1 Copper(II) sulfate exists as blue hydrated crystals and white anhydrous crystals. The enthalpy changes of solution for these two substances may be represented by the following simplified equations:

$$CuSO_4.5H_2O(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_1 \quad +11.5 \text{ kJ mol}^{-1}$$
blue

$$CuSO_4(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_2 \quad 66.1 \text{ kJ mol}^{-1}$$
white

(a) (i) Fill in the box and add labelled arrows to complete the Hess cycle to enable you to calculate $\Delta H_{reaction}$.

(3)

$$CuSO_4.5H_2O(s) \xrightarrow{\Delta H_{reaction}} CuSO_4(s) + 5H_2O(l)$$

(ii) Calculate a value for the enthalpy change $\Delta H_{reaction}$.

(2)

(b) Suggest why it is not possible to directly measure the enthalpy change for the conversion of the blue hydrated copper(II) sulfate crystals into the white anhydrous crystals.

(1)

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*(c) (i) $CuSO_4.5H_2O(s) + aq \rightarrow CuSO_4(aq)$ ΔH_1 +11.5 kJ mol ^{1}

Describe briefly the experimental procedure that **you** would use to obtain the data necessary to calculate ΔH_1, given a known mass of hydrated copper(II) sulfate crystals, $CuSO_4.5H_2O(s)$.

You should state the apparatus that you would use and any measurements that you would make.

You are **not** required to calculate the amounts of substances or to explain how you would use the data obtained.

(4)

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(ii) The value for the enthalpy change from (c)(i) obtained by experiments in a school laboratory is likely to be significantly different from a data book value.

List **three** possible reasons for this which do **not** relate to the quality of the apparatus or chemicals used or possible mistakes in carrying out the procedure.

(3)

1 .....

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2 .....

.....

3 .....

.....

(Total for Question 13 marks)

2 This question is about methanol and the energy changes that accompany some of its reactions.

(a) Complete the diagram (using dots and crosses) to show the bonding in methanol, CH_3OH. You should show outer electrons only.

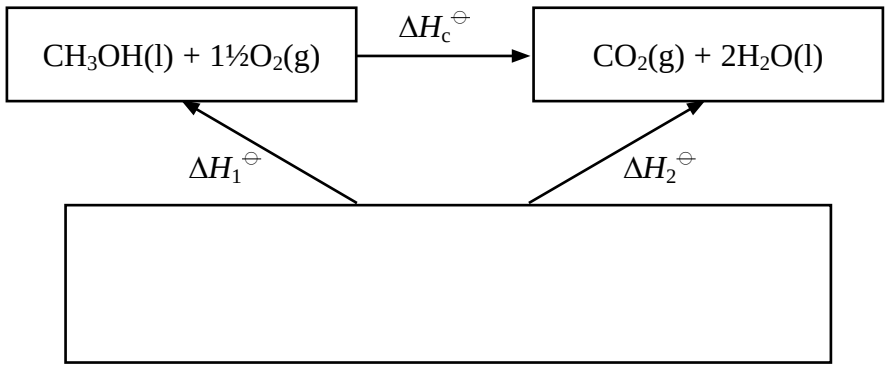
(2)

H

H C O H

H

(b) The Hess cycle below can be used to calculate the standard enthalpy change of combustion of methanol, using standard enthalpy changes of formation.



(i) Complete the cycle by filling in the empty box.

(2)

*(ii) Define the term **standard enthalpy change of formation** of a compound, making clear the meaning of **standard** in this context.

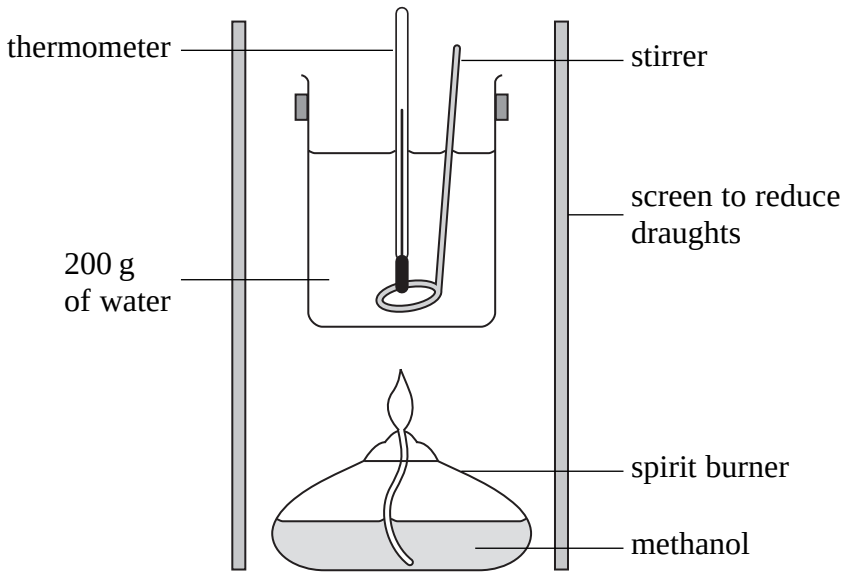
(3)

