chloride + hydrogen
2. **Sulfuric acid** + sodium hydroxide → sodium sulfate + water
3. Sulfuric acid + magnesium carbonate → **magnesium sulfate** + water + **carbon dioxide**
4. Nitric acid + **potassium hydroxide OR potassium oxide** → potassium nitrate + water
5. **Ethanoic acid** + calcium hydroxide → calcium ethanoate + water
6. Nitric acid + iron → **iron nitrate** + **hydrogen**

Task C

1. Magnesium chloride: $MgCl_2$
2. Sodium sulfate: Na_2SO_4
3. Copper(II) sulfate: $CuSO_4$
4. Iron(III) nitrate: $Fe(NO_3)_3$
5. Aluminium sulfate: $Al_2(SO_4)_3$

Task D

1. $\mathbf{2}HCl + Mg \rightarrow MgCl_2 + H_2$
2. $H_2SO_4 + \mathbf{2}NaOH \rightarrow Na_2SO_4 + \mathbf{2}H_2O$
3. $\mathbf{2}HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$
4. $\mathbf{2}HCl + Zn \rightarrow ZnCl_2 + H_2$
5. $H_2SO_4 + Fe(OH)_2 \rightarrow FeSO_4 + \mathbf{2}H_2O$
6. $\mathbf{2}HNO_3 + CuCO_3 \rightarrow Cu(NO_3)_2 + H_2O + CO_2$
7. $H_2SO_4 + \mathbf{2}KOH \rightarrow K_2SO_4 + \mathbf{2}H_2O$
8. $\mathbf{2}HCl + CaO \rightarrow CaCl_2 + H_2O$
9. $\mathbf{2}HNO_3 + MgCO_3 \rightarrow Mg(NO_3)_2 + H_2O + CO_2$
10. $\mathbf{6}HCl + \mathbf{2}Al \rightarrow \mathbf{2}AlCl_3 + \mathbf{3}H_2$

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Task E

1. $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$
   Splitting into ions gives: $2H^+ + SO_4^{2-} + 2Na^+ + 2OH^- \rightarrow 2Na^+ + SO_4^{2-} + 2H_2O$
   Removing spectators gives: $2H^+ + 2OH^- \rightarrow 2H_2O$
   Which simplifies to: $H^+ + OH^- \rightarrow H_2O$
2. a. $2H^+ + Mg \rightarrow Mg^{2+} + H_2$
   b. $H^+ + OH^- \rightarrow H_2O$
   c. $2H^+ + CaCO_3 \rightarrow Ca^{2+} + H_2O + CO_2$
3. $2H^+ + Mg \rightarrow Mg^{2+} + H_2$
   $2H^+ + 2e^- \rightarrow H_2$ reduction
   $Mg \rightarrow Mg^{2+} + 2e^-$ oxidation
   Both oxidation and reduction are occurring in the same equation, so it is a redox equ

Exam-style questions

1. a. $H_2SO_4\ _{(aq)} + Ca\ _{(s)} \rightarrow CaSO_4\ _{(aq)} + H_2\ _{(g)}$ (1 mark for reactants and products, 1 mark
   b. $2H^+ + Ca \rightarrow Ca^{2+} + H_2$ (1 mark for hydrogen species, 1 mark for calcium species)
   c. $Ca \rightarrow Ca^{2+} + 2e^-$ (1)
   Calcium has been oxidised (1) as it has lost electrons (1)
   d. Calcium has been oxidised and hydrogen has been reduced (1) so electrons hav
   sp[illegible])
2. a. Neutralisation (1)
   b. An indicator (1)
   c. $H^+ + OH^- \rightarrow H_2O$ (1)

Chapter 7

Task A

1. Activation energy is the **minimum energy requirement** for a reaction to occur
2. Exothermic, as energy is released to surroundings. This means the energy required t
   energy which was released when bonds were formed.
3. The reaction shown is endothermic, not exothermic. The student has also mislabelle
   go from reactants to the top of the curve, not from the products.

Task B

1. Balanced equation: $2H_2 + O_2 \rightarrow 2H_2O$
   Bonds broken = $[2 \times (2 \times 436)] + (1 \times 498) = 2242$ kJ mol^{-1}
   Bonds formed = $[2 \times (2 \times 464)] = 1856$ kJ mol^{-1}
   Energy transferred = +386 kJ mol^{-1}
2. Balanced equation: $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$
   Bonds broken = $2 \times [(3 \times 413) + (1 \times 464)] + (3 \times 498) = 4900$ kJ mol^{-1}
   Bonds formed = $[2 \times (2 \times 805)] + ([4 \times (2 \times 464)] = 6932$ kJ mol^{-1}
   Energy transferred = -2032 kJ mol^{-1}
3. Balanced equation: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
   Bonds broken = $(4 \times 413) + 243 = 1895$ kJ mol^{-1}
   Bonds formed = $(3 \times 413) + 242 + 432 = 1913$ kJ mol^{-1}
   Energy transferred = -18 kJ mol^{-1}
4. Bond-breaking = +928 kJ mol^{-1}
   Bond-forming = -928 kJ mol^{-1}
   The values are the same, but one is positive and one is negative

Task C

1. a. 32 − 21 = 11 °C
   b. Exothermic, as the temperature increased
   c. The student used a beaker in place of an insulated container, such as a polystyr
   a lid
2. a. Concentration of hydrochloric acid
   b. Any two from: the volume of hydrochloric acid, the mass of magnesium / surfa
   the magnesium strip, starting temperature
   c. The more concentrated the acid, the higher the temperature change

