Recording data on properties

1 Draw up a table, like the one below, to record information on the properties of **alkali metals**.

Alkali metal	Melting point (°C)	Boiling point (°C)	Density (g/dm^3)	Hard or soft?	Conductor or insulator?	Reaction with oxygen	Reaction with water

Considering your results/conclusions

2 Describe how the physical properties of alkali metals compare with those of other common metals, like iron, zinc and copper.

3 Write word equations and balanced equations with state symbols for the reactions of the first three alkali metals with: **a** oxygen **b** water.

4 Write the first three alkali metals in order of **reactivity**, with the most reactive last.

5 Describe how the reactivity of the alkali metals is linked to their position in the **periodic table**.

6 Describe how the reactivity of the alkali metals is linked to the structure of their atoms.

Extra challenge

7 Describe any trends in physical properties in the alkali metal **group**.

Edexcel GCSE (9–1)
Sciences SC17a.1 The alkali metals

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Extra challenge

7 Describe any trends in physical properties in the alkali metal group.

Name _____ **Class** _____ **Date** _____

EASIER

1 Complete the following statements. Compared with most common metals, **alkali metals**:

a are _____ and can be easily cut with a knife

b have _____ melting points and boiling points

c have low densities and _____ on water.

2 Complete the first drawing and the three descriptions of the reactions of lithium, sodium and potassium with water.

With water, lithium metal forms b _____ of gas and fizzes about on the surface.	Sodium floats on the surface and reacts quickly, producing enough heat to m _____ the metal into a ball.	Potassium reacts violently on the surface of the water, producing lilac-coloured f _____ .

3 Complete the equations for the reaction of sodium and water.

sodium + water → _____ _____ + hydrogen

2____(s) + $2H_2O(l)$ → _____ NaOH(aq) + _____ (g)

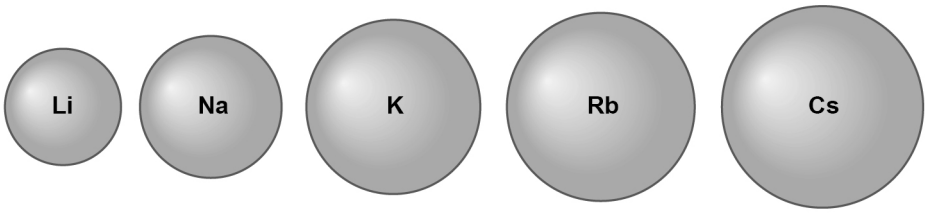
S1 Name three alkali metals and describe their main physical and chemical properties.

HARDER

4 Draw lines to link the phrases to form sentences about the alkali metals lithium, sodium and potassium.

The least reactive of these metals is	has the largest atoms.
After cutting, these metals become dull	potassium.
When alkali metals react	lose electrons more easily.
The most reactive of these alkali metals	as they react with oxygen.
The metals with the larger atoms	lithium.
Of these, the metal with the largest atoms is	their atoms lose one electron.

1 The relative sizes of the atoms of five **alkali metals** are shown below. Use the diagrams to help explain the order of **reactivity** of the alkali metals.



2 Chemical equations can be described and written in different ways. Look at these examples for the reaction between sodium and water.

- word equation: sodium + water → sodium hydroxide + hydrogen
- balanced equation: $2Na + 2H_2O \rightarrow 2NaOH + H_2$
- balanced equation with state symbols: $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
- ionic equation with state symbols: $2Na(s) + 2H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g)$

Write chemical equations to fit the following descriptions of chemical reactions.

a a word equation for the reaction between:

i lithium and water

ii rubidium and oxygen

b a balanced equation for the reaction between:

i $Cs + H_2O$

ii $K + O_2$

c a balanced equation with state symbols for the reaction between:

i K and H_2O

ii Li and O_2

d an ionic equation for the reaction between:

i rubidium and water

ii lithium and water.

E1 **a** Explain the difference in reactivity between rubidium and caesium.

b **H** Write ionic equations for the reactions of rubidium and caesium with water.

3 Compare and contrast the metals sodium and iron in terms of:

a melting point and boiling point

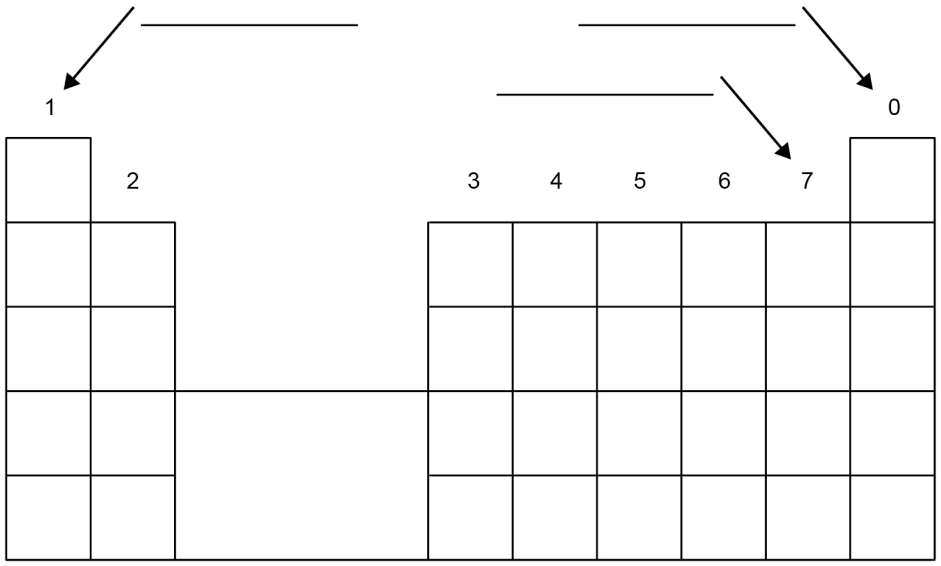
b density

c conductivity

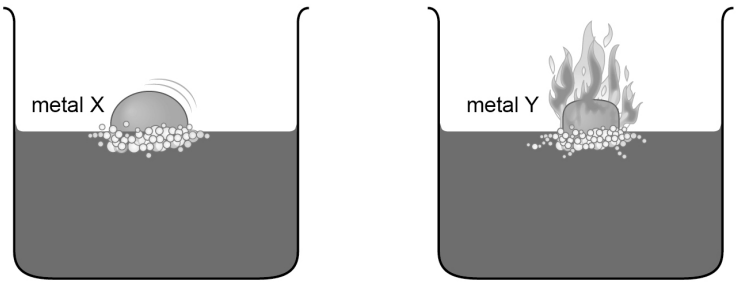
d whether they are soft or hard.

Name _____ **Class** _____ **Date** _____

1 Write the names of **groups** 1, 7 and 0 in the **periodic table** below and add the symbols for the first three elements in group 1.



2 The diagrams opposite show two **alkali metals** reacting with water.



a Which metal is more reactive? _____

b If metal X is sodium, suggest a name for metal Y. _____

c Name a less reactive alkali metal than X and Y.

_____

d Complete the word and balanced equations for sodium reacting with water.

sodium + _____ → _____ + _____

__Na + _____ → _____ + _____

3 Some data on four metals is shown in the table below. Identify the alkali metal and explain your choice.

Metal	Melting point (°C)	Boiling point (°C)	Soft or hard?
P	1535	2750	hard
Q	98	883	soft
R	1083	2567	hard
S	660	2467	hard

_____

_____

_____

These examples will help you to answer question **2d**.

word equation: lithium + water → lithium hydroxide + hydrogen

balanced equation: $2Li\ (s) + 2H_2O\ (l) \rightarrow 2LiOH\ (aq) + H_2\ (g)$

1 Descriptions of the reaction of the first three **group** 1 metals with water are given below.

Lithium	Sodium	Potassium
fizzes on the surface of the water	melts into a ball and fizzes about on the surface of the water	bursts into flames and flies about the surface of the water

Suggest what the reaction of water with the next group 1 metal, rubidium, would look like.

2 Write balanced equations with state symbols to show the reactions of rubidium and lithium with water.

3 A small block of sodium is cut with a knife. Its shiny surface soon becomes dull.

a Explain the changes that happen to the cut surface.

b A small block of another metal in the same group is also cut. The cut surface of this metal becomes dull more slowly. Explain whether this metal would be found above or below sodium in the **periodic table**.

4 Write the equations described below.

a a word equation for the reaction between lithium and oxygen

b a balanced equation for the reaction of potassium and oxygen. Include state symbols.

5 **a** Copy and complete this table.

Element	Atomic radius (nm)	Atomic number	Electronic configuration	Number of occupied electron shells
lithium	0.157			
sodium	0.191			
potassium	0.235	19		
rubidium	0.250	37	2.8.18.8.1	5
caesium	0.272	55	2.8.18.18.8.1	6

b Explain why the atoms get larger as you go down the group.

c Explain how the **reactivity** of the **alkali metals** is linked to their electronic configuration.

6 Some data on two metals is shown in the table below.

Metal	Melting point (°C)	Boiling point (°C)	Hardness (Mohs scale)
X	1535	2750	hard
Y	98	883	soft

Identify the alkali metal and explain your choice.

Extra challenge

7 The melting points of these alkali metals are:

	Lithium	Sodium	Potassium	Rubidium	Caesium
melting point (°C)	181	98	64		28

Predict the melting point of rubidium. Explain how you worked out your prediction.

8 Write an ionic equation for the reaction between caesium and water.

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 What are the main properties of alkali metals?

_____

_____

2 How do alkali metals react with water?

_____

_____

3 Why do alkali metals have different reactivities?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

SC17b.1 Properties of halogens

Name _____ **Class** _____ **Date** _____

Your teacher may watch to see if you can:
- collect and record data neatly and accurately.

Aim

To observe, research and record data about the **halogens**.

Method

Apparatus

- sealed sample of chlorine
- sealed sample of bromine
- sealed sample of iodine
- chlorine water
- blue litmus paper
- test tube and bung
- data sources (texts or Internet access)

⚠ Safety

Do not touch samples of halogens.

When asked to smell chlorine, follow the instructions carefully.

A Look at the halogen samples and note their formulae, appearance and state.

B Find out about the main sources and uses of the three halogens you have been given.

C Research data on their boiling points, melting points and densities.

D Research their atomic number, atomic size, bonding and structure.

E Place 1 cm depth of chlorine water into a test tube and place a piece of wet blue litmus paper in the mouth of the test tube. Observe what happens.

F Following your teacher's instructions, carefully smell the chlorine gas in the test tube by gently fanning the vapours towards your nose. Keep the test tube at least 30 cm away from your face. Place the bung in the test tube when you have finished.

Recording your results

1 Record the information you found in parts **A** and **B** in the table below.

	Formula	Appearance and state	Main sources of the element	Uses
chlorine		smell:		
bromine				
iodine				

2 Record the information you found in parts **C** and **D** in the table below.

	Atomic number	Atomic size	Bonding and structure	Melting point (°C)	Boiling point (°C)	Density (g/dm^3)
chlorine						
bromine						
iodine						

Considering your results/conclusions

3 Describe how the molecular formulae, bonding and structure of all halogens are similar.

4 Describe the trends in melting points and boiling points going down the halogen group.

5 Suggest values for the melting point and boiling point of astatine, the halogen below iodine.

6 Suggest what the appearance (state and colour) of the halogens fluorine and astatine, the first and fifth in the group, might be like.

7 Suggest an explanation for the link between atomic number and atomic size of the halogens.

8 Describe a test for chlorine gas.

Name _____ **Class** _____ **Date** _____

Remember	X_2 + 2M → 2MX	X_2 + H_2 → 2HX
	halogen + metal → metal **halide**	halogen + hydrogen → hydrogen halide

1 Complete the following word equations for the reactions of halogens.

a hydrogen + chlorine → _____

b _____ + _____ → sodium bromide

2 Complete then balance the following equations. Include the state symbols.

a Br_2(l) + Na( ) → _____(s)

b _____( ) + _____( ) → HF(g)

3 Write the following balanced equations with state symbols.

a the reaction between bromine and hydrogen forming hydrogen bromide gas

_____

b the reaction between iron and fluorine forming iron(II) fluoride solid.

_____

4 Write word equations and balanced symbol equations with state symbols for the following reactions.

a the formation of magnesium iodide from its elements

_____

b the reaction between chlorine and potassium

_____

c the reaction between hydrogen and chlorine.

_____

Extra challenge

5 Write balanced equations with state symbols for the following reactions.

a the reaction between aluminium and fluorine forming solid aluminium fluoride

_____

b the reaction between lead and bromine forming lead(IV) bromide solid

_____

c the formation of lithium fluoride from its elements

_____

d the formation of solid phosphorus(V) chloride formed from its elements.

_____

Name _____ **Class** _____ **Date** _____

EASIER

1 Complete the missing information in the table and the sentences below.

Halogen	Symbol	Formula	Colour	State
chlorine	Cl		pale green	
bromine		Br_2		
iodine	I	I_2		solid

The h _____, which are found in group 7 of the periodic table, have a m _____ structure formed by joining t _____ **halogen** atoms together with a c _____ bond.

2 Complete the sentences below by crossing out the incorrect word or value.

a The boiling points of the halogens increase/decrease down the group.

b The boiling point of astatine would be about 300 °C/30 °C.

Group 7	Boiling point (°C)
chlorine	−35
bromine	59
iodine	184
astatine	

S1 Describe how the halogens chlorine, bromine and iodine are similar, and how they show trends in properties down their group.

3 Complete the following word equations.

a hydrogen + iodine → _____ _____

b _____ + _____ → copper chloride

c hydrogen chloride + _____ → hydrochloric acid

4 **a** Place the elements bromine, chlorine and iodine in order of increasing reactivity with metals.

_____

b Predict the main reactions of the first and the fifth halogens, fluorine and astatine, and their position in the order of reactivity.

_____

_____

_____

_____

_____

_____

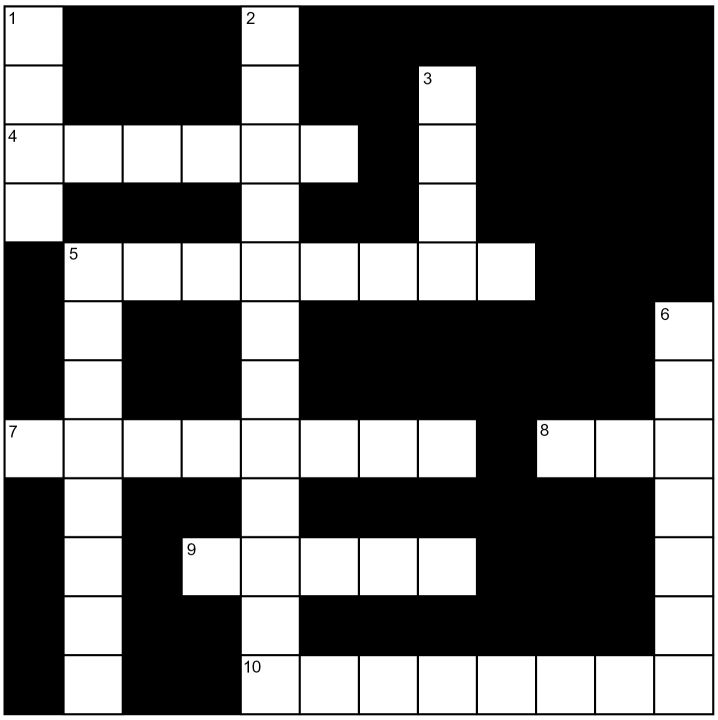
HARDER

You may find these words useful for question **1**.

Br	brown	Cl_2	covalent	halogens
gas	liquid	molecular	purple/black	two

Name _____ **Class** _____ **Date** _____

1 Complete the crossword.



Across

4 See 3 down (6)

5 A compound of fluorine (8)

7 Type of bonding holding **halogen** molecules together (8)

8 Number of atoms in a halogen molecule (3)

9 The colour of bromine (5)

10 A pale green gas at room temperature (8)

Down

1 See 2 down

2 and 1 Formed when hydrogen chloride dissolves in water (12) & (4)

3 down and 4 across The product of reacting lead and iodine (4) & (6)

5 The first element in group 7 (8)

6 The only halogen that is a liquid at room temperature (7)

2 Look at the table opposite.

a Describe the trend in the melting point of the halogens down the group.

_____

b Suggest what the missing information in the table could be. Add your answers to the table.

Halogen	State at 20 °C	Melting point (°C)
fluorine		
chlorine	gas	–101
bromine	liquid	–7
iodine	solid	114

3 Write a word equation for the reaction of sodium and iodine.

_____

4 Write a balanced equation with state symbols for the reaction between hydrogen, H_2, and fluorine, F_2.

_____

5 Zinc foil bursts into flames when it reacts with chlorine. It glows brightly and produces sparks with bromine, and glows red with iodine.

Suggest what the reaction between zinc foil and astatine would look like and explain how you predicted its reactivity. Name the product formed in the reaction.

_____

_____

6 Describe the chemical test for chlorine gas.

_____

Astatine is a **halogen** and is found below iodine in group 7 of the periodic table.

