



## SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 25 minutes on this section. For each question, select one answer from A to D and put a cross in the box (☒). If you change your mind, put a line through the box (☒) and then mark your new answer with a cross (☒).

Use the Periodic Table as a source of data.

1. Going across a period in the Periodic Table from left to right, the **general** trend is that

- A the bonding in the element itself changes from ionic to covalent
- B the number of neutrons in the nucleus increases
- C the first ionisation energy decreases
- D the metallic character increases

Q1

(Total 1 mark)

2. The electron configurations of argon, iron, chlorine and one other element are given below, but not in order. Which one represents the unnamed element?

- A  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$
- B  $1s^2 2s^2 2p^6 3s^2 3p^6$
- C  $1s^2 2s^2 2p^6 3s^2 3p^4$
- D  $1s^2 2s^2 2p^6 3s^2 3p^5$

Q2

(Total 1 mark)

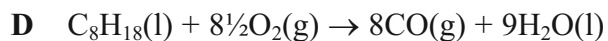
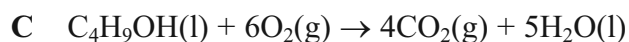
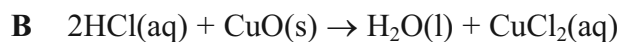
3. Buckminsterfullerene is a carbon molecule with formula  $C_{60}$  which can trap metal ions in its structure. Which of the following compounds of buckminsterfullerene would give a line of mass/charge ratio at 837.3 in a mass spectrometer?

- A  $Na_4C_{60}$
- B  $K_3C_{60}$
- C  $Ca_3C_{60}$
- D  $AgC_{60}$

Q3

(Total 1 mark)

4. This question is about the following equations:



(a) Which equation is **not** balanced?

A

B

C

D

(1)

(b) Which equation shows incomplete combustion?

A

B

C

D

(1)

(Total 2 marks)

Q4

Use this space for any rough working. Anything you write in this space will gain no credit.

5. Which of the equations shown below represents the reaction for which  $\Delta H$  is the standard enthalpy change of formation,  $\Delta H_{f298}^{\ominus}$ , for ethanol,  $C_2H_5OH$ . Ethanol melts at 156 K and boils at 352 K.

- A  $2C(g) + 6H(g) + O(g) \rightarrow C_2H_5OH(g)$
- B  $2C(s) + 3H_2(g) + O_2(g) \rightarrow C_2H_5OH(l)$
- C  $2C(s) + 3H_2(g) + O(g) \rightarrow C_2H_5OH(g)$
- D  $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$

Q5

(Total 1 mark)

6. Use the data about four fuels given below to answer this question.

| Fuel | Formula                        | Name     | Enthalpy change of combustion<br>/kJ mol <sup>-1</sup> | Molar mass<br>/g mol <sup>-1</sup> |
|------|--------------------------------|----------|--|------------------------------------|
| A    | CH <sub>4</sub>                | methane  | -890   | 16                                 |
| B    | CH <sub>3</sub> OH             | methanol | -726   | 32                                 |
| C    | C <sub>3</sub> H <sub>8</sub>  | propane  | -2219  | 44                                 |
| D    | C <sub>4</sub> H <sub>10</sub> | butane   | -2877  | 58                                 |

(a) Which fuel, A, B, C or D, produces most energy per gram on complete combustion?

- A
- B
- C
- D

(1)

(b) Scientists give governments advice on technical issues. What information would scientists use when advising governments on the choice of one of these fuels, if the aim was to minimise carbon dioxide production?

- A mass of carbon per gram of fuel
- B mass of carbon per kilojoules produced
- C number of kilojoules produced per gram
- D number of kilojoules produced per mole

(1)

Q6

(Total 2 marks)