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Task D

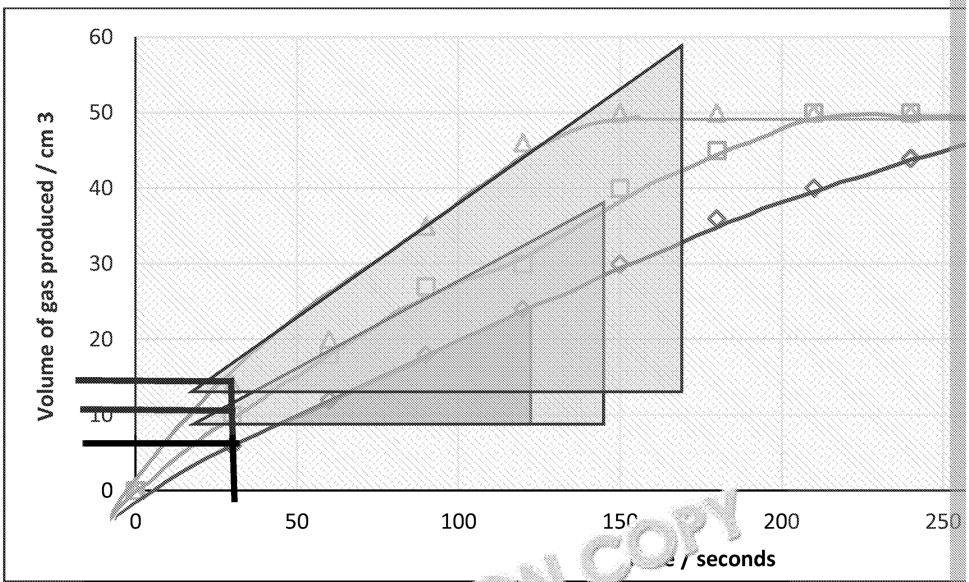
1. 8 × 1.5 = 12 V. Connect eight cells <u>in series</u>.
2. A reactant runs out and the reactions are irreversible
3. Zinc and copper as they have the biggest difference in reactivity
4. Concentration of electrolyte / temperature of electrolyte solution
5. The chemicals contained in the battery could be harmful/toxic/corrosive
6. Advantages – any one from: no toxic chemicals to dispose of at the end of the cell's li recharge rechargeable cells); travel further before refuelling (than before recharging efficiency (over time)
   Disadvantages – any one from: hydrogen is made from fossil fuels / non-renewable r store as it is flammable/explosive; it costs more to refuel (than recharging); costs mo hydrogen filling stations

Exam-style questions

1. a. Any two from: concentration of electrolyte solution; temperature of electrolyte solution; the compounds/ions in the electrolyte solution
   b. Order: (most) magnesium, cobalt, nickel, tin, copper, silver (least) (2 – 1 mark fo silver, 1 mark for correct order cobalt to copper)
   The higher the voltage, the more reactive the metal (1)
   Silver has a negative voltage because it is less reactive than copper (1)
   c. $2H_2$ + O_2 (1) → $2H_2O$ (1) balanced
   d. The reaction is reversible (1)
   e. Bonds broken = 2 × [(3 × 413) + 358 + 464] + [3 × 498] = 5616 (1)
   Bond formed = 2 × [2 × 805] + 4 × [2 × 464] = 6932 (1)
   Energy transferred = 5616 – 6932 = -1316 kJ/mol (1)

Chapter 8

Task A



1. The time the reaction is finished is the point where the line of best fit becomes flatte
   At 20 °C, this is at approximately 290 seconds
   For 30 °C this is at approximately 210 seconds
   At 50 °C it is at approximately 150 seconds
2. Relative rate = 1 / time taken to finish
   At 20 °C = 3.45×10^{-3} s^{-1} At 30 °C = 4.76×10^{-3} s^{-1} At 50 °C =
3. At 20 °C = (25 – 10) / (125 – 50) = 0.20 cm^3 / s
   At 30 °C = (40 – 10) / 150 – 25) = 0.24 cm^3 / s
   At 50 °C = (55 – 15) / (175 – 25) = 0.27 cm^3 / s
4. At 20 °C = 6 / 30 = 0.20 cm^3 / s   At 30 °C = 10 / 30 = 0.33 cm^3 / s   At 50 °C =
5. At 50 °C, the particles move with more energy. This leads to more frequent successf which exceed the activation energy, increasing the rate of the reaction.

