Zig Zag Education

Chemistry

GCSE (9–1) | AQA | 8462

Differentiated Homework Pack

for GCSE (9–1) AQA Chemistry Topics 6–10

zigzageducation.co.uk

POD 11629

Contents

Teacher's Introduction

These homework tasks are designed to be used with topics 6–10 of the AQA GCSE Chemistry course.

Remember!

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

Every major topic in the course is covered, allowing regular homework to be set approximately every two weeks of teaching. The tasks are designed to be handed out to students, and they contain all the instructions the students will need to complete the tasks. It is expected that students will be applying knowledge of content learned in lesson time, and so no new content is covered in the homeworks.

Twenty topics are covered, with each homework directly linked to the AQA specification. Each homework is created to check and reinforce learning, through interesting and challenging tasks which are original and focused.

Exam skills are explicitly tested at the end of every homework in brief exam-style questions. These are original exam-style questions, based on the exam questions from the sample assessment materials.

Differentiation

For each homework, two versions are provided.

- In the version with a  symbol, some tasks will have more scaffolding, more examples or more support as appropriate. The hardest aspects of the exam-style questions may also be broken down more.
- The version with a  symbol is designed for students who will need less support and are more confident with a topic. It is expected that individual students might get different versions for different topics.

Tiering

Some areas of the course contain Higher tier content only. In these instances, we have still provided two versions of the homework as some Higher tier students may still benefit from additional support. Conversely some Foundation tier students might need more support than others.

Answers

An answer sheet is provided for marking by either teachers or students. Marks are not given on the worksheets (except for exam-style questions), but are included on the answer sheet, to allow for the possibility of tracking progress across the year.

We hope that these homeworks will be useful for your teaching, and that they provide a valuable way to easily differentiate so that each student can make the best possible progress inside and outside the classroom.

May 2022

Specification map

Topic	AQ
1. Calculating rate of reaction	
2. Factors affecting rate of reaction	
3. Catalyst and collision theory	
4. Reversible reaction and energy changes	
5. Equilibrium (effect of temperature, pressure and concentration on equilibrium (HT))	
6. Crude oil, hydrocarbons and alkanes	
7. Fractional distillation and petrochemicals	
8. Properties of hydrocarbons	
9. Cracking and alkenes	
10. Pure substances	
11. Formulations	
12. Chromatography	
13. Test for gases	
14. The proportions of different gases in the atmosphere	
15. Earth's early atmosphere	
16. Oxygen – carbon dioxide	
17. Greenhouse gases	
18. Global climate change	
19. Using Earth's resources	
20. Potable water	

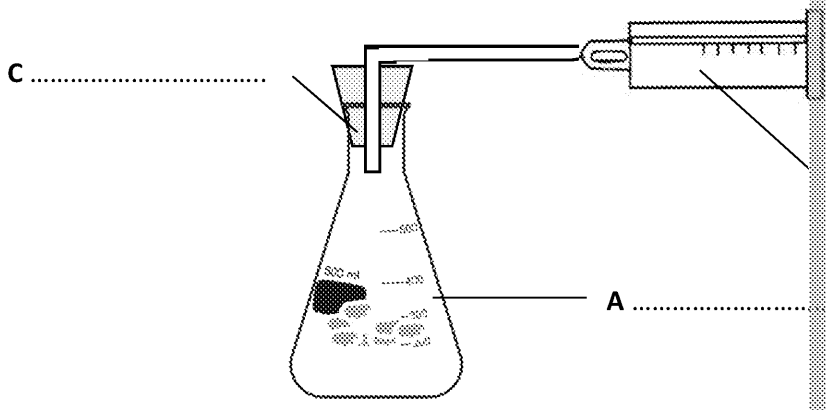
Calculating rate of react

Specification reference 4.6.1.1

Activity 1: Label the diagram

Label the equipment used to measure the amount of carbon dioxide produced wh
hydrochloric acid.

Bung	Conical flask	Syrin



Activity 2: Matchmaking

mean rate of reaction = quantity of reactant formed (mass in g or v
time taken (in seconds)

mean rate of reaction = quantity of product formed (mass in g or v
time taken (in seconds)

Using the above equations, match each question with the correct answer. There is

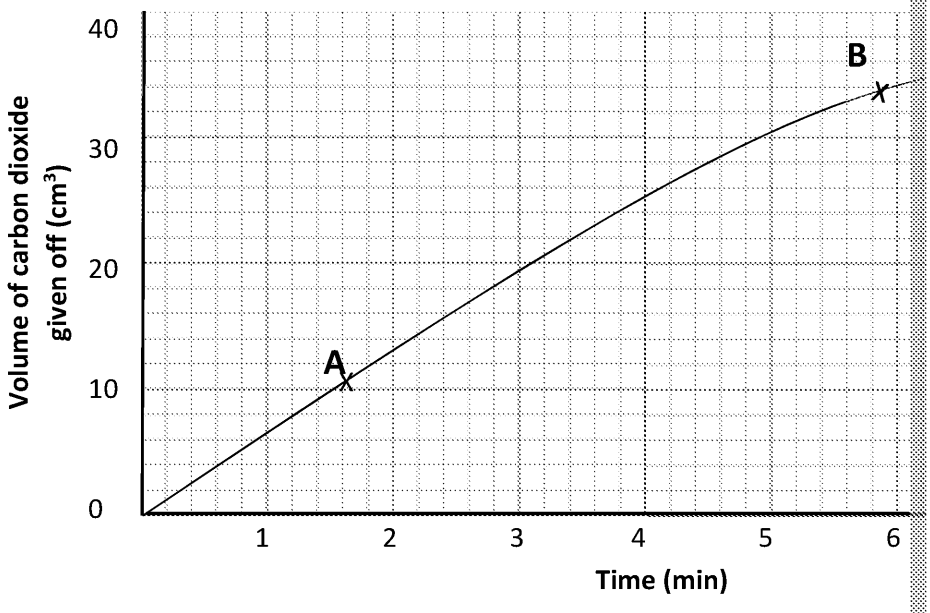
A.	Find the mean rate of reaction when 12 cm^3 of hydrogen is produced in three seconds.
B.	During a combustion reaction, carbon dioxide gas is produced. Calculate the mean rate of reaction if 30 cm^3 of carbon dioxide is produced in 10 seconds.
C.	In the first 60 seconds of the reaction, 60 cm^3 of water breaks down to produce hydrogen and oxygen. What is the mean rate of reaction for this equation?
D.	Marble chips were dropped into a flask containing hydrochloric acid. After 20 seconds, the mass changed from 42 grams to 37 grams. Calculate the mean rate of reaction in g/s.

Activity 3: Graph it!

Key information: The graph of the amount of product formed or the amo
reaction against time can be used to calculate the rate of reaction.

The steeper the line, the faster the rate of reaction. The point at which t
reaction has finished.

Use the graph to calculate the mean rate of reaction.



A. The total volume of carbon dioxide given off is .....

B. The mean rate of reaction in the first 5 minutes is .....

C. The mean rate of reaction between 4 and 8 minutes is .....

D. Add these labels to the graph at points A, B and C:

The reaction is s

The reaction is co

The reaction is f

Activity 4: Exam-style question

A. Carbon dioxide is released when calcium carbonate reacts with hydrochloric a

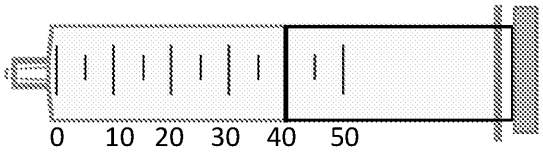
The equation represents the reaction. Balance the equation.

$$CaCO_3 + HCl \longrightarrow CaCl_2 + CO_2 + H_2O$$

.....

B. The syringe shows the amount of carbon dioxide collected in the reaction.

What is the volume of gas collected in the syringe?



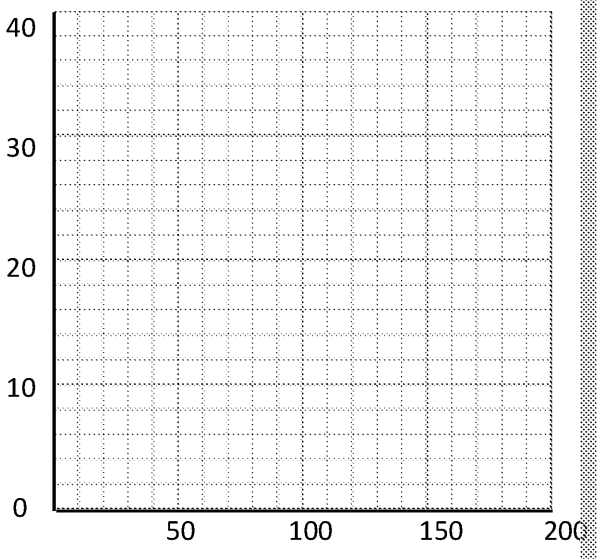
.....

C. The results of the experiment are given in the table below.

Time (s)	Volume of gas collected Mean result (cm^3)
0	0
50	18
100	32
150	38
200	40

i) Label the axes on the graph below.

ii) Plot the data from the table onto the graph.



Calculating rate of react

Specification reference 4.6.1.1

Activity 1: Label the diagram

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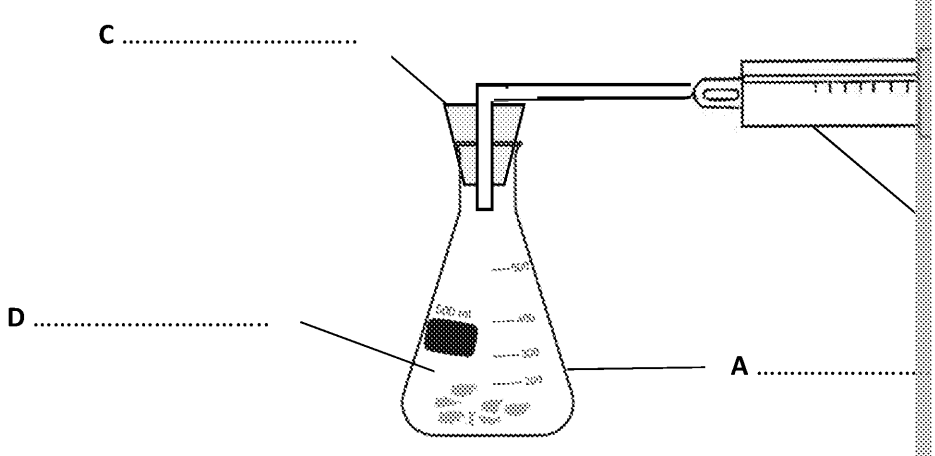
hydrochloric acid.



Activity 2: Calculate me if you can

Calculate the mean rate of reaction using the given formulae.

mean rate of reaction = quantity of reactant formed (mass in g or vo / time taken (in seconds)

mean rate of reaction = quantity of product formed (mass in g or vol / time taken (in seconds)

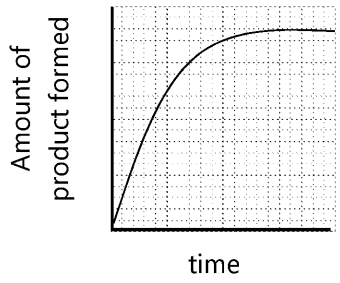
A. Calculate the mean rate of reaction when 12 cm^3 of hydrogen is produced in three seconds.	B. During a combu gas is produced reaction if 90 cr in the first two minutes.
C. In one minute, 60 cm^3 of water breaks down to produce hydrogen and oxygen. Calculate the mean rate of reaction for this equation.	D. Marble chips we containing hydr the mass chang Calculate the m
E. Calculate the volume of 2 mol of hydrogen at STP in cm^3.	F. The volume of o Calculate the nu

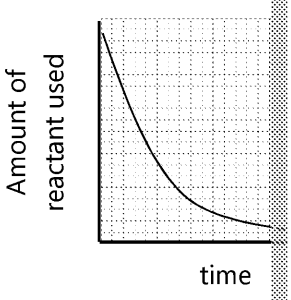
Rate of reaction can be calculated in mol/s **(HT only)**
At standard temperature and pressure (STP) one mole of any gas occ
Volume of gas = number of moles × 24 dm^3, 1 dm^3 = 1000 cm^3

Activity 3: Graph it!

Key information: The graph of the amount of product formed or the amo
reaction against time can be used to calculate the rate of reaction.

The steeper the line, the faster the rate of reaction. The point at which t
reaction has finished.





Use the graph to calculate the mean rate of reaction.

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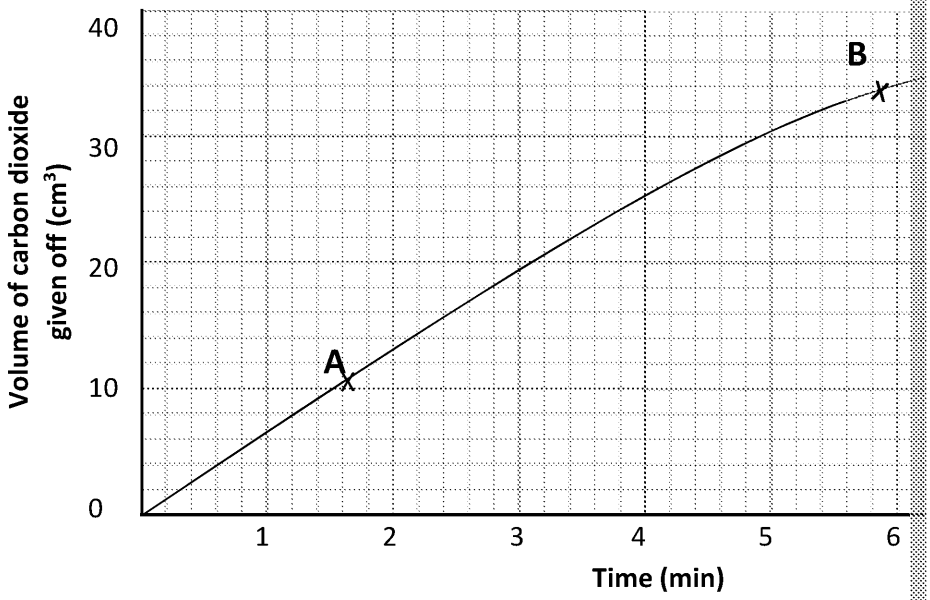


A. The total volume of carbon dioxide given off is .....

B. The mean rate of reaction in the first 5 minutes is .....

C. The mean rate of reaction between 4 and 8 minutes is .....

D. The rate of reaction is fastest at point ..... because .....

.....

E. The independent variable in this experiment is .....

F. The dependent variable in this experiment is .....

Activity 4: Exam-style question

A. Carbon dioxide is released when calcium carbonate reacts with hydrochloric a

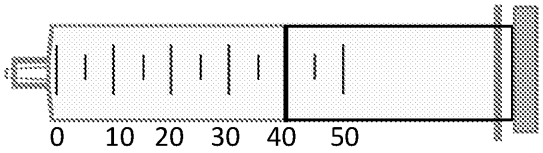
The equation represents the reaction. Balance the equation.

$CaCO_3$ + HCl ⟶ $CaCl_2$ + CO_2 + H_2O

.....

B. The syringe shows the amount of carbon dioxide collected in the reaction.

What is the volume of gas collected in the syringe?



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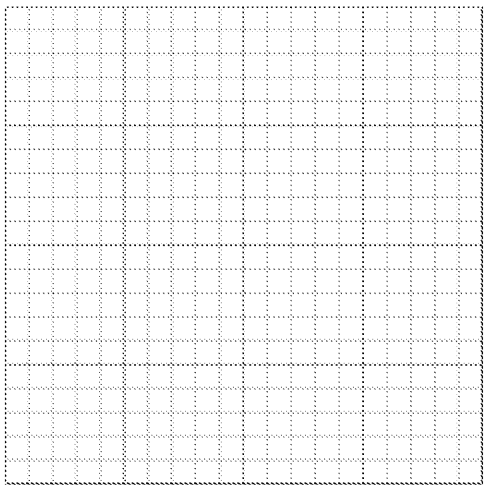
C. The results of the experiment are given in the table below.

Time (s)	Volume of gas collected Mean result (cm^3)
0	0
50	18
100	32
150	38
200	40

i) Label the axes on the graph below.

ii) Plot the data from the table onto the graph.

iii) Draw a line/curve of best fit.



Factors affecting rate of rea

Specification reference 4.6.1.2

Activity 1: Open the lock with the correct keyword

Match the definition to the correct keyword.

A. Substance that takes part in a chemical reaction	C
B. New substance formed in a chemical reaction	C
C. Substance that changes the rate of a chemical reaction without being used up	R
D. Measure of the amount of solute in a solution	P
E. Insoluble solid formed in a reaction	P

Activity 2: Tick-tock

Key information: Rate of reaction depends on the following factors: pres
concentration of reactants, and surface area of particles and presence of

Tick the correct answer.

A. At higher temperatures, particles will have more energy and the rate of react

- be faster ☐
- be slower ☐
- not be affected ☐

B. Hydrogen is a gas produced in a reaction. It is written as:

- $H_2(G)$ ☐
- $H_2(g)$ ☐
- H(g) ☐

Activity 3: Increase or decrease?

For each of the following, identify whether the rate of reaction **increases** or **decre**
appropriate symbol.

↑ or ↓

A. Using a catalyst

B. Temperature decreases

D. Concentration decreases

E. Temperature increases

Activity 4: Equation time

A. The equation shows the products formed when sodium thiosulfate reacts wit

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

The reaction takes place at 30 °C and is then repeated at 50 °C. What will be
rate of reaction? Explain your answer.

.....

.....

B. In the equation, each state symbol represents the state of the substance. Wr

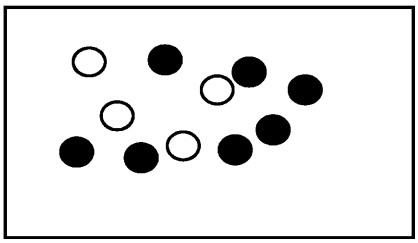
(s) ..... (aq) .....

(l) ..... (g) .....

C. Rate of reaction increases when the concentration of the reactant increases.
number of reactant particles when the concentration of both is higher.

Reactant 1 ●

Reactant 2 ○

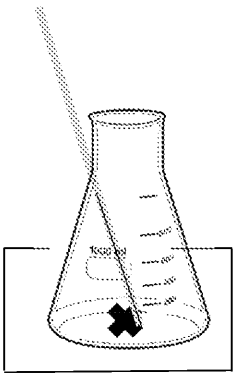


Activity 5: Exam-style question

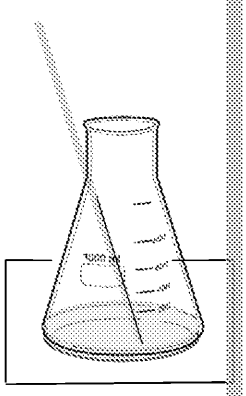
A flask containing sodium thiosulfate and hydrochloric acid was placed on a pape

Sodium thiosulfate + Hydrochloric acid → Sodium chloride + Wa

Sulfur makes the solution cloudy and the cross is not visible once the reaction is c



Before reaction



After reaction

The table below shows the time taken for the cross to disappear at different temp

Temperature (°C)	Time (s) 1 set	Time (s) 2 set	Time 3 s
30	32	30	9
50	11	10	12

A. Why does the cross disappear?

.....

.....

B. Find the mean time taken at 50 °C.

.....

C. What is the mean time taken at 30 °C?

.....

D. Identify the anomalous result and write it down.

.....

E. Name all the key practical equipment used in this experiment. Write the use

.....

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Factors affecting rate of rea

Specification reference 4.6.1.2

Activity 1: Open the lock with the correct keyword

Match the definition to the correct keyword.

A. Substance that takes part in a chemical reaction	C
B. New substance formed in a chemical reaction	C
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- be faster ☐
- be slower ☐
- not be affected ☐

B. Hydrogen is a gas produced in a reaction. It is written as:

- $H_2(G)$ ☐
- $H_2(g)$ ☐
- $H(g)$ ☐

Activity 3: Factors that matter

A. The equation shows the products formed when sodium thiosulfate reacts wit

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

The reaction takes place at 30 °C and is then repeated at 50 °C. Discuss the eff of reaction.

.....

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B. Sodium thiosulfate was used as small crystals and then crushed into powder. when sodium thiosulfate powder was used. Explain why.

.....

.....

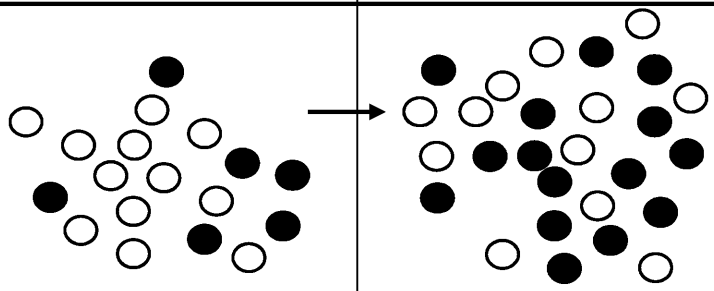
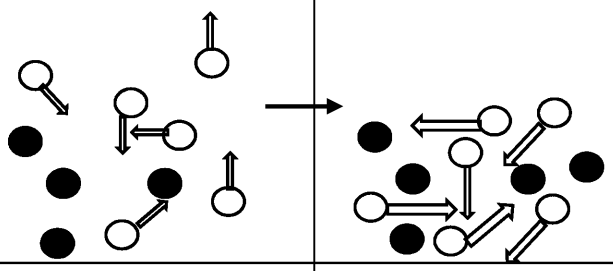
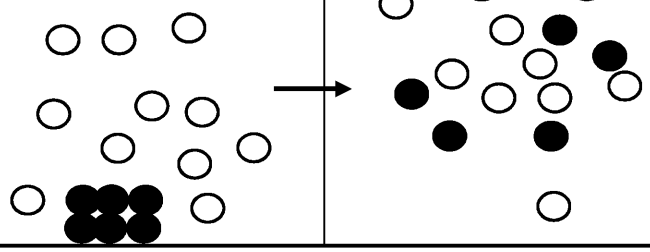
C. In the equation, each state symbol represents the state of the substance. Wr

(s) ..... (aq) .....