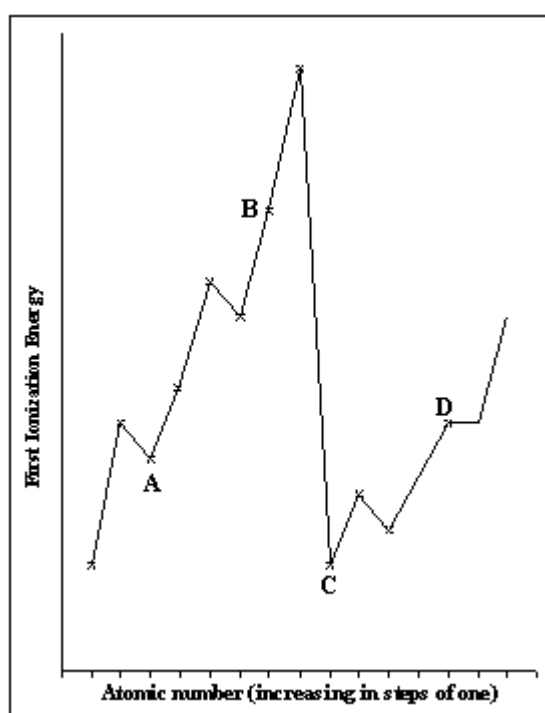
7. Which of the following equations represents the first ionisation of sulfur?

- A  $S(s) + e^- \rightarrow S^-(g)$
- B  $S(g) + e^- \rightarrow S^-(g)$
- C  $S(s) \rightarrow S^+(g) + e^-$
- D  $S(g) \rightarrow S^+(g) + e^-$

Q7

(Total 1 mark)

8. Which element marked on this graph is a halogen?



- A
- B
- C
- D

Q8

(Total 1 mark)

9. Question 9 is about the following ionisation energy sequences.

The values are all in  $\text{kJ mol}^{-1}$ .

A 1400 1000 950 830 700

B 420 3100 4400 5900 8000

C 1000 1250 1520 420 590

D 1520 2700 3900 5800 7200

Select from A to D the sequence which is most likely to represent the following:

(a) The first ionisation energies of five consecutive members of the same group in the Periodic Table, in order of increasing atomic number.

A

B

C

D

(1)

(b) The first five ionisation energies of an s-block element.

A

B

C

D

(1)

(c) The first five ionisation energies of a noble gas.

A

B

C

D

(1)

(Total 3 marks)

Q9

10. Question 10 is about four hydrocarbons with molecular formulae as shown.



(a) Which hydrocarbon has the same empirical formula as its molecular formula?

A

B

C

D

(1)

Use this space for any rough working. Anything you write in this space will gain no credit.

(b) Which has a molecular ion in the mass spectrum at mass/charge ratio = 58?

A

B

C

D

(1)

(c) Which is neither an alkane nor an alkene?

- A
- B
- C
- D

(1)

(d) Which could be 2-methylpropane?

- A
- B
- C
- D

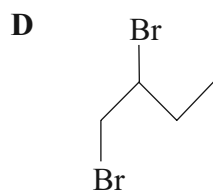
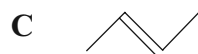
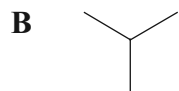
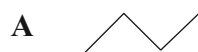
(1)

Q10

(Total 4 marks)



11. Question 11 is about the following organic compounds with skeletal formulae as shown:



(a) Which compound could be made from one of the others in an addition reaction?

A

B

C

D

(1)

Use this space for any rough working. Anything you write in this space will gain no credit.

(b) Which compound has E-Z isomers?

- A
- B
- C
- D

(1)

Q11

(Total 2 marks)

12. Chemists investigating the mechanism of the reaction of ethene and bromine thought that the first step was the addition of  $\text{Br}^+$ . To test this, they reacted bromine with ethene in the presence of sodium chloride.

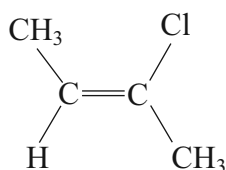
If their theory about the first step of the reaction was correct, which product might form as well as 1,2-dibromoethane?

- A  $\text{CH}_2\text{BrCH}_2\text{Na}$
- B  $\text{CH}_2\text{BrCH}_2\text{Cl}$
- C  $\text{CH}_2\text{ClCH}_2\text{Cl}$
- D  $\text{CH}_2\text{NaCH}_2\text{Na}$

Q12

(Total 1 mark)

13. Which of the following is the correct name for the compound below?



- A Z-3-chlorobut-2-ene
- B E-3-chlorobut-2-ene
- C E-2-chlorobut-2-ene
- D Z-2-chlorobut-2-ene

Q13

(Total 1 mark)

TOTAL FOR SECTION A: 21 MARKS

**SECTION B**

**Answer ALL the questions. Write your answers in the spaces provided.**

**14.** Copper(II) sulfate solution can be prepared from solid copper(II) carbonate by reaction with hot dilute sulfuric acid.

(a) Write the equation for the reaction, including state symbols.

