Oxford Cambridge and RSA

Friday 17 May 2024 – Morning

GCSE (9–1) Chemistry A (Gateway Science)

J248/03 (Higher Tier)

Time allowed: 1 hour 45 minutes

You must have:
- a ruler (cm/mm)
- the Data Sheet for GCSE (9–1) Chemistry A (inside this document)

You can use:
- a scientific or graphical calculator
- an HB pencil

H

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

Candidate number

First name(s)

Last name

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **90**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **28** pages.

ADVICE
- Read each question carefully before you start your answer.

Section A

You should spend a **maximum** of **30 minutes** on this section. A 15 Multi Choice.

Write your answer to each question in the box provided.

1 Which property is characteristic of a metal?

A It forms acidic oxides.

B It is brittle.

C It is malleable.

D It reacts with acid to form carbon dioxide gas.

Your answer C **[1]**

2 Graphite and graphene are allotropes of carbon.

Which statement is correct about graphite and graphene?

A Graphite has delocalised electrons, graphene uses all electrons in bonding.

B Graphite has four bonds from each carbon atom, graphene only has three.

C Graphite is a giant covalent structure, graphene is not.

D Graphite is made up of layers, graphene is a single layer.

Your answer D **[1]**

3 A lithium ion is Li^{+} and a phosphate ion is PO_4^{3-}.

What is the formula of lithium phosphate?

A $Li(PO_4)_3$

B Li_2PO_4

C $Li_2(PO_4)_3$

D Li_3PO_4

Li^{+} PO_4^{3-}
Li^{+}
Li^{+}
$3+$ $3-$

Your answer D **[1]**

Li_3PO_4

4 Which statement about a **reducing agent** is correct?

A It oxidises another species and is itself oxidised.

B It oxidises another species and is itself reduced.

C It reduces another species and is itself oxidised.

D It reduces another species and is itself reduced.

Your answer C **[1]**

5 Which statement about **alkalis** is correct?

A They form H^+ ions in solution.

B They have a pH value greater than 7.

C They react with metals to form a salt and hydrogen.

D They turn universal indicator red.

Your answer B **[1]**

6 Which equipment is needed to set up an electrolysis experiment?

A A battery, a beaker, a funnel and wires

B A battery, a beaker, electrodes and wires

C A battery, crocodile clips, electrodes and a thermometer

D A beaker, electrodes, a funnel and a thermometer

Your answer B **[1]**

+ Cl^- OH^-

− Na^+ H^+

7 Which products are formed in the electrolysis of sodium chloride solution?

	Anode	Cathode
A	chlorine ✓	hydrogen ✓
B	chlorine ✓	sodium
C	oxygen	hydrogen ✓
D	oxygen	sodium

Your answer A **[1]**

8 How did Mendeleev group elements together to develop his Periodic Table?

A Based on chemical properties and left gaps

B Based on mass number and atomic number

C Based on physical properties and atomic number

D Based on physical properties and left gaps

Your answer A **[1]**

9 What is the mass of one atom of beryllium, Be?

Relative atomic mass (A_r): Be = 9.0.

The Avogadro constant is 6.02×10^{23}.

A 6.64×10^{-24} g

B 1.50×10^{-23} g

C 2.41×10^{24} g

D 5.42×10^{24} g

Your answer B **[1]**

9.0 g/mole

1 mole weighs 9 g

1 atom weighs $\frac{9 \text{ g/mole}}{6.02 \times 10^{23} \text{ atoms/mol}}$

$= 1.5 \times 10^{23}$ g/atom

10 Zinc reacts with iron chloride to form zinc chloride and iron.

$Zn \rightarrow Zn^{2+}$

$Zn + FeCl_2 \rightarrow ZnCl_2 + Fe$

Fe^{2+} Fe

What is the **balanced ionic equation** for this reaction?