	Formula	Atomic number	Period number	Relative atomic mass	Melting point (°C)	Boiling point (°C)
chlorine	Cl	17	3	35.5	−101	−35
bromine	Br	35	4	80	−7	59
iodine	I	53	5	127	114	184
astatine	At	85	?	?	?	?

1 **a** Describe the colour and state of the halogens chlorine, bromine and iodine.

b Predict the colour and state of astatine.

2 Suggest the type of bonding found in astatine.

3 **a** Draw a scatter graph of relative atomic mass (vertical axis) against atomic number (horizontal axis).

b Draw a line of best fit on your graph and use it to predict the relative atomic mass of astatine.

4 **a** Draw a scatter graph of melting point (vertical axis) against atomic number (horizontal axis)

b Draw a line of best fit on your graph and use it to predict the melting point of astatine.

5 Write balanced equations with state symbols for the formation of the following ionic compounds.

a silver(I) chloride, AgCl, from silver and chlorine

b aluminium bromide, $AlBr_3$, from aluminium and bromine.

6 Describe the chemical test for chlorine gas.

7 Some information about the reactions and properties of halogens and their compounds is shown below.

	Chlorine	Bromine	Iodine
Reaction with zinc foil	burns quickly	glows brightly	glows dull red
Reaction with hydrogen	explodes in light	reacts when heated	reacts very slowly
Hydrogen halide solution pH (equal concentrations)	HCl(aq) pH = 2.0	HBr(aq) pH = 1.2	HI(aq) pH = 1.0

a Write balanced equations with state symbols for the reactions of:

i hydrogen and fluorine **ii** zinc and fluorine.

b Predict what the reaction of fluorine with zinc foil would look like.

c **i** Name the acid formed when hydrogen fluoride dissolves in water.

ii Write the formulae of the ions.

d Predict the pH of a solution of hydrogen fluoride that is the same concentration as the acids in the table. Briefly explain how you made your prediction.

Extra challenge

8 Using only the data for chlorine, bromine and iodine, draw scatter graphs of boiling point (vertical axis) against:

a period in the periodic table **b** atomic number.

9 The boiling point of astatine is usually reported as 337 °C. Using the two graphs from question **8**, compare and contrast the predicted value(s) of the boiling point of astatine with the reported value.

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 How do the physical properties of the halogens change, going down group 7?

_____

_____

2 How can we test for chlorine gas?

_____

_____

3 How do halogens react with metals and hydrogen?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

Your teacher may watch to see if you can:

- make careful observations.

Aim

To investigate the order of reactivity of the halogens by observing **displacement reactions** of halogens and halide ions.

Method

Apparatus

- eye protection
- 12 test tubes
- bungs
- test tube rack
- teat pipettes
- chlorine water
- bromine water
- iodine water
- potassium chloride solution
- potassium bromide solution
- potassium iodide solution
- blue litmus paper

⚠ Safety

Wear eye protection at all times.

Wash off splashes of all solutions that contact skin immediately, using plenty of water. Wipe up all other spills.

Take care not to inhale halogen vapours.

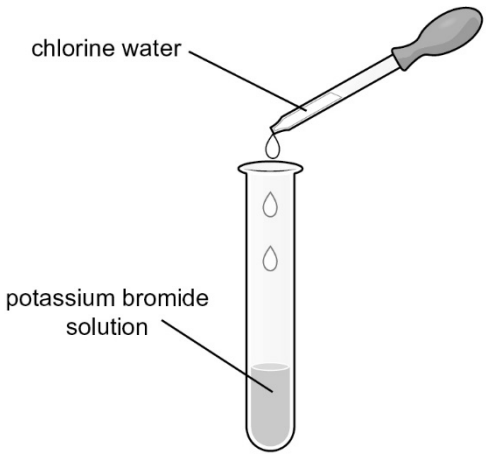
A Pour 1 cm depth of each halide solution (potassium chloride, potassium bromide and potassium iodide) into three separate test tubes.

B Use the teat pipette to slowly add the same volume (1 cm) of chlorine water to each of the halide solutions.

C Observe carefully to see if any changes occur during mixing.

D Repeat steps **A**–**C** using bromine water instead of chlorine water. Then repeat using iodine water.

Remember that even if no reaction occurs, the colour of the halogen water (chlorine, bromine and iodine) will become paler, because it is being diluted.



Extra challenge

E Pour a few drops of chlorine, bromine and iodine water into three different test tubes.

F Add a piece of blue litmus paper to each test tube and observe what happens and how quickly it happens.

Recording your results

1 Record all your observations in a suitable table.

Considering your results/conclusions

2 Arrange the three halogens in order of decreasing reactivity. Explain your reasoning.

3 Predict the reactivities of fluorine and astatine. Explain your reasoning.

4 Choose one of the displacement reactions. Explain what is happening to the atoms and ions during the reaction.

5 Explain how this experiment confirms the idea, about the trend in reactivity of the halogens, introduced in the last topic.

Name _____ **Class** _____ **Date** _____

Recording your results

1 Record whether a reaction occurs (✓) or there is no reaction (×) in the table below.

Halogen	Potassium chloride solution	Potassium bromide solution	Potassium iodide solution	
chlorine water				
bromine water				
iodine water				

Considering your results/conclusions

2 Arrange the three halogens in order of decreasing reactivity.

_____

3 Describe how the trend in reactivity of the halogens is linked with their position in the periodic table.

_____

4 Explain how the displacement reactions of halogens are linked to their position in the periodic table.

_____

_____

_____

5 Predict the reactivity of fluorine (the halogen at the top of group 7) and explain your answer.

_____

_____

6 Predict the reactivity of astatine (the halogen below iodine in the periodic table) and explain your answer.

_____

_____

Evaluation

7 Explain how errors might occur in the results obtained in this investigation. (*Hint:* How easy was it to decide whether a reaction had occurred?)

_____

_____

8 What could you do to confirm your order of reactivity?

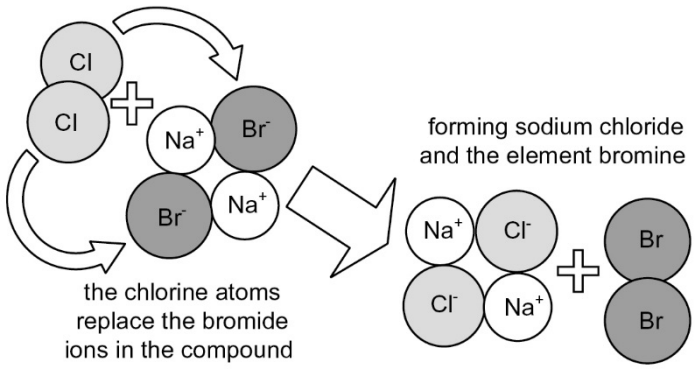
_____

_____

_____

Name _____ **Class** _____ **Date** _____

1 The diagram below shows the reaction between chlorine gas and a solution of sodium bromide. The table gives information about three of the group 7 elements.



Group 7 element	Number of electron shells
chlorine	3
bromine	4
iodine	5

a The equations for the reaction are:

word equation: sodium bromide + chlorine → sodium _____ + _____

balanced equation: _____ + $Cl_2(g)$ → $2NaCl(aq)$ + _____ (aq)

b This is an example of a _____ reaction, as it involves one element _____

another element from a _____ in solution.

2 **a** State the order of increasing reactivity for the three group 7 elements in question **1**.

_____ then _____ then _____

b Explain the link between reactivity and the number of electron shells.

_____

_____

3 State which of these two pairs of substances will react.

chlorine + sodium iodide, and iodine + sodium chloride.

Justify your answer.

_____

_____

---

4 **H** **a** Write the balanced equation and ionic equation (omitting spectator ions) for the reaction between sodium chloride and fluorine. Both should show the correct state symbols.

_____

H **b** Name the spectator ion in this reaction and explain why it can be missed out of the ionic equation.

_____

H **c** Explain why this is a **redox** reaction, naming the substances that are **oxidised** and **reduced**.

_____

Name _____ **Class** _____ **Date** _____

EASIER

1 Complete the table below then complete the sentences that follow.

Halogen	Atomic number	Electrons in outermost shell	Number of occupied electron shells	Reactivity of halogens	Reaction with tin foil
fluorine	9	7	2	___ ___ C R E A S I N G	_____
chlorine	17	7	_____		burns slowly
_____	35	_____	4		sparks and flashes
iodine	____	_____	5		colour darkens

All halogens have _____ electrons in their outer shell.

When halogens react they _____ one electron to form a 1– _____.

The smallest halogens with the fewest _____ shells attract electrons _____ strongly, so they are the most reactive.

Reactivity _____ down the group of halogens, as an _____ shell of electrons is added and there is less attraction between the positive nucleus and the outer electrons.

2 Which of the following pairs of solutions will not react when added together? Explain your choice.

iodine + lithium chloride	chlorine + sodium bromide	bromine + potassium chloride

HARDER

S1 Design a summary table or diagram to describe and explain the trend in reactivity of the halogens.

3 Complete the following word and balanced equations for other **displacement reactions**.

a potassium bromide + chlorine → _____ _____ + _____

b _____ _____ + _____ → lithium chloride + iodine

c _____(aq) + Cl_2(aq) → 2KCl (aq) + Br_2(aq)

d 2NaCl(aq) + F_2(g) → _____(aq) + _____(aq)

Name _____ **Class** _____ **Date** _____

1 Tick the correct box to say whether these statements are true or false.

		True	False
a	The order of increasing reactivity of group 7 elements is $Cl_2<Br_2<F_2<I_2$.	☐	☐
b	Chlorine will displace bromine from sodium bromide solution.	☐	☐
c	Iodine will displace fluorine from lithium fluoride solution.	☐	☐
d	The reactivity of halogens decreases as their atomic size increases.	☐	☐

2 Rewrite the false statements from question **1** to make them correct.

_____

_____

_____

3 Join up the correct starts and ends of these sentences about fluorine.

The halogen fluorine is the …	occupied electron shells than other halogens.
When fluorine reacts it forms …	electrons more easily than other halogens.
Fluorine atoms have fewer …	fluoride ions by gaining electrons.
The fluorine atoms gain …	most reactive in the group.

4 Astatine, symbol At, is found at the bottom of group 7.

a Using the pattern of reactivity of the other halogens, predict the relative reactivity of astatine and justify your answer.

_____

_____

_____

b Explain the relative reactivity of astatine with reference to its atomic structure.

_____

_____

_____

c Complete the following chemical equations.

i sodium + astatine → _____ _____

ii $Br_2(aq)$ + 2KAt(aq) → _____ + _____

9
F
2.7

17
Cl
2.8.7

35
Br
2.8.18.7

53
I
2.8.18.18.7

1 List the four halogens in the boxes on the left-hand side of the page in order of increasing reactivity, least reactive first. Briefly explain your order of reactivity.

2 Explain, in terms of the electronic configurations of their atoms, the difference in reactivity between fluorine and chlorine.

3 The **displacement reaction** between chlorine and sodium bromide can be represented by the equation below.

$Cl_2(aq) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(aq)$

a Describe what happens in a displacement reaction.

b Write a similar equation for the reaction of bromine water and potassium iodide solution.

4 Explain why only one of these pairs of solutions will react when mixed together.

chlorine + sodium bromide, and bromine + potassium chloride.

5 **H** The halogens are reactive non-metals which tend to take part in **redox** reactions. Redox reactions involve **oxidation** and **reduction** processes that always occur together.

a Describe in terms of electron transfers the difference between oxidation and reduction.

b Are halogen molecules usually **oxidised** or **reduced**? Explain your answer.

6 **H** Calcium and chlorine react together to form calcium chloride.

$Ca + Cl_2 \rightarrow CaCl_2$

A half equation that models the change to chlorine in the reaction is shown below.

$Cl_2 + 2e^- \rightarrow 2Cl^-$

a Explain whether chlorine is oxidised or reduced in the reaction.

b Write a half equation that models the change to calcium in the reaction.

7 **H** The ionic equation below represents a displacement reaction.

$F_2(g) + 2Br^-(aq) \rightarrow 2F^-(aq) + Br_2(aq)$

a State what is oxidised and what is reduced in this reaction.

b Write half equations with state symbols to show what happens in the oxidation and reduction reactions that occur in this displacement reaction.

Extra challenge

8 **a** What does the term spectator ion mean?

b Write an ionic equation, with state symbols and omitting spectator ions, for the reaction between sodium iodide solution and bromine water.

c Write half equations to identify the oxidation and reduction reactions in the reaction described below.

$Br_2(aq) + 2KI(aq) \rightarrow 2KBr(aq) + I_2(aq)$

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 How can displacement reactions be used to work out the reactivity of halogens?

_____

_____

2 How can we explain the reactivity of halogens?

_____

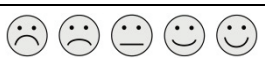
_____

3 **H** What happens to halogen atoms and halide ions during displacement?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

1 Carry out the following instructions using the group 0 data cards on page 2 of this worksheet.

- **A** Cut out all the data cards for atomic radius.
- **B** Place the data cards in order of increasing atomic radius.
- **C** Place the card for xenon where you think it fits in the order.
- **D** Check the order of your cards with your teacher.
- **E** Glue the cards onto a sheet of paper.
- **F** Repeat steps **A–E** using the data cards for: relative atomic mass, boiling point, density.

2 Describe the trends that can be seen in the four properties for the group 0 elements.

3 Draw a scatter graph of atomic number (horizontal axis) against boiling point (vertical axis) and use a line of best fit to predict the missing data for xenon (write your prediction on the card).

4 Choose one more of the properties from question **1** to draw a scatter graph. Atomic number should be on the horizontal axis and use a line of best fit on your graph to predict the missing data for xenon (write your prediction on the card).

5 State which of your predictions you expect to be the most accurate. Explain your choice with reference to the scatter graphs you used.

6 Find the actual values of the missing data for xenon. Compare these with your predicted values and comment on the accuracy of your predictions.

Edexcel GCSE (9–1)
Sciences SC17d.1 Properties of Group 0

1 Carry out the following instructions using the group 0 data cards on page 2 of this worksheet.

- **A** Cut out all the data cards for atomic radius.
- **B** Place the data cards in order of increasing atomic radius.
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- **E** Glue the cards onto a sheet of paper.
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3 Draw a scatter graph of atomic number (horizontal axis) against boiling point (vertical axis) and use a line of best fit to predict the missing data for xenon (write your prediction on the card).

4 Choose one more of the properties from question **1** to draw a scatter graph. Atomic number should be on the horizontal axis and use a line of best fit on your graph to predict the missing data for xenon (write your prediction on the card).

5 State which of your predictions you expect to be the most accurate. Explain your choice with reference to the scatter graphs you used.

6 Find the actual values of the missing data for xenon. Compare these with your predicted values and comment on the accuracy of your predictions.

18 **Ar** argon atomic radius 71 pm	18 **Ar** argon relative atomic mass 40.0	18 **Ar** argon boiling point –186 °C	18 **Ar** argon density 0.0018 g cm^{-3}
2 **He** helium atomic radius 31 pm	2 **He** helium relative atomic mass 4.0	2 **He** helium boiling point –269 °C	2 **He** helium density 0.0002 g cm^{-3}
36 **Kr** krypton atomic radius 88 pm	36 **Kr** krypton relative atomic mass 83.8	36 **Kr** krypton boiling point –152 °C	36 **Kr** krypton density 0.0037 g cm^{-3}
10 **Ne** neon atomic radius 38 pm	10 **Ne** neon relative atomic mass 20.2	10 **Ne** neon boiling point –246 °C	10 **Ne** neon density 0.0009 g cm^{-3}
54 **Xe** xenon atomic radius ?	54 **Xe** xenon relative atomic mass ?	54 **Xe** xenon boiling point ?	54 **Xe** xenon density ?

Read the following passage before answering the questions that follow.

Many large office buildings contain a lot of computer equipment. A fire in a computer room can cause a lot of very expensive damage to the hardware, as well as the loss of important data. Many fire safety systems involve spraying water into an area if the temperature goes above a certain value. However, spraying water into computers could cause almost as much damage as a fire. Computer rooms are therefore usually fitted with fire suppressant systems using **inert** gases, like nitrogen, carbon dioxide or one of the **noble gases**.

There are three main systems in use.

Halons are small hydrocarbon molecules where one or more of the hydrogen atoms has been replaced with a halogen molecule. When halon gas is released into an area, chemical reactions cause any fires to go out, even if there is still enough fuel, oxygen and heat present. The halon gases can produce giddiness if they are breathed in, and may sometimes form toxic products at high temperatures. These gases also destroy the ozone layer when they are released into the atmosphere, and so halon systems are now being replaced throughout Europe.

Carbon dioxide puts out fires if it is at a concentration of around 40 per cent, by depriving the fire of oxygen. The gas is cheap and readily available. However, there is a risk of suffocation if anyone is in the area, and people have died in rooms where carbon dioxide fire suppressant has been used.

The third type of system uses a mixture of *nitrogen and argon*. Nitrogen reacts more readily than argon, but is still fairly inert compared with many other gases. A measured amount of this mixture of nitrogen and argon is released into a room so that it reduces the oxygen concentration to around 14%. People can still breathe at this oxygen concentration, but there is not enough oxygen to allow fires to continue burning.