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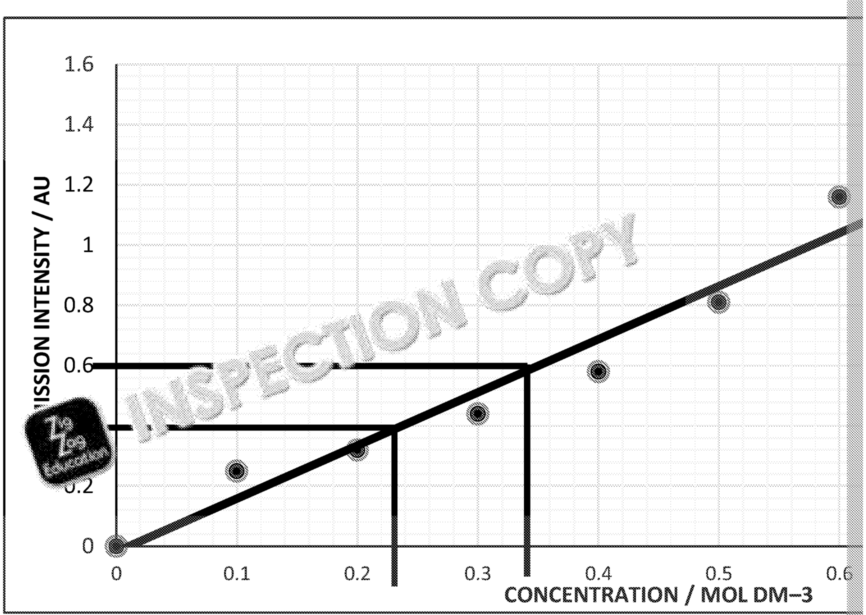
Task B

1. a. Multivitamins B and C contain Cu^{2+} ions
   b. B and C contain Cu^{2+} ions, A does not
   A, B and C contain some common ingredients
   C is likely to contain multivitamin B plus some further ingredients
2. a.



   b. Multivitamin B has a copper ion concentration of approximately 0.36 mol dm^{-3}, ion concentration of approximately 0.24 mol dm^{-3}. Multivitamin B has the high

Chapter 9

Task A

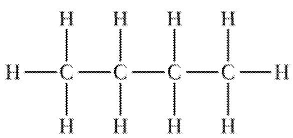
Properties of diamond	Properties of graphite
• 4 covalent bonds between atoms • Large network of atoms • Very strong covalent bonds • High melting point • Electrical insulator • Very hard substance	• 3 covalent bonds between atoms • Large network of atoms • Very strong covalent bonds • Weak forces between layers • High melting point • Electrical conductor • Soft and slippery substance

Task B

1. Dot-and-cross diagram is most appropriate as it is the only representation which sho
2. Ball-and-stick diagrams are the only representation which shows the 3D structure of
3. Displayed formulae are easy to draw, and so would be the best option to compare th representations are also useful here, they are **not** easy to draw!
4. Names or chemical formulae are most useful for quick labelling of hydrocarbon samp
5. The easiest option here would be the chemical formulae! If Maymuna wanted to exp she could also draw the displayed formulae.

Task C

1. C_nH_{2n+2}
2. Propane
3.



4. As the length of the carbon chain increases, boiling point increases. This is because longer forces, which require more energy to overcome. Therefore, a higher temperature is requi
5. $C_7H_{16} + 11\ O_2 \rightarrow 7CO_2 + 8\ H_2O$
6. The alkane is heated to 550 °C and passed over a hot zeolite catalyst
   $C_{20}H_{42} \rightarrow C_6H_{12} + C_{14}H_{30}$

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Task D

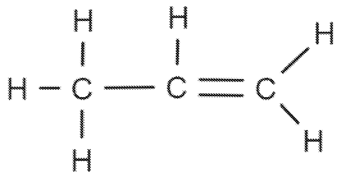
1. a. $C_{11}H_{24}$ is different because it does not contain a carbon–carbon double bond
   b. $C_2H_4 + H_2O \rightarrow C_2H_5OH$ (see structure on right)
   c. Add bromine water. If C=C is present, the bromine water will be decolourised.
2. C_8H_{16}
3. a. $C_4H_8Cl_2$
   b. C_3H_8
   c. C_3H_7OH

Task E

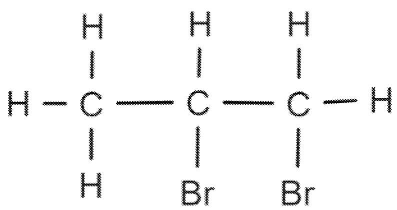
1. Butanol is used as a solvent and fuel
2. $C_3H_5OH + 4.5\ O_2 \rightarrow 3\ CO_2 + 3\ H_2O$
3. Butanoic acid
4. Fizzing would be seen
5. Ethanol + ethanoic acid → ethyl ethanoate + water

Exam-style questions

1. a. A compound which only (1) contains carbon and hydrogen (1)
   b. Alkanes contain only carbon–carbon single bonds (1)
      Alkenes contain a carbon–carbon double bond (1)
      Alkenes decolourise bromine water whereas alkanes do not (1)
   c. Saturated alkanes contain only carbon–carbon single bonds / the maximum am
      Alkenes are unsaturated (1)
      Because they contain a carbon–carbon double bond (1)
2. a. Propene: note the double bond can be on the left or the right. Bond angle does
      3 carbons and 6 hydrogens (1)
      Double bond represented correctly (1)



   b. 3 carbons and 6 hydrogens (1)
      2 bromine atoms on **different carbons** (1)



   c. 300 °C (1)
      60 atm pressure (1)
      Phosphoric acid catalyst (1)
      $C_3H_6 + H_2O \rightarrow C_3H_7OH$ (1)
3. a. Each carbon atom makes four (1) covalent bonds (1) to other carbon atoms. This
   b. Graphite has weak intermolecular forces between layers (1) which means layers
      diamond, the structure is held together by rigid, strong covalent bonds (1).
   c. The structure is held together by many / a giant network (1) of strong covalent
      a lot of energy to overcome (1) to melt the substance.