A $Zn + Fe^{+} \rightarrow Zn^{+} + Fe$

B $Zn + Fe^{2+} \rightarrow Zn^{2+} + Fe$

C $Zn + 2Fe^{+} \rightarrow Zn^{2+} + 2Fe$

D $2Zn + Fe^{2+} \rightarrow 2Zn^{+} + Fe$

Your answer B **[1]**

11 Molten aluminium oxide, Al_2O_3, is electrolysed.

Which row of the table shows the reactions at the electrodes?

	Cathode	Anode
A	$Al^{3+} + 3e^{-} \rightarrow Al$	$O^{2-} \rightarrow O_2 + 2e^{-}$
B	$Al^{3+} \rightarrow Al + 3e^{-}$	$O^{2-} + 2e^{-} \rightarrow O_2$
C	$Al^{3+} + 3e^{-} \rightarrow Al$	$2O^{2-} \rightarrow O_2 + 4e^{-}$
D	$Al^{3+} \rightarrow Al + 3e^{-}$	$2O^{2-} + 4e^{-} \rightarrow O_2$

Your answer C **[1]**

12 An element has the electronic configuration 2.8.4.

Which group and period is the element in?

A Group 2 as it has 2 electron shells. Period 4 as it has 4 electrons in the outer shell.

B Group 2 as it has 2 electrons in the outer shell. Period 4 as it has 4 electron shells.

C Group 4 as it has 4 electron shells. Period 3 as it has 3 electrons in the outer shell.

D Group 4 as it has 4 electrons in the outer shell. Period 3 as it has 3 electron shells.

Your answer D **[1]**

13 Copper nitrate decomposes into copper oxide, nitrogen dioxide and oxygen.

2 : 2 : 4 : 1

$2Cu(NO_3)_2 \rightarrow 2CuO + 4NO_2 + O_2$

How many moles of products are formed if 18 mol of copper nitrate decomposes?

$\frac{18}{2} = 9$

	CuO (mol)	NO_2 (mol)	O_2 (mol)
A	18 ✓	18	18
B	18 ✓	36 ✓	9 ✓
C	36	18	9 ✓
D	36	36 ✓	18
	9 × 2 = 18	9 × 4 = 36	9 × 1 = 9

Your answer B **[1]**

14 Solutions can have different pH values.

Which two solutions have concentrations of H^+ ions that differ by a factor of 100?

A pH 1 and pH 2 2 - 1 = 1

B pH 1 and pH 4 4 - 1 = 3

C pH 2 and pH 4 4 - 2 = 2

D pH 3 and pH 6 6 - 3 = 3

$pH = -\log[H^-]$

$100 = 10^2$ differ by pH 2

Your answer C **[1]**

15 At 25 °C, fluorine is a gas, bromine is a liquid and iodine is a solid.

Which statement is correct?

A At 25 °C, bromine does not have enough heat energy to melt.

B At 25 °C, fluorine does not have enough heat energy to condense.

C Bromine has a higher boiling point than fluorine and a higher melting point than iodine.

D Iodine has a higher boiling point than bromine and a higher melting point than fluorine.

Your answer D **[1]**

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Section B

16

(a) A scientist investigates dissolving four different tablets in water.

Each tablet has a different surface area.

They add each tablet to 20 cm^3 of water and time how long it takes for the tablet to dissolve.

The table shows their results.

$\frac{2.8}{0.3} : \frac{0.3}{0.3}$

Tablet	Surface area of tablet (cm^2)	Volume of tablet (cm^3)	Surface area to volume ratio	Time taken to dissolve (seconds)
A	2.8	0.3	9.33 : 1	43
B	2.5	0.2	12.5 : 1	27
C	1.5	0.2	$\frac{1.5}{0.2} : \frac{0.2}{0.2}$	62
D	3.0	0.2	15.0 : 1	

(i) Calculate the surface area to volume ratio of tablet C.

$$\frac{1.5}{0.2} : \frac{0.2}{0.2}$$

$$7.5 : 1$$

Surface area to volume ratio = 7.5 : 1 **[2]**

(ii) Complete the sentence to describe the relationship between the surface area to volume ratio and the time taken to dissolve.