1 Explain why water sprinkler fire suppressant systems are not suitable for use in a computer room.

2 State one property of noble gases that makes them suitable to use for putting out fires.

3 In computer rooms fitted with halon systems, there is usually a warning alarm. The alarm gives people time to leave the room before the gas is released. Explain why the warning alarm is needed.

4 Describe the difference between the way that the halon system and the nitrogen–argon system works.

5 **a** Explain why engineers fitting a nitrogen and argon fire suppressant system need to know the volume of the room.

b Describe what could happen if the engineers used a value that was too large in their calculations.

c State what could happen if the value for the volume was too small.

6 Explain why carbon dioxide systems are usually used to protect unoccupied rooms.

7 Summarise the advantages and disadvantages of the three different systems.

Extra challenge

8 An advert for a nitrogen–argon fire suppressant system states:

‘The gases are obtained from the atmosphere, so there are no harmful effects from their use.’

Comment on this statement.

Name _____ **Class** _____ **Date** _____

EASIER

1 a Complete the configuration diagrams by drawing in the electrons.

b Write in the missing numbers in the electronic configurations.

helium (___) He atomic number = 2	**lithium** (2.1) Li atomic number = 3
fluorine (___.___) F atomic number = 9	**neon** (___. ___) Ne atomic number = 10

2 What is special about the arrangement of electrons in group 0 elements?

_____

3 When lithium in group 1 reacts with fluorine in group 7, electrons are lost and gained.

a Describe how the electronic configuration of both elements changes when they react and form a bond.

_____

_____

b Explain why group 0 elements are so unreactive.

_____

S1 Explain how the electronic configuration of **noble gases** affects their properties.

HARDER

4 State two reasons why helium is suitable for use in airships and weather balloons.

_____

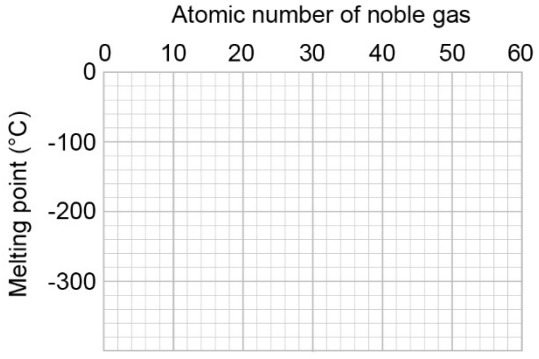
5 Using the axes opposite, draw a scatter graph of the melting points of the following noble gases against their atomic numbers, which are given in brackets.

helium (2) –272 °C neon (10) –248 °C

argon (18) –189 °C xenon (54) –112 °C

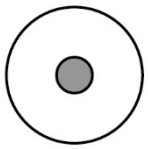
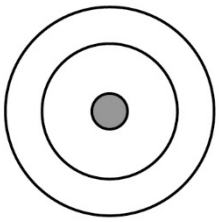
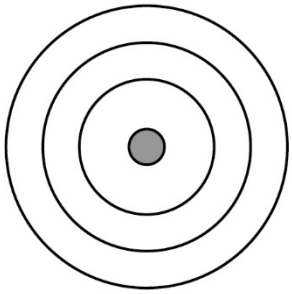
The melting point of krypton (atomic number 36) is missing. Draw a line of best fit and predict the melting point of krypton.

_____ °C



Name _____ **Class** _____ **Date** _____

1 **a** Add electrons to the diagrams, complete the electronic configurations and the sentences below.

helium (___) He atomic number = 2	**neon** (___. ___) Ne atomic number = 10	**argon** (___. ___ . ___) Ar atomic number = 18
		

b The group 0 elements all have an electronic configuration that includes a c_____ outer shell of electrons.

c Most group 0 elements, called the n_____ gases, have an outer shell of _____ electrons, except helium which has _____ electrons in its outer shell.

d This is a very stable arrangement of electrons and this makes the **noble gases** i_____, which means they do not r_____ easily with other substances.

2 Link the uses of group 0 elements listed below with the descriptions of properties that make each element suitable for that use. Each use can be linked to more than one property.

Argon is used in welding to stop the hot metal reacting with oxygen in the air.	very reactive
Helium is used in airships and party balloons.	non-flammable
Argon is used to put out fires in computer rooms.	high density gas
Argon is used inside filament lamps to stop the hot filament reacting with oxygen.	low density gas
	brightly coloured
	relatively **inert**

3 The boiling points of some group 0 elements are given below, and their atomic numbers are shown in brackets.

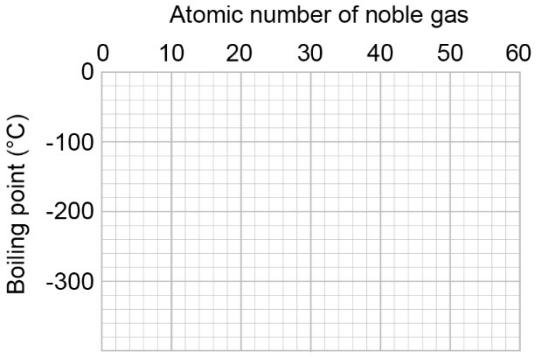
helium (2) –269 °C argon (18) –186 °C

krypton (36) –153 °C xenon (54) –108 °C

a Draw a scatter graph using the axes opposite.

b Predict the boiling point of neon (atomic number 10):

_____ °C



1 The following statements describe how argon was discovered.

A Lord Rayleigh measured the density of the samples of nitrogen.

B Ramsay thought about it and made a hypothesis that there was another, denser, gas mixed in with the nitrogen obtained from the air.

C Ramsay made some very careful experiments to test his hypothesis, by carrying out reactions to remove nitrogen from the gas obtained from the air.

D Lord Rayleigh made some nitrogen by chemical reactions, and also obtained some nitrogen from the air by removing the other gases.

E He discovered that pure nitrogen from chemical reactions was less dense than the nitrogen he had obtained from the air.

F Ramsay discovered that the new gas was very unreactive, and called it argon.

G Sir William Ramsay read Lord Rayleigh's paper.

H Lord Rayleigh wrote a paper about the difference in density, and wondered what the explanation was.

a Write the letters of the statements in the correct order. Start with letter **D**.

b Which step or steps are describing scientists:

i making observations

ii communicating with one another

iii using creative thought to formulate a hypothesis

iv testing a hypothesis?

2 Some of the data about the **noble gases**, in the table below, is missing.

Element	Atomic number	Number of occupied electron shells	Density (g/dm^3)	Boiling point (°C)
helium	2	1	0.2	−269
neon	10	2	0.9	
argon	18	3		−186
krypton	36	4	3.7	−152
xenon	54	5	5.9	−107

a State the electronic configurations of helium, neon and argon.

b Explain, in terms of electronic configuration, why the noble gases are chemically **inert** compared with the other elements.

c Leaving a space for argon, draw a scatter graph to show the density (vertical axis) of the noble gases against atomic number (horizontal axis). Use your graph to estimate the density of argon.

d Explain why drawing a graph makes it easier to estimate data.

3 Unlike most noble gases, xenon forms several compounds, for example xenon hexafluoride (XeF_6).

Suggest an explanation for why xenon forms compounds more easily than the noble gases higher up in group 0.

Extra challenge

4 Find out why the discovery of helium in 1868 disagreed with Mendeleev's periodic table of 1869, but the discovery of other noble gases later in the century confirmed the periodic table.

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 Why are the noble gases unreactive?

_____

_____

2 How can noble gases be used?

_____

_____

3 What trends are there in the physical properties of the noble gases?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

Your teacher may watch to see if you can…

- carefully control variables during investigations
- measure change accurately.

Aim

To investigate the effect on the **rate** of reaction of changing the surface area of solids and the concentration of solutions, by measuring the production of a gas.

Method

Apparatus

- eye protection
- balance
- water trough
- 100 cm^3 measuring cylinder
- stop clock
- conical flask
- delivery tube and bung
- stand and clamp
- five dilute hydrochloric acid solutions (1.0, 0.8, 0.6, 0.4 and 0.2 mol dm^{-3})
- marble chips (small)
- marble chips (large)

⚠ Safety

Wear eye protection at all times.

Care is needed with acid solutions. Wash off splashes immediately.

Task 1

A Set up the apparatus as shown in the diagram.

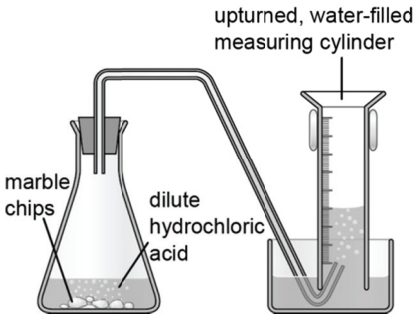
B Measure 40 cm^3 of 1.0 mol dm^{-3} hydrochloric acid into a conical flask.

C Add 5 g of small marble chips to the flask.

D Immediately stopper the flask and start the stop clock.

E Note the total volume of gas produced after every 30 seconds for five minutes or until the reaction has finished.

F Repeat steps **A–E** using 5 g of larger marble chips.



Task 2

G Follow steps **A–D** above.

H Note the amount of carbon dioxide produced in one minute.

I Repeat steps **G** and **H** using 0.8, 0.6, 0.4 and 0.2 mol dm^{-3} acid.

Recording your results

1 Record your results for each task separately, in tables with suitable headings.

Considering your results/conclusions

2 Use your results to draw a scatter diagram, including lines of best fit, to look for correlations between the **variables** under investigation.

3 Use your results and graphs to write a conclusion for each of the tasks.

Evaluation

4 Suggest possible sources of error in these investigations and possible changes to the method that could improve the reliability of the results.

Name _____ **Class** _____ **Date** _____

Task 1

Recording your results

1 Record your results in the table below.

Time (min)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Small chips – volume of gas (cm^3)											
Large chips – volume of gas (cm^3)											

Considering your results/conclusions

2 Use your results to draw a graph of volume of gas against time for small chips and the same graph for large chips on the same axes. Put time on the horizontal axis and volume of gas on the vertical axis. Draw a line of best fit for each graph, using different coloured lines and labels.

3 Explain how you can tell from the graphs when the reactions were finished.

4 Describe how the size of the marble chips is related to the surface area for a fixed mass of chips.

5 Describe how increasing the surface area affects the rate of reaction.

6 Explain how your results and graph fit with your conclusion in question **5**.

Evaluation

7 Suggest possible sources of error in this investigation.

8 Suggest possible changes to the method that could improve the reliability of the results.

Task 2

Recording your results

9 Record your results in the table below.

Concentration of acid ($mol\ dm^{-3}$)	0.2	0.4	0.6	0.8	1.0
Volume of gas produced in one minute (cm^3)					

Considering your results/conclusions

10 Use your results to draw a scatter graph of concentration of acid against volume of gas produced in one minute. Put volume of gas on the horizontal axis and concentration on the vertical axis.

11 Describe how the rate of the reaction is related to the concentration of the acid.

12 Explain how your results and graph fit with your conclusion in question **11**.

Evaluation

13 Suggest possible sources of error in this investigation.

14 Suggest possible changes to the method that could improve the reliability of the results.

Three experiments were carried out to show how concentration of solutions, temperature and surface area affect reaction **rates**.

1 The effect of concentration on the reaction between magnesium and acid

A student reacts magnesium with hydrochloric acid. The reaction produces hydrogen gas. She does the experiment several times, changing the concentration of the hydrochloric acid. Each time, she measures how much gas is produced in the first 10 seconds. The more gas that is produced in 10 seconds, the faster the reaction.

Concentration of hydrochloric acid (mol dm^{-3})	0	0.5	1.0	1.5	2.0
Volume of hydrogen in 10 seconds (cm^3)	0	15	28	46	62

a What is the independent **variable** in this experiment?

b Identify three control variables that the student must keep the same to make this experiment a fair test.

c Describe the relationship between the concentration of acid and the rate of the reaction.

2 The effect of temperature on the reaction between calcium carbonate and hydrochloric acid

A student reacts calcium carbonate with hydrochloric acid and measures the time taken to produce 40 cm^3 of carbon dioxide gas. The experiment is repeated at four different temperatures. The shorter the time taken to produce 40 cm^3 of gas, the faster the reaction.

Temperature (°C)	21	33	40	49	61
Time to collect 40 cm^3 of gas (s)	126	61	37	19	8

a What is the independent variable in this experiment?

b Identify three control variables that the student must keep the same to make this experiment a fair test.

c Describe the relationship between the temperature of the reaction mixture and the rate of the reaction.

3 The effect of surface area on a reaction involving rhubarb

A student carries out a series of reactions involving rhubarb, potassium manganate(VII), ethanedioic acid and sulfuric acid. The actual reaction is complex, but rhubarb contains a substance that reacts with potassium manganate(VII), which is purple, and the **product** of the reaction is colourless. She carries out each experiment with the same mass of rhubarb, but chops it up into a different number of pieces. She measures the pieces to work out the total surface area of the rhubarb. She measures how long it takes for the reaction mixture to turn from purple to colourless. The quicker the mixture goes colourless, the faster the reaction.

Surface area of rhubarb (cm^2)	10	18	25	30	34
Time to go colourless (s)	84	48	30	26	21

a What is the independent variable in this experiment?

b Identify three control variables that the student must keep the same to make this experiment a fair test.

c Describe the relationship between the surface area of the rhubarb and the rate of the reaction.

Extra challenge

4 Present the results of each experiment using an appropriate graph or chart.

5 Comment on the shape of each graph.

Name _____ **Class** _____ **Date** _____

EASIER

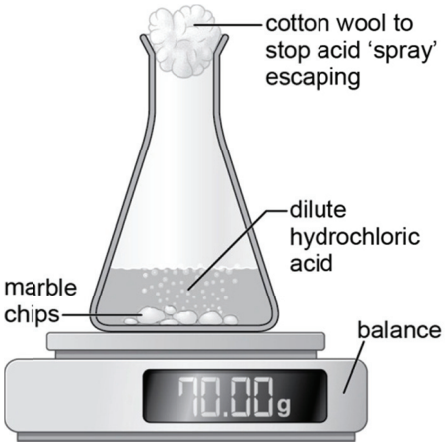
1 The diagram below shows an experimental set-up to investigate the effect of changing conditions on the **rate** of reaction. Complete the missing information in the sentences below.

a Three **variables** that could be investigated are:

c _____

t _____

s _____ a _____



These words may help you to answer question **1**.

carbon dioxide	concentration	decreases	flask	
mass	**reactants**	surface area	temperature	volume

The rate of a reaction can be followed by measuring the loss in m _____. As the reaction takes place, c _____ d _____ gas is given off and the mass of the conical f _____ and the r _____ decreases. To follow this reaction, we could also measure the v _____ of gas produced or the d _____ in concentration of acid.

S1 Look at the reaction in the diagram above.

a What is being measured in this experiment?

b What happens to the concentration of the acid as the reaction proceeds?

c What other change could be measured to follow this reaction?

HARDER

2 The table on the right shows results of an investigation into the reaction of calcium carbonate and acid using the apparatus above.

Trial	Temperature (°C)	Time for 0.5 g loss in mass (s)
1	21	60
2	33	28
3	42	13
4	50	7

a Name the variable being investigated. _____

b Name three variables that would need to be controlled.

_____

_____

_____

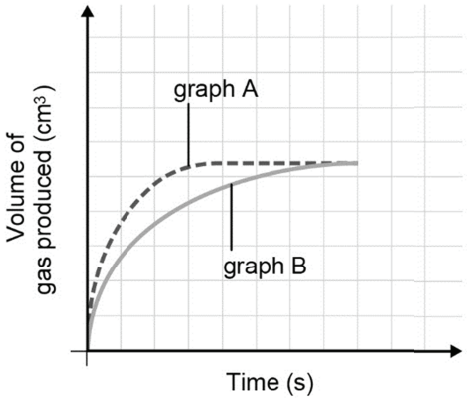
c Explain what these results tell us about rates of reaction.

_____

_____

Name _____ **Class** _____ **Date** _____

1 The graph shows the results obtained when investigating the reaction between nickel carbonate and hydrochloric acid at different temperatures.



a Which graph shows the reaction carried out at the higher temperature?

_____

b Explain your answer.

_____

_____

_____

2 Complete the word equation for the reaction between nickel carbonate and hydrochloric acid.

nickel carbonate + hydrochloric acid → _____ _____ + carbon dioxide + _____

3 Use the box opposite to draw a labelled diagram of how you would set up apparatus for the investigation in question **1**. You need to measure the volume of gas produced at different temperatures.

4 In this experiment, the dependant variable is the _____ of gas produced and the independent variable is the _____.

5 Two control variables are the _____ of acid and the size of the solid lumps of _____.

6 Look at the graph at the top of the page.

Explain why both lines on the graph become less steep with time and eventually level off.

_____

_____

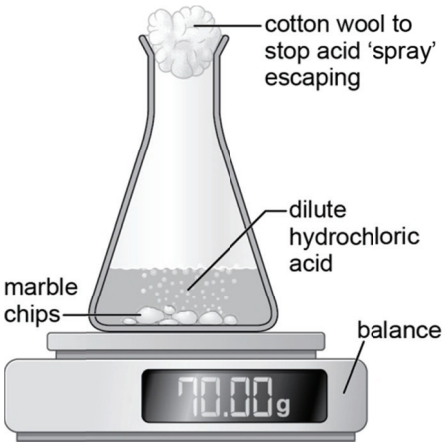
Marble chips (calcium carbonate) react with hydrochloric acid as follows.

calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide

One way to measure the **rate** of this reaction is to find the time taken to form 0.5 g of carbon dioxide.