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Chapter 10

Task A

1. Stationary phase: chromatography paper; mobile phase: solvent (water, in this case)
2. C is the most soluble, as it has travelled the greatest distance up the chromatograph
   greatest solubility, and the lowest attraction for the chromatography paper.
3. The unknown is a mixture, as it is made up of two constituent parts
4.

Substance	Distance travelled / cm	
A	2.0	
B	3.5	
C	5.5	
U: Spot 1 Spot 2	[illegible] [illegible]	

5. The student can conclude that the [illegible] mixture of A and B, as the R_f values

Task B

1. Hydrog[illegible] P[illegible] splint into a sample of the gas. A squeaky pop sound woul
2. First, pl[illegible]**owing** splint into the neck of both tubes. The tube which relights the
   hydroge[illegible] in the other tube, place a lit splint.
3. Carbon dioxide gas would extinguish the splint – it is a common chemical in fire exti
4. $MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + CO_2 + H_2O$
   Bubble the gas produced through limewater. The limewater should turn cloudy.

Task C

1. a. Place a sample of copper(II) ions into a blue Bunsen flame. The flame colour sh
   copper(II) ions.
   b. Add sodium hydroxide solution to the solution containing copper(II) ions. A blu
   c. $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(OH)_{2\,(s)}$
2. One colour could 'mask' the colour of another, e.g. Na^+ ions produce a bright yellow
   paler colours, such as lilac K^+ ions
3. Add sodium hydroxide. Both would form white precipitates. When excess NaOH is
   precipitate would redissolve, the calcium hydroxide would not.

Task D

1. a. White precipitate
   b. Fizzing/effervescence seen
   c. Pale yellow precipitate forms
2. Formation of the white precipitate (1a):
   $Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$
   Formation of pale yellow precipitate (1c):
   $Ag^+_{(aq)} + I^-_{(aq)} \rightarrow AgI_{(s)}$

Exam-style questions

1. a. Calcium ions produce an orange [illegible] and a white precipitate (1); the oran
   lithium ions, which wo[illegible] precipitate (1)
   b. Acid removes a[illegible] contaminants which would precipitate (1)
   M[illegible] as other acids would form precipitates and give false positiv
   c. Ag[illegible] $Cl^-_{(aq)} \rightarrow AgCl_{(s)}$ (1 mark for correct species, 1 mark for state symbols)
2. a. Hy[illegible]oric acid would form a precipitate / silver chloride precipitate would fo
   $HCl_{(aq)} + AgNO_{3\,(aq)} \rightarrow AgCl_{(s)} + HNO_{3\,(aq)}$ (1)
   b. $Ba^{2-}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$ (1 mark for species, 1 mark for state symbols)
   c. White precipitate (1)
3. a. Crimson/red flame (1)
   b. Silver nitrate (1), white precipitate (1)
4. a. Ca^{2+} and Cl^-
   b. Add sodium hydroxide solution (1)
   $Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2\,(s)}$ (1 mark for species and state symbols, 1 mark f

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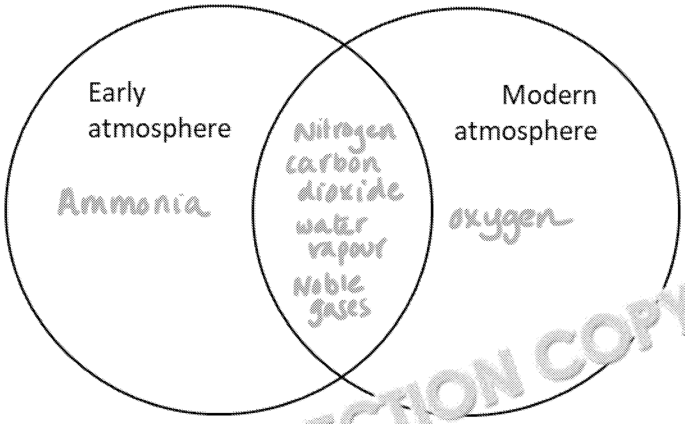
Chapter 11

Task A

1.



2. a. Nitrogen or oxygen
   b. Nitro[illegible] or [illegible]
   c. Th[illegible] ot [illegible]ough oxygen to support life
   d. Th[illegible] would boil/evaporate OR the temperature is above 100 °C / boiling p

Task B

Event	Effect on N_2	Effect on CO_2
During Earth's first billion years, there was **intense volcanic activity**, releasing CO_2, CH_4, NH_3* and H_2O. * Which later formed nitrogen through chemical processes	↑	↑
As Earth cooled, water vapour **condensed** to form oceans. Carbon dioxide dissolved in the water, and carbonates precipitated to produce sediments. Sedimentary rock formed.	N/A	↓
Around 2.7 billion years ago, plants and algae formed, undergoing photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	N/A	↓
When plants and animals died and decayed, **fossil fuels** such as coal (from land biomass) and crude oil (from marine biomass) formed.	N/A	N/A (but carbon becomes 'locked up'

Task C

1. a. Bar drawn at approximately 12 %
   b. i. Carbon dioxide = (15 / 16) × 100 = 94 %
      Argon = (0.5 / 16)*100 = 3 %
      Water vapour = 3 %
      ii. Both atmospheres contain carbon dio[illegible]de [illegible]er vapour and noble gases. much less carbon dioxide [illegible] X. Earth's atmosphere had much m
      Planet X.
2. a. Percentage of ni[illegible] [illegible] / 50)*100 = 78 %
   b. 0.[illegible] × [illegible] .05 × 10^{18} kg
   c. i. [illegible]osynthesis caused oxygen to increase and carbon dioxide to decrease
      ii. [illegible]$O_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
      iii. Photosynthesis allowed oxygen to be produced, which is vital for complex fossilised plant remains, scientists can pinpoint when life was able to evol
   d. i. Water vapour from volcanic eruptions
      ii. The proportion decreased, as Earth cooled and water vapour condensed t
      iii. Carbon dioxide dissolved into oceans which caused its proportion in the a