**(1)**

(b) The experiment was carried out using 0.025 moles of sulfuric acid of concentration  $2.0 \text{ mol dm}^{-3}$ . What volume of this sulfuric acid was used?

**(1)**

(c) (i) It is usual to react the sulfuric acid with a slight excess of copper(II) carbonate.

Calculate the mass of copper(II) carbonate needed if a 10% excess is required.

[Molar mass of copper(II) carbonate =  $123.5 \text{ g mol}^{-1}$ ]

**(2)**

(ii) A student doing this experiment chose to use a balance reading to 0.01 g in an attempt to work accurately.

Was this choice of balance necessary from the point of view of accuracy? Explain your answer.

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**(1)**

(d) The sulfuric acid is heated to boiling and the copper(II) carbonate is added in small portions.

State the next step needed to prepare pure copper(II) sulfate solution. Justify your answer.

.....  
 .....  
 .....

**(1)**

(e) When the solution of copper(II) sulfate is allowed to crystallise, the crystals which are produced have the formula  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ .

(i) What is the molar mass of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ?

**(1)**

(ii) 3.98 g of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  crystals were obtained. Calculate the percentage yield in this experiment.

**(2)**

**(Total 9 marks)**

**Q14**

15. This question is about magnesium and magnesium oxide.

\*(a) Describe the bonding in magnesium and explain why it is a good conductor of electricity.

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**(3)**

(b) Draw a diagram (using dots or crosses) for the ions in magnesium fluoride showing **all** the electrons and the ionic charges on:

(i) the magnesium ion

**(1)**

(ii) the fluoride ion.

**(1)**

(c) Under what conditions does magnesium fluoride conduct electricity?

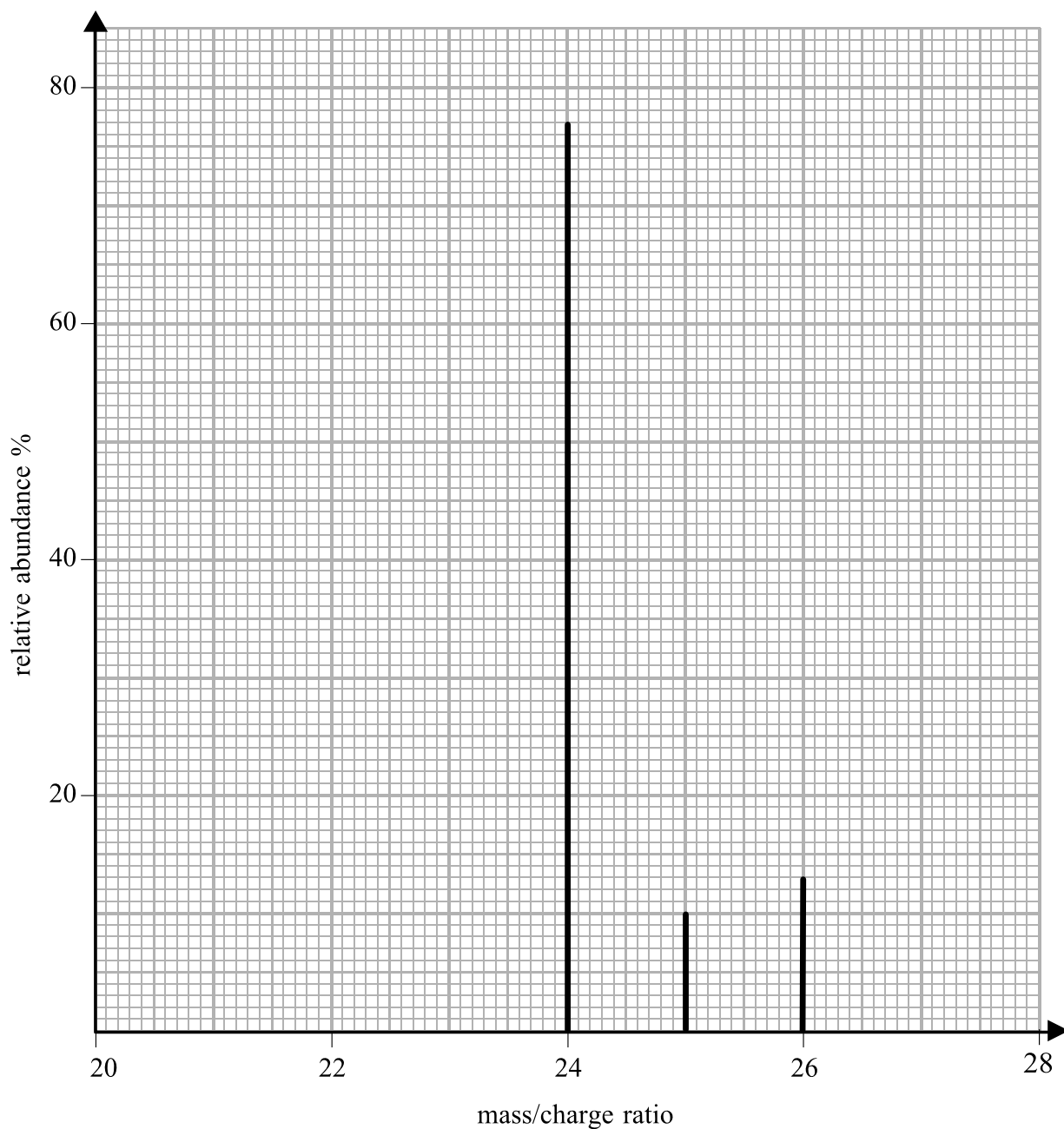
Explain your answer.