As the surface area to volume ratio increases ,

the tablet will take less time to dissolve. **[1]**

(iii) The scientist thinks that tablet D will dissolve **slowest** in 20 cm^3 of water.

Explain why the scientist is **incorrect**.

Tablet D has the highest surface area to volume ratio

So will take the least time to dissolve

[2]

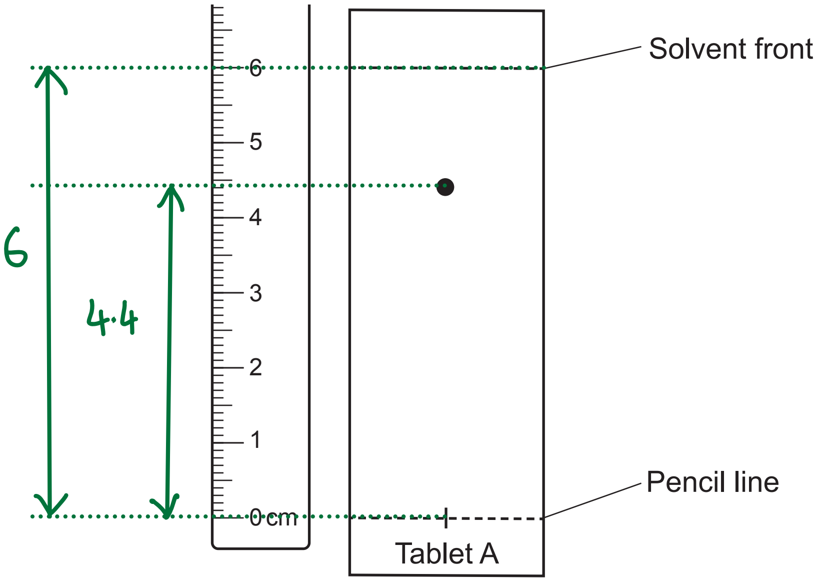
(b) The scientist performs thin layer chromatography on solutions of each of the tablets.

(i) The spots on the chromatogram are **colourless**.

State what the scientist could use to see the spots.

UV light or a locating agent .... **[1]**

(ii) After the scientist uses a method to see the spots, the chromatogram for Tablet A is shown.



Calculate the R_f value for the spot seen from tablet A.

$$R_f = \frac{\text{Distance moved by sample spot}}{\text{Distance moved by solvent front}} = \frac{4.4}{6.0}$$

$$= 0.73$$

Always a fraction, so < 1 !

R_f value = ... 0.73 .... **[3]**

17 A student wants to separate a mixture of compounds.

Different separation methods are used depending on the mixture.

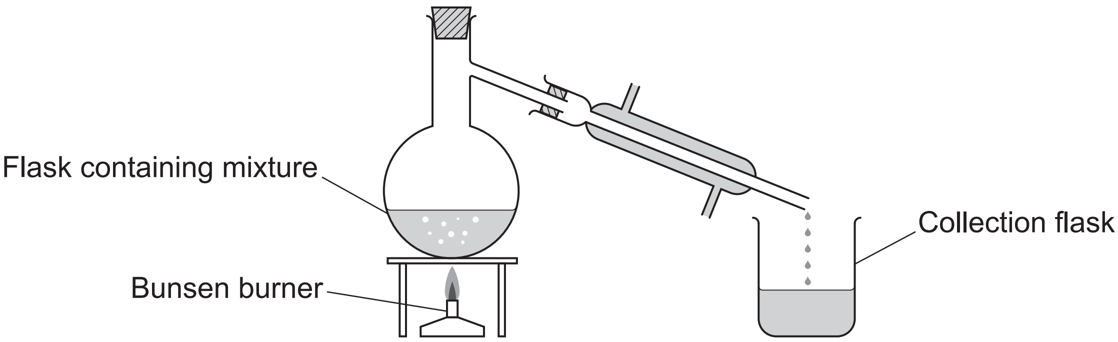
(a) Draw lines to connect each **separation method** to the correct **mixture**.