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Task D

1. China, approximately 11,000 million tons
2. a. The USA has estimated CO_2 emissions of approximately 5000 million tons, wher million tons
   b. The USA emits almost double that of India. It has a population around a quarte economy, which means more green technology is available when compared to I USA contributes a large share of CO_2 emissions.
3. Generally, the larger the population, the greater the CO_2 emissions. China and India are both within the top three CO_2 emitters.
4. This question relates to the USA, Russia, Germany and South Korea.
   a. 10 + 5 + 2 + 1 = 18 % share of the world's population
   b. 18 % share of the population, and approximately 8400 million tons of CO_2 emiss double the emissions of India, which has more than double the population size!
5. Approximately 2.24×10^{10} tons
6. Countries could invest in more renewable energy sources such as wind, solar and tid hybrid vehicle technology to reduce reliance on fossil fuels. They could introduce in of single-use plastic products and encourage consumers to buy locally produced pro

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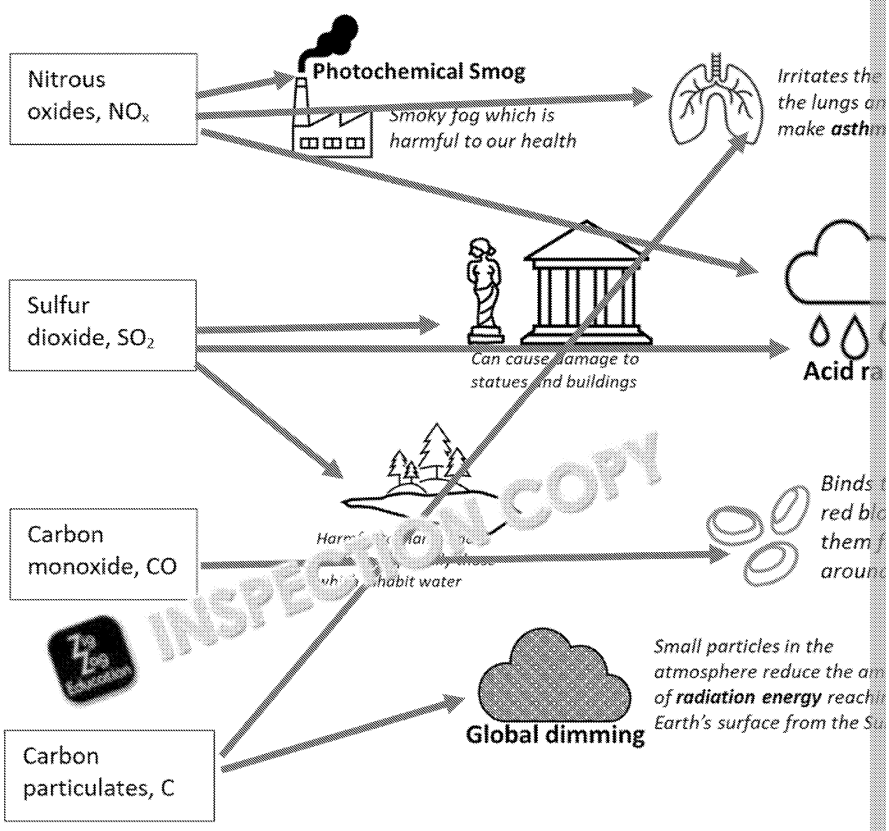
Task E

1. Carbon footprint is the total amount of carbon dioxide and other greenhouse gases e product, a service or an event. The student could ensure they recycle where possible sustainable diet (sourcing local food, eating less meat/rice). They could walk to scho
2. Carbon-neutral means no net effect on carbon dioxide (or equivalent greenhouse gas invest in cleaner energy technologies such as solar panels at factories. They could so UK instead of abroad, and make use of hybrid vehicles to transport product. They co fabrics, such as cotton, rather than polymers. They might consider promoting recycli costly to maintain, and the technology and infrastructure may not be available for th

Task F

1.



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2. Nitrous oxides – nitrogen from the air reacts with oxygen in the heat of a combustio
   Sulfur dioxide – sulfur impurities from fuel react with oxygen
   Carbon monoxide – incomplete combustion of a fuel, in a limited oxygen supply
   Carbon particulates – incomplete combustion of a fuel, in a limited oxygen supply

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3. $C_8H_{18} + 8.5O_2 \rightarrow 8CO + 9H_2O$ – binds to haemoglobin in red blood cells, causing carb
OR $C_8H_{18} + 4.5O_2 \rightarrow 8C + 9H_2O$ – particulates cause global dimming, can cause lung d

4. a. Sulfur comes from impurities in fossil fuels
   b. Sulfur dioxide oxidises in the air to form SO_3. This dissolves in rainwater in clou causes damage to buildings, and is harmful to living organisms and the environ
   c. Acid rain can be caused by nitrous oxides. Nitrogen from the air reacts with ox engine. This dissolves in rainwater in clouds to form acid rain.