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**(1)**

(d) The mass spectrum of a sample of magnesium is shown below.



- (i) Use the data above to estimate the percentage isotopic composition of the sample of magnesium. Hence calculate the average atomic mass of the sample of magnesium.

(2)

(ii) Why do the three isotopes have the same chemical properties?

.....  
.....

(1)

(e) (i) Oceanographers studying plankton found that a sample of seawater contained 1.20 nanomol dm<sup>-3</sup> of chlorophyll, C<sub>55</sub>H<sub>77</sub>MgN<sub>4</sub>O<sub>5</sub>. (1 nanomol = 1 × 10<sup>-9</sup> mol)

What mass of magnesium would be present in 1.00 cm<sup>3</sup> of this sample of seawater? Give your answer to **three** significant figures.

(2)

(ii) X-ray diffraction can be used to locate atoms or ions in molecules like chlorophyll. X-rays are scattered by the electrons in atoms and ions. In chlorophyll the atoms of one of the elements still cannot be located with certainty by this technique.

Suggest which element is most difficult to locate.

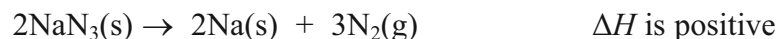
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(1)

Q15

(Total 12 marks)

16. Airbags, used as safety features in cars, contain sodium azide,  $\text{NaN}_3$ . An airbag requires a large volume of gas to be produced in a few milliseconds. The gas is produced in this reaction:



When the airbag is fully inflated,  $50 \text{ dm}^3$  of nitrogen gas is produced.

- (a) Calculate the number of molecules in  $50 \text{ dm}^3$  of nitrogen gas under these conditions.

[The Avogadro constant =  $6.02 \times 10^{23} \text{ mol}^{-1}$ . The molar volume of nitrogen gas under the conditions in the airbag is  $24 \text{ dm}^3 \text{ mol}^{-1}$ ].

(2)

- (b) Calculate the mass of sodium azide,  $\text{NaN}_3$ , that would produce  $50 \text{ dm}^3$  of nitrogen gas.

(3)



(c) What will happen to the temperature in the airbag when the reaction occurs?

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.....

(1)

\*(d) The airbag must be strong enough not to burst in an accident. An airbag which has burst in an accident is hazardous if the sodium azide in it has decomposed.

Explain why this is so.