Separation method	**Mixture**
Crystallisation	Insoluble solid and liquid
Filtration	Solution containing a soluble solid dissolved in a liquid
Fractional distillation	Three liquids with different boiling points

[2]

(b) The student decides to use simple distillation to separate a mixture.

They set up the apparatus shown in the diagram.



(i) A liquid in the mixture is **flammable**.

Suggest a change the student could make to the apparatus to make the distillation safer.

Use a water bath instead of a Bunsen burner
(or electric heating mantle) **[1]**

(ii) The student wants to record the boiling point of the pure liquid that is collected in the collection flask.

Suggest an improvement the student could make to the apparatus so that they can record the boiling point.

Add a thermometer to the top of the flask containing the mixture. **[1]**

(c) The pure liquid collected has the molecular formula $(C_2H_5)_2O$ and a boiling point of 35 °C.

Which statements about the pure liquid are **correct**?

Tick (✓) **two** boxes.

The empirical formula is CH_2. no O! ×	
The melting point is lower than 35 °C. ✓	✓
The pure liquid contains two compounds. ×	
The pure liquid is an element. ×	
The pure liquid will be a gas at above 35 °C. ✓	✓

[2]

(d) Calculate the relative formula mass of a $(C_2H_5)_2O$ molecule.

Relative atomic mass (A_r): C = 12.0 H = 1.0 O = 16.0

$((12.0 \times 2) + (1 \times 5)) \times 2 + 16.0$

$(24 + 5) \times 2 + 16.0$

$29 \times 2 + 16$

$58 + 16$

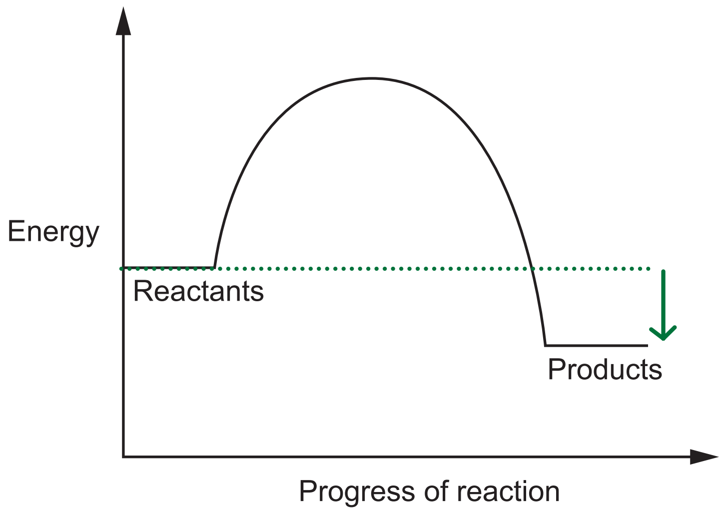
$= 74$

Relative formula mass = 74 **[3]**

18 A scientist is studying two chemical reactions.

One reaction is exothermic, and one reaction is endothermic.

(a) The reaction profile for the exothermic reaction is shown.



(i) Explain how you can tell the reaction profile is for an **exothermic** reaction.

The products are lower in energy than the reactants

[1]

(ii) Describe **one difference** and **one similarity** the scientist will see in the reaction profile for the endothermic reaction.

Difference: Energy of reactants will be lower in energy then the products.

Similarity: Both profiles will have an Activation Energy

[2]

(b) One of the reactions the scientist is studying is the combustion of propane.

This is the balanced symbol equation for the reaction.

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

The equation can be written using the following formulas.

8 C-H 2 C-C 5 O=O 6 C=O 8 O-H

The table shows the bond energies.

Bond	C–C	C–H	O=O	C=O	O–H
Bond energy (kJ/mol)	347	412	498	799	465

(i) Calculate the energy transferred when all the bonds form in the products.

Energy released on forming bonds $= (6 \times 799) + (8 \times 465)$
$= 8514$

Energy transferred = ...8514.... kJ/mol **[3]**

(ii) The energy transferred when all the bonds break in the reactants is 6480 kJ/mol.