The set-up for this investigation is shown opposite.

Two students carry out a series of reactions to see how changing the concentration of the hydrochloric acid, the surface area of the calcium carbonate (marble chips or powder) and the temperature of the reaction mixture affect the rate of reaction. Their results are shown in the table.



Experiment	Concentration of hydrochloric acid (mol dm^{-3})	Temperature (°C)	Type of calcium carbonate	Time to make 0.5 g of carbon dioxide (s)
1	2.0	21	small chips	60
2	4.0	21	small chips	32
3	8.0	21	small chips	15
4	4.0	21	large chips	84
5	4.0	21	powder	4
6	2.0	33	small chips	28
7	2.0	42	small chips	13
8	2.0	50	small chips	7

1 State two **variables** that the students need to control, in all these experiments, to make the tests fair.

2 State the link between the time taken to produce 0.5 g of carbon dioxide gas and the reaction rate.

3 **a** What is the effect of increasing the concentration of hydrochloric acid on the rate of reaction?

b Explain how the data in the table supports your answer to part **a**, by referring to specific results.

4 **a** Which type of calcium carbonate used in these experiments has the biggest surface area?

b What is the effect of changing the surface area of calcium carbonate on the rate of reaction?

c Explain how the data in the table supports your answer to part **b**, by referring to specific results.

5 **a** Draw a graph of temperature (horizontal axis) against time to make 0.5 g of gas (vertical axis).

b Explain what the graph tells you about the relationship between temperature and rate of reaction.

c State how much the temperature must increase to roughly double the rate of reaction.

6 Why, in the experiments in which temperature was changed, did students use small chips and not powdered calcium carbonate?

7 Give two reasons why students did not carry out the temperature experiments above 50 °C.

Extra challenge

8 Write a balanced equation for the reaction between hydrochloric acid and calcium carbonate. The equation should show that 2 moles of hydrochloric acid produces 1 mole of carbon dioxide gas.

9 When 5 moles of hydrochloric acid are reacted with excess calcium carbonate, calculate the number of moles of each of the following: calcium chloride, water and carbon dioxide.

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 What changes can occur as a reaction proceeds?

_____

_____

2 How can we investigate rates of reaction?

_____

_____

3 How are graphs used to show rates of reaction?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂	☹ ☹ 😐 🙂 🙂

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

Your teacher may watch to see if you can…

- carefully control variables during investigations
- measure change accurately

Aim

To investigate the effect of changing the temperature on the rate of reaction between sodium thiosulfate and hydrochloric acid, by observing a colour change in the solutions.

Method

Apparatus

- eye protection
- 250 cm^3 conical flask
- 10 cm^3 measuring cylinder
- 50 cm^3 measuring cylinder
- stop clock
- test tube and rack
- water bath
- white paper with cross
- sodium thiosulfate solution
- dilute hydrochloric acid

⚠ Safety

Wear eye protection at all times.

Care is needed with acid solutions. Wash off splashes immediately.

A Decide on four temperatures between 20 °C and 50 °C, which you are going to investigate.

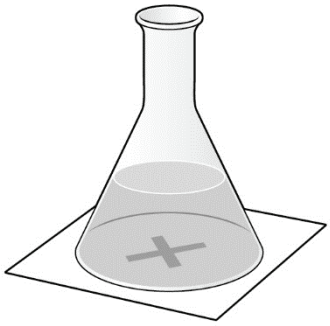
B Place 10 cm^3 of sodium thiosulfate solution and 40 cm^3 of water into a 250 cm^3 conical flask.

C Measure 5 cm^3 of dilute hydrochloric acid into a test tube.

D Clamp the conical flask in place in a water bath at your first chosen temperature. Place the test tube in a rack in the same water bath.

E Record your chosen temperature.

F After five minutes, remove the flask and place it on a piece of white paper marked with a cross, as shown opposite.



G Add the acid to the thiosulfate and start the stop clock.

H Looking down from above, stop the clock when the cross disappears.

I Note this time and the final temperature of the mixture.

J Repeat steps **A–I** for the other chosen temperatures.

Recording your results

1 Draw a table with two columns: one for average temperature, and the other for the time taken for the cross to disappear. Record the results of your experiments.

Considering your results/conclusions

2 Draw a scatter graph of your results, with temperature on the *x*-axis.) Draw a line of best fit.

3 **a** Describe how temperature affects the rate of the reaction.

b Explain your answer to part **a** by referring to the shape of your graph.

4 If the rate of reaction doubled, what would happen to the time taken for the cross to disappear?

5 **a** What temperature rise roughly doubles the rate of the reaction?

b Use the values from your graph to explain your answer to part **a**.

Evaluation

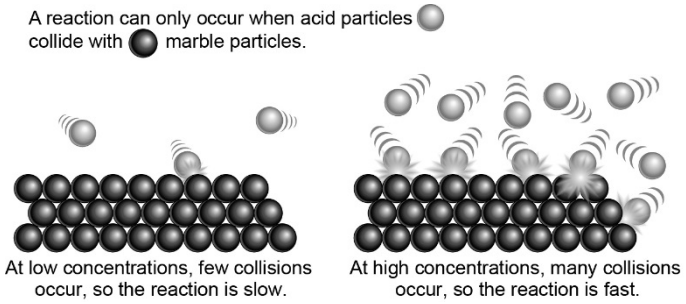
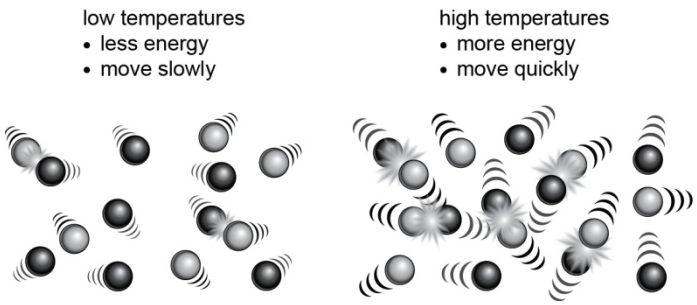
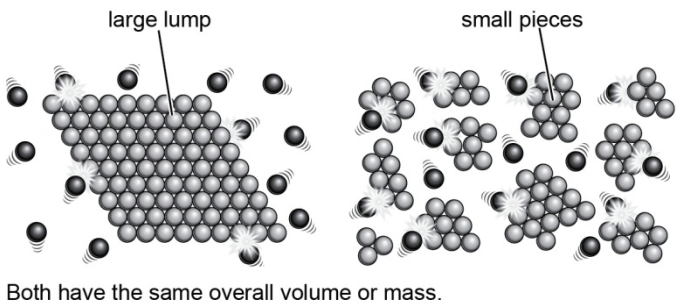
6 Describe two possible sources of error in this investigation.

7 Suggest a way of reducing one of these errors.

Name _____ **Class** _____ **Date** _____

EASIER

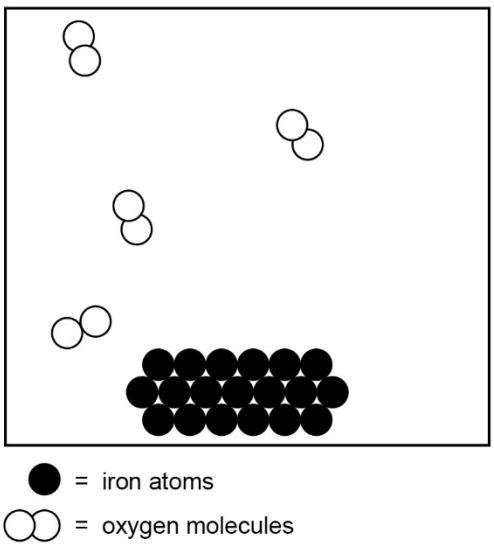
Use the notes and diagrams to help you write explanations for the effect of each factor on reaction rate.

Factor	Explanation
1 The effect of increasing concentration 	The reaction will only take place when the particles collide with enough energy. Increasing the concentration increases the rate of reaction. If there are more particles, ...
2 The effect of increasing temperature 	Increasing the temperature increases the rate, because the particles have more energy. This increases the rate of reaction in two ways. 1 .... 2 ....
3 The effect of increasing surface area 	Increasing the surface area ....

HARDER

S1 Use ideas about collisions and energy to explain how the rate of a reaction can be increased by changes in concentration, temperature and the size of pieces of a solid reactant.

1 Opposite is a simplified diagram of oxygen molecules reacting with iron atoms.



a Copy the diagram and beside it draw a new diagram to explain the effect of concentration on the rate of the reaction. Add labels as necessary to help your explanation.

b Below your copy of the diagram opposite, draw another diagram to explain the effect of changing the surface area of the solid on the rate of the reaction. Add labels as necessary to help your explanation.

c State two reasons why increasing the temperature increases the rate of a reaction.

2 The reaction between hydrogen and chlorine involves two gases containing diatomic (two-atom) molecules. The equation for the reaction is as follows.

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

a Describe what happens to the hydrogen and chlorine molecules if the pressure is increased.

b Explain how increasing gas pressure affects the rate of this reaction.

E1 Explain four ways in which the rate of reaction between iron lumps and oxygen from the air can be increased.

3 The balanced equation for the reaction between hydrochloric acid solution and solid lumps of marble (calcium carbonate) is as follows.

$2HCl + CaCO_3 \rightarrow CaCl_2 + CO_2 + H_2O$

a Rewrite this balanced equation to include state symbols.

b The table below shows how the volume of gas changed with time during the reaction of dilute hydrochloric acid with large lumps of marble.

Time (minutes)	0	1	2	3	4	5	6	7
Volume of gas (cm^3)	0	25	45	60	70	75	75	75

Draw a graph of this data with volume of gas (cm^3) on the vertical axis and time (min) on the horizontal axis.

c Explain why the volume of gas increases most quickly at the start of the reaction.

d Explain why the graph levels off.

e On the same axes used to answer part **b**, sketch the shape of the graph you would get if smaller lumps of marble were reacted with the same volume and concentration of hydrochloric acid.

f Use your graph to find the average rate of reaction between 0.5 and 1.5 minutes. Give your answer as 'increase in volume (cm^3/min)'.

g Use a tangent line to calculate the rate of reaction at 3.5 minutes. Give your answer as 'increase in volume (cm^3/min)'.

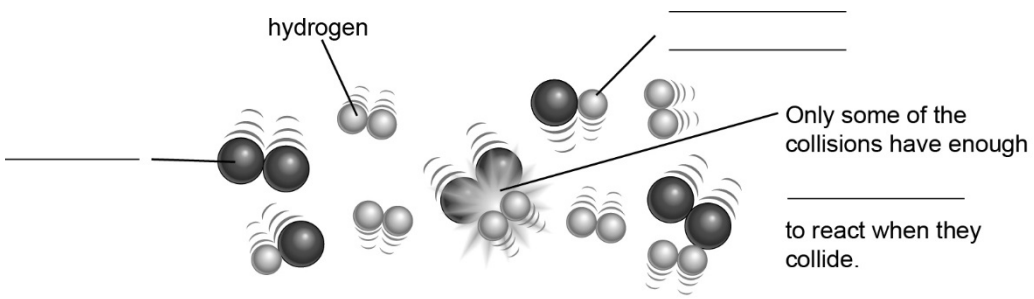
Name _____ **Class** _____ **Date** _____

1 Four factors that can affect the speed of a chemical reaction are:

a c _____ **b** t _____

c s _____ a _____ **d** g _____ p _____

2 The diagram below shows the reaction between hydrogen gas and chlorine gas.



a Complete the labels on the diagram.

b Complete the following sentences about changing the rate of this reaction.

The reaction between _____ and chlorine forms hydrogen chloride gas.

For a reaction to occur, the hydrogen and chlorine molecules must _____ with enough _____, called the _____ _____.

Increasing the concentration of either reactant _____ the rate of the reaction, because collisions occur more _____.

Decreasing the temperature _____ the rate of reaction, because collisions occur _____ frequently and fewer molecules have enough _____.

3 Explain, in terms of collisions and energy, why:

a Mince cooks faster than stew. _____

_____

_____

b Foods last longer in a fridge. _____

_____

_____

c Increasing pressure can make some fuels explode. _____

_____

_____

1 List four factors that can affect the speed of a chemical reaction.

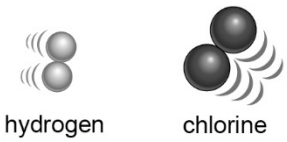
2 Scientists sometimes refer to an idea called the collision theory to explain how a reaction occurs and why changes in conditions can affect the rate of a reaction.

a Suggest a possible wording for the collision theory, in one sentence, starting with:

A chemical reaction occurs when ...

b Use the collision theory to explain how the size of marble chips affects the rate of their reaction with hydrochloric acid solution.

3 The reaction between hydrogen and chlorine involves two gases with diatomic (two-atom) molecules.



The equation for the reaction is: $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Draw two diagrams to explain how increasing the gas pressure will increase the rate of the reaction.

4 The reaction between copper carbonate powder and sulfuric acid solution was carried out in a conical flask placed on an electronic balance. The equation for the reaction is shown below.

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

The data collected is shown in the table below.

Time (min)	0	2	4	6	8	10	12	14	16
Total mass of apparatus (g)	20.0	19.7	19.4	19.15	18.9	18.75	18.7	18.7	18.7

a Show the data on a scatter diagram and draw a line of best fit. Put total mass of apparatus (g) on the vertical axis.

b Why does the apparatus lose mass?

c Explain what would happen to the steepness of the curve if the concentration of the acid were increased.

d Use your graph to find the average rate of reaction between 5 and 7 minutes. Give your answer as 'loss in mass (g/min)'.

e Use a tangent line to calculate the rate of reaction at 9 minutes. Give your answer as 'loss in mass (g/min)'.

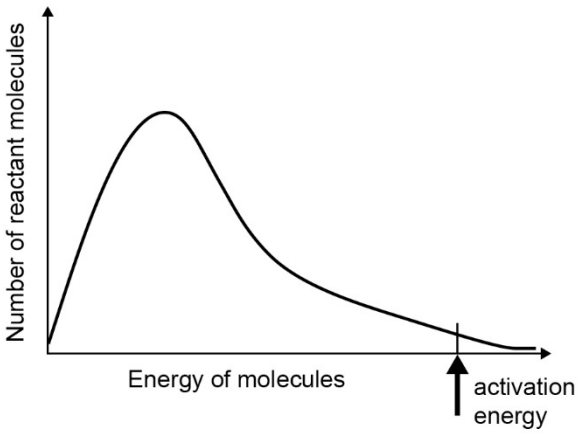
Extra challenge

5 The graph opposite shows the energy distribution of some reactant molecules at 20 °C. The **activation energy** for the reaction is marked on the horizontal axis of the graph.

a Explain why this is likely to be a slow reaction.

b Sketch a copy of the graph and draw and label the curve for the energy distribution at 30 °C.

c Use your graph to explain why the reaction is faster at the higher temperature.



Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 What has to happen for two particles to react?

_____

_____

2 How does the speed of particles affect the rate of reaction?

_____

_____

3 Why do changes in temperature, concentration, surface area and pressure affect rates of reaction?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

Your teacher may watch to see if you can…

- make qualitative observations and judgements to compare rates of reactions.

Aim

To compare the effect of different **catalysts** on the decomposition of hydrogen peroxide.

Apparatus

- eye protection
- 10 cm^3 measuring cylinder
- test tube rack
- five test tubes
- spatula
- aluminium oxide
- copper oxide
- iron(III) oxide
- manganese dioxide powder
- zinc oxide
- hydrogen peroxide solution

⚠ Safety

Wear eye protection at all times.

Hydrogen peroxide solution, copper oxide and manganese dioxide are harmful.

Method

A Draw a suitable table for your results – your observation of how fast oxygen gas is produced – with a column for each of the five metal oxides to be used as catalysts (listed above).

B Put five test tubes in a rack and pour exactly 5 cm^3 of hydrogen peroxide into each tube.

C Add about one-quarter of a spatula measure of a catalyst to one of the test tubes. Repeat until you have five test tubes each testing one catalyst.

D Observe and compare what happens in the test tubes.

Recording your results

1 Write your observations about the production of oxygen in your results table.

Considering your results/conclusions

2 Rank your catalysts in order of effectiveness.

3 Explain how you ranked the catalysts in order of effectiveness.

Evaluation

4 **a** Why was it important to use the same volume of hydrogen peroxide and the same amount of catalyst in each reaction?

b Comment on the accuracy of your measurements.