Exam-style questions

1. a. Little/no oxygen [1]; therefore photosynthesis has not occurred / no plants/alg oxygen-using organisms cannot have evolved on b-165 [1]
   b. Methane allows short wavelength / UV radiation to pass through [1] which wa wavelength / infrared radiation [1] which is absorbe[illegible] methane in the atmos
2. a. Increased population has higher energy req[illegible] [1] so more fossil fuels b emissions [1]
   b. Increased population has [illegible] requirements [1] so more use of methan as cattle [1] and ri[illegible] [1] and more waste going to landfill [1]
   c. Any [illegible] fr[illegible] g ice, rising sea levels, flooding, extreme weather events,
   d. A[illegible] d[illegible]cult to model; may be other reasons for the changes in the avera th[illegible] ycles of temperature change in the past [1]
3. a. Soot / carbon particulates, (solid) carbon (1). Incomplete combustion [1] due t
   b. Sulfur reacts with oxygen to form sulfur dioxide [1] which produces acid rain [1 statues [1]. Less sulfur means fewer sulfur dioxide emissions [1].
   c. In the high temperatures of combustion engines [1] nitrogen from the air react Nitrous oxides can cause photochemical smog / can contribute to the formatio

Chapter 12

Task A

1. a. The water is likely to be salt water from the sea.
   b. The water is likely to have a high concentration of dissolved substances.
2. Screening involves passing water through filter-like screens to remove large insolubl solids such as leaves and twigs.
3. Water is sterilised using chlorine, ozone, or UV light. This kills bacteria.
4. No, the student is not correct. Pure water contains only H_2O molecules. Potable wa consumption, but may still contain small concentrations of dissolved substances suc beneficial for our health.
5. Waste water comes from domestic, agricultural and industrial uses. It may contain c and drugs, dissolved substances and other contaminants.

Task B

1. Hot countries tend to use distillation to produce drinking water, as they have low su high supplies of groundwater, and treating groundwater uses much less energy than
2. Water is heated in a round-bottomed flask over a Bunsen burner. The water **evapor** than salt. The steam passes into a condenser, which is [illegible]. As the vapour cools, drips out into a receiver, where it is collected as [illegible].
3. Distillation involves evaporation and co[illegible]ion, and a high amount of energy is r osmosis uses a **high pressure** ar[illegible] [illegible]meable membrane, whereby water mo a concentrated salt so[illegible] [illegible] pressures require a large energy expenditure.
4. Cobalt ch[illegible]e [illegible] tests for the presence of water, not whether the water is Althou[illegible]g the pH of the water can tell us if the water is acidic, alkaline or neu contain[illegible]r amounts of dissolved solids, or if it contains bacteria, so Student B i analysis testing only tests for the presence of salt, and doesn't tell us how much is p whether bacteria is present, and how much.

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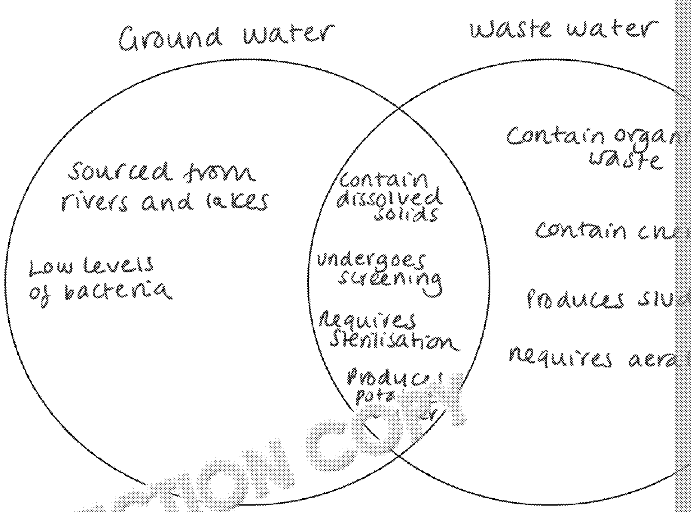
Task C



Exam-style questions

1. a. Potable water is water that is safe for human consumption [1]
   b. Desalination removes **salt** [1]. This process involves large amounts of energy to
   expensive. [1]
   c. i. Missing entry should read '0' as this is pure water, with a pH of exactly 7.0
      ii. Sample A is likely to be tap water [1] as the pH is almost neutral, and the am
      iii. Sample B is seawater, sample C is pure (distilled) water
2. a. Screening removes large objects such as nappies, wet wipes and menstrual pro
   b. Aeration involves bubbling air through the water [1]; this allows bacteria to dig
   c. Any **two** from: chlorine, ozone, UV light [2]
   d. Pure water is 100 % water molecules with nothing else added [1]
   e. Determine the boiling point [1] as pure water boils at exactly 100 °C [1]

Chapter 13

Task A

1.