Use your answer to part **(b)(i)** to calculate the energy change for this reaction.

Energy put in to break bonds $= (8 \times 412) + (2 \times 347) + (5 \times 498)$
$= 6480$

Energy Transferred $= 6480 - 8514$
$= -2034$

Energy change = ...−2034.... kJ/mol **[2]**

(c) A student studies a different reaction.

They want to find out if it is exothermic or endothermic.

(i) Some possible steps for a method are given in the list.

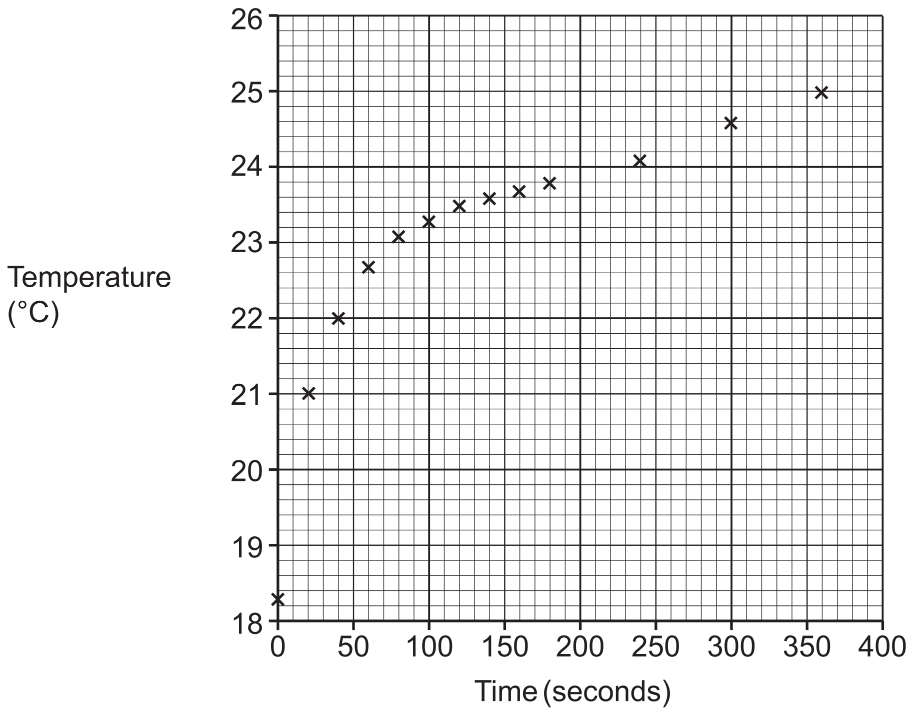
Write **five** steps from the list in the correct order to describe the method the student should use.

A	Add the solid to the solution.
B	Cover the top of the reaction with a lid.
C	Cover the top of the reaction with cotton wool.
D	Put on safety goggles.
E	Put the solution into a beaker and use a thermometer to record the temperature before the reaction starts.
F	Put the solution into a polystyrene cup and use a thermometer to record the temperature before the reaction starts.
G	Use a thermometer to record the temperature as the reaction progresses.

D	F	A	B	G
Step 1	Step 2	Step 3	Step 4	Step 5

[3]

(ii) The student plots their results on a graph.



The student concludes that the reaction is **exothermic**.

Explain why the student is **correct**.

The temperature of the surroundings increases.

Exothermic reactions give out or release heat / energy

[2]

19 Many scientists were involved in the development of the atomic model.

(a) Describe **two ways** Rutherford's atomic model was an improvement on Thomson's "plum pudding" atomic model.

1 Rutherford's model shows that an atom has a positively charged nucleus

2 Rutherford's model shows that negative electrons orbit around the nucleus.

[2]

(b) Atoms are either oxidised or reduced to form ions.

OIL RIG

(i) Complete the sentences about how atoms form ions.

Atoms are ......oxidised...... to form positive ions. Atoms ......lose......

electrons to form positive ions.

Atoms are ......reduced...... to form negative ions. Atoms ......gain......

electrons to form negative ions.