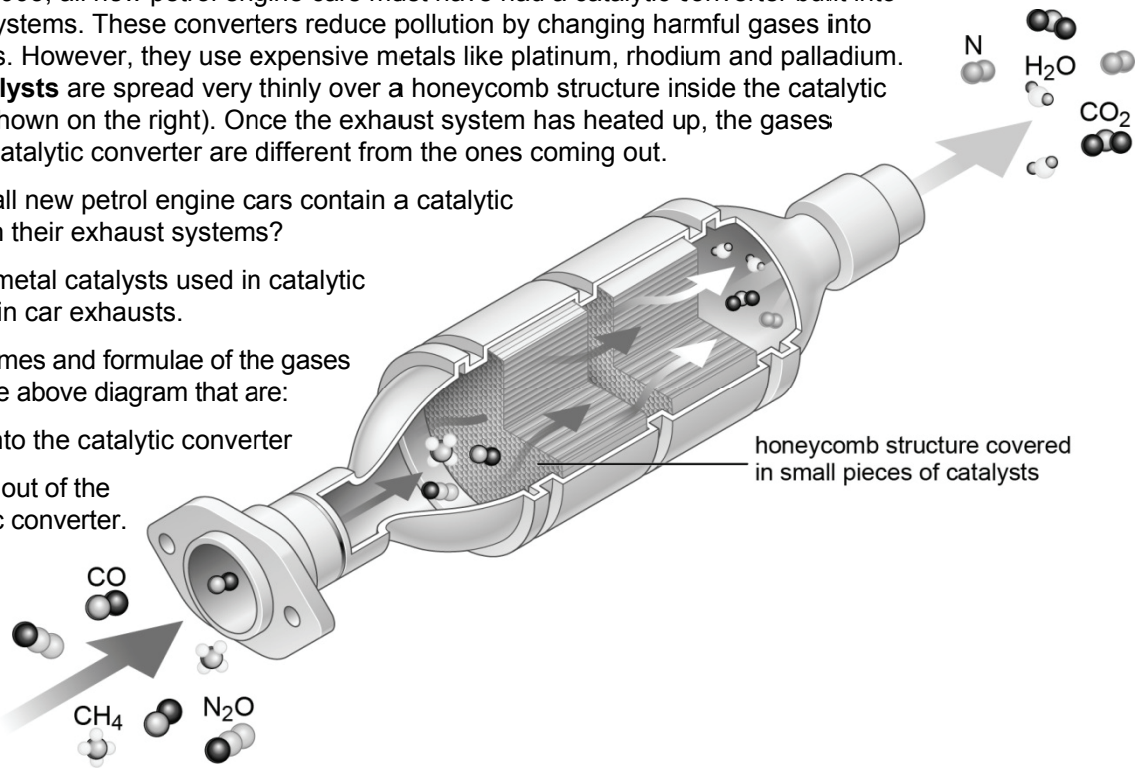
c Suggest a better way of measuring the same amount of catalyst in each case.

5 You judged your catalysts by looking at the reactions taking place.

a How sure were you about your order?

b Suggest a way to be more accurate when analysing which catalyst gives the fastest reaction.

The combustion of petrol in car engines produces a number of exhaust gases that can cause air pollution. These harmful gases include carbon monoxide, unburnt hydrocarbons and nitrogen oxides. Since 1993, all new petrol engine cars must have had a catalytic converter built into their exhaust systems. These converters reduce pollution by changing harmful gases into harmless gases. However, they use expensive metals like platinum, rhodium and palladium. The metal **catalysts** are spread very thinly over a honeycomb structure inside the catalytic converter (as shown on the right). Once the exhaust system has heated up, the gases going into the catalytic converter are different from the ones coming out.



1 Why must all new petrol engine cars contain a catalytic converter in their exhaust systems?

2 Name two metal catalysts used in catalytic converters in car exhausts.

3 Give the names and formulae of the gases shown in the above diagram that are:

a going into the catalytic converter

b coming out of the catalytic converter.

4 Describe a danger caused by carbon monoxide gas.

5 A number of reactions occur in the catalytic converter, for example carbon monoxide (CO) and dinitrogen oxide (N_2O) can be changed into carbon dioxide (CO_2) and nitrogen (N_2).

a Write a word equation and balanced equation for the reaction described above.

b Write a balanced equation for the reaction between methane (CH_4) and oxygen (O_2) to form carbon dioxide (CO_2) and water (H_2O).

6 **a** Explain why the catalyst is spread very thinly over a honeycomb.

b Suggest another possible reason why the catalysts are spread very thinly.

c Suggest a reason why the catalytic converter works better when the exhaust system is hot.

7 The table shows data for cars with and without catalytic converters. Note that diesel cars produce a lot of carbon particles (soot), whereas petrol cars do not. The levels of pollutants are given in comparison to those from a petrol car without a catalytic converter, which has a baseline value of 100.

Car type	Carbon monoxide	Unburnt hydrocarbon	Oxides of nitrogen	Carbon dioxide
Petrol car without catalytic converter (baseline values)	100	100	100	100
Petrol car with catalytic converter	42	19	23	100
Diesel car without catalytic converter	2	3	31	85

a Draw a suitable graph or chart to show the relative amounts of gases given out by each car.

b Describe the effect of the catalytic converter on emissions of these four types of gas.

c How do emissions from a diesel car compare with emissions from a petrol car with a catalytic converter?

Name _____ **Class** _____ **Date** _____

EASIER

1 Complete the following definitions.

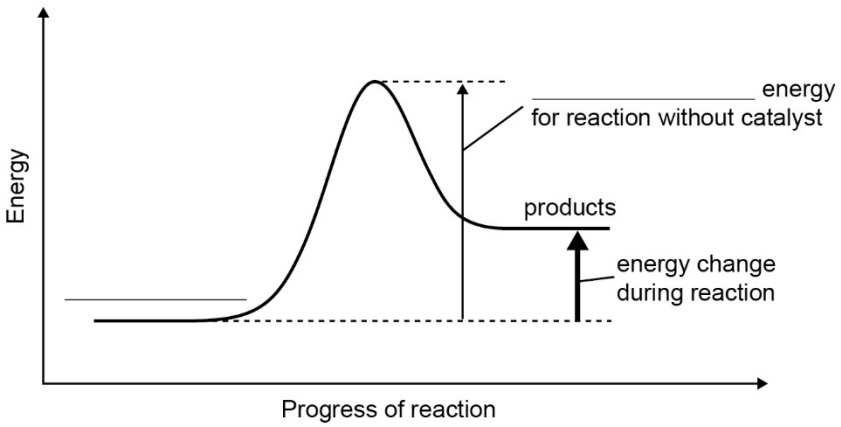
A **catalyst** is a substance that _____ the rate of a chemical reaction without being _____ itself. The catalyst will remain _____ at the end of the reaction.

An **enzyme** is a substance produced by _____ things that can act as a _____ to speed up biological reactions.

2 The diagram opposite shows the **reaction profiles** for a reaction carried out without the presence of a catalyst.

a Complete the labels on the diagram.

b Draw a dotted line on the diagram to represent the reaction profile for the same reaction when a catalyst is added.



c Draw an arrowed line to indicate the activation energy of the catalysed reaction, and label it.

d Explain, in terms of the energy of collisions, how a catalyst speeds up a reaction.

_____

_____

_____

3 Complete these sentences about enzymes.

Enzyme molecules have a part with a specific shape, called the a _____ site, that fits the shape of the reactant molecule, called the s _____. It works like a lock and k _____, and each enzyme catalyses only one reaction. Reactions catalysed by enzymes need less _____ so do not have to be heated to high temperatures. Both enzymes and catalysts can be _____ many times.

HARDER

S1 Explain, in terms of activation energy, how catalysts and enzymes work and why they are useful in industrial chemical reactions.

These words may help you to answer the questions.

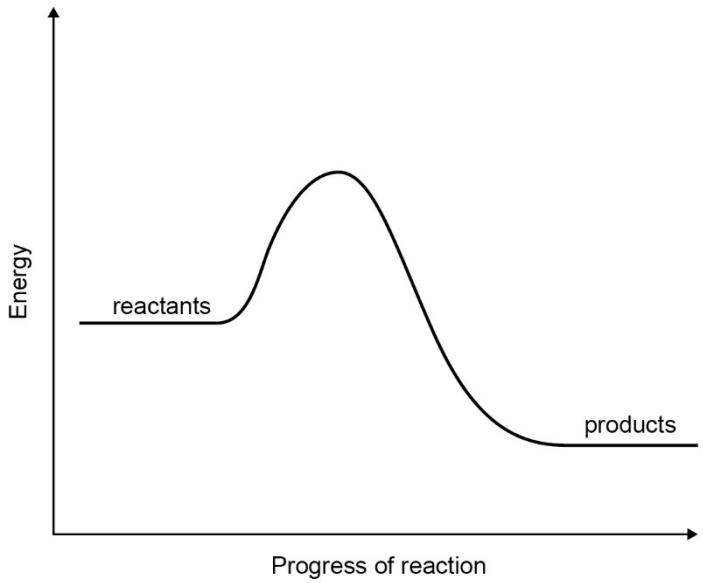
active	catalyst	energy	increases	key	living
reused	**substrate**	used up	unchanged		

Name _____ **Class** _____ **Date** _____

1 Draw lines to link the start and end of each of the sentences below to make correct statements.

Catalysts are used to ...	... the activation energy.
Catalysts allow chemical reactions to ...	... have enough energy needed for reaction.
Catalysts can be used again and again ...	... happen at lower temperatures.
Catalysts work by lowering ...	... speed up chemical reactions.
Using a catalyst means more molecules ...	... because they are not used up.

2 The graph below shows the **reaction profile** for an exothermic reaction with a catalyst added.



a Draw an arrowed line to indicate the activation energy of the catalysed reaction and label it.

b Draw a dotted line on the graph to represent the reaction energy profile for the same reaction without the catalyst present.

c Complete the following sentence to explain why the reaction is slower without a catalyst present.

Without the catalyst the activation energy is _____, so _____ reactant particles have enough _____ to react when they collide. This means fewer collisions result in a _____, and the overall rate of reaction is _____.

3 Choose one word or phrase from the box below to fit each of the following descriptions.

active site	catalyst	**enzyme**	**substrate**	**denatured**	**protein**

a a protein that acts as a biological catalyst: _____

b part of an enzyme molecule that fits the reacting molecules: _____

c a molecule that has changed shape due to changes in temperature or pH: _____

d the substance that is changed by a biological catalyst: _____

1 Read the paragraph below then answer the questions that follow.

The catalytic converters in car exhausts contain millions of tiny pieces of platinum, rhodium and palladium spread over a honeycomb structure. When exhaust gases like carbon monoxide (CO) and nitrogen dioxide (NO_2) pass over these metals, the metals act as a **catalyst** for the reactions that convert the exhaust gases into harmless gases like carbon dioxide (CO_2) and nitrogen (N_2).

a Write a balanced equation for the conversion of carbon monoxide and nitrogen dioxide into carbon dioxide and nitrogen.

b Describe what a catalyst is and explain how it works in terms of changing the activation energy of a reaction.

2 The results of an investigation into the decomposition of hydrogen peroxide using different metal oxides as catalysts are shown below.

a Plot the results on a chart or graph. Use the same axes for all the results. Time should be on the horizontal axis.

b Rank the three catalysts in order of increasing effectiveness. Explain how you decided on your order.

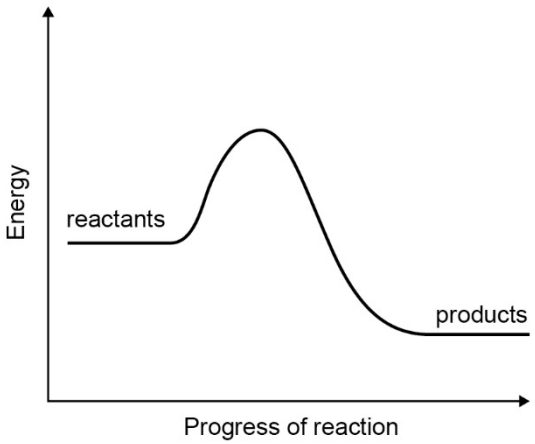
c List four variables that should be kept constant during the three experiments.

d The students used a spatula to measure the same amount of solid metal oxide in each experiment.

What could be done to improve the experiment instead of using a spatula?

Time (s)	Volume of oxygen formed with CuO catalyst (cm^3)	Volume of oxygen formed with MnO_2 catalyst (cm^3)	Volume of oxygen using ZnO catalyst (cm^3)
0	0	0	0
20	2	10	0
40	4	19	0
60	5	27	0
80	7	33	0
100	8	39	0
120	9	44	0

3 The diagram on the right shows the **reaction profile** for a reaction carried out with an **enzyme** present.



a Compare and contrast how enzymes and non-biological catalysts work.

b Copy the graph and add a dotted line to represent the same reaction without the enzyme present.

c Indicate and label the activation energy and overall energy change for each of the reactions on your graph.

d Use the diagram to explain why the reaction is slower without the enzyme.

Extra challenge

4 Metals can be protected by the addition of substances that slow corrosion. For example, the addition of zinc phosphate to paint can slow the corrosion of steel. These substances are called inhibitors or, sometimes, negative catalysts.

a Suggest how inhibitors may work.

b Suggest one other possible use for an inhibitor.

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 What is a catalyst?

_____

_____

2 How do catalysts work?

_____

_____

3 What are enzymes used for?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	1	2	3
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	1	2	3
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

Your teacher may watch to see if you can:

- carry out an experiment appropriately
- use apparatus accurately and safely.

Aim

A metal will displace a less reactive metal from its compounds in solution. For example, tin is more reactive than copper. It will displace copper from copper sulfate solution:

$$Sn(s) + CuSO_4(aq) \rightarrow Cu(s) + SnSO_4(aq)$$

You are going to investigate the temperature changes that accompany different **displacement** reactions.

Method

Apparatus

- eye protection
- 250 cm^3 beaker
- polystyrene cup
- 25 cm^3 measuring cylinder
- thermometer
- spatula
- magnesium powder
- zinc powder
- iron powder
- copper powder
- copper sulfate solution
- bowl for waste from the reaction mixtures

⚠ Safety

Wear eye protection.

Magnesium, iron and zinc powders are highly flammable.

Copper sulfate solution is harmful.

A Put the polystyrene cup into the beaker.

B Measure 20 cm^3 of copper sulfate solution into the polystyrene cup.

C Measure and record the temperature of the copper sulfate solution.

D Add two spatulas of magnesium powder to the polystyrene cup. Stir carefully with the thermometer and record the maximum temperature reached.

E Empty the contents of the polystyrene cup into a bowl. Wash and dry the polystyrene cup.

⚠ Safety

Take care to hold or support the thermometer so it does not tip over the polystyrene cup. Place the polystyrene cup and thermometer in a glass beaker to make them more stable.

F Repeat steps **A**–**E** but replace the magnesium powder with powdered zinc, iron or copper.

Recording your results

1 Record your results in a table with suitable headings, such as these.

Metal powder	Start temperature (°C)	Maximum temperature (°C)	Temperature change (°C)

Considering your results/conclusions

2 Calculate the temperature change for each metal powder used.

3 Explain the results obtained with copper powder, and whether the reactions are **exothermic** or **endothermic**.

4 Place the four metals in order of decreasing temperature change. Compare and contrast this list with the metal reactivity series.

Evaluation

5 Describe how energy transfer from the reaction mixtures to the air is reduced in this experiment.

6 Explain one way in which the experiment could be improved to further reduce energy transfers to the air.

Background information

Some reactions are used in hand warmers. Other reactions are used in 'instant' cold packs to treat sports injuries. Each card at the bottom of this sheet contains information about a reaction that might be used for one of these purposes.

Your task

1 Cut out the cards.

2 Sort the cards into two piles:

- **a** one pile with cards about a reaction that could be used in a hand warmer
- **b** one pile with cards about a reaction that could be used in a cold pack.

3 Organise each pile so that it tells you, in order:

- **a** the word equation and balanced equation for the reaction
- **b** why the reaction might be used for a hand warmer or for a cold pack
- **c** how the reaction is started, and any extra substance needed for the reaction to happen
- **d** what is left behind at the end of the reaction, and any problems that might cause.

4 Use your two organised piles to write a paragraph, small leaflet or poster about each reaction and its possible use. Include any reasons that explain why the reaction might *not* be suitable for that use.

Information cards

A cold corrosive slush is left at the end.	Sodium chloride and water are included to speed up rusting.
$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$	The reaction is started by opening an airtight container.
A hot powder similar to rusted iron is left at the end.	The reaction mixture reaches –25 °C.
The reaction gives out heat energy to the surroundings.	Ammonia gas is toxic and causes skin burns.
The reaction is **endothermic**.	barium hydroxide + ammonium thiocyanate → barium thiocyanate + water + ammonia
The reaction mixture reaches 40 °C.	iron + oxygen → iron(III) oxide
The reaction takes in heat energy from the surroundings.	The reaction is **exothermic**.
$Ba(OH)_2(s) + 2NH_4SCN(s) \rightarrow Ba(SCN)_2(s) + 2H_2O(l) + 2NH_3(g)$	The reaction is started by mixing the solids together.

Name _____ **Class** _____ **Date** _____

EASIER

1 Complete the table below about **exothermic** and **endothermic** reactions in solution by placing a tick (✓) in each correct box. You will need four ticks.