Formula of ionic compound	Product at positive electrode	Product at negative electrode	Oxidation equati
NaBr	Br_2 – bromine	Na – sodium	$2Br^-_{(l)} \rightarrow Br_2$
Fe_2O_3	O_2 – oxygen	Fe – iron	$2O^{2-}_{(l)} \rightarrow O_2$
Na_2O	O_2 – oxygen	Na – sodium	$2O^{2-}_{(l)} \rightarrow O_2$
$AlCl_3$	Cl_2 - chlorine	Al – aluminium	$2Cl^-_{(l)} \rightarrow Cl_2$
$ZnBr_2$	Br_2 – bromine	Zn – zinc	$2Br^-_{(l)} \rightarrow Br_2$

2. a. In solid state, ions are not free to move to the electrodes and cannot carry charge
   b. Chlorine, Cl_2, is formed. Fizzing will be seen
   c. $2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$ oxidation as electrons are **lost**

Note the
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you woul
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Task B

1. $Li^+ + e^-$
2. Using a lowers the melting point of the electrolyte, reducing energy costs
3. Lithium ions move towards the negative electrode (cathode) as they are **oppositely** c
   electrode
4. High energy cost due to high melting point of the mixture, and high energy cost with
5. A shortage of lithium ores would make the use of lithium unsustainable. Using recyc
   meet the demand for lithium.
6. Mr ($LiCoO_2$) = 7 + 59 + (2 × 16) = 98 Ar (Li) = 7
   So % by mass = (7 / 98) × 100 = 7 %
7. Lithium is a group 1 metal; 1 electron in its outer shell. This electron is easy to lose d
   also reactive in contact with water, causing an exothermic reaction.

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Task C

1.

Substance	Product at +ve electrode (anode)	Product at -ve electrode (cathode)	Oxidation (loss electrons)
$CaBr_{2\,(l)}$	Bromine, Br_2	Hydrogen, H_2	$2Br^- \rightarrow Br_2 + 2$
$CuCl_{2\,(aq)}$	Chlorine, Cl_2	Copper, Cu	$2Cl^- \rightarrow Cl_2 + 2$
$FeCl_{3\,(l)}$	Chlorine, Cl_2	Iron, Fe	$2Cl^- \rightarrow Cl_2 + 2$
$NaOH_{(aq)}$	Oxygen, O_2	Hydrogen, H_2	$4OH^- \rightarrow O_2 + 2H_2O$
$H_2SO_{4\,(aq)}$	Oxygen, O_2	Hydrogen, H_2	$4OH^- \rightarrow O_2 + 2H_2O$
$PtI_{2\,(l)}$	Iodine, I_2	Platinum, Pt	$2I^- \rightarrow I_2 + 2e$
$Ca(NO_3)_{2\,(aq)}$	Oxygen, O_2	Hydrogen, H_2	$4OH^- \rightarrow O_2 + 2H_2O$
$KNO_{3\,(aq)}$	Oxygen, O_2	Hydrogen, H_2	$4OH^- \rightarrow O_2 + 2H_2O$

2. a. At the positive electrode, fizzing would be seen. At the negative electrode, fizzi
   b. To identify the positive electrode, collect the gas and place a piece of **damp litm**
      The paper will be bleached, confirming the identity of **chlorine gas**. To ide
      electrode, collect the gas and hold a **lit splint** to the neck of the tube. A squeak
      hydrogen is produced.
   c. $2H^+ + 2e^- \rightarrow H_2$

Exam-style questions

1. a. So that ions can move (1) to the electrodes / to carry charge (1)
   b. Calcium ions are attracted to the electrode (1) where they gain (1) two electro
   c. Chlorine (1) **NOT CHLORIDE**
   d. $2H^+ + 2e^- \rightarrow H_2$ (1) *Ignore state symbols*
   e. No (1); calcium is produced in Experiment 1 (1), hydrogen is produced in Experi
      Because in solutions, H^+ (from water) are present (1)
      Calcium is more reactive than hydrogen, so hydrogen ions gain an electron (1)
2. a. Aluminium is more reactive than carbon / carbon is less reactive than aluminiu
   b. Aluminium ions are positive (1) and are attracted to the negative electrode (1)
      Where they gain electrons / are reduced (1)
      $Al^{3+} + 3e^- \rightarrow Al$ (1)
   c. Because they are made of graphite/carbon (1)
      Oxygen is produced (1)
      Which reacts with the electrodes (1)

Chapter 14

Task A

1. Proton, electron, neutron
2. Dalton proposed all atoms are indivisible, solid spheres (1). Dalton stated all atoms o to one another, and different from that of another element (1). In the modern mode **particles** called protons, neutrons and electrons (1).
3. Alpha particles were fired at thin gold foil (1). Most alpha particles passed straight th deflected (unexpected) (1). This suggested atoms have a small, dense, positively cha surround the nucleus in shells rather than being randomly studded within the atom (
4. Bohr proposed electrons orbit the nucleus in fixed shells (1). These shells are differe compared with the nuclear model, where all shells are at the same distance (1).
5. In the plum pudding model, the atom is a sphere of positive charge, whereas the nuc concentrated in the nucleus (1). In the plum pudding model, electrons are embedde model has electron shells (1). The nuclear model has a nucleus, the plum pudding m model has neutrons (1).
6. Early atomic models like Dalton's were based on **theory** (1). J J Thomson, Rutherford **experiments** (1). J J Thomson discovered the electron (1). Rutherford's gold scatteri existence of a nucleus containing protons, and electrons orbiting in shells (1). Bohr's give distinct electron orbits at fixed distances (1). Advances in mathematics allowed Schrodinger's quantum model (1).