[2]

(ii) The table shows information about three different ions.

Complete the table.

Ion	Number of protons	Number of neutrons	Number of electrons	Mass number
Mg^{2+}	12	12	10	24
F^{-}	9	10	9+1 10	19
Li^{+}	3	4	2	7

[2]

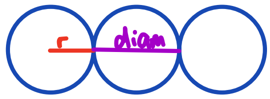
(iii) The element lithium exists as isotopes.

State one difference and one similarity between the Li^{+} ions formed from different isotopes of lithium.

Difference ......Different number of neutrons......

Similarity ......Same number of protons / electrons......

[2]



(iv) A sample of magnesium metal is 5.2 cm wide.

Estimate how many Mg^{2+} ions would fit across the width of the sample of magnesium metal.

Use your knowledge of the typical radius of atoms in your calculation.

Atomic radius $\approx 1 \times 10^{-10}$ m $\therefore$ diameter $= 2 \times 10^{-10}$ m
0.1 nm

Sample width $= 5.2$ cm $= \frac{5.2}{100}$ 0.052 m

N° of Mg^{2+} ions $= \frac{0.052}{2 \times 10^{-10}} = 2.6 \times 10^{8}$

Estimated number of Mg^{2+} ions = 2.6×10^{8} **[3]**

(c) Ions are also formed when acids and alkalis dissolve in water.

(i) Which statements about acid solutions are **correct**?

Tick (✓) **two** boxes.

A dilute solution has a low ratio of acid to volume of solution. ✓	✓
A dilute solution of acid contains more acid than a concentrated solution. ✗	
A strong acid can be made into a concentrated solution or a dilute solution. ✓	✓
A strong acid partially ionises in solution. ✗	
A weak acid can only be made into a dilute solution. ✗	

[2]

(ii) A student makes an acid solution with a pH of 3.

Describe two things the student could do to make a solution with a lower pH. more acidic

1 Add more acid to current solution

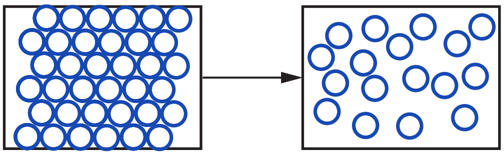
2 Prepare a new solution with a stronger acid.

[2]

20

(a) The particle model can be used to show changes of state.

(i) Complete the diagram to show what happens to the particles as a solid changes to a liquid.



solid liquid

[2]

(ii) Which statements about changes of state are **correct**?

Tick (✓) **two** boxes.

Boiling describes a gas turning into a liquid. ✗	
Freezing is a chemical change. ✗	
Melting is a physical change. ✓	✓
The amount of energy needed to melt a substance depends on the strength of the forces between particles. ✓	✓
The arrangement of particles becomes more random during condensing. ✗	

[2]

(iii) The particle model has limitations when showing changes of state.

Explain **two** limitations of the particle model.

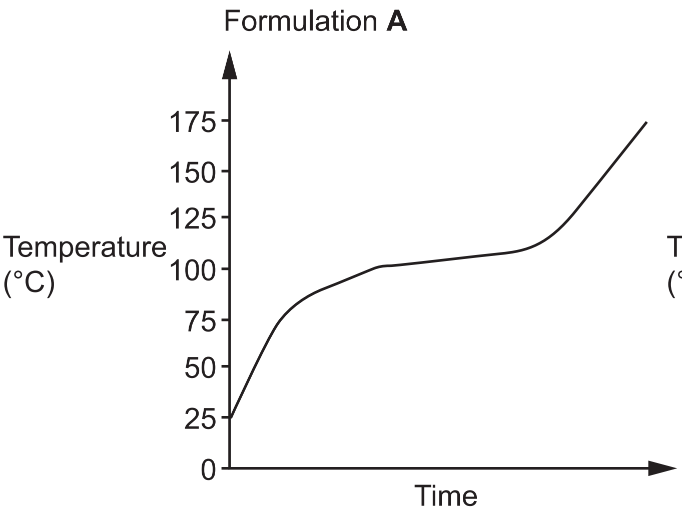
1 It does not account for forces of attraction between particles