(l) ..... (g) .....

Activity 4: Predict the effect

Describe the effect of the following factors on the rate of reaction.

	Low	High
Concentration		
Temperature		
Surface area of solid reactant		

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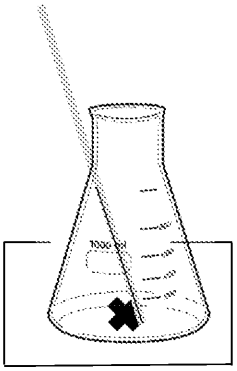
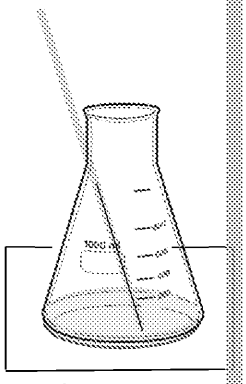
Sodium thiosulfate + Hydrochloric acid → Sodium chloride + Wa

Sulfur makes the solution cloudy and the cross is not visible once the reaction is c



Before reaction



After reaction

The table below shows the time taken for the cross to disappear at different temp

Temperature (°C)	Time (s) 1 set	Time (s) 2 set	Time 3 s
20	60	61	5
30	32	30	9
40	23	22	2
50	10	10	1

A. Why does the cross disappear?

.....

.....

B. Identify the anomalous result and write it down.

.....

C. Find the mean time taken at different temperatures and write your answer in

D. Name the dependent and independent variables in this experiment.

Dependent variable:.....

Independent variable:.....

E. Plan an investigation to show how temperature affects the rate of reaction.

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Catalyst and collision the

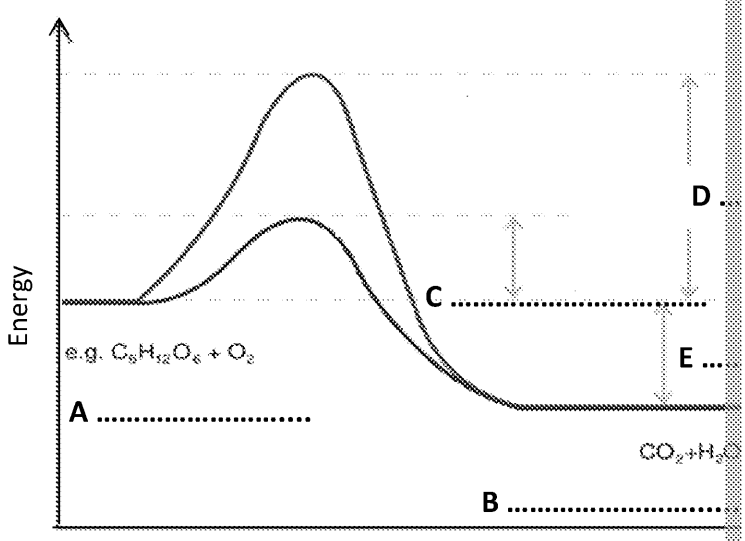
Specification reference 4.6.1.3-4.6.1.4

Activity 1: Label the diagram

⚠ **Key information:** A catalyst changes the rate of a chemical reaction – it p
with lower activation energy. A catalyst does not get used up in a chemi

Label the reaction profile for photosynthesis using the words below.

Activation energy with catalyst	Activation energy without catalyst	Reactant	Produ



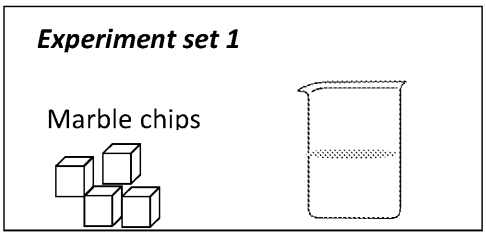
Activity 2: Glossary tessellate

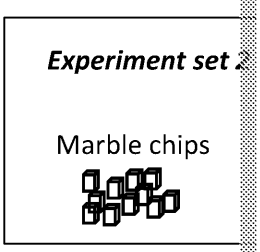
Cut out the following rectangles, arrange them, and then stick them down so that correct words.

1. Collision theory	5. Reaction pathway	A. Chart showing how the energy of reactants and products changes during a chemical reaction
2. Enzymes	6. Decomposition reaction	B. Biological molecules that speed up the rate of reaction
3. Catalytic convertor	7. Catalyst	C. A substance that changes the rate of a chemical reaction without being used up by the reaction
4. Reaction profile	8. Activation energy	D. The steps in a reaction required to produce a product from a particular set of reactants

Activity 3: Rock star

Marble reacts with hydrochloric acid to produce calcium chloride, water and carbo
The experiment was set up using two different sizes of marble chips, but the same





A. Balance the equation for the reaction: $CaCO_3 + HCl \longrightarrow CaCl_2 + ...$

.....

B. Experiment set 1 and Experiment set 2 have different rates of reaction. Whic higher rate of reaction?

.....

C. Explain why the rate of reaction will be higher.

.....

.....

Activity 4: Exam-style question

An experiment was done to produce methanol from carbon dioxide and hydroge four times; each time a chemical was added to see whether it works as a catalyst. given in the table.

Chemical added	Time taken to produce 30 c	
	Repeat 1	
1. No chemical	50	
2. A	50	
3. B	43	
4. C	15	

A. What is a catalyst?

.....

.....

B. Use the table above to identify the chemical which acts as a catalyst.

.....

C. Explain the reason for answer B.

.....

.....

D. A catalytic convertor is coated with a thin layer of platinum (expensive). It conv and carbon to carbon dioxide and nitrogen. Evaluate the use of platinum as a

.....

.....

.....

.....

Catalyst and collision the

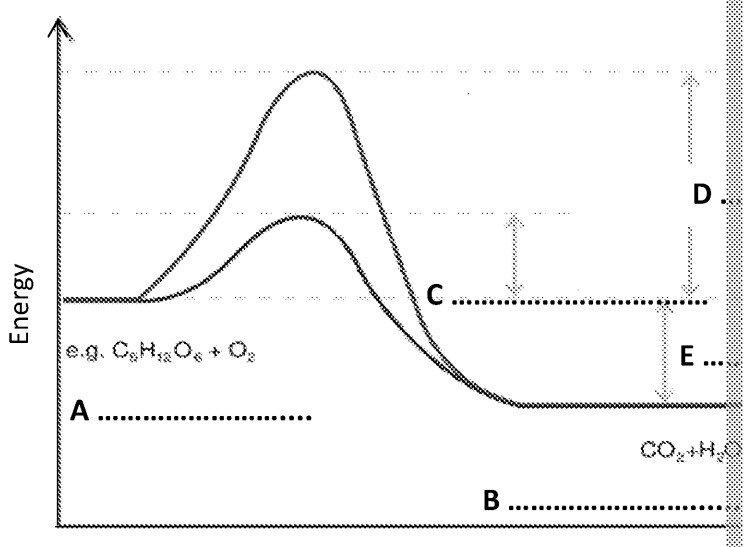
Specification reference 4.6.1.3-4.6.1.4

Activity 1: Label the diagram

Key information: A catalyst changes the rate of a chemical reaction – it p
with lower activation energy. A catalyst does not get used up in a chemi

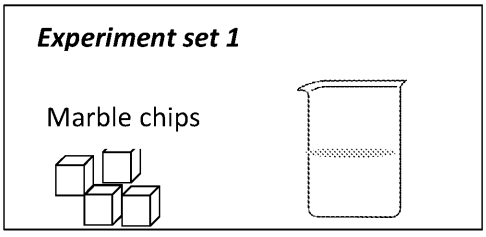
Label the reaction profile for photosynthesis using the words in the box.

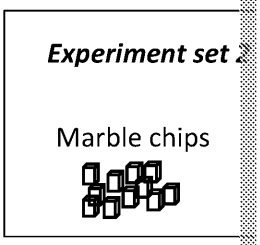
Activation energy with catalyst	Activation energy without catalyst	Reactant	Produ



Activity 2: Rock star

Marble reacts with hydrochloric acid to produce calcium chloride, water and carbo
The experiment was set up using two different sizes of marble chips, but the same





A. Balance the equation for the reaction: $CaCO_3 + HCl \rightarrow CaCl_2 +$ ..... $+ CO$

.....

B. Experiment set 1 and Experiment set 2 have different rates of reaction. Whic
higher rate of reaction?

.....

C. Explain why the rate of reaction will be higher.

.....

.....

Activity 3: Industrial processes

Cut out, rearrange and stick down the labels to match the equation and the catalys

Reaction	Equation	
Haber process	$2H_2O_2 \longrightarrow 2H_2O + O_2$	
Contact process	$N_2 + H_2 \longrightarrow NH_3$	
Decomposition of hydrogen peroxide	$2SO_2 + O_2 \rightleftharpoons 2SO_3$	

Activity 4: Exam-style question

An experiment was done to produce methanol from carbon dioxide and hydroger

$$\mathbf{CO_2 + 2H_2 \longrightarrow CH_3OH}$$

The experiment was repeated four times; each time a chemical was added to see w
The results for the experiment are given in the table.

Chemical added	Time taken to produce 30 cm^3 ethanol (s)	Ti
1. No chemical	50	
2. A	50	
3. B	No reaction	
4. C	15	

A. Why is a catalyst used in a chemical reaction?

.....

B. Which chemical acts as a catalyst?

.....

C. Explain the reason for answer B.

.....

.....

D. Why was no chemical added in experiment 1?

.....

E. A catalytic convertor is coated with a thin layer of platinum. It converts harm to carbon dioxide and nitrogen. Evaluate the use of a catalyst in this process

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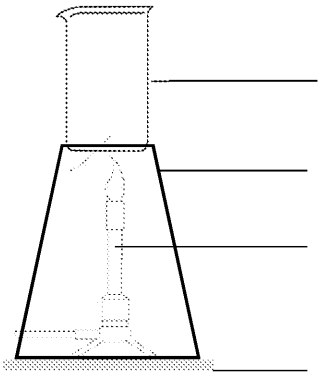
Reversible reaction and energy

Specification reference 4.6.2.1-4.6.2.2

Activity 1: Label the apparatus

Identify the equipment used for thermal decomposition of copper sulfate. Initial l



A. B_____

B. T_____

C. B_____

D. H_____ _____

Activity 2: Dual coding

Key information: In a chemical reaction, reactants combine to form produc
product can react to produce the reactants again. The point at which the ra
as the rate of reverse reaction is called equilibrium. A reversible reaction is r

Exothermic reaction: reaction in which energy is transferred to the surro

Endothermic reaction: reaction in which energy is taken in from the surr

Anhydrous substances contain no water.

Define each key term and draw a diagram to help you remember it. (Hint: key inf

A. Reversible reaction.....	B. Anhydrous.....
.....	.....
C. Endothermic reaction.....	D. Exothermic reac
.....	.....

Activity 3: True or false?

State whether each sentence is true or false. If you think that a sentence is false, why underneath.
A. The temperature of the surroundings increases in an exothermic reaction
B. A catalyst is part of a reaction and gets used up in the reaction
C. If the forward reaction is endothermic, energy will be released in the backw
D. The equation for a reversible reaction is **A + B ⟶ C + D**
E. The rate of reaction decreases when temperature increases
F. The balanced equation for the production of ammonia is **$NH_4Cl \rightleftharpoons NH_3 + H$**

Activity 4: Exam-style question

Hydrated copper sulfate is heated to produce anhydrous copper sulfate and wate
The equation for this reaction is:

Hydrated copper sulfate (blue) ⇌ Anhydrous copper sulfat

A. Explain why the forward reaction is endothermic.

.....

.....

.....

.....

B. How can you turn white anhydrous copper sulfate back to blue?

.....

.....

C. 5.0 g of hydrated copper sulfate was heated in the evaporating dish, and 4.7 was produced.

i. Calculate the mass lost in g .....

ii. There is a mass loss because .....

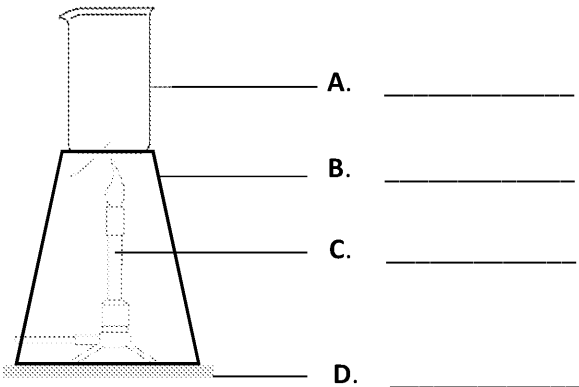
.....

Reversible reaction and energy

Specification reference 4.6.2.1-4.6.2.2

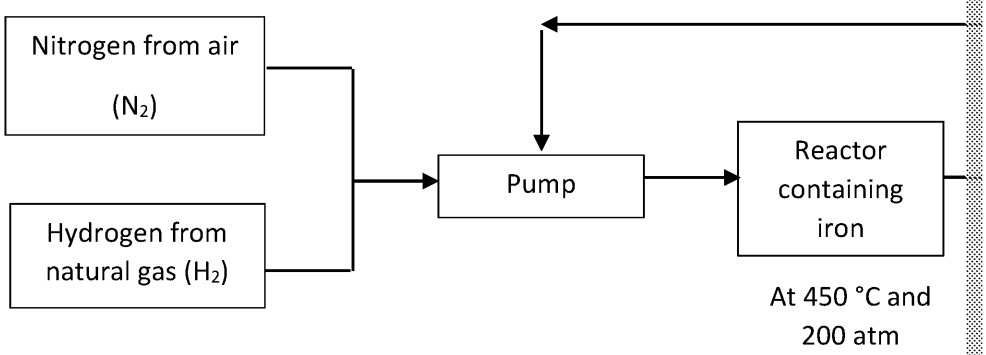
Activity 1: Label the apparatus

Identify the equipment used for thermal decomposition of copper sulfate.



Activity 2: Short questions

Ammonia is a nitrogen-based fertiliser produced by the Haber process. Nitrogen
form ammonia in the presence of iron. The figure below represents the steps in p
Haber process.



A. Complete the equation: $N_2 + 3H_2 \rightleftharpoons$	B. Why is iron used in the reactor?	C. ....
D. The forward reaction is exothermic; how can we increase the amount of ammonia produced?	E. From where is nitrogen obtained for this reaction?	F. ....

Activity 3: True or false?

State whether each sentence is true or false. If you think that a sentence is false, why underneath.
A. The temperature of the surroundings increases in an exothermic reaction
B. A catalyst is part of a reaction and gets used up in the reaction
C. If the forward reaction is endothermic, energy will be released in the backw
D. The equation for a reversible reaction is **A + B ⟶ C + D**
E. The rate of reaction decreases when temperature increases
F. The balanced equation for the production of ammonia is **$NH_4Cl \rightleftharpoons NH_3 + H$**

Activity 4: Exam-style question

Hydrated copper sulfate is heated to produces anhydrous copper sulfate and wat
The equation for this reaction is:

Hydrated copper sulfate (blue) ⇌ Anhydrous copper sulfat

A. State what is meant by a reversible reaction.

.....

.....

.....

.....

B. Explain why the reversed reaction is exothermic.

.....

.....

.....

.....

C. 5.0 g of hydrated copper sulfate was heated in the evaporating dish, and 4.7 was produced.

i. Calculate the mass lost in g .....

ii. There is a mass loss because .....

.....

Equilibrium

Specification reference 4.6.2.3-4.6.2.6

Activity 1: Match the cards

Match each card to the correct answer.

1. Equilibrium	A. Force applied per unit area
2. A + B ⇌	B. No chemical can move in or o
3. Closed	C. Rate of forward reaction is sa reaction
4. Pressure	D. Amount of product obtained
5. Yield	E. C + D

Activity 2: Tick it

In an experiment, oxidation of sulfur produces sulfur trioxide. The forward reactio when the temperature decreases. The word equation for the reaction is shown be

Sulfur dioxide + Oxygen ⇌ Sulfur trioxide

Tick the box to choose the correct answer.

A. What are sulfur dioxide and oxygen in this reaction? Catalyst Reactant Product Element	B. What does the symbol ⇌ mean? Endothermic Neutralisation Exothermic Reversible	C
D. At higher temperature the yield of sulfur trioxide: Increases Decreases Stays the same Is not reversible	E. Dynamic equilibrium is when: A reversible reaction takes place in an open container A reversible reaction takes place in a closed system A reversible reaction does not take place	F

Activity 3: Think and answer

Answer the questions on ammonium chloride.

Ammonium chloride is a white solid. It produces ammonia and hydrogen chloride

The reaction in a test tube is done by a student.

A. Why is ammonium chloride heated in this reaction?

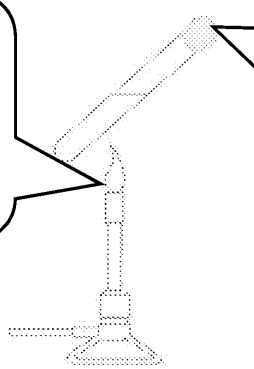
.....

.....

B. Why did the
at the top o

.....

.....



C. Complete the equation by putting the correct symbol in each box:

ammonium chloride ☐ ammonia ☐ hydrochloric acid

D. Explain what happens at equilibrium.

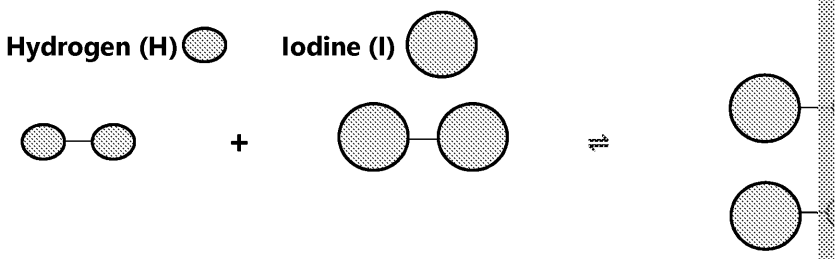
.....

Activity 4: Exam-style question

A. Name the three factors that affect equilibrium.

.....

B. Hydrogen and iodine molecules are shown below. Energy is released when h
hydrogen and iodine.



Write a balanced equation for the reaction. (Hint: use the molecular diagram

.....

C. Explain what would happen if the temperature changes in this reaction.

.....

.....

.....

Equilibrium

Specification reference 4.6.2.3-4.6.2.6

Activity 1: Match the cards

Match each card to the correct answer.

1. Equilibrium	A. Force applied per unit area
2. A + B ⇌	B. No chemical can move in or o
3. Closed	C. Rate of forward reaction is sa reaction
4. Pressure	D. Amount of product obtained
5. Yield	E. C + D

Activity 2: Think and answer

Answer the questions on ammonium chloride.

Ammonium chloride is a white solid. It produces ammonia and hydrogen chloride

The reaction in a test tube is done by a student.

A. Why is ammonium chloride heated in this reaction?

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B. Why did the at the top o

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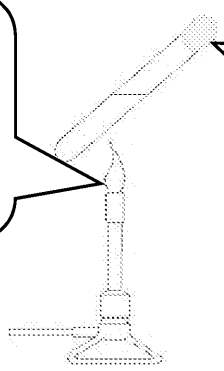


C. Complete the word equation for the reaction taking place. Put the correc

..... [ ] ..... + hydr

D. Explain what happens at equilibrium.

.....

Activity 3: Shade the area (HT only)

⚠	**Key information:** Le Chatelier's principle states that 'if the condition is ch system will respond to counteract the change'.

Shade the box which shows the change that will take place when the temperature following reactions.

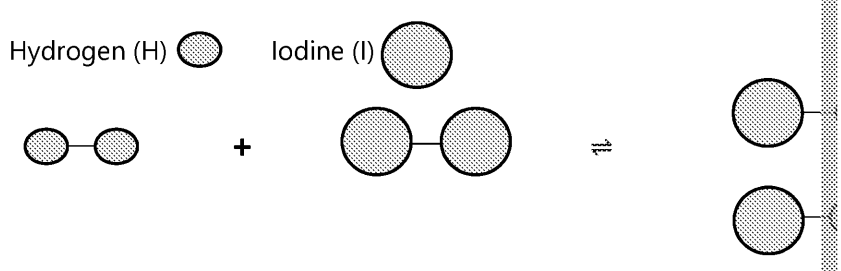
Equilibrium	Energy change (forward reaction)	Temperature increase	
		Reactant increases	Produc increase
A(g) + B(g) ⇌ C(g) + 2D(g)	endothermic		
A(g) ⇌ B(g) + C(g) + D(g)	exothermic		
A(g) + C(g) + D(g) ⇌ B(g)	endothermic		
A(g) + B(g) ⇌ 3C(g) + D(g)	exothermic		
2B(g) ⇌ C(g)	endothermic		

Activity 4: Exam-style question

A. Name the three factors that affect equilibrium.

.....

B. Hydrogen and iodine molecules are shown below. Energy is released when h hydrogen and iodine.



Write a balanced equation for the reaction. (Hint: use the molecular diagram

.....

C. What will happen if the concentration of hydrogen and iodine is increased?

.....