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Task B

1. Mendeleev arranged elements in order of increasing atomic weight (1). He placed el in the same group/column (1) but left gaps and swapped elements where he felt the
2. Mendeleev left gaps in his periodic table (1) and reversed the 'accepted' order of ele atomic weights (1).
3. Both periodic tables were ordered based on atomic weights (1). Both attempted to a similar properties (1). Newland did not leave gaps in his periodic table (1) and did no which meant they did not 'fit' in groups based on their properties (whereas Mendele
4. Mendeleev's periodic table was ordered mostly by atomic weight whereas the mode atomic number (1). Mendeleev's table had gaps whereas the modern-day table is co Mendeleev's table did not have regions for transition metals whereas the modern ta has noble gases whereas previously they had not yet been discovered (1).
5. Mendeleev's table was based on predictions of elements and their properties (1). Th such as the noble gases completed the periodic table (1) discoveries of elements wl filled the gaps he left (1). The discovery of protons and neutrons (and isotopes) expl periodic table (1). Synthetic elements have been created and filled gaps in the perio understanding of electron structure of elements have enabled transition metals to b 'd-block' elements (1).

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Task C

1. Data can be uncertain due to measurement limitations (1) and data can be incomple obtain precise measurements is not available (1). Some concepts are too complex to methods, e.g. global warming (1) which has multiple variables leading to uncertainty medical research, where long-term data of effects of a new drug may not yet be avai
2. Environmental impacts of plastics, such as biodegradability and pollution (1). Safety ecosystems (1). Potential benefits could be reduction in plastic waste and dependen harm could include the production of harmful by-products and the impact on existin sustainability of the product and the life cycle of the alternative needs to be evaluate between immediate gains and long-term consequences (1).
3. Benefits: nanoparticles improve the effectiveness of products (e.g. enhancing drug d (1), can provide unique properties such as increased strength / lightweight / improve surface area to volume ratio (1), only small amounts are needed compared to macro Cons: concerns over the potential health risks of nanoparticles, as their small size car and alter DNA (1), environmental impact is not fully understood, so they could dama arise due to the limited data on the long-term use of nanoparticles (1).
4. Raw materials: paper straws produced from timber (a renewable resource) whereas products of crude oil (non-renewable) (1), transportation and processing of timber is processing plastics, which are lightweight (1), lifetime of paper straws tends to be sin plastic straws could be used more than once (1), paper straws are biodegradable wh sent to landfill (1). Benefit of LCAs is that they evaluate environmental impact to allo decisions (1). However, LCAs can be incomplete, simplified, or misused to mislead co
5. Reducing carbon footprints is crucial to mitigate climate change and its impacts (1). responsibility to minimise their environmental impact for future generations (1). An carbon footprint by using public transport, reducing their energy consumption, utilis such as solar panels and hybrid vehicles, and adopting more sustainable practices su of food waste, etc. (1). Industries could implement energy efficient technologies suc resources, and improve the sustainability of their supply chains (1).
6. It can be challenging for individuals to change daily habits and routines such as reduc viable alternative (1). There are economic barriers such as affordability of organic fo There may be a lack of availability of facilities for recycling, which can impede individ calculations can sometimes be based on incomplete or inaccurate data (1). Some co 'greenwashing' to make products seem more sustainable than they are, by focusing o as raw materials (1).

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Exam-style questions

1. a. Solid sphere (1) which is indivisible (1). Each element has its own type of atoms
   b. Sphere of positive charge (1) with negative electrons embedded within it (1)
   c. Some alpha particles were unexpectedly deflected (1). This led to the finding th positive-charged nucleus (1) with electrons orbiting in shells (1).
   d. Both models have electrons orbiting the nucleus in shells (1). Both models have Planetary model has electron shells at fixed distances from the nucleus (1) whe shells at the same distance from the nucleus (1).
2. a. Elements are arranged in increasing atomic (proton) number (1). Elements are properties (1). There are eight groups, and transition metals (1).
   b. Elements arranged in trios or 'triads' of similar properties (1). This didn't work
   c. Mendeleev made predictions of chemical and physical properties of elements w discovered (1). Mendeleev arranged elements in groups according to their pro did not belong in particular groups (e.g. Te and I) (1
   d. Mendeleev ordered by atomic weight, whereas the modern periodic table is o had not yet been discovered (1). Mendeleev left gaps for elements which had n noble gases had not been discovered (1). Transition metals were not fully unde electron arrangements) (1).
3. a. It happened billions of years ago before life existed (1)
   b. A number of variables involved (1) and evidence is limited (1)
   c. LCAs assess environmental impacts of products from production to eventual dis evaluates contributions to greenhouse gas emissions at each stage of the LCA (1 due to lack of evidence/technology (1) as well as misleading data used (1).

Challenge 1.1

Name of substance in balloon	Chemical formula of substance in balloon	M_r of substance in balloon	Number of moles of gas in balloon / mol	Mass of balloon / g
Nitrogen	N_2	28.0	0.625	17.5
Oxygen	O_2	32.0	0.625	20.0
Water	H_2O	18.0	0.625	11.3
Carbon dioxide	CO_2	44.0	0.625	27.5
Hydrogen	H_2	2.0	0.625	1.25

Challenge 1.2

Name of substance	Pressure / Pa	Volume of balloon / m^3	Temperature / K	Moles in balloon / mol	Mass balloo
Nitrogen	101 000	0.015	298	0.618	17.3
Oxygen	101 000	0.015	298	0.618	19.8
Water	101 000	0.015	298	0.618	11.1
Carbon dioxide	101 000	0.015	298	0.618	27.2
Hydrogen	101 000	0.015	298	0.618	1.24

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Appendix: Graph Pa

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