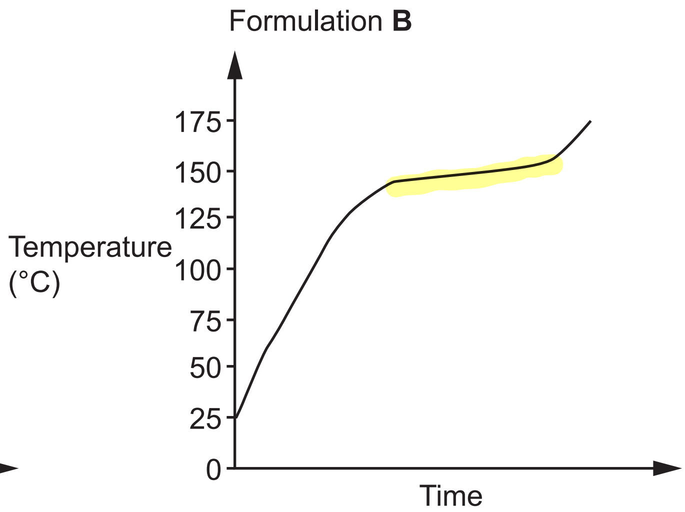
2 It does not account for the size of particles relative to the space between them

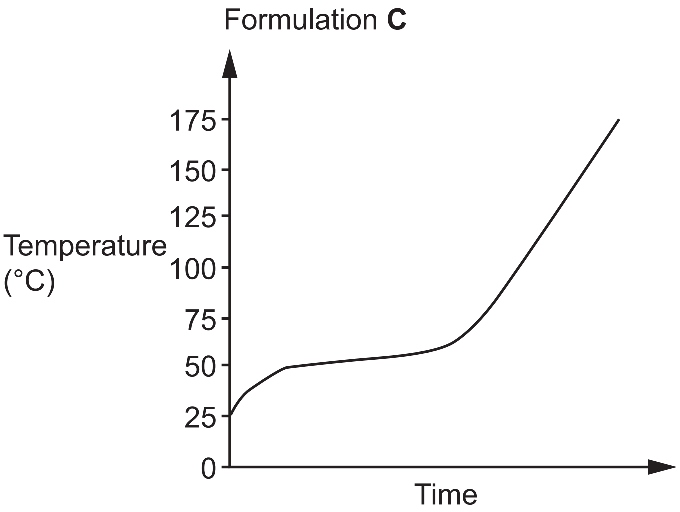
[2]

(b) A scientist needs to choose a **solid** formulation that will be used at **high** temperatures.

The graphs show how the temperature changes as three different formulations, **A**, **B** and **C**, are heated.







Which formulation should the scientist choose?

Explain your answer.

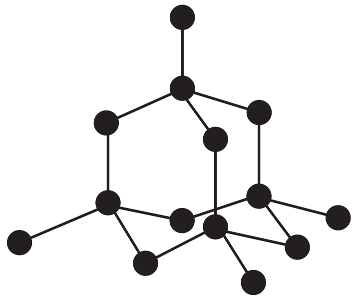
Formulation B

Explanation Formulation B has the highest melting point and is solid at the highest temperature.

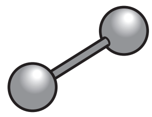
[2]

21

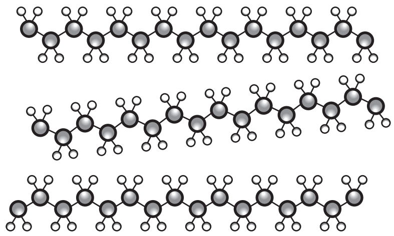
(a)* The structures of diamond, chlorine, Cl_2, and poly(ethene) are shown.



Diamond



Chlorine, Cl_2



Poly(ethene)

All the substances contain covalent bonds between the atoms.

Explain which substance has the highest melting point.