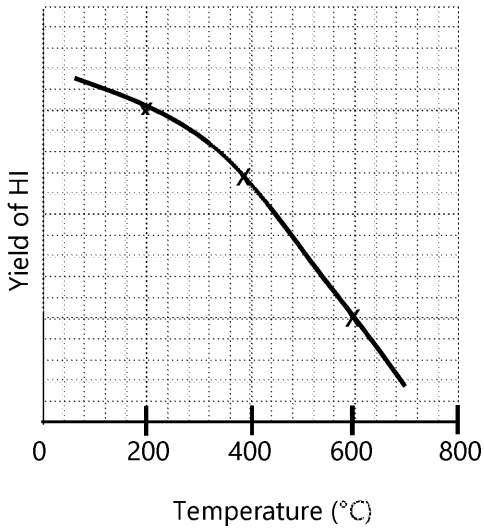
.....

D. What will happen if the temperature decreases in the reaction?

.....

.....

E. The graph shows yield of hydrogen iodide (HI) at different temperatures. (H



The forward reaction is exothermic; explain how the graph shows this.

.....

.....

Specification reference 4.7.1.1

Activity 1: What am I?

Read the properties and choose the correct answer from the list.

A. Mixture of hydrocarbons

B. Smallest unit of matter

C.

D. General formula for alkanes

E. Hydrocarbon with only one carbon

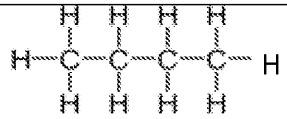
F.

Choose the correct answer (What am I?)

1. Hydrocarbon .....
2. Saturated .....
3. Methane .....
4. Atom .....
5. $C_nH_{(2n+2)}$ .....
6. Crude oil .....

Activity 2: Table talk

Complete the table by filling in the names of the alkanes and the missing molecul

Number of carbon atoms	Alkane	Molecular formula	Stru
1	Methane		
2		C_2H_6	
3	Propane		
4			

Activity 3: Mnemonic

Write a mnemonic to help you remember the number of carbon atoms in each alk

Alkanes have a general formula of C_nH_{2n+2}. The first four alkanes are methane

The prefixes determine the number of carbon atoms.

Meth – 1

Eth – 2

Prop – 3

But – 4

Write a mnemonic to help you remember the number of carbon atoms in each alkane.

.....

.....

.....

.....

Activity 4: Exam-style question

Crude oil is a mixture of hydrocarbons with different boiling points. The boiling p carbon atoms in the hydrocarbon. The table below shows the boiling point of dif

Alkane	Boiling poin
Methane	-163
Ethane	-88
Propane	
Butane	-0.5
Pentane	36

A. Predict the boiling point of propane.

.....

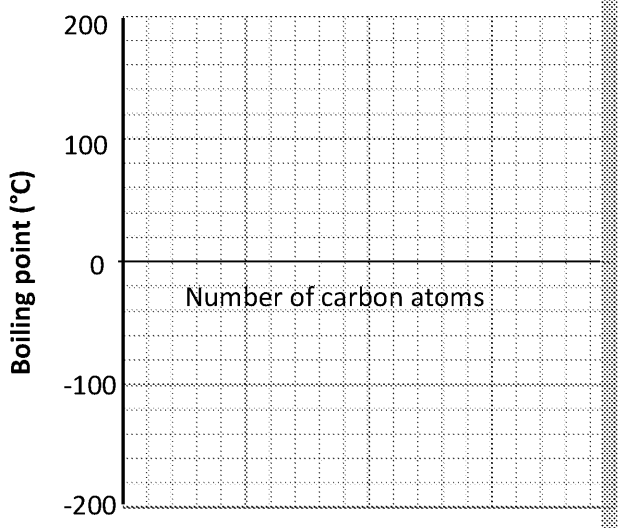
B. Which alkane is liquid at room temperature?

.....

C. Describe the relationship between the number of carbon atoms and the boili

.....

D. Use the table above to plot the boiling points of alkanes.

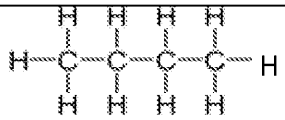


Crude oil, hydrocarbons and

Specification reference 4.7.1.1

Activity 1: Table talk

Complete the table by filling in the names of the alkanes and the missing molecul

Number of carbon atoms	Alkane	Molecular formula	Struc
1	Methane		
2		C_2H_6	
3	Propane		
4			

Activity 2: Word search

Use the clues to find the words in the grid.

A	C	A	B	Q	Z	D	E	F	R	X	C
M	H	Q	N	C	V	S	C	Q	A	S	A
E	Y	T	B	R	O	I	W	M	E	B	L
U	D	K	H	U	R	X	O	E	Y	I	R
T	R	A	S	D	I	P	E	T	R	O	L
R	O	L	F	E	F	A	C	H	N	M	Q
O	C	J	F	O	D	K	I	A	O	A	L
L	A	Y	H	I	U	D	W	N	F	S	P
F	R	O	J	L	O	R	T	E	P	S	D
I	B	R	G	E	F	O	S	L	F	E	R
B	O	I	L	I	N	G	P	O	I	N	T
R	N	S	O	Q	E	R	B	M	F	S	S

Clues

1. Ma hyc
2. Mix ove
3. The
4. Ter sub
5. Nur
6. Nur eth
7. Hyc
8. Dry

Activity 3: Mnemonic

Write a mnemonic to help you remember the composition of crude oil.

Crude oil composition
Liquefied petroleum gas
Petrol
Kerosene
Diesel
Heavy fuel
Bitumen

.....

.....

.....

.....

Activity 4: Exam-style question

Crude oil is a mixture of hydrocarbons with different boiling points. The boiling p
carbon atoms in the hydrocarbon. The table below shows the boiling point of dif

Alkane	Boiling poin
Methane	-163
Ethane	-88
Propane	
Butane	-0.5
Pentane	36

A. Which alkane is gas at room temperature?

.....

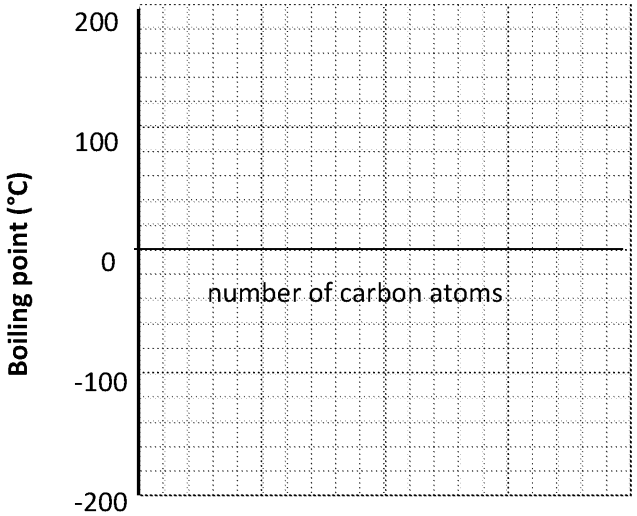
B. Predict the boiling point of propane.

.....

C. Describe the relationship between the number of carbon atoms and the boili

.....

D. Use the table above to plot the boiling points of alkanes.

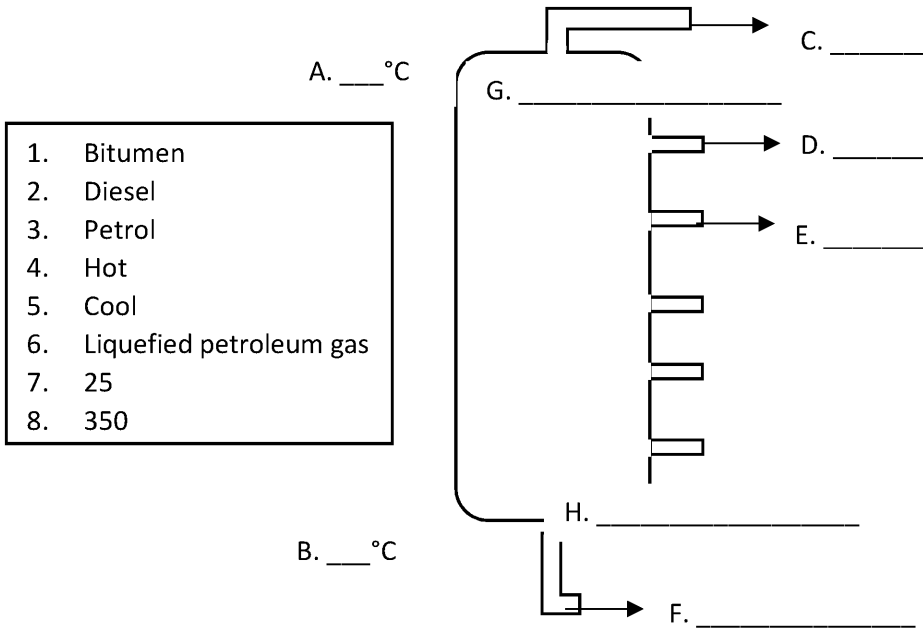


Fractional distillation and petro

Specification reference 4.7.1.2

Activity 1: Label the diagram

Label the diagram using the words in the box.



1.	Bitumen
2.	Diesel
3.	Petrol
4.	Hot
5.	Cool
6.	Liquefied petroleum gas
7.	25
8.	350

Activity 2: Code breaker

Decode the keywords using the code breaker table (Definitions are not in the cor

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
	®	£	©	≠	α	×	μ	π	≤	≥	÷	∞	∑	⫛	∩	Δ	ʒ	ɾ	и

A. ∩ ≠ и ʒ ⫛ ÷ ..... Made of h

B. © π ≠ ɾ ≠ ÷ ..... Used to m

C. ∞ ≠ и μ ∑ ≠ ..... Fuel for d

D. μ ¥ © ʒ ⫛ £ ʒ ® ⫛ ∑ ..... Fuel for c

E. ≠ ∂ ∩ ⫛ ʒ и π ⫛ ∑ ..... Mixture o

F. ® π и ɻ ∞ ≠ ∑ ..... Fuel for s

G. £ ʒ ɻ © ≠ ⫛ π ÷ ..... Takes pla

Activity 3: Gap fill

Fill in the gaps to complete the steps in the process of fractional distillation.

350 °C	liquid	condense	fractional distillation	cool	

A. The process by which crude oil is separated into fractions is _____

B. Crude oil mixture is heated to _____.

C. Some of the hydrocarbons remain as _____, and flow to the ___ fractionating column.

D. Some of the crude oil _____, and vapours rise up the fractionat through a pipe.

E. The fractionating column is _____ at the top and _____

F. Vapours _____ at different temperatures in the fractionating co

Activity 4: Exam-style question

A scientist wants to study the contents of a perfume. The perfume is made up of of water.

A. Name the process the scientist will use to separate the contents of the perfu

.....

B. The amount of perfume oil and water is given in the table. What is the perce

Content	P
Ethanol	
Perfume	
Water	

C. The boiling point of ethanol is 78 °C and the boiling point of water is 100 °C.

Explain how the scientist will be able to separate water and ethanol. Use the

boils	vaporises	fractional distillation	temperature

.....

.....

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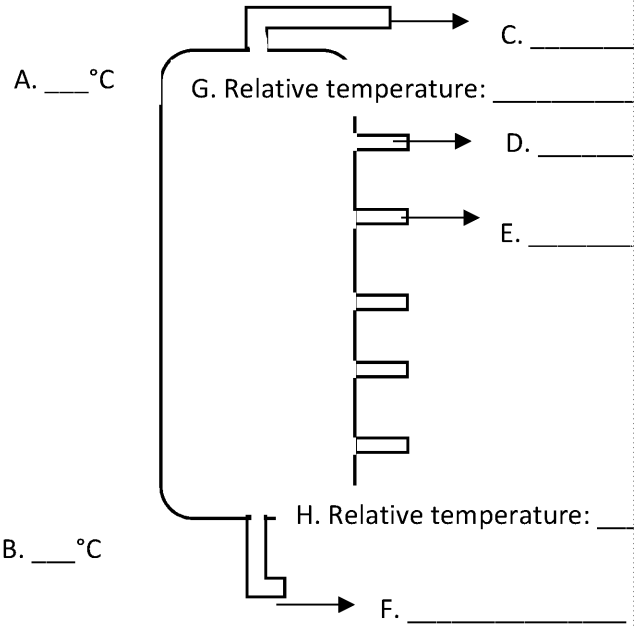
Fractional distillation and petro

Specification reference 4.7.1.2

Activity 1: Label the diagram

Label the diagram.

Fractio



Activity 2: Cut and rearrange

Cut out the steps and rearrange them to correctly describe the process of fraction

Some of the crude oil is evaporated.
Crude oil mixture is heated to about 350 °C, creating a temperature gradient in column which is cool at the top and hot at the bottom.
Some of the hydrocarbons remain as liquids and flow to the bottom of the frac
Vapours rise up the fractionating column and condense at different tempe fractionating column.
Gases flow out through a pipe.

Activity 3: Code breaker

Decode and define the keywords.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
	®	£	©	≠	α	×	μ	π	≤	≥	÷	∞	∑	⫛	∩	∩	ȝ	ɾ	ʁ

1. ∩≠ʁ ȝ⫛÷ .....

2. ©π≠ɾ≠÷ .....

3. ∞≠ʁμ ∑≠ .....

4. μ¥©ȝ⫛£ ȝ®⫛∑ .....

5. ≠∂ ∩⫛ȝ ʁπ⫛∑ .....

6. ®πʁɟ∞≠∑ .....

7. £ȝɟ©≠ ⫛π÷ .....

Activity 4: Exam-style question

A scientist wants to study the contents of a perfume. The perfume is made up of
of water.

A. Name the process the scientist will use to separate the contents of the perfu

.....

B. The amount of perfume oil and water is given in the table. What is the perce

Content	F
Ethanol	
Perfume	
Water	

C. The boiling point of ethanol is 78 °C and the boiling point of water is 100 °C.

Explain how the scientist will be able to separate water and ethanol.

.....

.....

.....

.....

.....

.....

.....

.....

Properties of hydrocarb

Specification reference 4.7.1.3

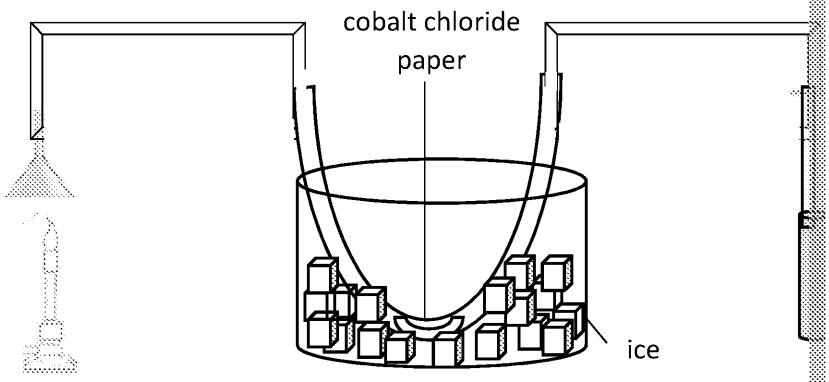
Activity 1: Tick-tock

Tick (✓) the correct box for the properties of hydrocarbons.

Property	Methane	Bu
Higher boiling point		
Less viscous		
Burns with a clean flame		
Easily flammable		

Activity 2: Products of combustion

The diagram shows the process of combustion.



1. The products of combustion are _____ and ___

2. Cobalt chloride paper can be used to test for the presence of _____

3. It changes colour from _____ to _____
   water is present.

4. Lime water is used to test for the presence of _____

   It changes from _____ to _____
   dioxide is present.

Activity 3: Balancing act

Write the balanced chemical equation for the combustion of the following alkanes:

Methane

$CH_4 + O_2 \longrightarrow$

Ethane

$C_2H_6 + O_2 \longrightarrow$

Combustion

(Products are CO_2 and H_2O)

Propane

$C_3H_8 + O_2 \longrightarrow$

Butane

$C_4H_{10} + O_2 \longrightarrow$

Activity 4: Exam-style question

A student is testing two samples of hydrocarbons.

Sample A

1. She has to determine which sample is the larger hydrocarbon.

   State two properties which the student can study to find the larger hydrocarb

   .....

2. Name the apparatus labelled X.

   .....

3. One of the samples has this symbol on the container:

   What does the symbol represent?

   .....

4. Sample A burns with a sooty flame. The time taken by Sample A and Sample in the table.

Hydrocarbon	Time taken to heat water (s)	Time taken to he water 2 (s)
Sample A	30	10
Sample B	50	45

   A. The mean time taken by Sample A to heat the water is .....

   B. Why is the experiment repeated three times?

   .....

   .....

   C. State one safety precaution that the student should take while doing thi

   .....

   .....

Properties of hydrocarb

Specification reference 4.7.1.3

Activity 1: Properties of hydrocarbons

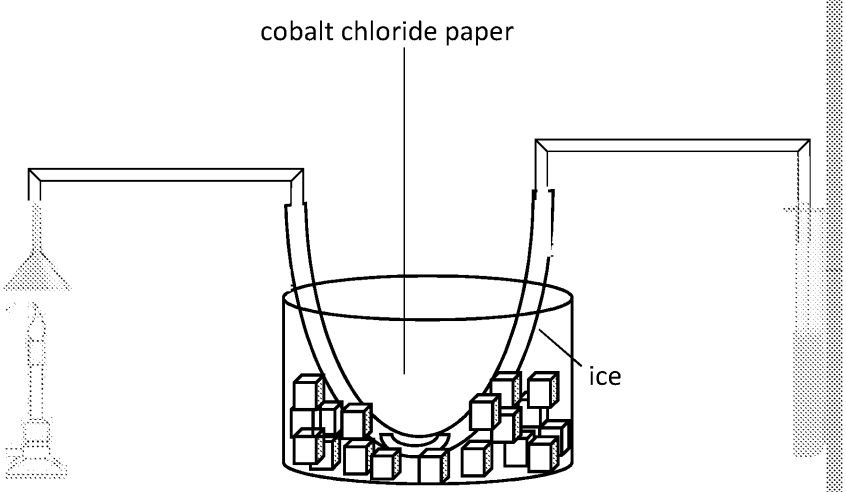
Draw arrows to show the changes in the properties of hydrocarbons as chain leng

Chain length	Viscosity	Flammability	Boiling po
C1 ↓ C6 increase			

Activity 2: Products of combustion

The diagram shows the process of combustion.

Explain how the products of combustion can be tested using this set-up.



Activity 3: Balancing act

Write the balanced chemical equation for the combustion of the following alkanes:

Methane	Ethane
Combustion (+ O_2)	
Propane	Butane

Activity 4: Exam-style question

Sam

A student is testing two samples of hydrocarbons.

1. She has to determine which sample is the larger hydrocarbon.

   State two properties which the student can study to find the larger hydrocarb

   .....

2. Name the apparatus labelled X.

   .....

3. One of the samples has this symbol on the container:

   What does the symbol represent?

   .....

4. Sample A burns with a sooty flame. The time taken by Sample A and Sample in the table.

Hydrocarbon	Time taken to heat water (s)	Time taken to water 2 (s
Sample A	30	10
Sample B	50	45

   A. The mean time taken by Sample A to heat the water is .....

   B. How can the student ensure their results are reliable?

   .....

   .....

   C. State two safety precautions that the student should take while doing th

   .....

   .....

Cracking and alkenes

Specification reference 4.7.1.4

Activity 1: Mind the gap

Fill the gaps using the keywords. (The words can be used more than once.)

catalyst	alkane	high temperature	thermal decomposition	

1. The process of _____ breaks down larger hydrocarbons into s hydrocarbons are more useful.
2. The starting hydrocarbon is always an _____ .
3. The products are an _____ and an _____ .
4. The conditions needed for this process are a _____ and ____
5. This reaction is _____ _____ because alkanes

Activity 2: Who am I?

Draw the structures of the compounds described below.

1. I am a hydrocarbon with four carbons and no double bonds. (Butane)

2. I am a hydrocarbon with two carbons and one double bond between the firs

3. I am a hydrocarbon with three carbons and one double bond. (Propene) (Ch double bond.)

Activity 3: Balance the equation

Large hydrocarbons (alkanes) are broken down into smaller alkanes (C_nH_{2n+2}) and … of cracking.

Write balanced equations for the breakdown of the following alkanes if one of the …

1. C_6H_{14} + C_3H_6 ⟶
2. $C_{10}H_{22}$ + C_3H_6 ⟶
3. $C_{16}H_{34}$ + C_3H_6 ⟶
4. $C_{20}H_{42}$ + C_3H_6 ⟶
5. $C_{25}H_{52}$ + C_3H_6 ⟶

Activity 4: Exam-style question

1. State two uses of the products of cracking.

   .....

   .....

   .....

   .....

2. Alkenes are unsaturated hydrocarbons.

   Tick the general formula for alkenes.

   C_nH_{2n+2} ☐

   C_nH_{2n-2} ☐

   C_nH_{2n} ☐

   $C_{2n}H_n$ ☐

3. Propene is an unsaturated hydrocarbon. It consists of a C=C double bond.

Describe the test done to check for the presence of propene.

.....

.....

.....

.....

4. The process of cracking is shown in Figure 1.

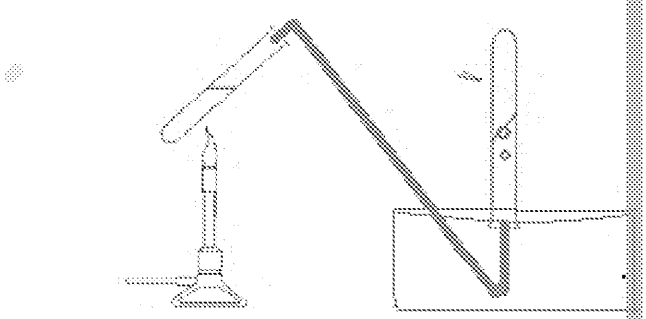


Figure 1

Describe the process of cracking.

.....

.....

.....

.....

.....

.....

.....

.....