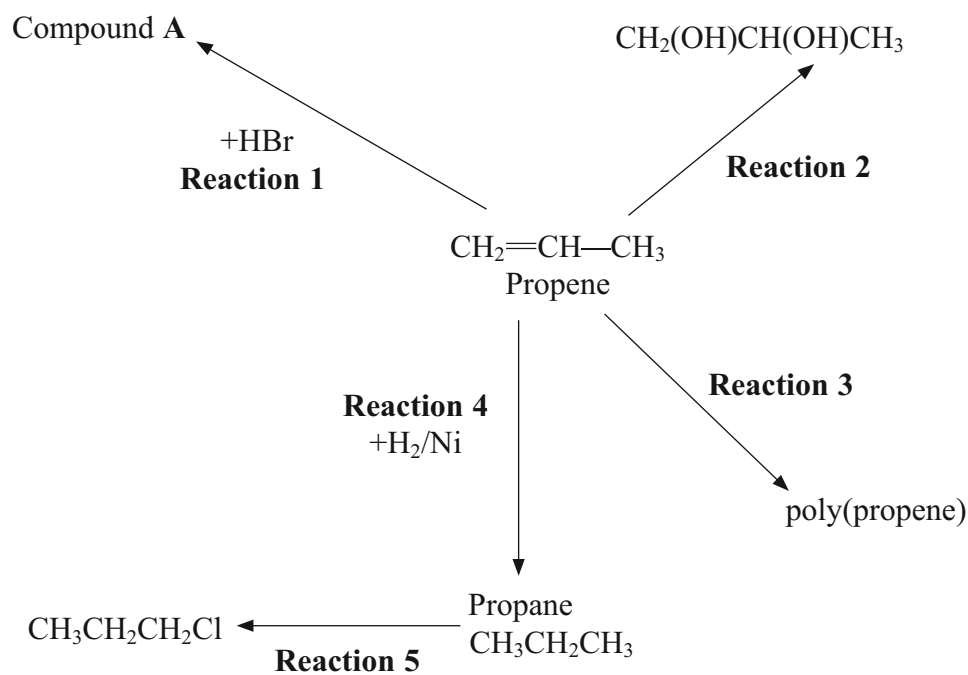
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(2)

**(Total 8 marks)**

Q16

17. Propene can be used to make other important chemical products. The processes involved can be summarised in the diagram:



(a) (i) Give the mechanism for **Reaction 1**.

(3)

(ii) Explain why compound **A** and **not** its structural isomer is the major product in **Reaction 1**.

.....  
 .....  
 .....

(1)

(iii) Name compound **A** formed in **Reaction 1**.

Name .....

(1)

(b) What is added in **Reaction 2** to make the product  $\text{CH}_2(\text{OH})\text{CH}(\text{OH})\text{CH}_3$ ?

.....

(1)

(c) Complete the balanced equation for the formation of poly(propene) in **Reaction 3** using **displayed** formulae.



(2)

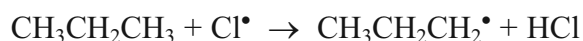
(d) Poly(propene) fibres can be used to make fleece which is used at several horse racing courses to prevent the ground becoming frozen.

State **one** advantage of using poly(propene) instead of natural fibres of similar cost.

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(1)

- (e) (i) One stage in the mechanism of **Reaction 5** is shown below.



What is this step?

..... (1)

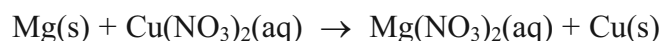
- (ii) Give the name **or** formula of the trace product present in the final mixture which gives evidence for this mechanism.

..... (1)

Q17

(Total 11 marks)

18. A student investigated a reaction which could be used to warm up coffee in self-heating cans.



In the self-heating cans, the bottom has a compartment containing copper(II) nitrate solution. When a button on the bottom of the can is pressed, the magnesium powder is released into the compartment where it reacts with the copper(II) nitrate solution.

- (a) A student investigated the enthalpy change for this reaction by measuring

50.0 cm<sup>3</sup> of 0.300 mol dm<sup>-3</sup> copper(II) nitrate solution into a 100 cm<sup>3</sup> beaker and adding 1 g (an excess) of magnesium powder.

The results are shown below.

|   |         |
|---|---------|
| Temperature of copper(II) nitrate solution at start | = 22 °C |
| Temperature of mixture after reaction               | = 43 °C |

- (i) Calculate the energy change which took place. The specific heat capacity of the solution is  $4.20 \text{ J g}^{-1}\text{K}^{-1}$ .

Which is the correct value for the energy change in joules?

**(1)**

- (ii) How many moles of copper(II) nitrate were used in the experiment?

**(1)**

- (iii) Calculate the enthalpy change for the reaction. You should include a sign and units in your answer.

**(2)**

\*(iv) Suggest **two** changes you would make to **the equipment** used in order to improve the accuracy of the result.

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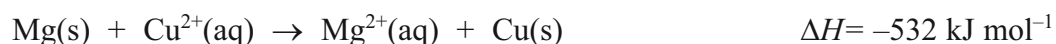
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**(2)**

(b) The ionic equation for the reaction is shown below:



Would the following affect the value of the experimental result?

Explain your answer, stating the effect, if any, on the value of the enthalpy change obtained.