Use your knowledge of structure and bonding.

Covalent bonds are very strong, a lot of energy is required to break them
Intermolecular forces are weaker than covalent bonds
More energy is needed to break covalent bonds than overcome intermolecular forces. More intermolecular forces require more energy to overcome.
Diamond only has covalent bonds - high energy to break
Chlorine has weak intermolecular forces. - low energy to break
Polythene has stronger/more intermolecular forces between the long chains - takes more energy to break than Cl_2

∴ Diamond has highest melting point. **[6]**

(b)
(i) Magnesium chloride is an ionic compound.

Explain why ionic compounds can conduct electricity when dissolved in water, but **not** when solid.

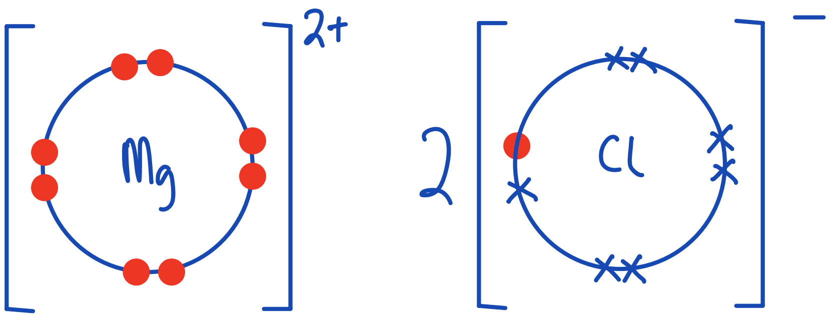
Ionic compounds contain ions (charge carriers)

Ions cannot move in a fixed lattice, so do not conduct when solid. When ionic compounds dissolve, the ions are free to move, and so conduct electricity. **[3]**

(ii) Construct the dot and cross diagram for the ions in magnesium chloride, $MgCl_2$.

Show the outer electron shells only. Mg^{2+} 2 Cl^-

Dot and cross diagram:



[2]

22 A student is making a sample of magnesium carbonate, $MgCO_3$.

The table gives information about four different methods the student could use.

Method	Cost of starting materials (£)	Mass of $MgCO_3$ produced (g)	Is the $MgCO_3$ pure?
1	12.11	6.24	yes ✓
2	11.37	16.90	no
3	15.23	15.34 ✓	yes ✓
4	20.50	10.86	no

(a) Which method should the student use to make their sample?

Explain your answer.

Method 3

Reason $MgCO_3$ produced is pure. Method 3 produces more $MgCO_3$ than Method 1 (also pure). Cost per gram is also less than Method 1.

[3]

(b) A teacher shows the student how to purify magnesium carbonate.

If the student knows how to purify magnesium carbonate, should they use the **same** method as they used in part **(a)**?

Explain your answer.

Yes, use the same method since purification takes time and resources. **[1]**

(c) The student reacts the magnesium carbonate they have made with hydrochloric acid.

(i) Complete the **balanced equation**.

Include state symbols.

$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ **[2]**

(ii) The student uses 0.2 mol of hydrochloric acid in the reaction. The hydrochloric acid is the **limiting reagent**.

At the end of the reaction, 0.82 g of magnesium carbonate is left unreacted.

Calculate the mass of magnesium carbonate that the student uses in the reaction.

Relative atomic mass (A_r): C = 12.0 Mg = 24.3 O = 16.0

M_r $MgCO_3$ = 24.3 + 12 + (3×16) = 84.3

$MgCO_3 + \overset{\text{limiting Reagent}}{2HCl} \longrightarrow MgCl_2 + H_2O + CO_2$

0.2 mol

0.2 mol HCl would react with $\frac{0.2}{2}$ = 0.1 mol $MgCO_3$

Mass of 0.1 mol $MgCO_3$ = 84.3 g/mol × 0.1 mol

= 8.43 g

If 0.82 g remain, starting weight = 8.43 + 0.82

= 9.25 g

Mass of magnesium carbonate = 9.25 g g **[4]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.