Cracking and alkenes

Specification reference 4.7.1.4

Activity 1: Mind the gap

Fill the gaps using the keywords. (The words can be used more than once.)

catalyst	alkane	high temperature	thermal decomposition	

1. The process of _____ breaks down larger hydrocarbons into s hydrocarbons are more useful.
2. The starting hydrocarbon is always an _____ .
3. The products are an _____ and an _____ .
4. The conditions needed for this process are a _____ and ____
5. This reaction is _____ _____ because alkanes

Activity 2: Who am I?

Draw the structures of the compounds described below.

1. I am a hydrocarbon with four carbons and no double bonds.

2. I am a hydrocarbon with two carbons and one double bond between the firs

3. I am a hydrocarbon with three carbons and one double bond. (Choose your o

Activity 3: Balance the equation

Large hydrocarbons (alkanes) are broken down into smaller alkanes (C_nH_{2n+2}) and alkenes in the process of cracking.

Write balanced equations for the breakdown of the following alkanes if one of the products is ethene.

1. C_6H_{14}	⟶
2. $C_{10}H_{22}$	⟶
3. $C_{16}H_{34}$	⟶
4. $C_{20}H_{42}$	⟶
5. $C_{25}H_{52}$	⟶

Activity 4: Exam-style question

1. Hydrocarbon chains are broken in the process of cracking.

   Define a hydrocarbon.

   .....

   .....

2. The products of cracking are an alkane and an alkene.

   The general formula for an alkene is _____

3. Propene is an unsaturated hydrocarbon. It consists of a C=C double bond.

   Describe the test done to check for the presence of propene.

   .....

   .....

   .....

   .....

4. The process of cracking is shown in Figure 1.

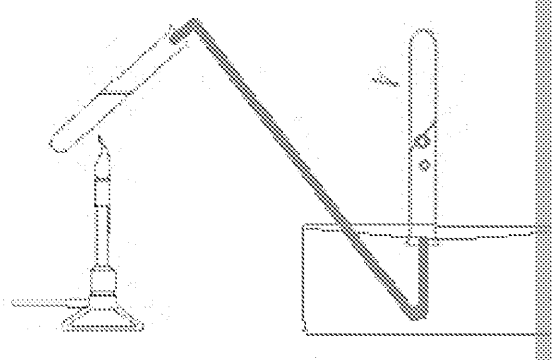


Figure 1

Describe the process of cracking.

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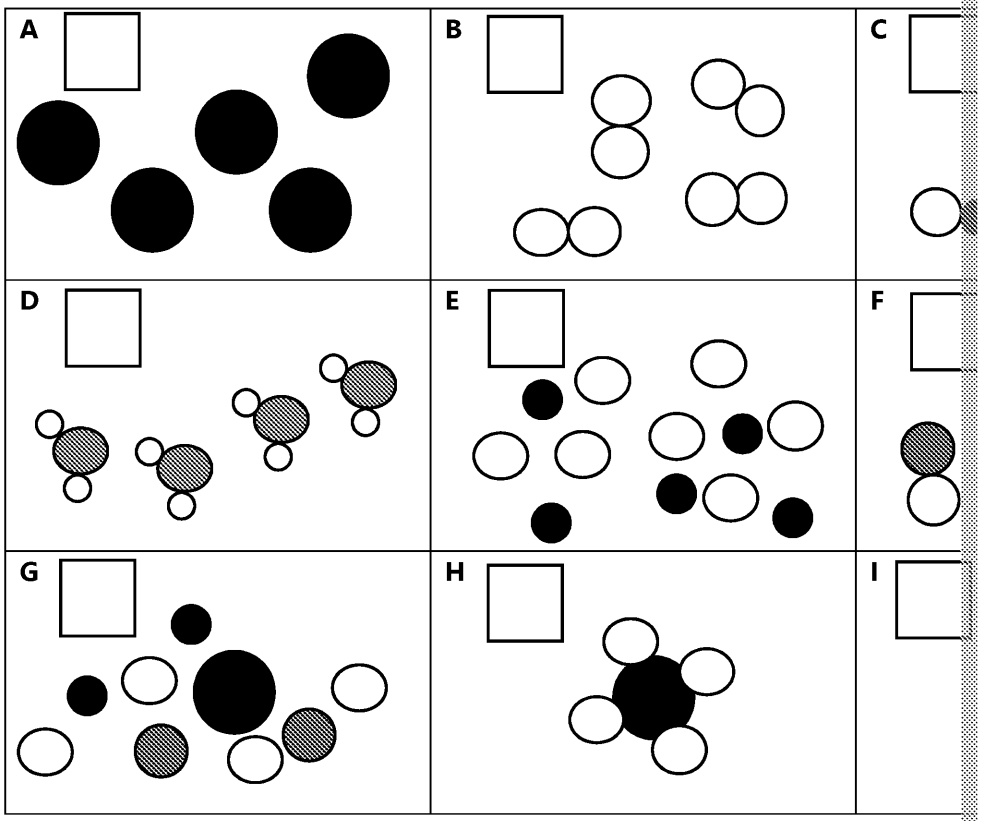
.....

Pure substances

Specification reference 4.8.1.1

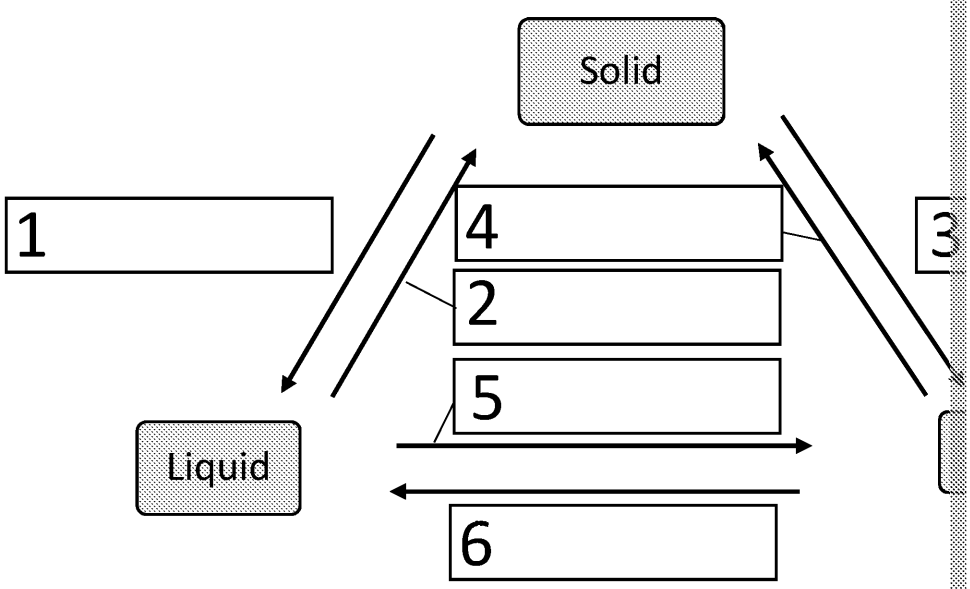
Activity 1: Elements, mixtures and compounds

Elements are made up of the same type of atoms.
Compounds are made up of two or more atoms chemically combined together.
Mixtures are made up of two or more compounds not chemically combined.
Identify the element, mixture or compound and write the letter **E, M or C** in the co



Activity 2: State change

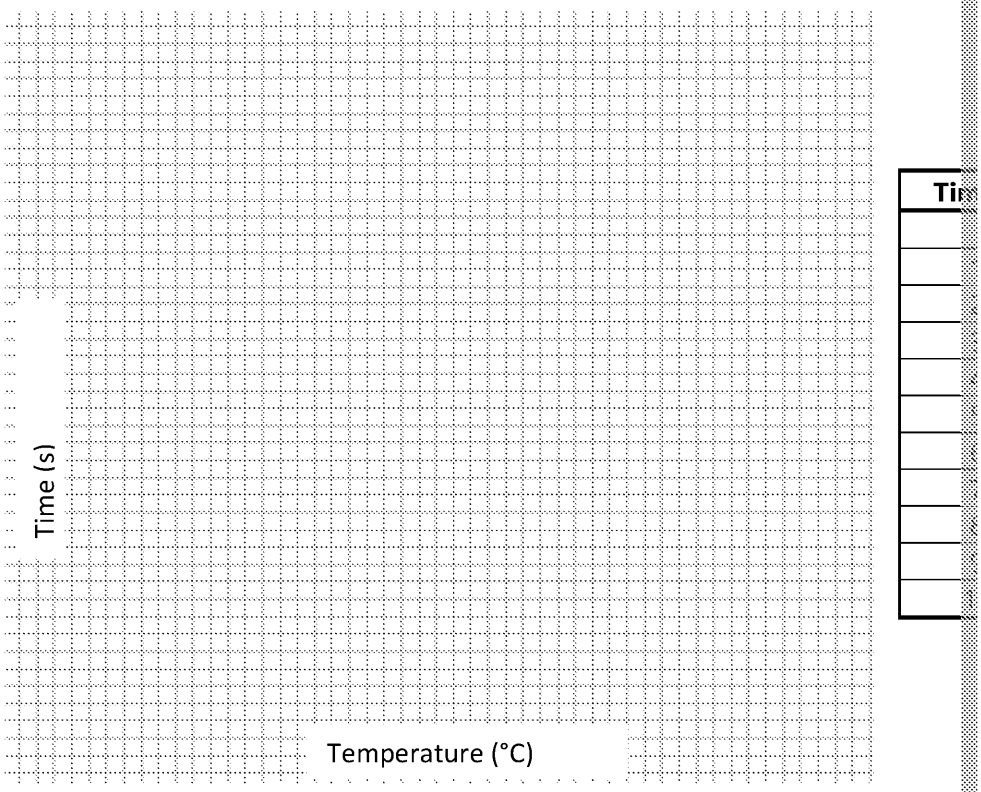
Identify the processes that occur when state change takes place between solids, liqu
the processes in the boxes.



Activity 3: The cooling curve

Plot the graph for the cooling curve using the data in the table.

Identify the melting point and the boiling point on the cooling curve.



Ti

Activity 4: Exam-style question

Sam did an experiment to identify which substances were pure and which were im

A. What is meant by a pure substance?

.....

.....

B. Sam plotted a graph of the substances he tested.

Identify which substance is pure and which substance is impure by using the

.....

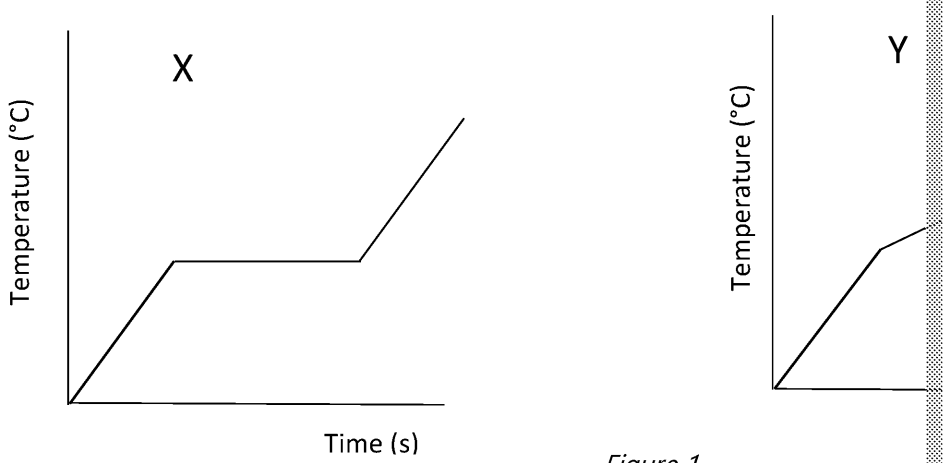


Figure 1

C. Complete the method for the heating and cooling of stearic acid using the w

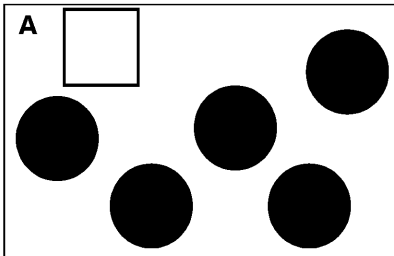
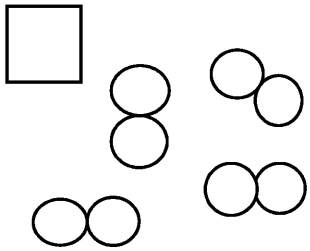
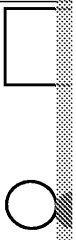
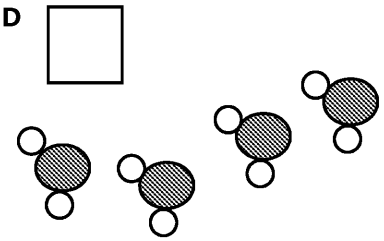
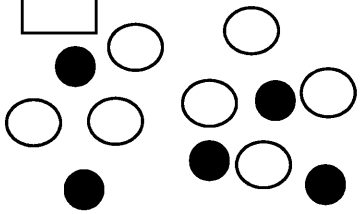
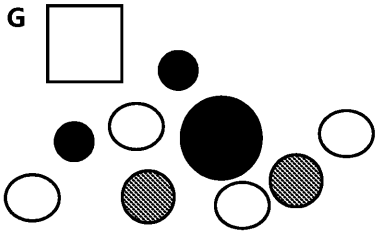
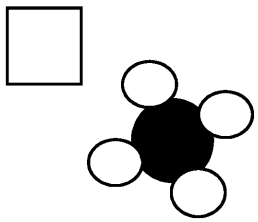
- Add 100 cm^3 _____ into the _____
- Put the Bunsen burner on a heatproof mat.
- Put the beaker on a _____ and _____
- Wait until the water just starts to _____ .
- Put the test tube containing _____ in the beaker and
- Record the _____ of the _____ ___
  minute until it reaches about 70 °C. Note the point at which the solid st
- Lift the test tube from the hot water.
- Record the temperature every minute until it reaches about 50 °C. Note
  stearic acid begins to _____ .

Pure substances

Specification reference 4.8.1.1

Activity 1: Elements, mixtures and compounds

Elements are made up of the same type of atoms.
Compounds are made up of two or more atoms chemically combined together.
Mixtures are made up of two or more compounds not chemically combined.
Identify the element (E), mixture (M) or compound (C) in boxes A–I below by writi

A 	B 	C 
D 	E 	F 
G 	H 	I
Draw particles of H_2O	Draw particles of a mixture of an element and a compound	D

Activity 2: State at room temperature

Determine the state of the following substances at room temperature.

Substance	Melting point (°C)	Boiling point (°C)
A	0	100
B	-150	-100
C	-10	35
D	30	900
E	20	59

Activity 3: The cooling curve

Plot the graph for the cooling curve using the data in the table.

Identify the melting point and the boiling point on the cooling curve.

Ti

Activity 4: Exam-style question

Sam did an experiment to identify which substances were pure and which were im

A. What is meant by a pure substance?

.....

.....

B. Sam heated two substances: substance X is a pure substance and substance Y

Sketch the graphs for substances X and Y.

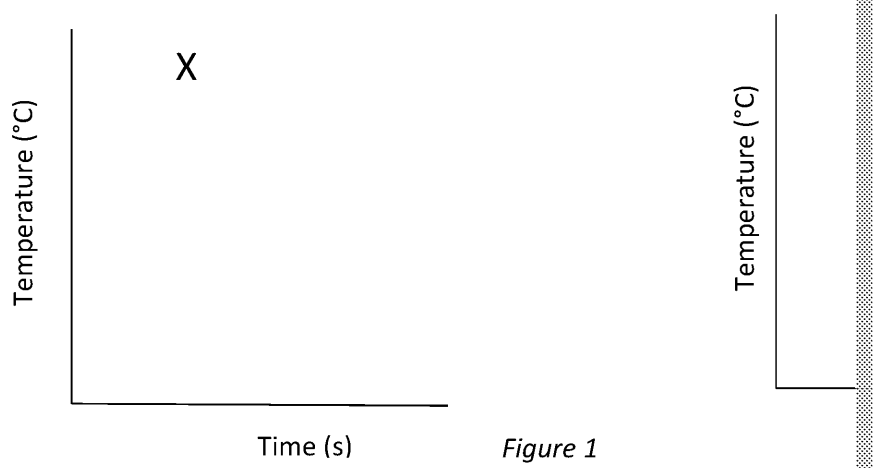


Figure 1

C. Write the method for the heating and cooling of stearic acid.

Formulations

Specification reference 4.8.1.2

Activity 1: Match up

Formulations are chemicals added in measured quantities to make useful product

Match each substance to its use.

Solvent	A Used to increase the shelf life of
Salt	B Used as a base for dissolving sub
Preservative	C Used to give colour to paint
Fragrance	D Used as a flavour enhancer
Dye	E Used to give scent to a product

Activity 2: Formulations

A. Write one difference between a pure substance and a formulation.

.....

.....

B. Give two examples of formulations, and state their uses.

.....

.....

.....

.....

Activity 3: Painkiller

Calculate the chemical formulas of the following medicine formulations.

A. Chemical formula for aspirin is $C_9H_8O_4$	B. Chemical formula
i. Name the elements in aspirin:	i. Name the ele
ii. Calculate the relative formula mass of aspirin. **Relative atomic mass of C is 12** **Relative atomic mass of H is 1** **Relative atomic mass of O is 16**	ii. Calculate the of paracetam **Relative ato** **Relative ato** **Relative ato** **Relative ato**

Activity 4: Exam-style question

Lagevrio is the first antiviral medicine used to treat coronavirus. Lagevrio consists active ingredient.

Before the medicine is rolled out in the market it is tested on patients to find the

A. What is meant by optimum dose?

.....

.....

The medicine was tested on 300 patients in each group. The patients were all 24– of COVID-19 and no underlying conditions.

The table gives the results used to find the optimum dose.

Dose of molnupiravir (mg)	Number of patients cured (Group 1)	Number of patients cured (Group 2)	Number patients c (Group
200	50	53	50
400	68	71	65
800	255	243	245
1000	42	46	44

B. Calculate the mean number of patients cured when 800 mg of molnupiravir v
up to 3 sf.)

.....

.....

.....

.....

C. What is the independent variable in this experiment?

.....

D. Give one way by which scientists ensure it is a fair test.

.....

.....

Formulations

Specification reference 4.8.1.2

Activity 1: Paint job

Paint is a formulation made up of the following substances.

Describe what each substance is used for in paint.

Solvent	
Pigment	
Additive	
Binder	

Activity 2: Hair dye

Hair dyes are formulations that are used to change natural hair colour.

Fill in the gaps to describe the features of hair dye that make it fit to be used.

- The formulation of the hair colourant should be _____.
- Colourant should colour the hair _____, without any patch
- It should not _____ hair.
- The hair should not lose its _____ or _____
- It should not contain any _____ or _____
- Coloured hair should not be affected by _____, _____

Activity 3: Painkiller

Calculate the relative formula mass of the following medicine formulations.

A. Aspirin $C_9H_8O_4$	B. Paracetamol C_8H_9N

Activity 4: Exam-style question

Lagevrio is the first antiviral medicine used to treat coronavirus. Lagevrio consists active ingredient.

Before the medicine is rolled out in the market it is tested on patients to find the o

A. What is meant by optimum dose?

.....

.....

The medicine was tested on 300 patients in each group. The patients were all 24– of COVID-19 and no underlying conditions.

The table gives the results used to find the optimum dose.

Dose of molnupiravir (mg)	Number of patients cured (Group 1)	Number of patients cured (Group 2)	Numl patient (Gro
200	50	53	5
400	68	71	6
800	255	120	24
1000	42	46	4

B. Identify the anomalous result and write it down.

.....

.....

C. Calculate the mean number of patients cured when 800 mg of molnupiravir v

.....

.....

.....

.....

D. What is the independent variable in this experiment?

.....

.....

E. Give one way by which scientists ensure it is a fair test.

.....

.....

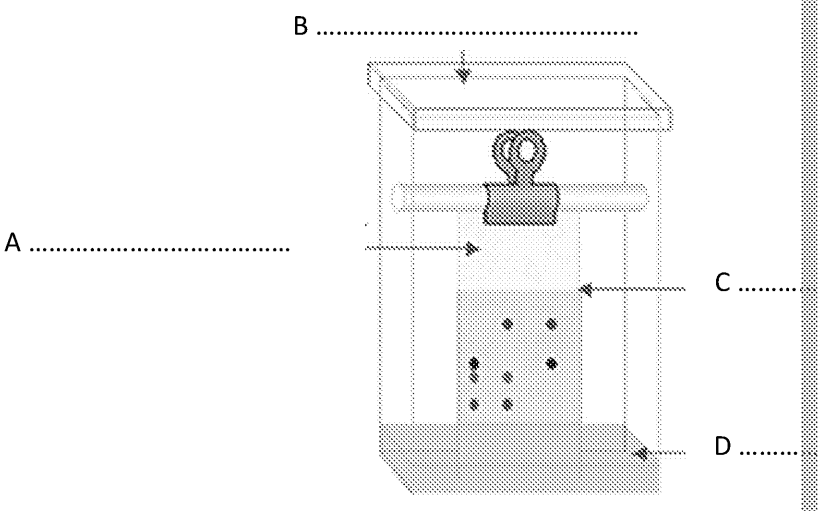
Chromatography

Specification reference 4.8.1.3

Activity 1: Label the diagram

Chromatography is a method used to separate substances.