\*(i) The student used 2 g rather than 1 g of magnesium.

.....

.....

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.....

**(2)**

\*(ii) The heat losses that occurred from the student's beaker.

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**(2)**

(c) The temperature in the self-heating can needs to increase by 60 °C to produce a hot drink.

Suggest a change you could make to the mixture in the experiment in (a) to produce a greater temperature rise. You are **not** expected to do a calculation.

.....  
 .....

(1)

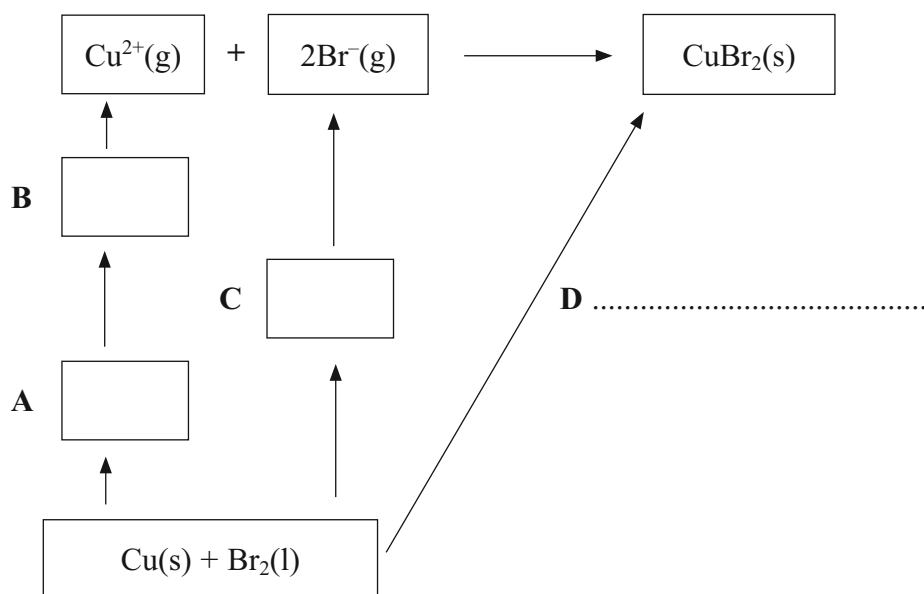
Q18

(Total 11 marks)

19. The following data can be used in a Born-Haber cycle for copper(II) bromide, CuBr<sub>2</sub>.

|  |                              |
|--|------------------------------|
| Enthalpy change of atomisation of bromine $\Delta H_{\text{at}}^{\ominus}[\frac{1}{2}\text{Br}_{2(l)}]$  | +111.9 kJ mol <sup>-1</sup>  |
| Enthalpy change of atomisation of copper, $\Delta H_{\text{at}}^{\ominus}[\text{Cu}(s)]$                 | +338.3 kJ mol <sup>-1</sup>  |
| First ionisation energy of copper, $E_{\text{m1}}[\text{Cu}(g)]$   | +746.0 kJ mol <sup>-1</sup>  |
| Second ionisation energy of copper, $E_{\text{m2}}[\text{Cu}(g)]$  | +1958.0 kJ mol <sup>-1</sup> |
| Electron affinity of bromine, $E_{\text{aff}}[\text{Br}(g)]$   | -342.6 kJ mol <sup>-1</sup>  |
| Enthalpy change of formation of CuBr <sub>2</sub> (s), $\Delta H_{\text{f}}^{\ominus}[\text{CuBr}_2(s)]$ | -141.8 kJ mol <sup>-1</sup>  |

(a) On the following outline of a Born-Haber cycle complete the boxes **A**, **B**, and **C** by putting in the formula and state symbol for the appropriate species and writing the name of the enthalpy change **D**.



(3)

(b) Use the data to calculate a value for the lattice energy of copper(II) bromide.

Give a sign and units in your answer.

(3)

(c) When the lattice energy of copper(II) bromide is calculated from ionic radii and charges, the result is a value numerically about 10% less than the one obtained from the Born-Haber cycle.

(i) What does this suggest about the nature of the bonding in copper(II) bromide?

.....  
.....

(1)

(ii) Draw a diagram to show how the smaller copper ion alters the shape of the larger bromide ion.

(1)

Q19

(Total 8 marks)

**TOTAL FOR SECTION B: 59 MARKS**

**TOTAL FOR PAPER: 80 MARKS**

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