(iii) Use your cycle and the data below to calculate the standard enthalpy change of combustion of methanol, $\Delta H_c^{\ominus}$.

	$\Delta H_f^{\ominus}$/kJ mol^{-1}
$CO_2(g)$	–393.5
$H_2O(l)$	–285.8
$CH_3OH(l)$	–239.1

(2)

(c) An experiment was carried out, using the apparatus below, to estimate the standard enthalpy change of combustion of methanol.



After burning the methanol for a few minutes, the temperature of water in the beaker had risen by 20.7 °C and the mass of methanol burnt was 0.848 g.

(i) Calculate the amount of energy transferred to the water.

Energy transferred (J) = mass of water × 4.18 × temperature change

(1)

(ii) Calculate the number of moles of methanol, CH_3OH, burnt during the experiment.

(1)

(iii) Use your answers to (c)(i) and (ii) to calculate the experimental value for the standard enthalpy change of combustion. Include a sign and units in your answer, which should be given to **three** significant figures.

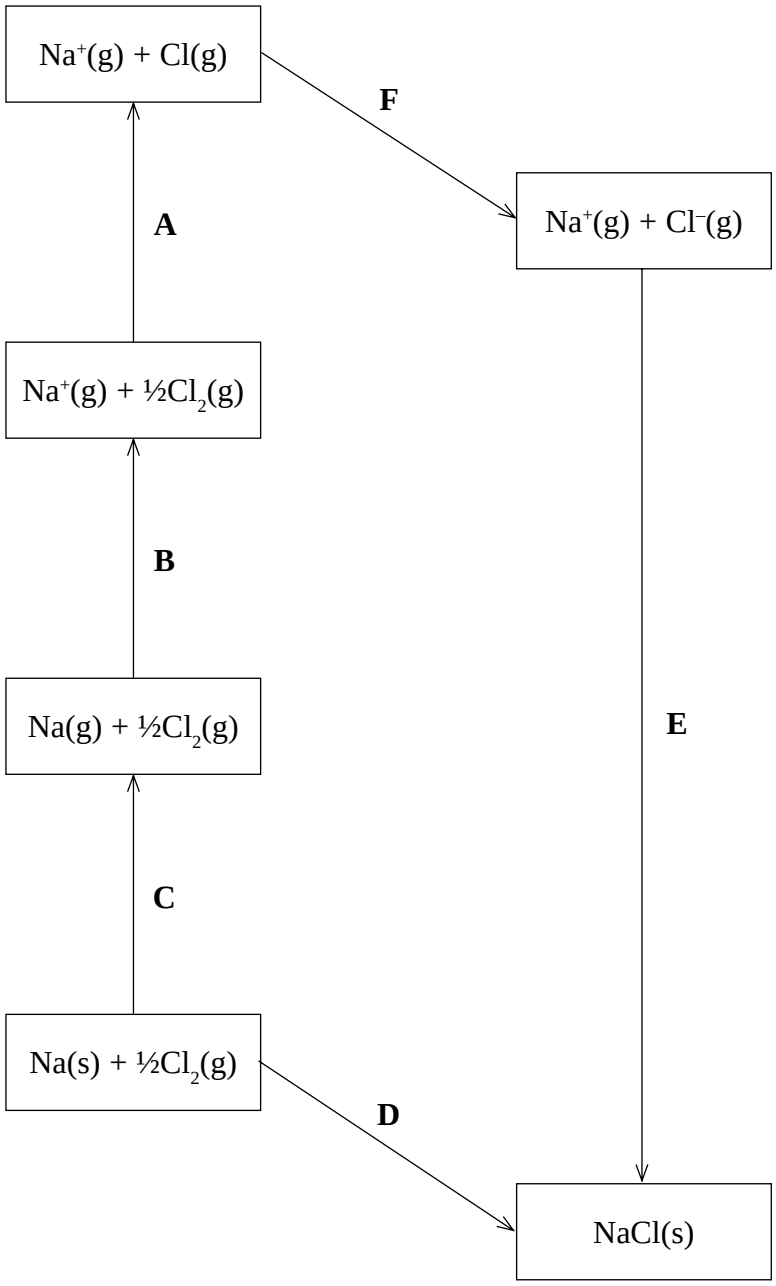
(1)

(iv) Compare your answers to (b)(iii) and (c)(iii) and give TWO reasons to explain any differences.