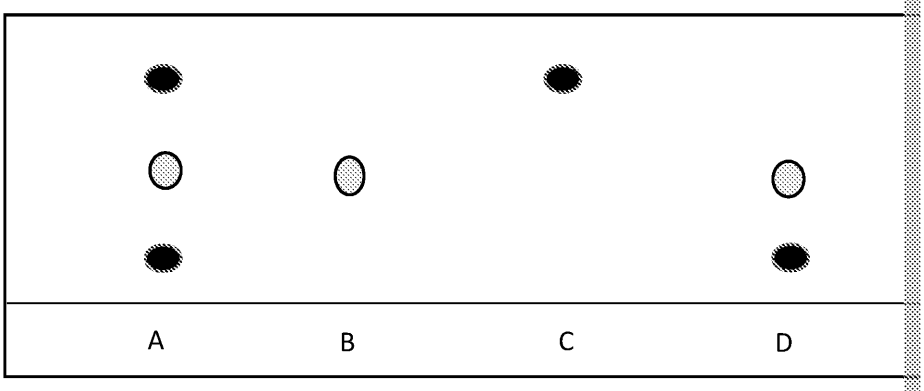
Use the following keywords to label the equipment used in this practical: *Solvent,*



Activity 2: Complete the chromatogram

A chromatogram can be used to determine whether a substance is pure or impure.
A pure substance produces only one spot.
An impure substance produces two or more spots. Substances are the same if the spots which have travelled the same distance.
Identify the substances A–D using the chromatogram.

1. A pure substance and produces a yellow spot. ☐
2. A mixture and produces red and yellow spots. ☐
3. A pure substance and produces a green spot. ☐
4. A mixture of substance C and substance D. ☐



Activity 3: R_f value

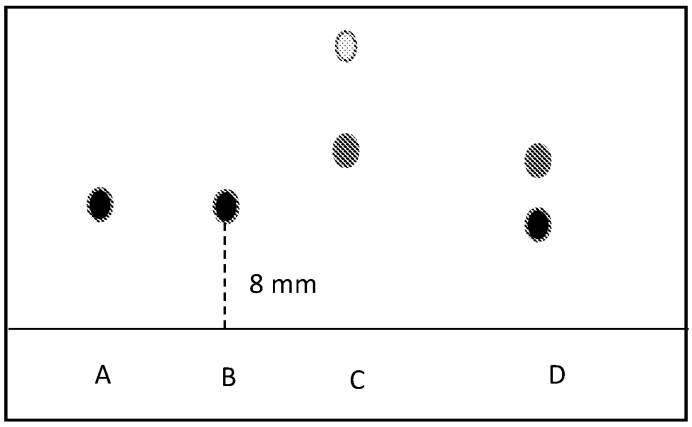
Calculate the R_f value for the substances using the formula given:

$$R_f = \frac{\textit{distance travelled by substance}}{\textit{distance travelled by solvent}}$$

	Distance (mm)	
Substance **A**	7	
Substance **B**	14	
Substance **C**	12	
Substance **D**	18	
Distance moved by solvent	39	

Activity 4: Exam-style question

A student did an investigation to find the colours mixed in food dyes.



1. Which of the substances are pure?

.....

2. Calculate the R_f value for substance B. Distance travelled by solvent is 40 mm

.....

.....

3. The line on a chromatogram is drawn with a pencil. Explain why.

.....

.....

4. Which substance is the most soluble? Give a reason for your answer.

.....

.....

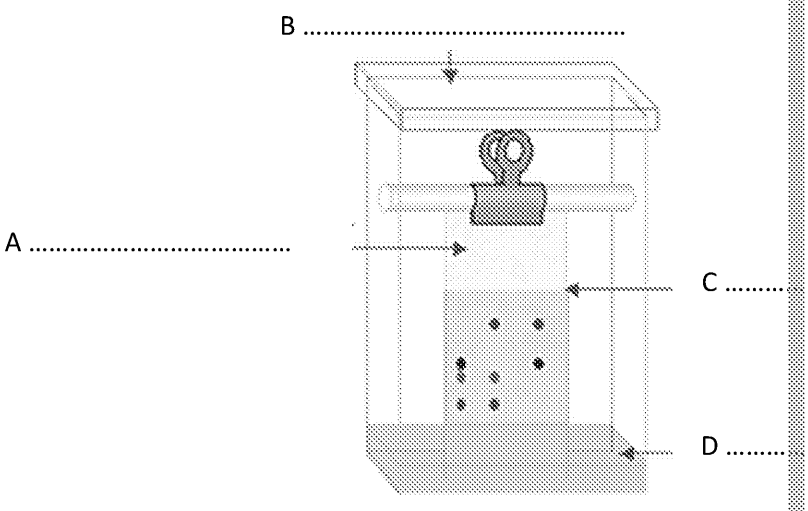
Chromatography

Specification reference 4.6.1.3

Activity 1: Label the diagram

Chromatography is a method used to separate substances.

Use the following keywords to label the equipment used in this practical: *Solvent,*

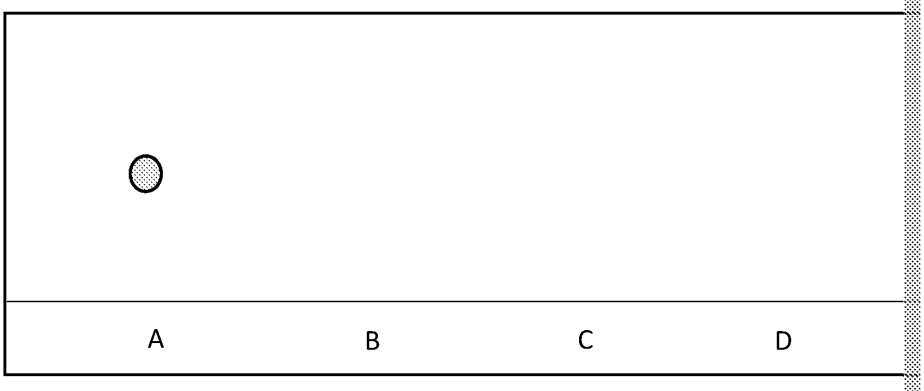


Activity 2: Complete the chromatogram

A chromatogram can be used to determine whether a substance is pure or impure
A pure substance produces only one spot.
An impure substance produces two or more spots. Substances are the same if the
spots which have travelled the same distance.

Use the information to complete the chromatogram.

1. ***Substance A is a pure substance and produces a yellow spot. (It has bee***
2. ***Substance B is a mixture and produces red and yellow spots.***
3. ***Substance C is a pure substance and produces a green spot.***
4. ***Substance D is a mixture of substance B and substance C.***



Activity 3: R_f value

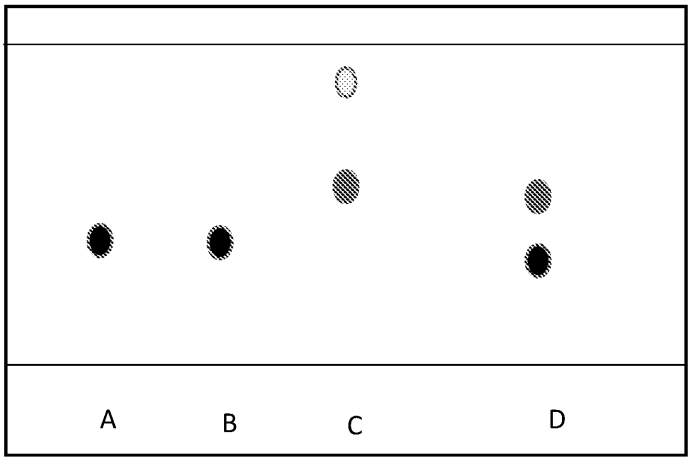
Calculate the R_f value for the substances using the formula given:

$$R_f = \frac{\textit{distance travelled by substance}}{\textit{distance travelled by solvent}}$$

	Distance (mm)	
Substance **A**	7	
Substance **B**	14	
Substance **C**	12	
Substance **D**	18	
Distance moved by solvent	39	

Activity 4: Exam-style question

A student did an investigation to find the colours mixed in food dyes.



So

1. How do we know that substances A and B are pure substances?

   .....

2. Calculate the R_f value for substance A.

   .....

   .....

   .....

3. Plan a chromatography experiment to investigate the mixtures in different fo

   .....

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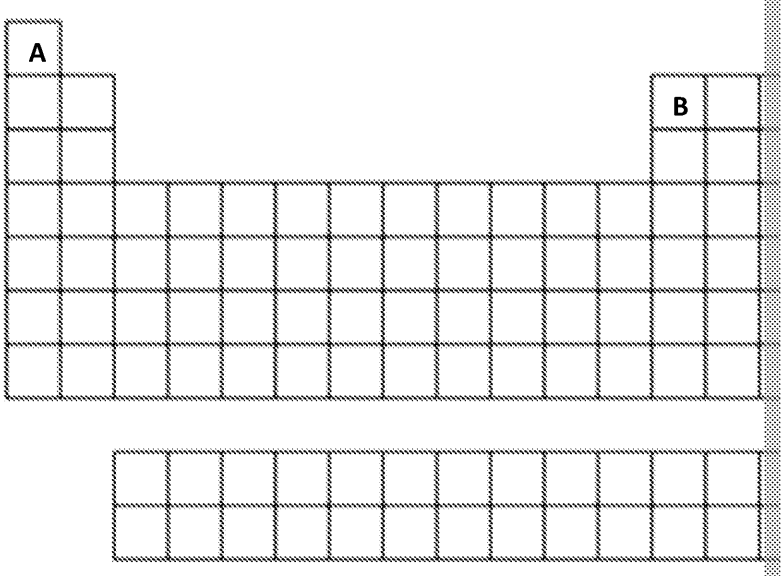
Test for gases

Specification reference 4.8.2.1–4.8.2.2

Activity 1: Identify the elements

Identify the elements (A–D) of the periodic table.



A. .....

B. .....

C. .....

D. .....

Activity 2: Identify the gases

Identify the gases by looking at the properties.

1. A lighted wood splint makes a pop sound in the presence of this gas in a test tube.	2. A glowing splint rel this gas in a test tu .....
3. Lime water turns milky in a test tube when this gas passes through.	4. This gas bleaches lit .....

Activity 3: Chemical reactions

Complete the equations for the chemical reactions.

Lithium + Water	→	Lithium hydroxide + ...
Magnesium + Hydrochloric acid	→	Magnesium chloride + ...
Methane + Oxygen	→	Water + ...
Copper carbonate heated	→	Copper oxide + ...

Activity 4: Exam-style questions

Chlorine is added to water to make it safe for drinking. Chlorine reacts with water

The chemical formula for hypochlorous acid is HOCl.

A. Calculate the relative atomic mass of hypochlorous acid.

Hydrogen-1, Oxygen-16, Chlorine-35.5

.....

.....

.....

.....

B. Give the test and result for the presence of chlorine.

.....

.....

C. Household bleach was mixed with water to make a disinfectant. Find the per
3.5 ml of bleach was made up to 100 ml of solution by adding water.

.....

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.....

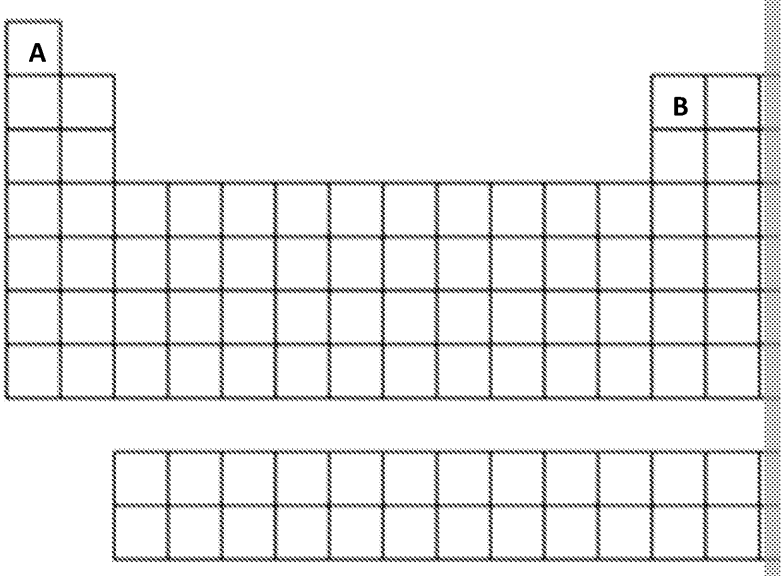
.....

Test for gases

Specification reference 4.8.2.1–4.8.2.2

Activity 1: Identify the elements

Identify the elements (A–D) of the periodic table.



A. .....

B. .....

C. .....

D. .....

Activity 2: Test for gases

Describe how to test for the gases given in the table below.

1. Oxygen Test: ..... Result:	2. Hydrogen Test: ..... Result: ....
3. Carbon dioxide Test: ..... Result:	4. Chlorine Test: ..... Result: ....

Activity 3: Chemical reactions

Write the balanced symbol equations for the chemical reactions.

Lithium + Water ⟶
Magnesium + Hydrochloric acid ⟶
Methane + Oxygen ⟶
Copper carbonate heated ⟶

Activity 4: Exam-style questions

Chlorine is added to water to make it safe for drinking. Chlorine reacts with water

The chemical formula for hypochlorous acid is HOCl.

A. Calculate the relative atomic mass of hypochlorous acid.

Hydrogen-1, Oxygen-16, Chlorine-35.5

.....

.....

.....

.....

B. Give the test and result for the presence of chlorine.

.....

.....

C. Household bleach was mixed with water to make a disinfectant. Find the per
3.5 ml of bleach was made up to 100 ml of solution by adding water.

.....

.....

.....

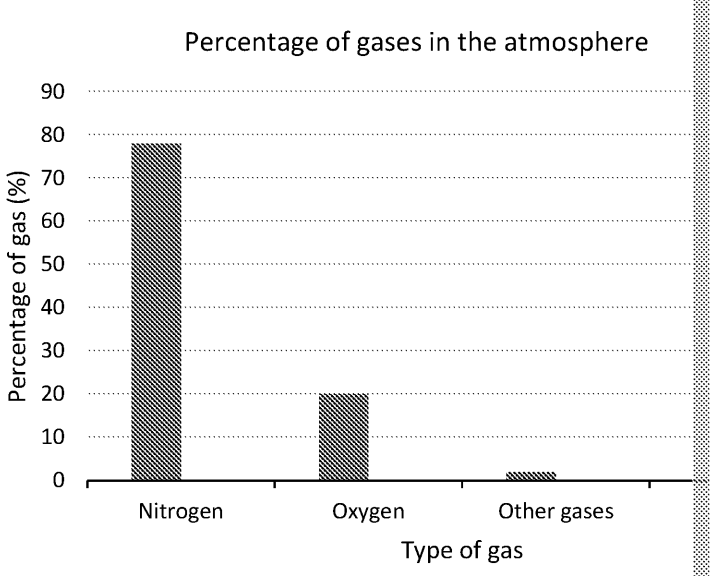
.....

The proportions of different gases in the

Specification reference 4.9.1.1

Activity 1: Gas percentage

Our atmosphere consists of a mixture of gases. The most abundant gas in the atm
Use the graph to calculate the percentage of different gases in the atmosphere.



Gas	Percentage
Nitrogen	
Oxygen	
Other gases	

Activity 2: Uses of gases

Match each gas to its use.

Nitrogen

Hydrogen

Oxygen

Carbon dioxide

Is used as a refrigerant and in fire ext

Is soluble in water and is used for oxi

Is flammable; used as rocket fuel an

Is used to make fertilisers and for rap

Activity 3: NPE

Isotopes are forms of the same elements – they have the same number of protons of neutrons.

Find the number of neutrons, protons and electrons in the following isotopes.

$^{14}_{7}N$ $^{15}_{7}N$

Isotope	Neutrons	Protons
^{14}N		
^{15}N		

Activity 4: Exam-style question

Perseverance was a man-made rover that landed on the surface of Mars to collect The atmosphere of Mars was compared to the atmosphere of Earth to determine supporting life.

Planet	Nitrogen (%)	Carbon dioxide (%)	
Earth	78	0.004	
Mars	2.8	95	

A. Name the gas most abundant on Mars.

.....

B. Name the gas least abundant on Earth.

.....

C. Compare the atmosphere of Mars with the atmosphere of Earth.

.....

.....

.....

.....

.....

.....

D. Explain why conditions on Mars are unsuitable for life.

.....

.....

.....

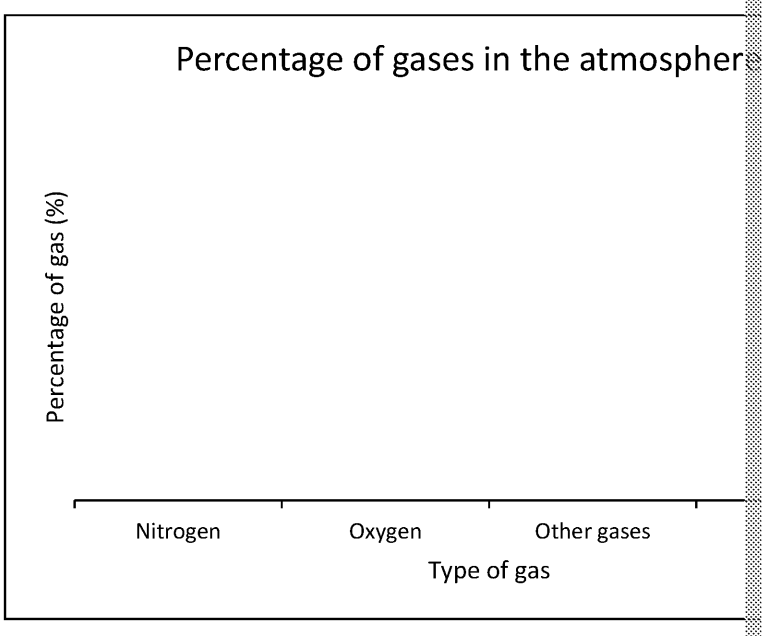
.....

The proportions of different gases in the

Specification reference 4.9.1.1

Activity 1: Gas percentage

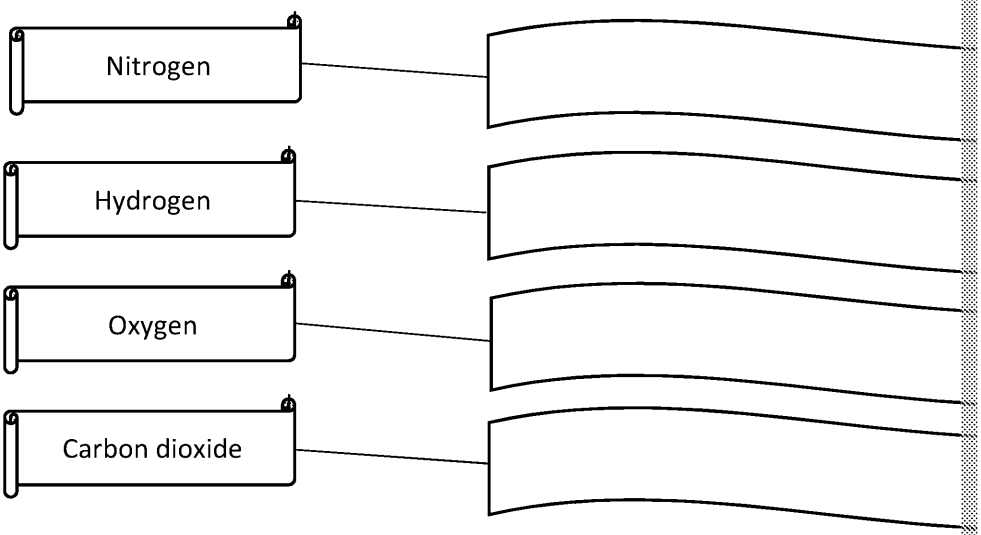
Our atmosphere consists of a mixture of gases. The most abundant gas in the atm
Use the table to plot the graph for the gases.



Gas	Percentage
Nitrogen	78
Oxygen	20
Other gases	2

Activity 2: Make them useful

Give one use of these gases found in the atmosphere.



Activity 3: NPE

Isotopes are forms of the same elements – they have the same number of protons of neutrons.

Find the number of neutrons, protons and electrons in the following isotopes.

Isotope	Neutrons	Protons
$^{14}_{7}N$		
$^{15}_{7}N$		
$^{12}_{6}C$		
$^{13}_{6}C$		
$^{14}_{6}C$		

Activity 4: Exam-style question

Perseverance was a man-made rover that landed on the surface of Mars to collect The atmosphere of Mars was compared to the atmosphere of Earth to determine supporting life.

Planet	Nitrogen (%)	Carbon dioxide (%)	
Earth	78	0.004	
Mars	2.8	95	

A. Compare the atmosphere of Mars with the atmosphere of Earth.

.....

.....

.....

.....

.....

.....

B. Explain why conditions on Mars are unsuitable for life.

.....

.....

.....

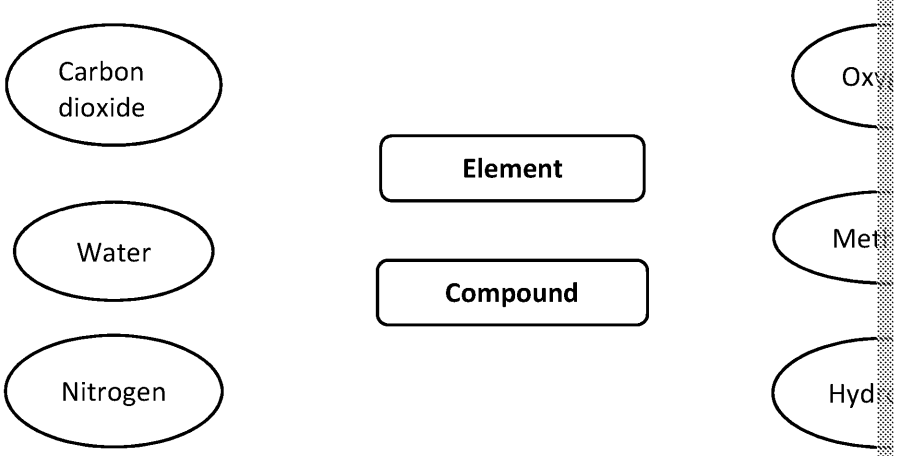
.....