	Exothermic reactions	Endothermic reactions
Heat energy is given out		
Heat energy is taken in		
Temperature goes up		
Temperature goes down		

2 Use the correct answers to question **1** to help you write a sentence to describe what happens to heat energy and the temperature of the reaction mixture when:

a sodium hydroxide solution reacts with dilute hydrochloric acid in an exothermic reaction

_____

_____

b citric acid reacts with sodium hydrogen carbonate solution in an endothermic reaction.

_____

_____

3 Temperature changes accompany heat energy changes in solution.

a Name the simple piece of laboratory apparatus that is used to measure the temperature of a solution.

_____

b State *two* measurements needed to show that a heat energy change in solution has happened.

_____

_____

c Explain how you would use the measurements described in part **b** to show that an exothermic reaction has happened.

_____

_____

HARDER

S1 How can you work out whether a reaction in solution is exothermic or endothermic?

4 In the table below, place a tick (✓) in the box if heat energy changes happen in that type of reaction in solution.

	Heat energy changes happen
neutralisation reactions	
displacement reactions	
precipitation reactions	

5 Ammonium nitrate, NH_4NO_3, dissolves in water to form a solution. An endothermic change takes place.

State what happens to the temperature of the solution when ammonium nitrate is dissolved.

_____

Name _____ **Class** _____ **Date** _____

1 Which row in the table (A, B, C or D) correctly describes what happens during reactions in solution?

	Exothermic reactions		Endothermic reactions	
A	heat energy taken in	temperature increases	heat energy given out	temperature decreases
B	heat energy given out	temperature decreases	heat energy taken in	temperature increases
C	heat energy taken in	temperature decreases	heat energy given out	temperature increases
D	heat energy given out	temperature increases	heat energy taken in	temperature decreases

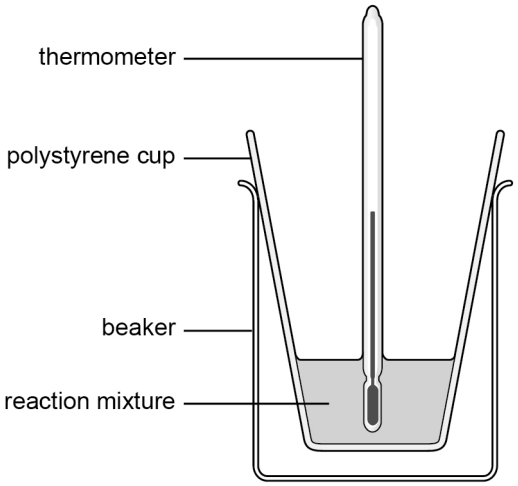
Answer _____

2 Zinc powder reacts with copper sulfate solution:

$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

A student uses the apparatus shown in the diagram to investigate temperature changes in this reaction.

The starting temperature of the copper sulfate solution was 18.7 °C. The maximum temperature reached after the zinc was added was 43.3 °C.



a Calculate the change in temperature during the experiment.

_____

b Explain, using your answer to part **a**, whether the reaction was **exothermic** or **endothermic**.

_____

c The student stirred the mixture continually with the thermometer. Suggest *two* reasons for this.

_____

_____

d State and explain *one* improvement to the apparatus that would produce more accurate results.

_____

_____

3 Reactions between an acid and an alkali are exothermic. Name a type of reaction in solution that can be exothermic *or* endothermic, depending on the substances used.

_____

4 When a salt dissolves in water, the change can be exothermic *or* endothermic, depending on the salt used. A student dissolves 1 g of sodium chloride in 250 cm^3 of water. Suggest a reason why he does not observe a temperature change, even though the dissolving of sodium chloride is known to be an endothermic process.

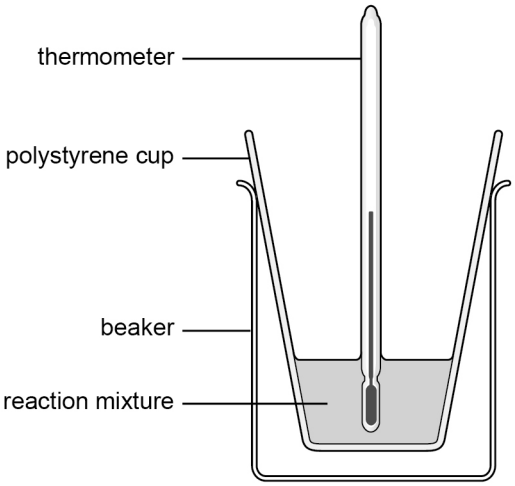
_____

_____

1 Zinc powder reacts with copper sulfate solution. Zinc sulfate solution and copper form in the reaction.

A student uses the apparatus shown in the diagram to investigate temperature changes in this reaction.

The starting temperature of the copper sulfate solution is 18.7 °C. The maximum temperature reached after the zinc is added was 43.3 °C.



a Name the type of reaction that occurs between zinc and copper sulfate solution.

b Calculate the change in temperature during the experiment.

c Explain whether the reaction was **exothermic** or **endothermic**.

d Suggest *two* reasons why the student stirred the mixture continually, during the experiment.

e State and explain *one* improvement to the apparatus that would produce more accurate results.

2 When a salt dissolves in water, the change can be exothermic *or* endothermic, depending on the salt used. 1.0 g of sodium chloride is dissolved in 250 cm^3 of water. Suggest a reason that explains why a temperature change is *not* observed, even though this reaction is known to be an endothermic process.

3 Magnesium nitrate solution, $Mg(NO_3)_2(aq)$, reacts with sodium carbonate solution, $Na_2CO_3(aq)$. Sodium nitrate solution and a precipitate of magnesium carbonate form.

a Write a balanced equation, including state symbols, for this reaction.

b The reacting ions take in energy from the surroundings. The 'surroundings' includes the water in which the ions are dissolved, the container and a thermometer.

i Explain, in terms of heat energy, whether the reaction is exothermic or endothermic.

ii Describe what happens to heat energy in the surroundings during the reaction.

iii Explain, in terms of heat energy, what happens to the temperature of the reaction mixture during the reaction.

Extra Challenge

4 It is possible to calculate the heat energy change in a reaction that takes place in solution:

$\Delta Q = m \times c \times \Delta\Theta$ where: ΔQ = change in heat energy, J

m = mass of water, kg

c = specific heat capacity of water, 4180 J/kg °C

$\Delta\Theta$ = change in temperature, °C

50.0 cm^3 of 36.5 g dm^{-3} hydrochloric acid is mixed with 50.0 cm^3 of 40.0 g dm^{-3} sodium hydroxide solution.

a The mass of 1 dm^3 of water is 1 kg. Calculate the total mass of water in the reaction mixture in kg.

b The temperature of the reaction mixture changes by 5.5 °C. Calculate the heat energy change in the water, in kJ. Give your answer to 2 significant figures.

c Using values from a data book, the heat energy change for this reaction should be 2.9 kJ. Suggest a reason, other than a mistake, that explains why the answer to part **b** may be different to this value.

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 What are exothermic and endothermic reactions?

_____

_____

2 What are some examples of exothermic and endothermic reactions?

_____

_____

3 How can heat changes in solution be investigated?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

Your teacher may watch to see if you can:

- follow instructions carefully.

Aim

You are going to use a molecular modelling kit to model the changes that happen during chemical reactions. You will use **bond energy** data to determine the amounts of energy transferred in these reactions.

Method

Apparatus

- molecular modelling kit

A For reaction **1** shown in the table, make a model of all the reactant molecules involved.

B Count the number of each type of bond. Write these into a suitable table.

C Use your reactant models to make models of all the product molecules made.

D Count the number of each type of bond. Write these in a suitable table.

E Repeat steps **A**–**D** with the other reactions shown in the table.

Reaction	Balanced equation	Reaction	Balanced equation
1	$2HCl \rightarrow H_2 + Cl_2$	3	$2H_2O_2 \rightarrow 2H_2O + O_2$
2	$CH_4 + Cl_2 \rightarrow CH_2Cl_2 + H_2$	4	$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$

Recording your results

1 Record, in a table or tables, the number of each type of bond in the reactants and the products.

Considering your results

2 For each reaction, using the information in the table of bond energies below:

a add together the bond energies for *all* the bonds in *all* the reactant molecules.

b add together the bond energies for *all* the bonds in *all* the product molecules.

c Use your answers to part **a** and part **b** to determine whether the reaction is exothermic or endothermic:

- if answer **b** is greater than answer **a**, the reaction is exothermic
- if answer **b** is less than answer **a**, the reaction is endothermic.

Evaluation

3 Like most bond energies, the bond energy for the C–H bond shown in the table is a mean value, taken from many different molecules. The actual value for the C–H bond in CH_4 is 435 kJ mol^{-1}.
Explain whether this makes a difference when deciding if reaction **2** is exothermic or endothermic.

Covalent bond	Bond energy (kJ mol^{-1})	Covalent bond	Bond energy (kJ mol^{-1})
H–H	436	O–H	464
Cl–Cl	243	O–O	144
H–Cl	432	O=O	498
C–H	413	C=O	805
C–Cl	346		

Tally charts

Reaction 1

Bonds in reactant molecules		
Type	Number	Bond energy (kJ mol^{-1})
H–Cl	2	432

Bonds in product molecules		
Type	Number	Bond energy (kJ mol^{-1})
H–H	1	436
Cl–Cl	1	243

Reaction 2

Bonds in reactant molecules		
Type	Number	Bond energy (kJ mol^{-1})
C–H	4	
Cl–Cl		

Bonds in product molecules		
Type	Number	Bond energy (kJ mol^{-1})
C–H	2	
C–Cl	2	
H–H		

Reaction 3

Bonds in reactant molecules		
Type	Number	Bond energy (kJ mol^{-1})
O–H		
O–O	1	

Bonds in product molecules		
Type	Number	Bond energy (kJ mol^{-1})
O–H		
O=O	1	

Reaction 4

Bonds in reactant molecules		
Type	Number	Bond energy (kJ mol^{-1})
C–H		
O–H		

Bonds in product molecules		
Type	Number	Bond energy (kJ mol^{-1})
C=O		
H–H		

Reaction number _____

Bonds in reactant molecules		
Type	Number	Bond energy (kJ mol^{-1})

Bonds in product molecules		
Type	Number	Bond energy (kJ mol^{-1})

Instructions to cut out and laminate

Drawing a reaction profile diagram

Stage 1

- Draw the horizontal axis and label it:
  - progress of reaction.
- Draw the vertical axis and label it:
  - heat energy.
- Write the diagram title (write out the balanced equation and whether the reaction is exothermic or endothermic).

Stage 2

- Draw a horizontal line on the left. Label it with the left-hand side of the balanced equation.
- Draw a horizontal line to the right of the first line, leaving a gap for stage 3. Label this line with the right-hand side of the balanced equation.
- Draw a vertical arrow from the level of the reactants line to the level of the products line.

  Label the vertical arrow:
  - overall energy change.

Stage 3

- Draw a curved line from the reactants line to the products line, to represent supplying the activation energy.
- Draw a vertical arrow from the level of the reactants to the top of the activation energy line.
- Label the vertical arrow:
  - activation energy.

Drawing a reaction profile diagram

Stage 1

- Draw the horizontal axis and label it:
  - progress of reaction.
- Draw the vertical axis and label it:
  - heat energy.
- Write the diagram title (write out the balanced equation and whether the reaction is exothermic or endothermic).

Stage 2

- Draw a horizontal line on the left. Label it with the left-hand side of the balanced equation.
- Draw a horizontal line to the right of the first line, leaving a gap for stage 3. Label this line with the right-hand side of the balanced equation.
- Draw a vertical arrow from the level of the reactants line to the level of the products line.

  Label the vertical arrow:
  - overall energy change.

Stage 3

- Draw a curved line from the reactants line to the products line, to represent supplying the activation energy.
- Draw a vertical arrow from the level of the reactants to the top of the activation energy line.
- Label the vertical arrow:
  - activation energy.

Reactions to cut out and laminate

A	**Complete combustion of methane** $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ exothermic	**E**	**Electrolysis of molten lead bromide** $PbBr_2 \rightarrow Pb + Br_2$ endothermic
B	**Decomposition of copper carbonate** $CuCO_3 \rightarrow CuO + CO_2$ endothermic	**F**	**Magnesium and steam** $Mg + H_2O \rightarrow MgO + H_2$ exothermic
C	**Neutralisation of an acid** $HCl + NaOH \rightarrow NaCl + H_2O$ exothermic	**G**	**Ammonia manufacture** $N_2 + 3H_2 \rightarrow 2NH_3$ exothermic
D	**Reactive metal and water** $2Na + 2H_2O \rightarrow 2NaOH + H_2$ exothermic	**H**	**Hydrogen manufacture** $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$ endothermic

Name _____ **Class** _____ **Date** _____

EASIER

1 Place a tick (✓) in each correct box to show what happens to the reactants and products during a reaction.

	Reactants	Products
Bonds break		
Bonds form		
Energy transferred to the substances		
Energy transferred to the surroundings		

2 Use the correct answers to question **1** to explain what happens to bonds and energy in the:

a reactants in a reaction

_____

_____

b products in a reaction.

_____

_____

3 In chemical reactions, energy is transferred to substances and to the surroundings.

a Cross out the incorrect **bold** word in the sentence below:

In an exothermic reaction, **more** | **less** energy is given out than is taken in from the surroundings.

b Use the correct answer to part **a** to help you write a sentence describing an endothermic reaction.

_____

_____

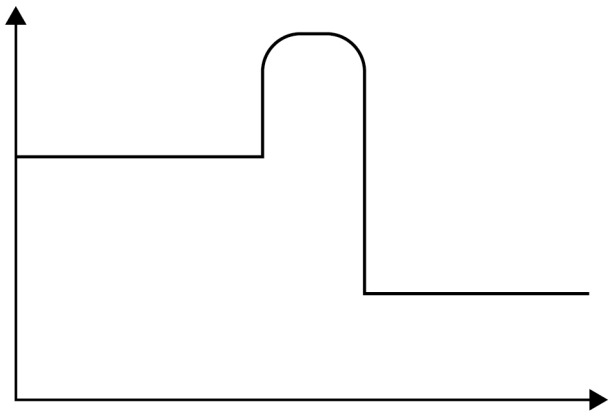
S1 What happens in exothermic and endothermic reactions when bonds are broken and made?

HARDER

4 The diagram below is an incomplete **reaction profile** diagram.

a Label both axes then complete the diagram by adding:

- dashed horizontal lines to continue the two horizontal lines and at the top of the hump
- labels and arrows to show the reactants, products, overall energy change and **activation energy**.



b Explain whether the reaction profile represents an exothermic reaction or an endothermic reaction.

_____

_____

S2 What information do reaction profiles give us?

Name _____ **Class** _____ **Date** _____

1 During chemical reactions, bonds in the reactants break and bonds form in the products.

a Which process, breaking of bonds or making of bonds, is **exothermic**?

_____

b Which process, breaking of bonds or making of bonds, is a process in which heat energy is taken in?

_____

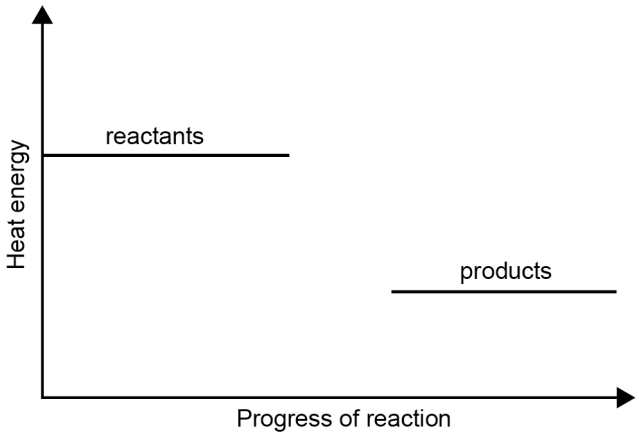
2 Magnesium reacts with dilute hydrochloric acid: $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

The diagram below shows the heat energy contained in the reactants and products.

Use the diagram to explain why the reaction is an exothermic reaction.

_____

_____



3 Explain what is meant by the term **activation energy**.

_____

_____

4 The reaction between nitrogen and oxygen is endothermic: $N_2(g) + O_2(g) \rightarrow 2NO(g)$

a Use the axes below to draw a **reaction profile** diagram for this reaction. Identify the overall energy change and activation energy in your diagram.

b Explain, in terms of energy transfers when bonds break and when bonds form, why this reaction is **endothermic**.

_____

_____

1 Explain, in terms of energy transfers when bonds break and when bonds form, why the combustion of methane is an exothermic reaction.

2 Explain what is meant by the term **activation energy**.

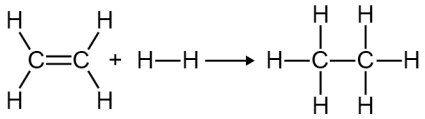
3 This reaction between nitrogen and oxygen is endothermic: $N_2(g) + O_2(g) \rightarrow 2NO(g)$

Draw a **reaction profile** for the reaction, identifying the overall energy change and activation energy.

The table shows some **bond energies**. Use these to answer questions **4** to **6**.