(2)

(Total for Question = 14 marks)

3 The Born-Haber cycle for the formation of sodium chloride from sodium and chlorine may be represented by a series of steps labelled **A** to **F** as shown.



(a) (i) Complete the table below by adding the letters **A** to **F** next to the corresponding energy changes.

(3)

Energy change	Letter	ΔH /kJ mol^{-1}
Lattice energy for sodium chloride		–775
Enthalpy change of atomization of sodium		+109
Enthalpy change of atomization of chlorine		+121
First ionization energy of sodium		+494
First electron affinity of chlorine		
Enthalpy change of formation of sodium chloride		–411

(ii) Calculate the first electron affinity of chlorine, in kJ mol^{-1}, from the data given.

(2)

(b) Lattice energies can be calculated from electrostatic theory (theoretical values) as well as by Born-Haber cycles (experimental values).

Compound	Experimental lattice energy / kJ mol^{-1}	Theoretical lattice energy / kJ mol^{-1}
NaCl	–770	–766
Agl	–889	–778

(i) Comment on the fact that there is close agreement between the values for sodium chloride, NaCl.

(1)

*(ii) Explain, in terms of chemical bonding, why the experimental value for silver iodide, AgI, is more exothermic than the value calculated theoretically for the same compound.

(2)

*(c) Suggest why the first ionization energies of the Group 1 elements decrease down the group.

(2)

(Total for Question = 10 marks)

4 Propanone, C_3H_6O, undergoes complete combustion to form carbon dioxide and water.

$$C_3H_6O(l) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(l)$$

(a) In an experiment to calculate the enthalpy change of combustion for propanone, 2.90 g of propanone was burned completely in oxygen.

The heat energy from this combustion raised the temperature of 200 g of water from 20.2 °C to 78.4 °C.

The specific heat capacity of water is 4.18 J g^{-1} °C^{-1}.

(i) Calculate the number of moles of propanone present in 2.90 g.

[The molar mass of propanone is 58 g mol^{-1}.]

(1)

(ii) Use the expression

$$\text{energy transferred (J)} = \text{mass} \times \begin{matrix}\text{specific heat}\\ \text{capacity}\end{matrix} \times \begin{matrix}\text{temperature}\\ \text{change}\end{matrix}$$

to calculate the heat energy transferred to raise the temperature of 200 g of water from 20.2 °C to 78.4 °C.

(2)

(iii) Use your answers to (a)(i) and (ii) to calculate a value for the enthalpy change of combustion of propanone. Give your answer to **three** significant figures and include a sign and units.

(3)

(b) In another experiment, the enthalpy change of combustion for butanone, C_4H_8O, was found to be –1300 kJ mol^{-1}.

A Data Book value for the standard enthalpy change of combustion for butanone is –2440 kJ mol^{-1}.

(i) Suggest a reason why the value obtained in the experiment is so different from the Data Book value.

(1)

(ii) This Data Book value (–2440 kJ mol^{-1}) refers to the following equation.

$$C_4H_8O(l) + 6½O_2(g) \rightarrow 4CO_2(g) + 4H_2O(l)$$

How would the value be different if it referred to the formation of water in the **gaseous** state? Justify your answer.

(2)

(c) Standard enthalpy changes of combustion can be used to calculate the standard enthalpy change of formation of a compound.

(i) Define the term **standard enthalpy change of formation**, making clear the meaning of **standard** in this context.

(3)

(ii) Use the standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$, given in the table below to find the standard enthalpy change of formation for ethanoic acid, CH_3COOH, in kJ mol^{-1}.

Substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
C(s, graphite)	–394
$H_2(g)$	–286
$CH_3COOH(l)$	–870

$$2C(s, \text{graphite}) + 2H_2(g) + O_2(g) \rightarrow CH_3COOH(l)$$

(3)

(Total for Question = 15 marks)