Earth's early atmosphe

Specification reference 4.9.1.2

Activity 1: Match-up

Draw lines to match the substance to the correct description.



Activity 2: Earth's atmosphere

State whether the statements are true or false. Correct the false statement(s).

A. Earth's atmosphere consists of a mixture of gases.

.....

.....

B. The atmosphere consists of 20 % carbon dioxide.

.....

.....

C. Earth's atmosphere has been stable for nearly 200 million years.

.....

.....

D. Volcanic activities resulted in the production of nitrogen and water vapour.

.....

.....

Activity 3: Percent change

Use the table to calculate the percentage increase in nitrogen in Earth's atmosphe

Gas	Early Earth (ppm)	
Nitrogen	25 000	
Oxygen	1200	
Argon	18 000	
Carbon dioxide	100 000	
Other gases	500	

.....

.....

Activity 4: Exam-style question

A. The age of Earth is 4.6 billion years.
Write 4.6 billion in standard form.

.....

B. Explain how volcanic activity led to the formation of oceans.

.....

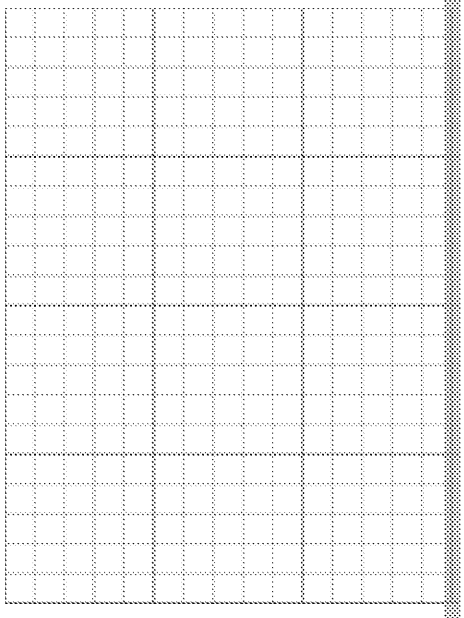
.....

.....

.....

C. In the atmosphere, nitrogen is the most abundant gas. The table gives the p
Plot the graph to show the percentage of each gas in the atmosphere.

Gas	Percentage (%)
Nitrogen	78
Oxygen	19.2
Other gases	0.8



Earth's early atmosphe

Specification reference 4.9.1.1

Activity 1: Who am I?

Identify the elements present in the atmosphere by the given properties.

A. I am a noble gas .....

B. I am a group 5 non-metal .....

C. I have six electrons in my outer shell .....

D. I bond with oxygen to form a greenhouse gas .....

Activity 2: Earth's atmosphere

State whether the statements are true or false. Correct the false statement(s).

A. Earth's atmosphere consists of a mixture of gases.

.....

.....

B. The atmosphere consists of 20 % carbon dioxide.

.....

.....

C. Earth's atmosphere has been stable for nearly 200 million years.

.....

.....

D. Volcanic activities resulted in the production of nitrogen and water vapour.

.....

.....

Activity 3: Percent change

Use the table to calculate the percentage increase in nitrogen in Earth's atmosphe

Gas	Early Earth (ppm)	
Nitrogen	25 000	
Oxygen	1200	
Argon	18 000	
Carbon dioxide	100 000	
Other gases	500	

.....

.....

Activity 4: Exam-style question

A. The age of Earth is 4.6 billion years.
Write 4.6 billion in standard form.

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B. Explain how volcanic activity led to the formation of oceans.

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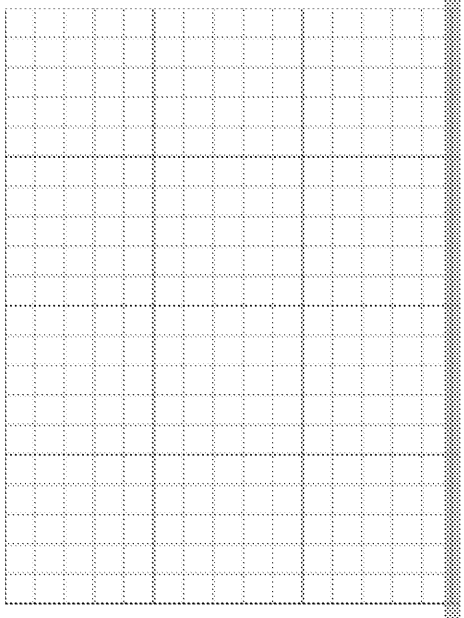


Oxygen – carbon dioxid

Specification reference 4.9.1.3-4.9.1.4

Activity 1: Oxygen levels

Oxygen was added to Earth's atmosphere about 2.7 billion years ago.

Algae produce oxygen by the process of photosynthesis.

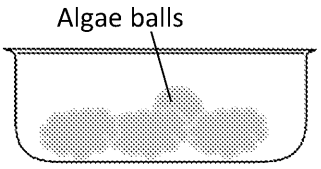
Complete the table by filling in the chemical formula and state symbol – (s), (l), (g) which take part in and are produced by photosynthesis.

The first one has been done for you:

Substance	Chemical formula	
Oxygen	O_2	
Carbon dioxide		
Water		
Glucose		

Activity 2: Photosynthesis analysis

Sienna did an experiment to measure the rate of photosynthesis in algae. She pu
measured the oxygen produced at different times of the day.
Use the results table to answer the questions.



Time of day	Oxy
04:00	
08:00	
12:00	
16:00	
20:00	

A. At what time of day is oxygen production the highest?

.....

B. At what time of day is oxygen production the lowest?

.....

C. Give a reason for the answer to A.

.....

.....

Activity 3: Equation time

Complete the word equations.

A. Carbon + Oxygen → .....

B. Hydrogen + Oxygen → .....

C. Carbon dioxide + Water → ..... + ...

D. Methane + Oxygen → ..... + ...

Activity 4: Exam-style question

A. Explain how the solubility of carbon dioxide in water led to the reduction of c

.....

.....

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.....

.....

.....

B. Carbon dioxide in the ocean was absorbed by algae. Describe the process by w

.....

.....

C. The algae were turned into fossil fuels. Describe how crude oil is formed.

.....

.....

D. Explain why the percentage of nitrogen in Earth's early atmosphere was different fr

.....

.....

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.....

Oxygen – carbon dioxid

Specification reference 4.9.1.3-4.9.1.4

Activity 1: Oxygen levels

Oxygen was added to Earth's atmosphere about 2.7 billion years ago.

Algae produce oxygen by the process of photosynthesis.

Complete the table by filling in the chemical formulae and state symbols for the s
are produced by photosynthesis.

Substance	Chemical formula	
Oxygen	O_2	
Carbon dioxide		
Water		
Glucose		

Activity 2: Fossilisation

A. Explain how the solubility of carbon dioxide in water led to the reduction of c

.....

.....

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.....

.....

.....

B. Carbon dioxide in the ocean was absorbed by algae. Describe the process by w

.....

.....

C. The algae were turned into fossil fuels. Describe how crude oil is formed.

.....

.....

D. Explain why the percentage of nitrogen in Earth's early atmosphere was different fr

.....

.....

.....

.....

Activity 3: Equation time

Write the balanced symbol equation for the following chemical reactions.

A. $C + O_2$ ⟶ .....

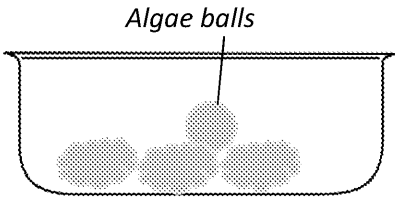
B. $H_2 + O_2$ ⟶ .....

C. $CO_2 + H_2O$ ⟶ ..... + ...

D. $CH_4 + O_2$ ⟶ ..... + ...

Activity 4: Exam-style question

Sienna did an experiment to measure the rate of photosynthesis in algae. She pu
measured the oxygen produced at different times of the day.
Use the results table to answer the questions.



Time of day
04:00
08:00
12:00
16:00
20:00

A. At what time of day is oxygen production the highest?

.....

B. At what time of day is oxygen production the lowest?

.....

C. Name two control variables in this experiment.

1. .....

2. .....

D. Identify the anomalous result from the table.

.....

Greenhouse gases

Specification reference: 4.9.2.1-4.9.2.2

Activity 1: Tick box

Tick the boxes that correspond to the answers.

1. Identify the **two** activities in the list below that increase the concentration of environment.

   Walking to school

   Farming rice in paddy fields

   Burning fossil fuels

   Growing vegetables in your garden

2. Identify the greenhouse gases from the following options.

   nitrogen, hydrogen, oxygen

   carbon dioxide, oxygen, nitrogen

   carbon dioxide, methane, water vapour

3. Temperature and carbon dioxide concentration have a strong correlation. Ti

   As carbon dioxide concentration increases, temperature increases.

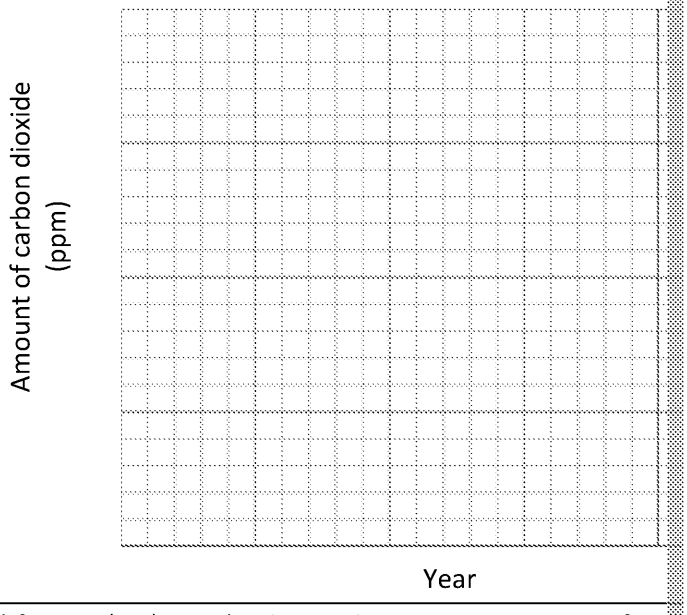
   As carbon dioxide concentration increases, temperature decreases.

   As carbon dioxide concentration increases, temperature remains the sar

Activity 2: Plot the graph

Use the table to plot the graph for the change in carbon dioxide concentration be

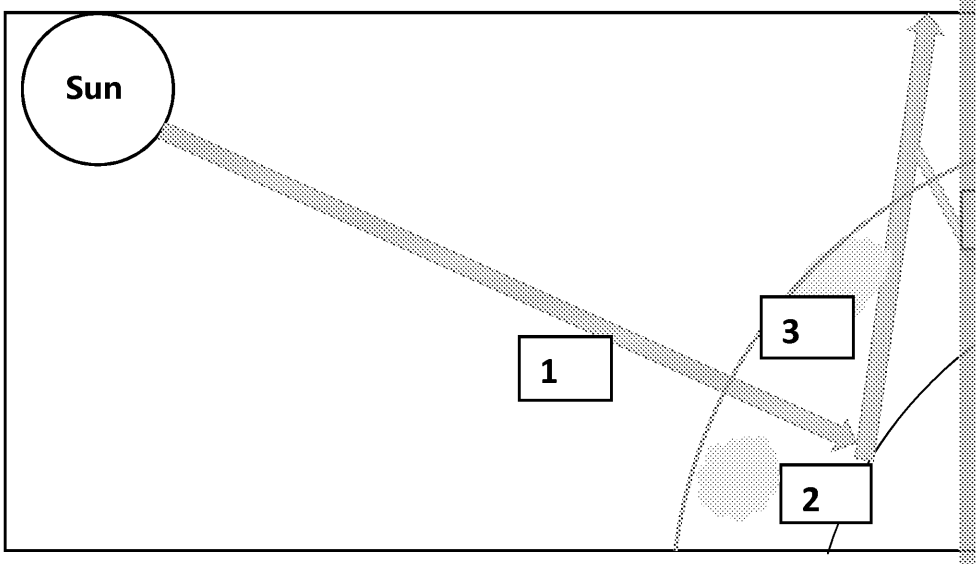
Year	Amount of carbon dioxi
1960	310
1970	320
1980	340
1990	350
2000	370



Activity 3: Add labels

Label the diagram by matching up each description (A–E) with the correspon

A. The lower atmosphere warms up
B. Earth absorbs the majority of the radiation, increasing in temperature
C. Most wavelengths of electromagnetic radiation pass through Earth's atmosp
D. Some energy is radiated from Earth as infrared radiation
E. Greenhouse gases in the atmosphere absorb some of the remaining energy



Activity 4: Exam-style question

Carbon dioxide is the gas most responsible for the greenhouse effect. An excessi
the atmosphere causes global warming.

A. Describe how we can test for the presence of carbon dioxide.

.....

.....

.....

.....

B. The percentage of carbon dioxide in the atmosphere has increased from 0.0
50 years. Give two reasons why the concentration of carbon dioxide has incr

1. .....

.....

2. .....

.....

C. The use of catalytic convertors has reduced the concentration of carbon diox
Explain how a catalytic convertor works to remove toxic gases from the envir

.....

.....

.....

.....

Greenhouse gases

Specification reference: 4.9.2.1-4.9.2.2

Activity 1: Greenhouse

1. State two activities that increase the concentration of greenhouse gases in th

   1. .....

   2. .....

2. Explain the greenhouse effect.

   .....

   .....

   .....

3. How does an increase in carbon dioxide cause global warming?

   .....

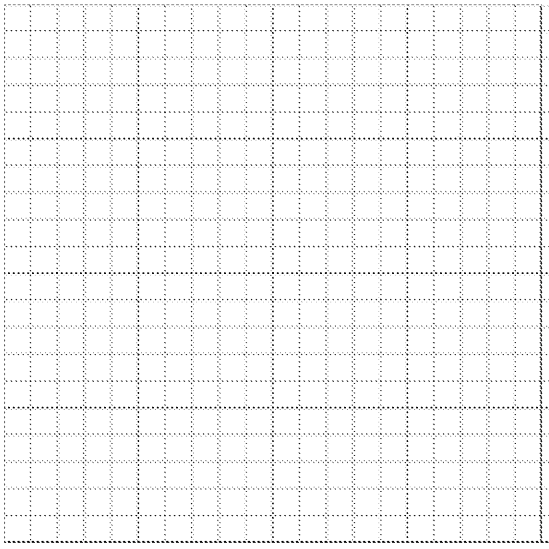
   .....

   .....

Activity 2: Plot the graph

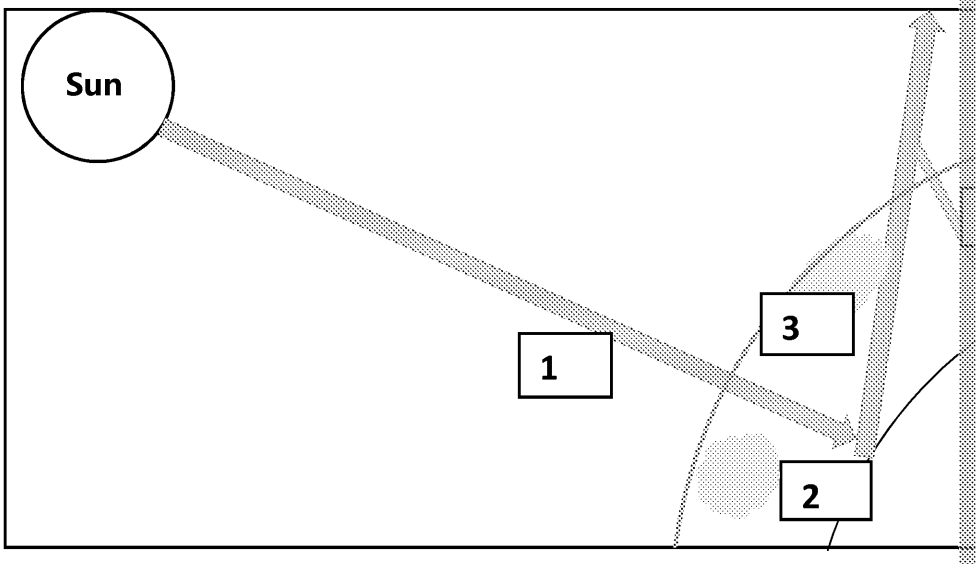
Use the table to plot the graph for the change in carbon dioxide concentration be

Year	Amount of carbon dioxi
1960	310
1970	320
1980	340
1990	350
2000	370



Activity 3: Add labels

Write the correct description for each step.



1. .....

2. .....

3. .....

4. .....

5. .....

Activity 4: Exam-style question

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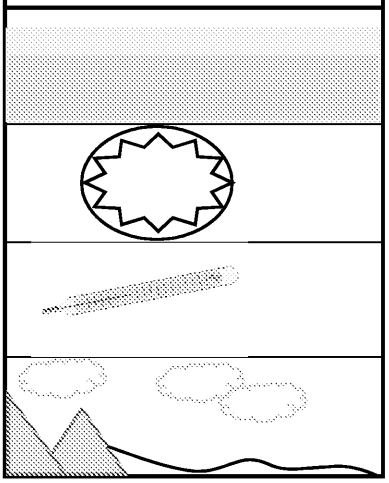
.....

Global climate change

Specification reference 4.9.2.3-4.9.3.2

Activity 1: Climate change

Increased levels of carbon dioxide as a gas since 1900 have raised Earth's average
There are different forms of evidence that can be used to measure the extent of c
Match the evidence to the corresponding diagram and description.

Evidence	Diagram	
Thermometer readings		The world's g sea levels to
Rising sea level		Average sea the last two c
Glacier retreat		Snowfall trap used to calcu previous yea
Ice core		Readings sh temperature few decades

Activity 2: Factors affecting climate change

There are several factors that affect climate change – some of the factors are natu
Put the factors into the correct category.

Agriculture	Solar output	Dumping waste in landfill	Volcanic activity	Deforestation

Natural factors affecting climate change	Human factors a

Activity 3: Alternative energy

The use of alternative energy sources reduces the use of fossil fuels.

A. State two alternatives to fossil fuels.

.....

.....

B. Describe how carbon capture reduces the amount of carbon dioxide in the a

.....

.....

C. Explain how plants remove excess carbon dioxide from the environment.

.....

.....

Activity 4: Exam-style question

The table below shows the percentage of gases in Earth's atmosphere.

Gas	Percentage of gas in Earth's early atmosphere (%)	
Nitrogen	traces	
Oxygen	traces	
Carbon dioxide	95	
Water vapour	4	

A. Which gas was the most abundant in the early atmosphere of Earth?

.....

B. State two activities which reduced the most abundant gas from Earth's early

.....

.....

C. The average temperature of Earth's early surface was 400 °C.
Explain why the temperature was so high.

.....

.....

.....

.....

.....

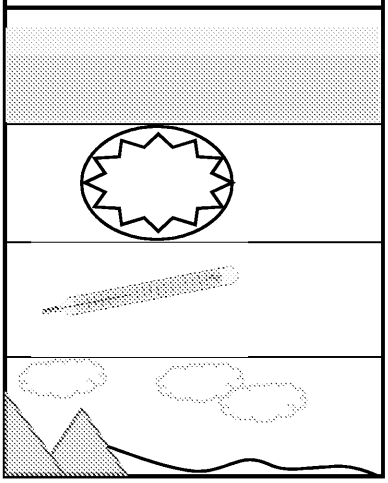
.....

Global climate change

Specification reference 4.9.2.3-4.9.3.2

Activity 1: Climate change

Increased levels of carbon dioxide as a gas since 1900 have raised Earth's average
There are different forms of evidence that can be used to measure the extent of c
Match the evidence to the corresponding diagram and write a short description fo

Evidence	Diagram	
Thermometer readings		
Rising sea level		
Glacier retreat		
Ice core		

Activity 2: Factors affecting climate change

There are several factors that affect climate change – some of the factors are natu
State **three** natural factors and **three** human factors that affect climate change.

Natural factors affecting climate change	Human factors a

Extension: Explain how these factors affect climate change.

.....

.....

.....

.....

Activity 3: Alternative energy

The use of alternative energy sources reduces the use of fossil fuels.

A. State two alternatives to fossil fuels.

.....

.....

B. Describe how carbon capture reduces the amount of carbon dioxide in the a

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Explain why the temperature was so high.

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Using Earth's resource

Specification reference 5.10.1.1

Activity 1: Renewable and non-renewable resources

Fill in the gaps in the sentences using the correct words from the box.

renewable	Haber	fractional distillation	non-renewable	sy

A. Resources which will not run out in the near future because their extraction is ... are called _____ resources.

B. Petrol and diesel are obtained from crude oil by the process of _____

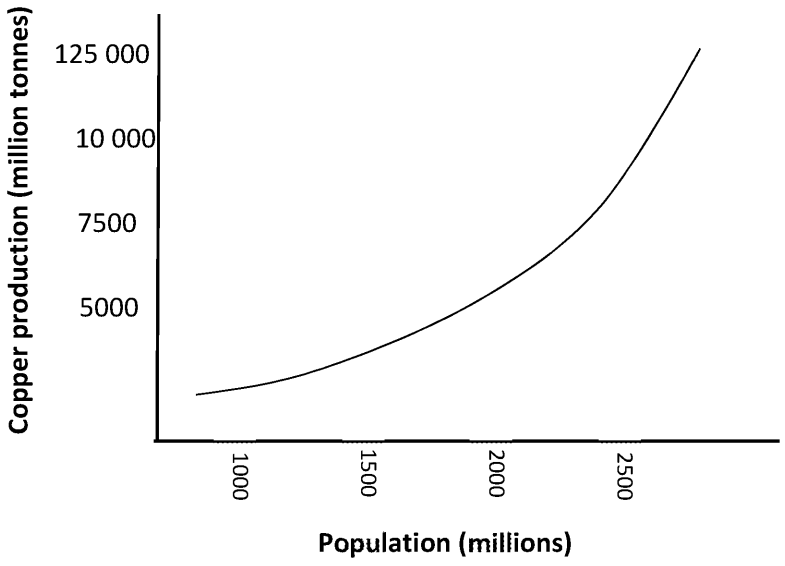
C. Crude oil is available in finite quantities so it is an example of a _____

D. Nitrogen-based fertilisers are now produced synthetically by the _____

E. Substances made by processes that do not occur naturally are called _____

Activity 2: Copper production

As the population of Earth increases, the more resources are being used by indivi...
The graph tells us the relationship between use of resources and increase in popu...