Covalent bond	C–O	C–C	C–H	H–H	O–H	O=O	C=C	C=O	C≡O
Bond energy (kJ mol^{-1})	336	347	413	436	464	498	612	805	1077

4 Ethene reacts with hydrogen to produce ethane.



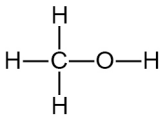
a Calculate the energy required to break all the bonds in the reactants.

b Calculate the energy released when all the bonds form in the products.

c Use your answers to parts **a** and **b** to calculate the overall energy change in the reaction.

d Explain what your answer to part **c** tells you about the reaction.

5 The diagram shows the structure of methanol, CH_3OH, which is useful as a fuel.



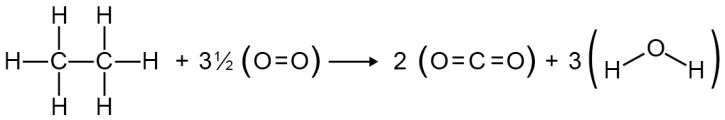
Methanol is manufactured from carbon monoxide and hydrogen: $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

Carbon monoxide, CO, contains a C≡O bond.

a Calculate the overall energy change in the forward reaction.

b State the overall energy change in the backward reaction (you do not need to carry out a calculation).

6 Ethane burns completely in oxygen, forming carbon dioxide and water:



Calculate the overall energy change for this reaction, and explain whether it is exothermic or endothermic.

Extra Challenge

7 The table shows some information about the complete combustion of three alcohols.

Alcohol	**Equation for complete combustion**	**Energy change in reaction (kJ mol^{-1})**
methanol	$CH_3OH + 1½O_2 \rightarrow CO_2 + 2H_2O$	to be calculated
ethanol	$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$	–1298
propanol	$C_3H_7OH + 4½O_2 \rightarrow 3CO_2 + 4H_2O$	–1916

a Calculate the overall energy change in the combustion of methanol.

b Predict the overall energy change in the combustion of butanol, C_4H_9OH, and explain your answer.

Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 How can exothermic and endothermic reactions be explained in terms of bonds?

_____

_____

2 How are exothermic and endothermic reactions modelled?

_____

_____

3 **H** How are energy changes in reactions calculated?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

SC17a Group 1

Word	Pronunciation	Meaning
alkali metals		A group of very reactive metals found in group 1 of the periodic table.
group (chemistry)		A vertical column of elements in the periodic table. Elements in the same group generally have similar properties.
periodic table		The chart in which the elements are arranged in order of increasing atomic number.
reactivity		A description of how quickly or vigorously something reacts.

SC17b Group 7

Word	Pronunciation	Meaning
bleach		To take the colour out of something.
diatomic		Two atoms chemically bonded together.
disinfectant		Something that destroys or neutralises disease-carrying microorganisms.
halide		A compound formed between a halogen and another element such as a metal or hydrogen.
halogen		An element in group 7 of the periodic table.
salt		A compound formed by neutralisation of an acid by a base.

SC17c Halogen reactivity

Word	Pronunciation	Meaning
displacement reaction		When a more reactive element displaces a less reactive element from one of its compounds.
oxidation	*ox-id-**day**-shun*	A reaction in which oxygen is added to a substance loss of electrons by an atom or negative ion.
oxidised	***ox**-id-eyes'd*	When a substance has gained oxygen (or lost electrons) in a reaction.
redox		A reaction in which both oxidation and reduction occur.
reduced	*red-**yoos**'d*	When a substance has lost oxygen (or gained electrons) in a reaction.
reduction	*red-**duck**-shun*	A reaction in which oxygen is removed from a substance; gain of electrons by an atom or positive ion.

SC17d Group 0

Word	Pronunciation	Meaning
inert		Does not react.
noble gas	***nO**-bul **gas***	An unreactive gas in group 0 of the periodic table.

SC18a Rates of reaction

Word	Pronunciation	Meaning
product		A substance formed in a reaction.
rate		How quickly something happens.
reactant		A substance used up in a chemical reaction.
variable	***vair**-ee-ab-el*	A factor that can change.

SC18b Factors affecting reaction rates

Word	Pronunciation	Meaning
activation energy		The minimum amount of energy needed to start a reaction.
endothermic		A type of reaction in which energy from the surroundings is transferred to the products. The products have more stored energy than the reactants have.
exothermic		A type of reaction in which energy is transferred to the surroundings from the reactants. The products have less stored energy than the reactants have.

SC18c Catalysts and activation energy

Word	Pronunciation	Meaning
active site		The space in an enzyme where the substrate fits during an enzyme-catalysed reaction.
catalyst		A substance that increases the rate of a reaction without itself being used up.
denatured		An enzyme in which the shape of the active site has changed so much that its substrate no longer fits and the reaction can no longer happen.
enzyme		A protein produced by living organisms that acts as a catalyst to increase the rate of a reaction.
protein		A polymer made up of amino acids.
reaction profile		A diagram to show how the energy stored in substances changes during a chemical reaction.
substrate		A substance that is changed during a reaction.

SC19a Exothermic and endothermic reactions

Word	Pronunciation	Meaning
displacement reaction		A reaction where a more reactive element takes the place of a less reactive element in a compound.
endothermic	*end-O-**ther**-mik*	A reaction in which energy is transferred to the reactants from the surroundings. The temperature of the surroundings decreases.
exothermic	*ex-O-**ther**-mik*	A reaction in which energy is transferred from the reactants to the surroundings. The temperature of the surroundings increases.
neutralisation	*new-tral-i-**zay**-shun*	A reaction in which an acid reacts with an alkali or a base to produce a salt and water only.
precipitation		A reaction in which an insoluble product is formed from soluble reactants.
reaction profile		A diagram to show how the energy stored in substances changes during the course of a chemical reaction.

SC19b Energy changes in reactions

Word	Pronunciation	Meaning
activation energy		The minimum amount of energy needed by colliding particles for a reaction to happen.
bond energy		Energy needed to break one mole of a specified covalent bond.
covalent bond		A bond formed when a pair of electrons is shared between two atoms.
mole		A mole of something is 6.02×10^{23} particles of it. The mass of a mole of a substance is the relative formula mass expressed in grams.
reaction profile		A diagram to show how the energy stored in substances changes during the course of a chemical reaction.

Name _____ **Class** _____ **Date** _____

A copy of the periodic table can be found at the end of this question paper.

1 The elements in group 0 are called the **noble gases**.

a Which one of the following is a **chemical** property shared by all group 0 elements?

Tick **one** box.

- ☐ **A** they are coloured
- ☐ **B** they are gases
- ☐ **C** they are unreactive
- ☐ **D** they form diatomic molecules

(1)

b The elements in group 0 all have low densities.

Figure 1 shows the densities of the first five elements in group 0.

The value for krypton is missing.

Element	Density (g/dm^3)
helium	0.18
neon	0.90
argon	1.8
krypton	
xenon	5.9

Figure 1

i Describe the trend in density down group 0.

_____

_____

(1)

ii Predict, using data in **Figure 1** to help you, the density of krypton.

density of krypton = _____ g/dm^3

(1)

c A party balloon or airship will rise in air if it is filled with a lifting gas.

State and explain **one** gas in **Figure 1** that will act as a lifting gas.

(Assume that the density of air is 1.2 g/dm^3.)

_____

_____

_____

(2)

d Which of the following is the electronic configuration of an element in group 0?

Tick **one** box.

- ☐ **A** 2.8.2
- ☐ **B** 2.8.4
- ☐ **C** 2.8.6
- ☐ **D** 2.8.8

(1)

(Total for Question 1 = 6 marks)

2 The elements in group1 of the periodic table are called the **alkali metals**.

a Which of the following group 1 metals is the **least** reactive?

Tick **one** box.

- ☐ **A** caesium
- ☐ **B** lithium
- ☐ **C** potassium
- ☐ **D** sodium

(1)

b What colour flame is seen when potassium reacts with water?

Tick **one** box.

- ☐ **A** blue
- ☐ **B** lilac
- ☐ **C** red
- ☐ **D** yellow

(1)

c A student added lithium to water.

When the reaction was complete, the student added a few drops of universal indicator solution to the mixture.

State and explain the **colour** change the student observed.

_____

_____

_____

(2)

(Total for Question 2 = 4 marks)

3 Copper carbonate reacts with hydrochloric acid to form copper chloride, water and carbon dioxide gas.

a Name the type of reaction in which energy is transferred **from** the surroundings **to** the products.

_____

(1)

b A student reacted copper carbonate and hydrochloric acid in an open conical flask.

The student measured the mass of the flask and its contents every 10 seconds.

Figure 2 shows the results of this experiment.

Time (s)	Mass (g)
0	124.92
10	124.65
20	124.52
30	124.42
40	124.35
50	124.32
60	124.32

Figure 2

Calculate the mean rate of this reaction.

Give the appropriate units.

(3)

c The student repeats the experiment using a higher concentration of hydrochloric acid.

State and explain the effect on the rate of reaction.

_____

_____

_____

(2)

(Total for Question 3 = 6 marks)

4 Chlorine is an element in group 7 of the periodic table.

a Describe the test for chlorine.

_____

_____

(2)

b Write the **word** equation for the reaction of chlorine with sodium.

_____ + _____ → _____

(2)

c Bromine is another element in group 7 of the periodic table.

Chlorine reacts with potassium bromide to form potassium chloride and bromine in a displacement reaction.

i State and explain whether chlorine or bromine is the more reactive group 7 element.

_____

_____

(2)

ii Complete the balanced equation for the reaction between chlorine and potassium bromide.

$$Cl_2 + \_\_\_KBr \rightarrow \_\_\_KCl + Br_2$$

(1)

(Total for Question 4 = 7 marks)

5 **Figure 3** shows the reaction profiles for two different reactions (reaction **A** and reaction **B**).

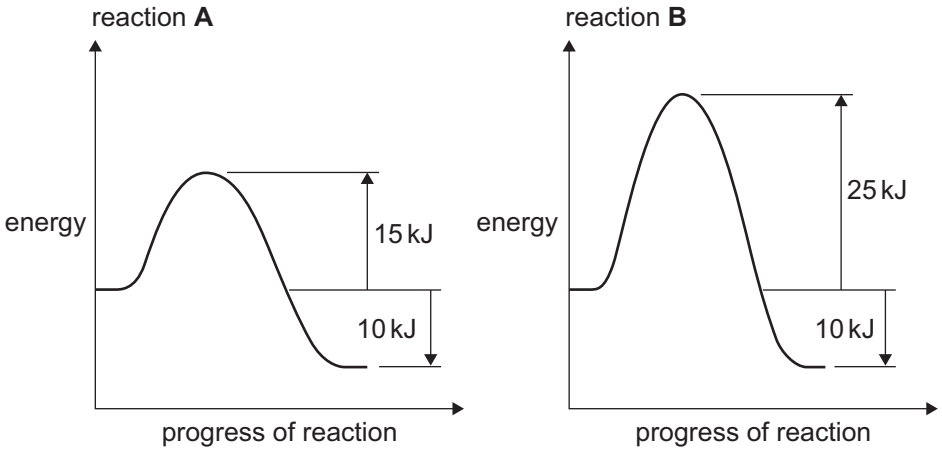


Figure 3

a Determine the **energy change** of reaction **A**.

_____

(1)

b Determine the **activation energy** of reaction **B**.

_____

(1)

(Total for Question 5 = 2 marks)

6 Zinc metal reacts with dilute hydrochloric acid to form zinc chloride solution and hydrogen gas.

a The balanced equation for this reaction is shown below.

Complete the equation by adding the **state symbols**.

$$Zn(\_\_\_) + 2HCl(\_\_\_) \rightarrow ZnCl_2(\_\_\_) + H_2(\_\_\_)$$

(1)

b A student wanted to investigate if copper metal would act as a **catalyst** in this reaction.

Describe what a catalyst does.

_____

_____

(1)

c The student set up two identical conical flasks, each containing the same volume and concentration of hydrochloric acid.

- The first flask contained zinc.
- The second flask contained copper powder and the same mass of zinc as the first flask.

During the experiment, the student measured the volume of gas produced in exactly one minute.

Name a suitable piece of apparatus to measure the volume of gas produced.

_____

(1)

d Describe **two** ways in which the student designed their investigation to give **valid** results.

1 _____

_____

2 _____

_____

(2)

e The mass of the flask and its contents decreased as the hydrogen escapes.

Explain why the loss in mass during the reaction **cannot** easily be measured using a balance.

_____

_____

(2)

f Explain how the student could use their results to compare the reaction rate with and without copper.

_____

_____

_____

_____

(2)

(Total for Question 6 = 9 marks)

7 Group 1 in the periodic table contains reactive metals, and group 7 contains reactive non-metals (the halogens).

Explain why the trends in reactivity in these two groups are different, including examples of typical chemical reactions of elements of the two groups in your answer.

(6)

(Total for Question 7 = 6 marks)

TOTAL FOR PAPER = 40 MARKS

The Periodic Table of the Elements

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4		Key relative atomic mass **atomic symbol** name atomic (proton) number									11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **TC** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

The lanthanoids (atomic numbers 58-71) and the actinoids (atomic numbers 90-103) have been omitted.

The relative atomic masses of copper and chlorine have not been rounded to the nearest whole number.

Name _____ **Class** _____ **Date** _____

A copy of the periodic table can be found at the end of this question paper.

1 The elements in group 0 of the periodic table are called the **noble gases**.

a Describe a chemical property shared by the group 0 elements.

_____

_____

(1)

b The elements in group 0 all have low densities.

Figure 1 shows the densities of the first five elements in group 0.

The value for krypton is missing.

Element	Density (g/cm^3)
helium	0.00018
neon	0.00090
argon	0.0018
krypton	
xenon	0.0059

Figure 1

Predict the density of krypton.

Use data in **Figure 1** to help you.

density of krypton = _____ g/cm^3

(1)

c Which of the following is the electronic configuration of an element in group 0?

Tick **one** box.

☐ **A** 2.8.2

☐ **B** 2.8.4

☐ **C** 2.8.6

☐ **D** 2.8.8

(1)

(Total for Question 1 = 3 marks)

2 The elements in group 1 of the periodic table are called the **alkali metals**.

a Describe the trend in reactivity **down** the group of alkali metals.

_____

_____

(1)

b What colour flame is seen when potassium reacts with water?

Tick **one** box.

☐ **A** blue

☐ **B** lilac

☐ **C** red

☐ **D** yellow

(1)

c Potassium reacts with water to produce potassium hydroxide solution and hydrogen.

Complete the balanced equation for the reaction between potassium and water.

Include state symbols for each substance.

$$2K(s) + 2H_2O(l) \rightarrow \_\_\_\_\_(\_\_\_) + \_\_\_\_\_(\_\_\_)$$

(3)

(Total for Question 2 = 5 marks)

3 Some students investigated factors affecting the rate of reactions involving dilute hydrochloric acid.

a Hydrogen is one of the products when hydrochloric acid reacts with **magnesium**.

Explain why the loss of hydrogen during the reaction **cannot** easily be measured using a balance.

_____

_____

(2)

b Carbon dioxide is one of the products in the reaction between hydrochloric acid and **calcium carbonate**.

The students carried out the reaction in a conical flask fitted with a bung and delivery tube.

They measured the volume of gas produced using an upturned measuring cylinder in a trough of water.

i Name **one** suitable piece of apparatus to replace the upturned measuring cylinder.

_____

(1)

ii Describe how the students could improve the experiment by avoiding the use of a trough of water.

_____

_____

(1)

c Sulfur dioxide gas is one of the products in the reaction between hydrochloric acid and **sodium thiosulfate solution**.

i Describe how the students could decide from their observations of the reaction whether sulfur dioxide is soluble or insoluble in water.

_____

_____

_____

(2)

ii The students measured reaction times by timing how long it took for a cross to disappear from view, when seen through the reaction mixture.

Give **two** reasons why it is only necessary to record these reaction times to the nearest whole second (1 second), rather than to the nearest hundredth of a second (0.01 seconds).

1 _____

_____

2 _____

_____

(2)

(Total for Question 3 = 8 marks)

4 Chlorine and bromine are two elements in group 7 of the periodic table.

a Describe the test for chlorine.

_____

_____

(2)

b Chlorine displaces bromine from sodium bromide solution:

$$Cl_2(g) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(aq)$$

i Explain why this reaction is an example of a **redox** reaction.

_____

_____

(2)

ii Write an ionic equation for this reaction, ignoring state symbols.

_____

(2)

(Total for Question 4 = 6 marks)

5 Nitrogen and hydrogen react together to form ammonia:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

a **Figure 2** shows the **reaction profile** for the reaction between nitrogen and hydrogen without a catalyst.

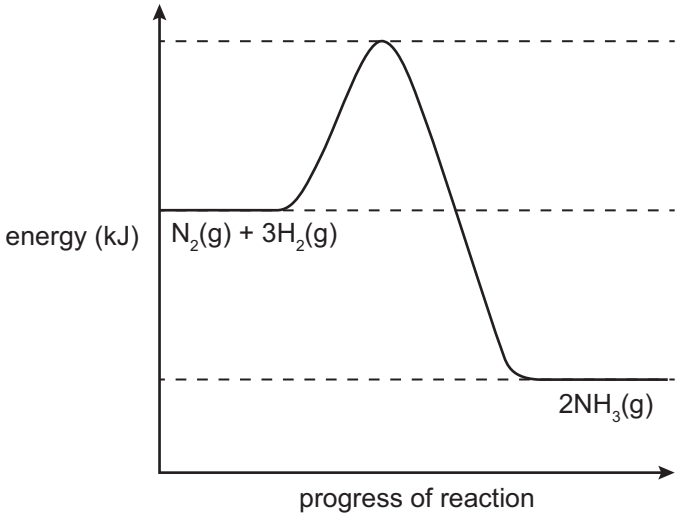


Figure 2

i Draw an arrow on **Figure 2** to show the activation energy for the reaction **without** a catalyst.