A. There is a correlation between population and copper production.
What is meant by a correlation?

.....

.....

B. Explain why copper production increased over time.

.....

.....

C. Give two uses of copper.

1. .....

2. .....

D. Copper is less reactive than many metals. State two metals that are more rea

.....

.....

Activity 3: Sustainable development

'Sustainable development is a type of development whereby the needs of th
without compromising the potential of future generations to m

Write a paragraph on the importance of sustainable development. Use the keywo

people	planet	community	ecosystem	

.....

.....

.....

.....

.....

.....

Activity 4: Exam-style question

A. Copper is extracted from ores cuprite by mining and smelting. Find the perc
(Cu) in cuprite (Cu_2O).

Cu = 63.5 **O = 16**

.....

.....

.....

.....

B. State three properties of copper that make it suitable to be used in wiring.

.....

.....

.....

C. Explain the steps of extracting copper by phytomining.

.....

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.....

Using Earth's resource

Specification reference 5.10.1.1

Activity 1: Renewable and non-renewable resources

Make a glossary of the following terms:

Renewable resources

.....

.....

Fractional distillation

.....

.....

Haber process

.....

.....

Synthetic substances

.....

.....

Activity 2: Copper production

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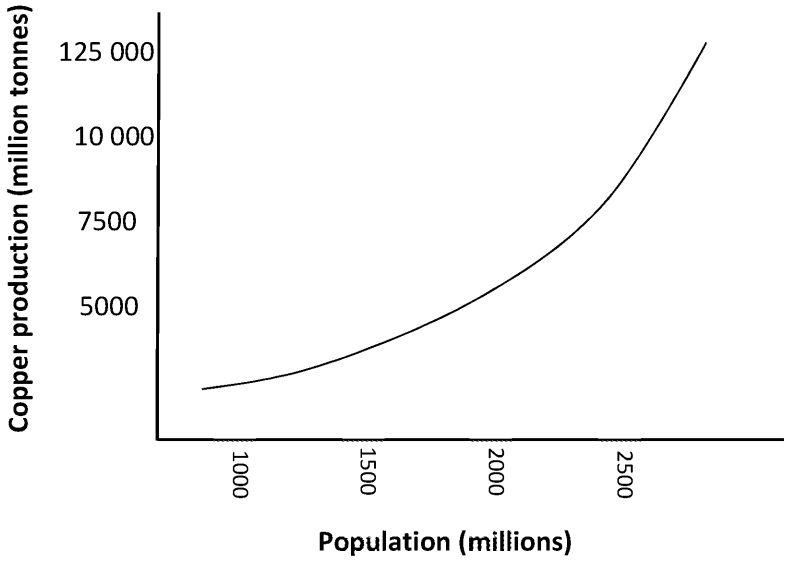

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C. Explain the steps of extracting copper by phytomining.

.....

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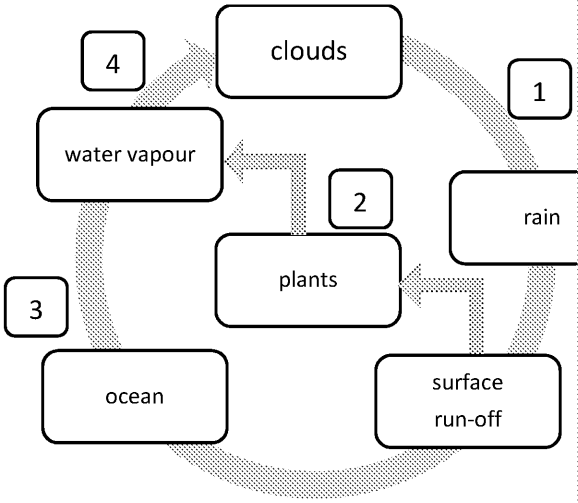
Potable water

Specification reference 5.10.1.2

Activity 1: Water cycle

Label the processes in the water cycle using the following keywords:

Evaporation	Condensation	Precipitation	



1 .....

2 .....

3 .....

4 .....

Activity 2: Pure water

Pure water can be obtained by desalination.
Complete the two methods of purification of water using the words provided.

water	membrane	high	potable	condensed	steam	eva

Distillation	Rev
Seawater is heated until it _____ . Water _____ and the salt remains, and the _____ is pure water. The steam is cooled and _____ to make _____ water.	Water under _____ through a _____ pores. _____ m membrane, but most _ pass through.

Activity 3: Waste water treatment

Put the steps of waste water treatment in the correct order.

A.	Sewage sludge is digested anaerobically by bacteria	
B.	Effluent enters an aeration tank; oxygen is pumped into water	
C.	Screening is done to remove large particles	
D.	Aerobic bacteria break down the waste	
E.	Sedimentation produces sewage sludge and effluent	

Activity 4: Exam-style question

A. Water that is safe for drinking is called .....

B. Water is a compound formed from hydrogen and oxygen.
Calculate the relative formula mass of water.

H – 1 **O – 16**

.....

.....

.....

.....

C. Groundwater consists of some soluble solutes.
Write a method for measuring the mass of impurities dissolved in 10 ml of w

.....

.....

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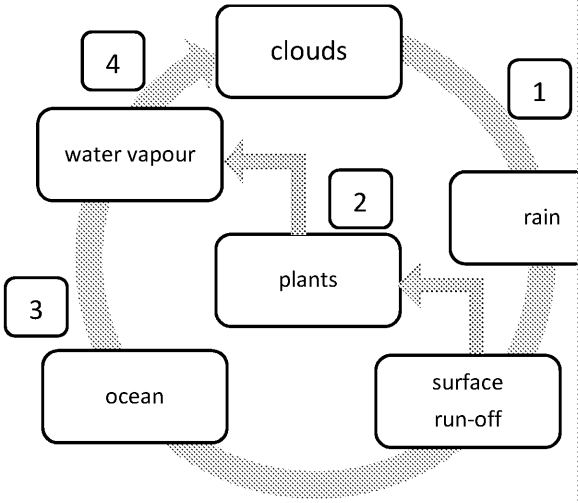
Potable water

Specification reference 5.10.1.2

Activity 1: Water cycle

Label the processes in the water cycle using the following keywords:

Evaporation	Condensation	Precipitation



1 ..... 3 .....

2 ..... 4 .....

Activity 2: Pure water

Pure water can be obtained by desalination.
Describe the two methods of purification of water.

Distillation	Rev
.....	.....
.....	.....
.....	.....
.....	.....
.....	.....
.....	.....

Activity 3: Waste water treatment

Put the steps of waste water treatment in the correct order.

A. Sewage sludge is digested anaerobically by bacteria	
B. Effluent enters an aeration tank; oxygen is pumped into water	
C. Screening is done to remove large particles	
D. Aerobic bacteria break down the waste	
E. Sedimentation produces sewage sludge and effluent	

Activity 4: Exam-style question

A. Water that is safe for drinking is called .....

B. Water is a compound formed from hydrogen and oxygen.
Calculate the relative formula mass of water.

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Answers

Calculating rate of reaction

Activity 1: Label the equipment

A. Conical flask
B. Syringe
C. Bung

A. Conical flask
B. Gas syringe/ Syringe
C. Bung
D. Calcium carbonate / R

Activity 2: Matchmaking

A. 4 cm^3/s
B. 3 cm^3/s
C. 1 cm^3/s
D. 0.25 g/s

Activity 2: Calculate me if you can

A. 4 cm^3/s
B. 0.75 cm^3/s
C. 1 cm^3/s
D. 0.25 g/s
E. 48 000 cm^3
F. One mole / 1 mol

Activity 3: Graph it!

A. 36 cm^3
B. 0.1 cm^3/s (or 6 cm^3/min)
C. 0.0458 cm^3/s (or 2.75 cm^3/min)
D.

A The reaction is fastest
B The reaction is slowest
C The reaction is complete

A. 36 cm^3
B. 0.1 cm^3/s (or 6 cm^3/m
C. 0.0458 cm^3/s
D. Point A because the gr
E. Time
F. Volume of gas released

Activity 4: Exam style-question

A. $CaCO_3 + \underline{2}HCl \longrightarrow CaCl_2 + CO_2 + H_2O$ [1]
B. 40 cm^3 [1]
C. i. x-axis (time in seconds) [1], y-axis (volume of gas) [1]
ii. All points correctly plotted [1]

A. $CaCO_3$
B. 40 cm^3
C. i. x-
y-
ii. A
iii. L

Factors affecting rate of reaction

Activity 1: Open the lock with the correct keyword / Match the co

A. Reactant
B. Product
C. Catalyst
D. Concentration
E. Precipitate

Activity 2: Tick the correct answer

A. be faster
B. $H_2(g)$

Activity 3: Increase or decrease?

A. 

B. 

C. 

D. 

E. 

F. 

Activity 3: Factors that matter

A. At 50 °C the rate of reaction will be faster as particles have more energy and will co
higher energy.
B. Smaller particle size has larger surface area providing more area for collisions / m
rate of reaction.
C. (s) solid (aq) aqueous (solvent is water)
(l) liquid (g) gas

Activity 4: Equation time

A. At 50 °C the rate of reaction will be faster as particles have more energy and will col
B. (s) solid (aq) aqueous (solvent is water)
(l) liquid (g) gas
C. Drawing should show eight or more particles of Reactant 1 or five or more particle

Activity 4: Predict the effect

- Increasing the concentration of reactants increases the frequency of collisions, the
- Increasing the temperature of the reacting gases increases the frequency (and ener
rate of reaction.
- Increasing the surface area of solid reactants increases the frequency of collisions,

Activity 5: Exam-style question

A. Sulfur is formed, which is a precipitate [1]
B. 11 s [1]
C. 31 s (exclude anomaly) [1]
D. Time set 3 at 30 °C [1]
E. Conical flask – to hold the solution; measuring cylinder – to measure the volume of
temperature; stopwatch – to measure time [2 for all, 1 if one missing / not explaine

A. Sulfur is formed, which is a precipitate [1]
B. Time set 3 at 30 °C [1]
C.

Temperature (°C)	Mean time (s)
20	60
30	31
40	22
50	10

[2 for all, 1 if one wrong]

D. Independent variable – temperature [1]
Dependent variable – time [1]
E. **Level 3: Steps are written logically and clearly, in the correct sequence.**
Level 2: Most steps are written but are not logically sequenced.
Level 1: Some steps are written, but there is no valid outcome.

1. Use a measuring cylinder to add 50 cm^3 of dilute sodium thiosulfate solution
2. Draw a black cross on a piece of paper and place the conical flask on it.
3. Add 10 cm^3 of dilute hydrochloric acid to the conical flask – use a different m
4. Swirl the flask to mix and start a stop clock.
5. Record the time on the stop clock when the cross is no longer visible.
6. Measure and record the temperature of the reaction mixture.
7. Repeat the experiment at different starting temperature of reactant.

Catalyst and collision theory

Activity 1: Label the diagram

A. Reactant
B. Product
C. Activation energy with catalyst
D. Activation energy without catalyst
E. Overall energy released in a reaction

Activity 2: Glossary tessellates

	Keywords	Definition
1.	Collision theory	Reaction takes place when reactant molecules collide
2.	Enzymes	Biological molecules that speed up the rate of reaction
3.	Catalytic convertor	Contains platinum and rhodium; helps to reduce the r exhaust pipe
4.	Reaction profile	Chart showing how the energy of reactants and produ
5.	Reaction pathway	The steps in a reaction required to produce a product
6.	Decomposition reaction	The reaction in which a reactant breaks down into tw
7.	Catalyst	A substance that changes the rate of a chemical reaction
8.	Activation energy	Minimum amount of energy that colliding particles m

Activity 3: Rock star (Activity 2)

A. $CaCO_3 + 2\ HCl \longrightarrow CaCl_2 + H_2O + CO_2$
B. Experiment set 2
C. Smaller surface-area-to-volume ratio, greater exposed surface, more frequent colli

Activity 3: Industrial processes

Reaction	Equation	Catalys
Haber process	$N_2 + H_2 \longrightarrow NH_3$	Iron
Contact process	$2SO_2 + O_2 \rightleftharpoons 2SO_3$	Vanadium
Decomposition of hydrogen peroxide	$2H_2O_2 \longrightarrow 2H_2O + O_2$	Manganese d

Activity 4: Exam-style question

A. A substance that changes the rate of a chemical reaction [1] without being used up
B. Chemical C [1]
C. Product is formed in shortest time, 15 seconds [1]
D. Platinum is very expensive but it is spread very thinly so is used in minimal quanti energy [1] but does not get used up in the chemical reaction. [1]

A. Catalyst lowers activation energy without being used in the reaction itself [1]
B. Chemical C [1]
C. Product is formed in shortest time, 15 seconds [1]
D. It is the control set [1]
E. Platinum is very expensive but it is spread very thinly so is used in minimal quanti energy [1] but does not get used up in the chemical reaction. [1]

Reversible reaction and energy changes

Activity 1: Label the apparatus

A. Beaker
B. Tripod
C. Bunsen burner
D. Heatproof mat

Activity 2: Dual coding

A. Reaction in which the products of the reaction can react together to produce the re
B. Substance containing no water
C. Reaction in which energy is taken in from the surroundings
D. Reaction in which energy is released into the surroundings

Activity 2: Short questions

A. $N_2 + 3H_2 \rightleftharpoons 2NH_3$
B. It is a catalyst
C. It goes back to the pump / is recycled
D. More ammonia will be produced if the temperature decreases
E. From air
F. Any sensible question

Activity 3: True or false?

A. True
B. False – A catalyst does not get used up in the reaction
C. True
D. False – **A + B ⇌ C + D**
E. False – Rate of reaction increases when temperature increases
F. True

Activity 4: Exam-style question

A. Forward reaction takes place when hydrated copper sulfate is heated [1] – energy is absorb
B. By adding water [1]
C. i. 0.3 g [1]
ii. Water is evaporated [1]

A. The reactions in which the product of the reaction can react [1] to produce reactan
B. The reverse reaction takes place when water is added to anhydrous copper sulfate reaction is exothermic [1]
C. i. 1.07 g [1]
ii. Water is evaporated [1]

Equilibrium

Activity 1: Match the cards

1. Equilibrium	C. Rate of forward reaction is same as rate
2. A + B ⇌	E. C + D
3. Closed system	B. No chemical can move in or out
4. Pressure	A. Force applied per unit area
5. Yield	D. Amount of product obtained

Activity 2: Tick it

A. Reactant
B. Reversible
C. SO_3
D. Decreases
E. A reversible reaction takes place in a closed system
F. Exothermic

Activity 3: Think and answer (Activity 2)

A. Because the reaction is endothermic, energy is absorbed
B. To prevent ammonium chloride particles from escaping
C. Ammonium chloride ⇌ Ammonia + Hydrogen chloride
D. The forward reaction and the backward reaction happen at the same rate in a close

Activity 3: Shade the area (HT only)

Equilibrium	Energy change (forward reaction)	Temperature increase	
		Reactant increases	Product increases
A(g) + B(g) ⇌ C(g) + 2D(g)	endothermic		
A(g) ⇌ B(g) + C(g) + D(g)	exothermic		
A(g) + C(g) + D(g) ⇌ B(g)	endothermic		
A(g) + B(g) ⇌ 3C(g) + D(g)	exothermic		
2B(g) ⇌ C(g)	endothermic		

Activity 4: Exam-style question

A. Temperature, pressure and concentration [1]
B. $H_2 + I_2 \rightleftharpoons 2\ HI$ [1]
C. More hydrogen iodide will be produced [1] when temperature decreases [1] as the reverse logic)

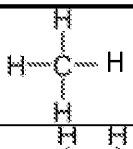
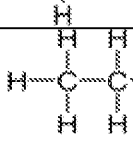
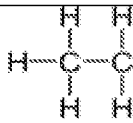
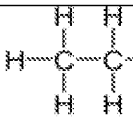
A. Temperature, pressure and concentration [1]
B. $H_2 + I_2 \rightleftharpoons 2\ HI$ [1]
C. More product will be formed, more hydrogen iodide produced [1]
D. More hydrogen iodide will be produced when temperature decreases as the reactio
E. Yield of product decreases [1] when temperature increases [1]

Crude oil, hydrocarbons and alkanes

Activity 1: What am I?

1. C
2. F
3. E
4. B
5. D
6. A

Activity 2: Table talk (Activity 1)

Number of carbon atoms	Alkane	Molecular formula	
1	Methane	CH_4	
2	Ethane	C_2H_6	
3	Propane	C_3H_8	
4	Butane	C_4H_{10}	

Activity 2: Word search

	1.H			2.C		6. S					
	Y			R		I		3. M		8. B	
	D			U		X		E		I	
	R			D		7. P	E	T	R	O	L
	O		5. F	E				H		M	
	C			O				A		A	
	A			I	U			N		S	
	R			L		R		E		S	
	B										
4. B	O	I	L	I	N	G	P	O	I	N	T
	N										

Activity 3: Mnemonic

Any mnemonic including all the fractions

Activity 4: Exam-style question

A. -42 (any value between -20 and -60) [1]
B. Pentane [1]
C. As the number of carbon atoms increases the boiling point increases [1]
D. All points correctly plotted [2 for all, 1 if one wrong]

A. Methane/Ethane/Propane/Butane (name any one) [1]
B. -42 (any value between -20 and -60) [1]
C. As the number of carbon atoms increases the boiling point increases [1]
D. All points correctly plotted [2 for all, 1 if one wrong]

Fractional distillation and petrochemicals

Activity 1: Label the diagram

1. F
2. E
3. D
4. H
5. G
6. C
7. A
8. B

A. 25
B. 350
C. Liquefied petroleum g
D. Petrol
E. Diesel
F. Bitumen
G. Cool
H. Hot

Activity 2: Code breaker (Activity 3)

A. Petrol – Fuel for cars and motorcycles
B. Diesel – Fuel for some cars and trains
C. Methane – Fuel for domestic heating and cooking
D. Hydrocarbon – Made of hydrogen and carbon only
E. Evaporation – Takes place at boiling point
F. Bitumen – Used to make road surfaces
G. Crude oil – Mixture of hydrocarbons

Activity 2: Cut and rearrange

1.	Crude oil mixture is heated to about 350 °C, creating a temperature gradient in th cool at the top and hot at the bottom.
2.	Some of the hydrocarbons remain as liquids and flow to the bottom of the fractio
3.	Some of the crude oil is evaporated.
4.	Vapours rise up the fractionating column and condense at different temperatures
5.	Gases flow out through a pipe.

Activity 3: Gap fill

A. fractional distillation
B. 350 °C
C. liquid, bottom
D. evaporates
E. cool, hot
F. condense

Activity 4: Exam-style question

A. Fractional distillation [1]
B. 80.95 % [1]
C. Mixture of ethanol and water can be separated using fractional distillation. [1] temperature (80 °C) than water. [1] The ethanol vaporises. [1] Water has a boi water remains a liquid. [1]

Properties of hydrocarbons

Activity 1: Tick-tock

Property	Methane	Bu
Higher boiling point		
Less viscous	✓	
Burns with a clean flame	✓	
Easily flammable	✓	

Activity 1: Properties of hydrocarbons

Chain length	Viscosity	Flammability	Boiling point
C1 ↓ increase ↓ C6	↓	↑	↓

Activity 2: Products of combustion

1. carbon dioxide and water
2. water
3. blue to pink
4. carbon dioxide
5. clear to cloudy

- The products of combustio
- Cobalt chloride paper can
- It changes colour from pin
- Lime water is used to test changes from clear to clou

Activity 3: Balancing act

A. $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

B. $C_2H_6 + 7/2\ O_2 \longrightarrow 2CO_2 + 3H_2O$ / $2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$

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

D. $C_4H_{10} + 13/2\ O_2 \longrightarrow 4CO_2 + 5H_2O$ / $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$

Activity 4: Exam-style question

1. Two from: larger hydrocarbons are viscous, difficult to ignite and burn with a soot
2. Conical flask [1]
3. Flammable [1]
4. a. 29.5 seconds (ignore anomaly) [1]
   b. To improve accuracy, to identify anomaly, to take a mean (any two) [1]
   c. One from: wear goggles, do not heat over direct flame [1]

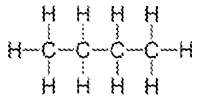
1. Two from: larger hydrocarbons are viscous, difficult to ignite and burn with a soot
2. Conical flask [1]
3. Flammable [1]
4. a. 29.5 seconds (ignore anomaly) [1]
   b. By repeating the experiment [1]
   c. Wear goggles, [1] do not heat over direct flame [1]

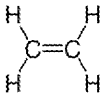
Cracking and alkenes

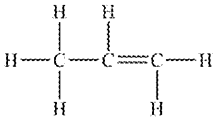
Activity 1: Mind the gap

1. cracking
2. alkane
3. alkane, alkene (either order allowed)
4. catalyst, high temperature
5. thermal decomposition

Activity 2: Who am I?

1. 

2. 

3. 