(1)

ii Draw a line on **Figure 2** to represent the reaction profile when a catalyst is used.

(2)

b Explain whether **Figure 2** represents an endothermic reaction or an exothermic reaction.

Give your answer in terms of bonds and energy transfers.

(3)

c **Figure 3** shows the reaction profiles for two different reactions (reaction **A** and reaction **B**).

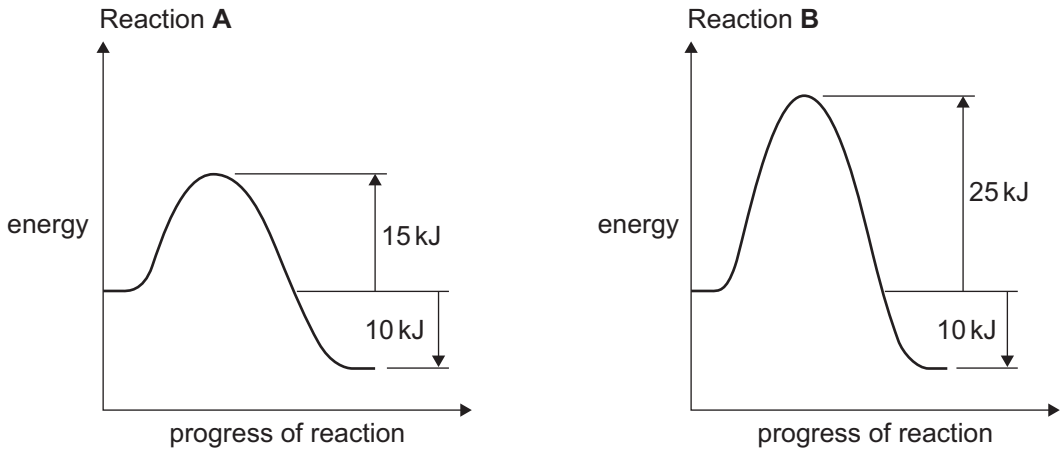


Figure 3

Explain why reaction **A** might happen faster than reaction **B** if both are carried out under the same conditions.

Use information in **Figure 3** to help you.

(2)

(Total for Question 5 = 8 marks)

6 The complete combustion of ethene in oxygen produces carbon dioxide and water:

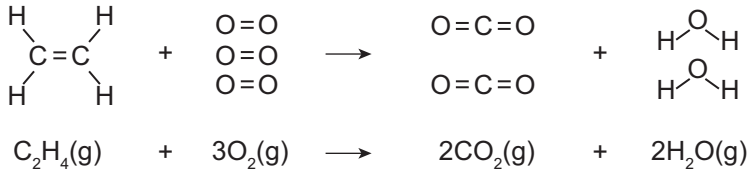


Figure 4 shows the bond energies for some covalent bonds.

Covalent bond	C–H	O–H	O=O	C=O	C–C	C=C
Bond energy (kJ mol^{-1})	413	464	498	805	347	612

Figure 4

Calculate the **energy change** for the complete combustion of 1 mol of ethene.

_____kJ mol^{-1}

(4)

(Total for Question 6 = 4 marks)

7 Hydrogen reacts with iodine to form hydrogen iodide:

$$H_2(g) + I_2(g) \rightarrow 2HI(g)$$

Figure 5 models how the reactant molecules react together to form the product molecules.

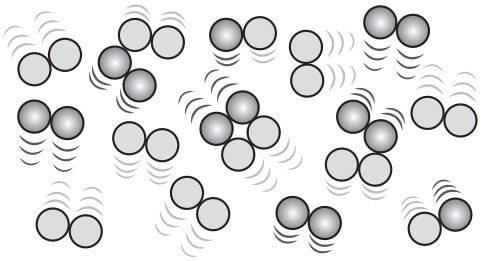


Figure 5

Explain how the rate of this reaction is affected:

- by the presence of a suitable catalyst
- by changes in pressure and temperature.

(6)

(Total for Question 7 = 6 marks)

TOTAL FOR PAPER = 40 MARKS

The Periodic Table of the Elements

1	2											3	4	5	6	7	0
							1 H hydrogen 1										4 He helium 2
7 Li lithium 3	9 Be beryllium 4											11 B boron 5	12 C carbon 6	14 N nitrogen 7	16 O oxygen 8	19 F fluorine 9	20 Ne neon 10
23 Na sodium 11	24 Mg magnesium 12											27 Al aluminium 13	28 Si silicon 14	31 P phosphorus 15	32 S sulfur 16	35.5 Cl chlorine 17	40 Ar argon 18
39 K potassium 19	40 Ca calcium 20	45 Sc scandium 21	48 Ti titanium 22	51 V vanadium 23	52 Cr chromium 24	55 Mn manganese 25	56 Fe iron 26	59 Co cobalt 27	59 Ni nickel 28	63.5 Cu copper 29	65 Zn zinc 30	70 Ga gallium 31	73 Ge germanium 32	75 As arsenic 33	79 Se selenium 34	80 Br bromine 35	84 Kr krypton 36
85 Rb rubidium 37	88 Sr strontium 38	89 Y yttrium 39	91 Zr zirconium 40	93 Nb niobium 41	96 Mo molybdenum 42	[98] TC technetium 43	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54
133 Cs caesium 55	137 Ba barium 56	139 La* lanthanum 57	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	195 Pt platinum 78	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

The lanthanoids (atomic numbers 58-71) and the actinoids (atomic numbers 90-103) have been omitted.

The relative atomic masses of copper and chlorine have not been rounded to the nearest whole number.

Question number	Part	Step	Answer	Additional guidance	Marks
1	a	3	**C** they are unreactive		**1 mark**
	bi	5	(Density) increases down the group.		**1 mark**
	bii	5	any number between 3.2 and 4.5		**1 mark**
	c	5	helium/neon (1) The density is less than the density of air/less than 1.2 g/dm^3. (1)		**2 marks**
	d	8	**D** 2.8.8		**1 mark**
2	a	5	**B** lithium		**1 mark**
	b	5	**B** lilac		**1 mark**
	c	7	(Green) to dark blue/purple (1) as the solution/water is now alkaline/alkali produced. (1)		**2 marks**
3	a	5	endothermic		**1 mark**
	b	7	rate = $\frac{(124.92 - 124.32)}{50}$ (1) = 0.012 (1) g/s (1)	Allow correct answer without working Allow 1 mark for correct working and answer if reaction time is taken to be 60 s in error (0.010)	**3 marks**
	c	7	(Increases because) there are more reacting particles in the same volume (1) so collisions occur more frequently/often. (1)	Do not accept more collisions unless in the context of a given time	**2 marks**
4	a	5	Place **damp** blue litmus paper in the gas. (1) The paper will be bleached/turn white/is decolourised. (1)	Do not allow goes clear/goes colourless	**2 marks**
	b	3–4	chlorine + sodium $\rightarrow$ sodium chloride LHS: chlorine + sodium (1) RHS: sodium chloride (1)	LHS in either order Do not allow chlorine for chloride	**2 marks**
	ci	7	Chlorine (1) as it displaced/replaced the bromine. (1)		**2 marks**
	cii	7	$Cl_2 + \mathbf{2}KBr \rightarrow \mathbf{2}KCl + Br_2$	Balancing needs to be correct on both halides	**1 mark**
5	a	7	10 (kJ)	Allow –10	**1 mark**
	b	7	25 (kJ)	Do not accept a negative value	**1 mark**

Question number	Part	Step	Answer	Additional guidance	Marks
6	a	5	$Zn(\mathbf{s}) + 2HCl(\mathbf{aq}) \rightarrow ZnCl_2(\mathbf{aq}) + H_2(\mathbf{g})$ In order: s, aq, aq, g	Allow upper case letters Allow words Do not allow any additional small numbers/changes to reactants or products	**1 mark**
	b	7	It speeds up/increases the rate of a chemical reaction.		**1 mark**
	c	7	a gas syringe	Accept **upside down** (inverted) burette/measuring cylinder	**1 mark**
	d	7	Any **two** from: • same volume of acid (1) • same concentration of acid (1) • same mass of zinc (1) • volume measured over the same time (1)	Do not accept same temperature	**2 marks**
	e	8	Hydrogen has a low mass/relative formula mass. (1) The change in mass would be too small to measure. (1)	Accept it has a very low density Accept a balance with a high resolution would be needed	**2 marks**
	f	7	Measure/record/read the volume of gas produced (in one minute). (1) (The reaction which produces) most gas has the fastest reaction. (1)		**2 marks**
7		7–8	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **Indicative content AO1 (3 marks) and AO2 (3 marks)** **Trends of reactivity:** • The reactivity of the alkali metals in group 1 increases down the group, • as moving down the group there are more occupied electron shells. • The outer electrons get further away from the positive nucleus		**6 marks**

Question number	Part	Step	Answer	Additional guidance	Marks
			• so an outer electron is lost more easily (to form a positive ion). • This makes the metals at the bottom of the group more reactive. • The reactivity of the halogens (group 7) decreases down the group/halogens are more reactive at the top of the group. • At the top of the group, halogen atoms have fewer occupied electron shells. • The reactivity of the halogens decreases as the outer electrons get further away from the positive nucleus • so it is harder to gain an outer electron (to form a negative ion). **Typical chemical reactions:** • For example, the alkali metals react with oxygen, • forming metal oxides. • The alkali metals react with water, • forming an alkali (metal hydroxide) and hydrogen. • descriptions of reactions of alkali metals with water linked to reactivity • The halogens react with metals, • forming metal halides. • The halogens react with hydrogen, • forming hydrogen halides. • Hydrogen halides form acids in solution. • More reactive halogens can displace less reactive halogens from a halide compound in solution. • examples of word and/or balanced equations written for the above reactions		

Step	Marks	Descriptor
U	0	No awardable content.
6	1–2	**Level 1** • Demonstrates elements of chemical understanding, some of which are inaccurate. Understanding of scientific ideas, enquiry, techniques and procedures lacks detail. (AO1) • Lines of reasoning are unsupported or unclear. (AO2)
7	3–4	**Level 2** • Demonstrates chemical understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas, enquiry, techniques and procedures is not fully detailed and/or developed. (AO1) • Lines of reasoning are mostly supported through the application of relevant evidence. (AO2)
8	5–6	**Level 3** • Demonstrates accurate and relevant chemical understanding throughout. Understanding of the scientific ideas, enquiry, techniques and procedures is detailed and fully developed. (AO1) • Lines of reasoning are supported by sustained application of relevant evidence. (AO2)

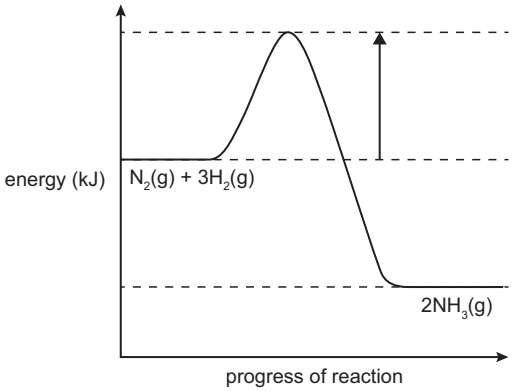
Step boundaries

Step	Marks
U	0–1
1	2–4
2	5–8
3	9–11
4	12–13
5	14–16
6	17–18
7	19–22
8	23+

Indicative grade boundaries

Indicative grade	Marks
U	0–4
1	5–8
2	9–13
3	14–18
4	19–22
5	23+

Question number	Part	Step	Answer	Additional guidance	Mark
1	a	5	They are unreactive/inert.		**1 mark**
	b	7	Any number between 0.0032 and 0.0045		**1 mark**
	c	8	**D** 2.8.8		**1 mark**
2	a	8	Reactivity increases down the group/decreases up the group.		**1 mark**
	b	5	**B** lilac		**1 mark**
	c	8	Correct products (KOH and H_2) (1) Correct products correctly balanced (**2**KOH) (1) Correct state symbols: (aq) for KOH and (g) for H_2 (1)	Accept upper case state symbols Do not accept words	**3 marks**
3	a	8	Hydrogen has a low mass/relative formula mass. (1) The change in mass would be too small to measure. (1)	Accept it has a very low density Accept a balance with a high resolution would be needed	**2 marks**
	bi	7	Any **one** from: • burette (1) • graduated pipette (1) • volumetric pipette (1)		**1 mark**
	bii	7	Use a gas syringe to measure the volume of gas produced. (1)		**1 mark**
	ci	8	They would see bubbles if the gas is insoluble (1) but no bubbles if the gas is soluble. (1)	Ignore references to odour or measurement of pH	**2 marks**
	cii	8	Any **two** from: • It takes time to start/stop the stop watch. (1) • It takes time to add the two reactants together. (1) • It takes time to mix the reactants thoroughly. (1) • It is difficult to judge when the cross has just disappeared from view. (1) • The error is small if the reaction times are long. (1)		**2 marks**
4	a	5	Place **damp** litmus paper in the gas. (1) The paper is bleached/it turns white/is decolourised. (1)	Do not allow goes clear/goes colourless	**2 marks**
	bi	10	EITHER Oxidation and reduction happen at the same time. (1) transfer of electrons/loss and gain of electrons (1) OR	Both marks from the same pair	**2 marks**

Question number	Part	Step	Answer	Additional guidance	Mark
			The Br^-/bromide ions lose electrons. (1) Cl_2/chlorine atoms/molecules gain electrons. (1)		
	bii	10	$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$ • correct formulae (1) • correct formulae correctly balanced (1)	Ignore state symbols	**2 marks**
5	ai	9	 arrow, from the starting point of the original graph to a point level with the highest point of the peak of the graph	Arrow must point upwards to award the mark	**1 mark**
	aii	10	line starting and finishing at the same points as the original graph (1) rising to a peak at a lower point than the original graph (1)		**2 marks**
	b	10	(Exothermic because) energy change is negative/energy is given out in the reaction (1) energy of reactants is higher than energy of products (1) more heat energy released forming bonds in products than needed to break bonds in reactants (1)	Accept opposite arguments	**3 marks**
	c	8	Activation energy for reaction **A** is lower than for reaction **B** (1) so more/higher proportion of reactant particles/molecules can react on collision in reaction **A**. (1)	Accept reverse argument for reaction **B**	**2 marks**
6		11	Energy needed to break bonds = 612 + (4 × 413) + (3 × 498) = 612 + 1652 + 1494 = 3758 ($kJ\,mol^{-1}$) (1) Energy released when bonds are formed = (4 × 805) + (4 × 464) = 3220 + 1856	Award full marks for correct numerical answer without working	**4 marks**

Question number	Part	Step	Answer	Additional guidance	Mark
			= 5076 (kJ mol^{-1}) (1) Energy change = 3758 – 5076 = (–)1318 (kJ mol^{-1}) (1) negative sign or 'energy released' (1)	Allow 5076 – 3758 (1) Ignore sign here Allow exothermic Allow error carried forward in calculation	
7		11–12	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **Indicative content AO1 (4 marks) and AO2 (2 marks)** A reaction occurs when molecules collide with enough energy/the activation energy. • Reacting molecules need a minimum amount of energy to break bonds • for the collision to be successful. • Reaction rate increases in the presence of a **catalyst**. • A catalyst reduces the activation energy needed. • So a greater number/proportion/percentage of collisions are successful. • Increased **pressure** increases rate of reaction. • Increased pressure means molecules are closer together • so there is a higher frequency/rate of (successful) collisions. • Increases in **temperature** greatly increase the rate. • Increased temperature increases the speed (energy) of molecules. • Collisions occur more frequently. • More molecules have the activation (enough) energy • so there is a higher frequency/rate of (successful) collisions.	Do not allow answers in terms of number of collisions unless in the context of a given time	**6 marks**

Step	Marks	Descriptor
U	0	No awardable content.
10	1–2	**Level 1** • Demonstrates elements of chemical understanding, some of which are inaccurate. Understanding of scientific ideas, enquiry, techniques and procedures lacks detail. (AO1) • Presents an explanation with some structure and coherence. (AO1)
11	3–4	**Level 2** • Demonstrates chemical understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas, enquiry, techniques and procedures is not fully detailed and/or developed. (AO1) • Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
12	5–6	**Level 3** • The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2) • Lines of reasoning are supported by sustained application of relevant evidence (AO2)

Step boundaries

Step	Marks
U	0–6
5	7–8
6	9–10
7	11–14
8	15–18
9	19–22
10	23–26
11	27–31
12	32+

Indicative grade boundaries

Indicative grade	Marks
U	0–6
3	7–10
4	11–14
5	15–18
6	19–22
7	23–26
8	27–31
9	32+