Activity 3: Balance the equation

1	$C_6H_{14} \longrightarrow C_3H_8 + C_3H_6$
2.	$C_{10}H_{22} \longrightarrow C_7H_{16} + C_3H_6$
3.	$C_{16}H_{34} \longrightarrow C_{13}H_{28} + C_3H_6$
4.	$C_{20}H_{42} \longrightarrow C_{17}H_{36} + C_3H_6$
5.	$C_{25}H_{52} \longrightarrow C_{22}H_{46} + C_3H_6$

Activity 4: Exam-style questions

1. Petrol, gases – used as fuel (any lighter hydrocarbons with their uses) [1]
   Alkenes – used as feedstock to manufacture chemicals, plastics and other petroche
2. C_nH_{2n} [1]
3. When bromine water is added to the solution [1] it changes from orange to colourl
4. Large alkanes vaporise [1], pottery pieces act as catalyst [1]
   Large hydrocarbon chain is broken into smaller alkanes, which are more useful [1]

1. Hydrocarbons are compounds of hydrogen and carbon only [1]
2. C_nH_{2n} [1]
3. When bromine water is added to the solution [1] it changes from orange to colourl
4. Large alkanes vaporise [1], pottery pieces act as catalyst [1]
   Large hydrocarbon chain is broken into smaller alkanes, which are more useful [1]

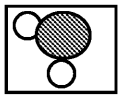
Pure substances

Activity 1: Elements, mixtures and compounds

A. E – element
B. E – element
C. C – compound
D. C – compound
E. M – mixture
F. C – compound
G. M – mixture
H. C – compound
I. E – element

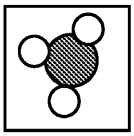
A. Element
B. Element
C. Compound
D. Compound
E. Mixture
F. Compound
G. Mixture
H. Compound
I. Element

Water



Mixture of elements and cor

NO_3



Activity 2: State change

1. Melting
2. Freezing
3. Sublimation
4. Deposition
5. Evaporation/boiling
6. Condensation

Activity 2: State at room temperature

Substance	State at room temperature (25 °C)
A	Liquid
B	Gas
C	Liquid
D	Solid
E	Liquid

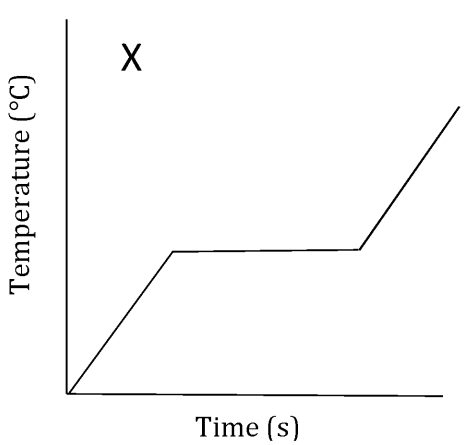
Activity 3: The cooling curve

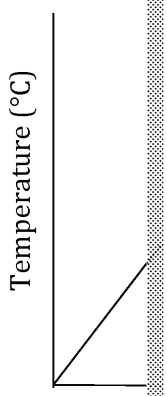
All points correctly plotted
Flat lines showing change of state (boiling point: 70; melting point: 30)

Activity 4: Exam-style question

a. A pure substance consists of only one type of element or compound [1]
b. X – pure substance
Y – impure substance [1]
c. Add 100 cm^3 **water** into the **beaker**. [1]
Put the Bunsen burner on a heatproof mat.
Put the beaker on a **tripod** and **gauze**. [1]
Wait until the water just starts to **boil**. [1]
Put the test tube containing **stearic acid** in the beaker and start the **timer**. [1]
Record the **temperature** of the **stearic acid** every minute until it reaches about 70
starts to **melt**. [1]
Lift the test tube from the hot water.
Record the temperature every minute until it reaches about 50 °C. Note the tempe
solidify. [1]

a. A pure substance consists of only one type of element or compound [1]
b.





c. The method for the practical is:
1. Add 100 cm^3 water into the beaker. [1]
2. Put the Bunsen burner on a heatproof mat and put the beaker on a tripod and
3. Wait until the water just starts to boil and put the test tube containing stearic
timer. [1]
4. Record the temperature of the stearic acid every minute until it reaches abou
solid starts to melt. [1]
5. Lift the test tube from the hot water. [1]
6. Record the temperature every minute until it reaches about 50 °C. Note the t
begins to solidify. [1]

Formulations

Activity 1: Match up

Solvent – B – Used as a base for dissolving substances
Salt – D – Used as a flavour enhancer
Preservative – A – Used to increase the shelf life of edible products
Fragrance – E – Used to give scent to a product
Dye – C – Used to give colour to paint

Activity 1: Paint job

Solvent: Used as a base for dissolving substances
Pigment: Used to give colour to paint
Additive: Used to change the properties of paint
Binder: Holds the dye in place after painting

Activity 2: Formulations

A. A pure substance is made of only one substance; a formulation is made up of differen quantities.
B. Two from: medicines/paint/foods/alloys/perfumes, etc. with uses, e.g. dyes used i sunscreen to keep the skin hydrated / salt in processed food to enhance flavour

Activity 2: Hair dye

- The formulation of the hair colourant should be **stable**.
- Colourant should colour the hair **evenly**, without any patches.
- It should not **damage** hair.
- The hair should not lose its **shine** or **moisture**.
- It should not contain any **irritants** or **toxic** substances.
- Coloured hair should not be affected by **water**, **light** or **oxygen**.

Activity 3: Painkiller

A. i. Carbon, Hydrogen, Oxygen
ii. (12 × 9) + (1 × 8) + (16 × 4)
= 108 + 8 + 64
= 180
B. i. Carbon, Hydrogen, Nitrogen, Oxygen
ii. (12 × 8) + (1 × 9) + (14 × 1) + (16 × 2)
= 96 + 9 + 14 + 32
= 151

A. (12 × 9) + (1 × 8) +
= 108 + 8 + 64
= 180
B. (12 × 8) + (1 × 9) +
= 96 + 9 + 14 + 32
= 151

Activity 4: Exam-style question

A. A dose of medicine that produces desired results [1]
B. 743/3 [1] = 247.66 [1] (answer to 3 sf = 248) [1]
C. Dose of molnupiravir in mg [1]
D. One from: [1]
Same number of people in each group
All patients had mild symptoms
All patients were in the same age range
None of them had any underlying conditions

A. A dose of medicine that produces desired results [1]
B. 120 is anomalous because it does not follow the trend [1]
C. 255 + 245/2 [1] = 250 (do not include the anomalous result) [1]
D. Dose of molnupiravir in mg [1]
E. Any one: [1]
Same number of people in each group
All patients had mild symptoms
All patients were in the same age range
None of them had any underlying conditions

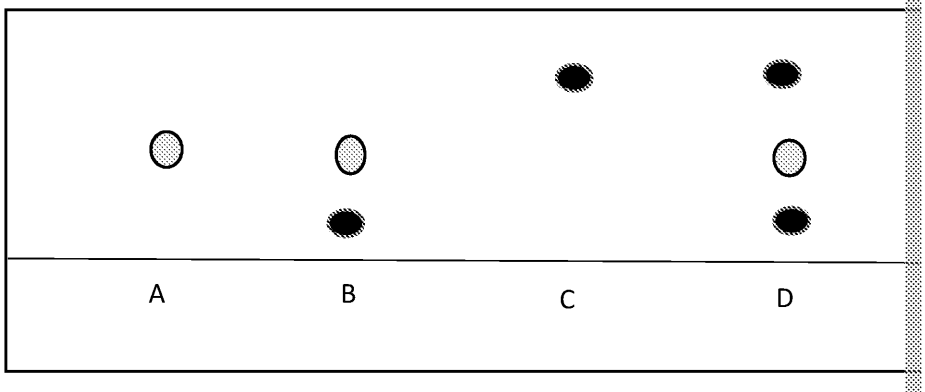
Chromatography

Activity 1: Label the diagram

A. Paper
B. Lid
C. Solvent front
D. Solvent

Activity 2: Complete the chromatogram

1. B
2. D
3. C
4. A



Activity 3: R_f value

	R_f value
Substance A	0.18
Substance B	0.36
Substance C	0.31
Substance D	0.46

Activity 4: Exam-style question

1. Substances A and B are pure substances [1]
2. 8/40 [1] = 0.2 [1]
3. The line is drawn in pencil so that it does not smudge when the paper is put in wat
4. C [1] because the ink travels the furthest [1]

1. Substances A and B produce only one spot [1]
2. Distance between line and spot B [1] divided by distance between line and solvent and calculated) [1]
3.
   - Draw a pencil line on the chromatography paper and place one dot of each fo
   - Place the chromatography paper in a solvent, with the pencil line above the s rise [1]
   - When the solvent is near the top of the paper, remove the paper from the sol
   - Compare positions of dots of food dyes [1]

Test for gases

Activity 1: Identify the elements

A. Hydrogen
B. Carbon
C. Oxygen
D. Chlorine

Activity 2: Identify the gases

1. Hydrogen
2. Oxygen
3. Carbon dioxide
4. Chlorine

Activity 2: Test for gases

1. **Oxygen:** A glowing splint relights in the presence of this gas in a test tube.
2. **Hydrogen:** A lighted wood splint makes a pop sound in the presence of this gas in
3. **Carbon dioxide:** Lime water turns milky in a test tube when this gas passes throug
4. **Chlorine:** This gas bleaches litmus paper.

Activity 3: Chemical reaction

Lithium + Water →	Lithium hydroxide + Hydro
Magnesium + Hydrochloric acid →	Magnesium chloride + Hyd
Methane + Oxygen →	Water + Carbon dioxide
Copper carbonate heated →	Copper oxide + Carbon dio

1. $Li(s) + H_2O(l) \rightarrow LiOH(s) + H_2(g)$
2. $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
3. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
4. $CuCO_3(s) + \Delta \rightarrow CuO(s) + CO_2(g)$

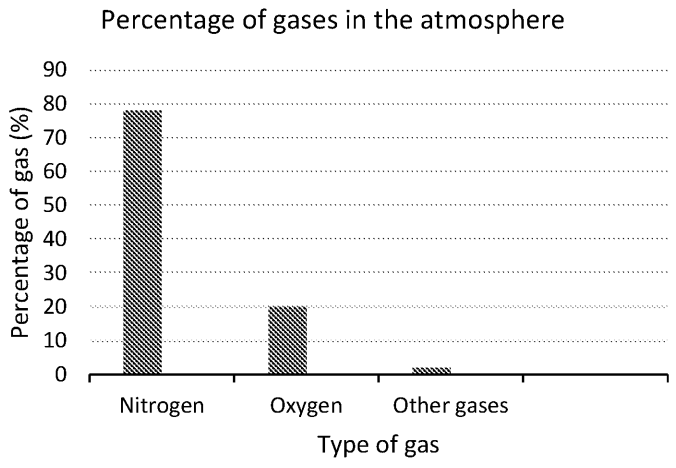
Activity 4: Exam-style question

A. 1 + 16 + 35.5 [1]
= 52.5 [1]
B. Damp litmus paper [1] is bleached [1]
C. 3.5/100 × 100 [1]
= 3.5 %[1]

The proportions of different gases in the atmosphere

Activity 1: Gas percentage

Gas	Percentage of gas (%)
Nitrogen	78 (77–79)
Oxygen	20
Other gases	2 (1–3)



Activity 2: Uses of gases / Make them useful

Nitrogen: Is used to make fertilisers and for rapid freezing
Hydrogen: Is flammable; used as rocket fuel and for hydrogenation
Oxygen: Is soluble in water and is used for oxidising
Carbon dioxide: Is used as a refrigerant and in fire extinguishers

Activity 3: NPE

Isotope	Neutrons	Protons	Electron
^{14}N	7	7	7
^{15}N	8	7	7

Isotope	Neutrons	Protons	Electron
^{14}N	7	7	7
^{15}N	8	7	7
$^{12}_{6}C$	6	6	6
$^{13}_{6}C$	7	6	6
$^{14}_{6}C$	8	6	6

Activity 4: Exam-style question

A. Carbon dioxide [1]
B. Carbon dioxide [1]
C. Earth's atmosphere has nitrogen as the most abundant gas; on Mars, the most abu
Oxygen is the next most abundant gas on Earth – it is 20 % of the total gases. On M
Carbon dioxide is the most abundant gas on Mars; on Earth, carbon dioxide is only
D. Oxygen is necessary for survival of life. On Mars, oxygen is only present in traces; c
in the absence of oxygen. [1]
Carbon dioxide constitutes 95 % of the atmosphere of Mars, which might lead to high

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in the absence of oxygen. [1]
Carbon dioxide constitutes 95 % of the atmosphere of Mars, which might lead to high

Earth's early atmosphere

Activity 1: Match-up

Oxygen – Element
Carbon dioxide – Compound
Water – Compound
Nitrogen – Element
Hydrogen – Element
Methane – Compound

Activity 1: Who am I?

A. Argon
B. Nitrogen
C. Oxygen
D. Carbon

Activity 2: Earth's atmosphere

A. True
B. False – the atmosphere consists of 0.004 % carbon dioxide
C. True
D. True

Activity 3: Percent change

$$= \frac{750\,000 - 25\,000}{25\,000} \times 100$$
$$= \frac{725\,000}{25\,000} \times 100$$
$$= 2900\ \%$$

Activity 4: Exam-style question

A. 4.6×10^9 years [1]
B. Volcanic activity released water vapour [1], which condensed to form oceans [1]
C. Bar graph correctly plotted [2 for all three, 1 for at least one correct], y-axis labelle

Oxygen – carbon dioxide

Activity 1: Oxygen levels

Substance	Chemical formula	State
Oxygen	O_2	(g)
Carbon dioxide	CO_2	(g)
Water	H_2O	(l)
Glucose	$C_6H_{12}O_6$	(aq)

Activity 2: Photosynthesis analysis

A. 12:00
B. 04:00
C. Rate of photosynthesis is highest at 12:00, so oxygen production is highest

Activity 2: Fossilisation

A. Carbon dioxide is a soluble gas.
It dissolves easily in water.
In the oceans, carbon dioxide dissolved to form soluble carbonate compounds, so t
the atmosphere decreased.
B. Algae absorb carbon dioxide by the process of photosynthesis.
C. Crude oil was formed from marine organisms, which were buried in oceans and lak
D. Earth's early atmosphere had traces of nitrogen; in the current atmosphere, nitrog
produced by volcanic activity and it accumulated in the atmosphere because nitrog

Activity 3: Equation time

A. Carbon dioxide
B. Water
C. Glucose + Oxygen
D. Carbon dioxide + Water

A. $C + O_2 \rightarrow CO_2$
B. $2H_2 + O_2 \rightarrow 2H_2O$
C. $6CO_2 + 6H_2O \rightarrow C_6H$
D. $CH_4 + 2O_2 \rightarrow CO_2 +$

Activity 4: Exam-style question

A. Carbon dioxide is a soluble gas and it dissolves easily in water. [1]
In the oceans, carbon dioxide dissolved to form soluble carbonate compounds [1],
the atmosphere decreased. [1]
B. Algae absorb carbon dioxide by the process of photosynthesis. [1]
C. Crude oil was formed from marine organisms, which were buried in oceans and lak
D. Earth's early atmosphere had traces of nitrogen; in the current atmosphere, nitrog
produced by volcanic activity [1] and it accumulated in the atmosphere because ni

A. 12:00 [1]
B. 04:00 [1]
C. Same size of algae balls, same temperature [1]
D. 20:00, 70 ppm [1]

Greenhouse gases

Activity 1: Tick box

1. Farming rice in paddy fields
   Burning fossil fuels
2. carbon dioxide, methane, water vapour
3. As carbon dioxide concentration increases, temperature increases.

Activity 1: Greenhouse

1. i. Farming rice in paddy fields
   ii. Burning fossil fuels
2. Greenhouse gases (carbon dioxide, methane, water vapour) trap the heat close to t
3. As the carbon dioxide concentration increases, more heat is trapped in the atmosp
   Earth's surface.

Activity 2: Plot the graph

Graph correctly plotted

Graph correctly plotted
Axes labelled

Activity 3: Add labels

1. C – Most wavelengths of electromagnetic radiation pass through Earth's atmosphere
2. B – Earth absorbs the majority of the radiation, increasing in temperature
3. D – Some energy is radiated from Earth as infrared radiation
4. E – Greenhouse gases in the atmosphere absorb some of the remaining energy
5. A – The lower atmosphere warms up

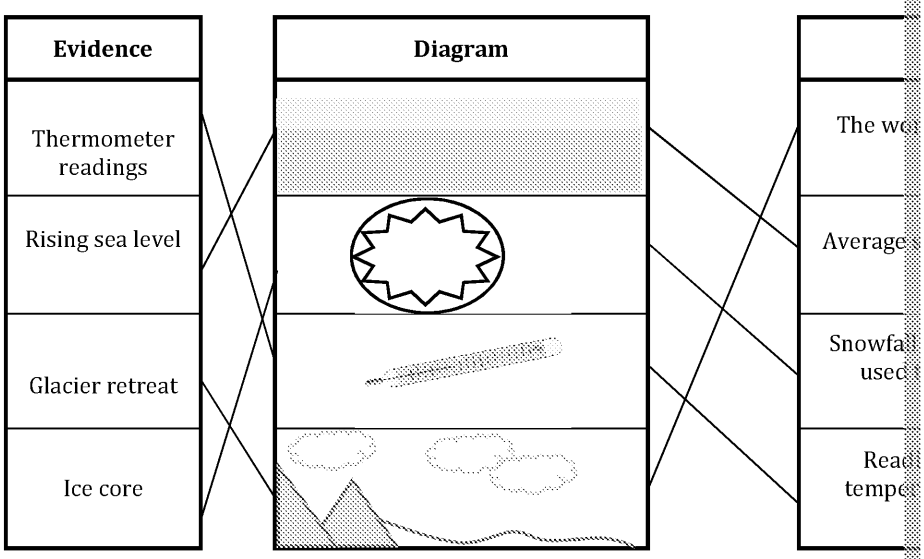
1. Most wavele
   pass through
2. Earth absorb
   increasing in
3. Some energy
   infrared radia
4. Greenhouse g
   of the remain
5. The lower atr

Activity 4: Exam-style question

1. Add carbon dioxide to lime water [1]; it turns milky [1]
2. Two from: burning of fossil fuel, deforestation, increased agriculture [2]
3. Catalytic converter converts toxic oxides of carbon and nitrogen into less harmful c
   reaction is platinum. [1]

Global climate change

Activity 1: Climate change



Activity 2: Factors affecting climate change

Natural factors	Human factors
Orbital change	Burning fossil fuels
Volcanic activity	Deforestation
Solar output	Dumping waste in landfill
	Agriculture

Extension: correctly describing any one of the above

Activity 3: Alternative energy

A. Two from: solar, wind, tidal (allow nuclear)
B. Carbon capture removes carbon dioxide from power stations by storing it in old oil fields and coal mines underground
C. Plants use carbon dioxide for the process of photosynthesis; they fix the carbon dioxide and water to make glucose and oxygen

A. Solar, wi
B. Carbon ca power st and coal
C. Plants us photosyn and wate

Activity 4: Exam-style question

A. Carbon dioxide was the most abundant gas in Earth's early atmosphere [1]
B. Two from: absorbed by plants, fossil fuel was formed, dissolved in water [2]
C. Earth's early surface temperature was high because the atmosphere consisted of 9 absorbed heat from the Sun (greenhouse effect) [1] and increased the temperature

Using Earth's resources

Activity 1: Renewable and non-renewable resources

A. Resources which will not run out in the near future because their extraction is slow **renewable** resources.
B. Petrol and diesel are obtained from crude oil by the process of **fractional distillati**
C. Crude oil is available in finite quantities so it is an example of a **non-renewable** re
D. Nitrogen-based fertilisers are now produced synthetically by the **Haber** process.
E. Substances made by processes that do not occur naturally are called **synthetic** sub

Activity 2: Copper production

A. When one set of data increases the other also increases
B. More copper was used in buildings, cars, turbines, etc., so as the population increas (higher demand)
C. Wires and pipes
D. Sodium, potassium (any two from the reactivity series)

Activity 3: Sustainable development

A short paragraph describing the importance of sustainable development using all the k

Activity 4: Exam-style questions

A. $63.5 \times 2 + 16 = 127$ [1]
$127/143 \times 100 = 88.8\ \%$ [1]
B. Good conductor of electricity (low resistance) [1]
Ductile [1]
Does not oxidise [1]
C. Plants are grown in soil containing ores of copper [1]
Plants absorb compounds of copper [1]
Plants are burned, ash contains copper [1]
Copper is extracted by electrolysis and pure copper is produced [1]

Potable water

Activity 1: Water cycle

1. Precipitation
2. Transpiration
3. Evaporation
4. Condensation

Activity 2: Pure water

Distillation	Reverse osmosis
Seawater is heated until it boils. Water evaporates and the salt remains, and the steam is pure water. The steam is cooled and condensed to make potable water.	Water under high pressure is passed through a membrane with tiny pores. Water molecules pass through the membrane, but most ions cannot pass through.

Activity 3: Waste water treatment

C.	Screening is done to remove large particles
E.	Sedimentation produces sewage sludge and effluent
B.	Effluent enters an aeration tank; oxygen is pumped into water
A.	Sewage sludge is digested anaerobically by bacteria
D.	Aerobic bacteria break down the waste

Activity 4: Exam-style question

A. Potable water [1]

B. $1 \times 2 + 16$ [1]
$= 18$ [1]

C. Measure the mass (mass 1) of the evaporating basin using scales [1]
Add 10 cm^3 of water to the evaporating basin [1]
Heat the evaporating basin to evaporate the water [1]
Reweigh the basin mass (mass 2) [1]
Subtract mass 1 from mass 2 [1]