Hess's Law

Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	The Core Principles of Chemistry
Sub Topic	Hess's Law
Booklet	Question Paper 2

Time Allowed: **70 minutes**

Score: **/58**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 For some reactions, the enthalpy change can be determined by experiment.

(a) Define the term **enthalpy change of reaction**.

(2)

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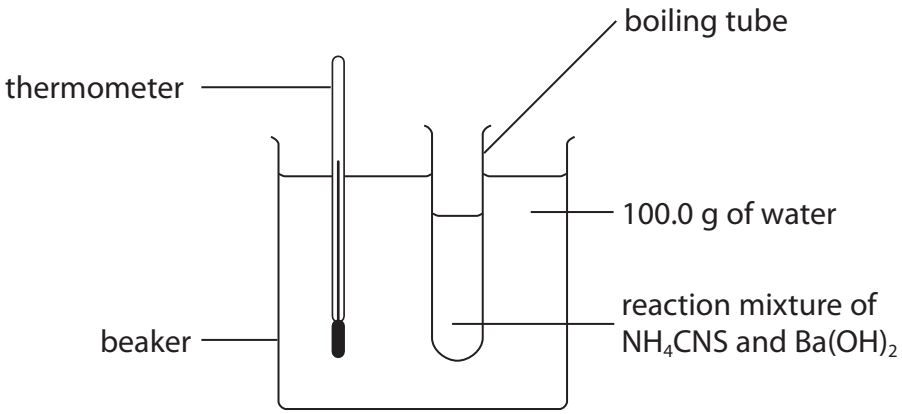
(b) An equation for the reaction between the two solids ammonium thiocyanate, NH_4CNS, and barium hydroxide, $Ba(OH)_2$, is shown below.

$$2NH_4CNS(s) + Ba(OH)_2(s) \rightarrow Ba(CNS)_2(s) + 2H_2O(l) + 2NH_3(g)$$

The following apparatus was set up in order to determine the enthalpy change for the reaction.



In the experiment, 15.22 g of NH_4CNS was reacted with an excess of $Ba(OH)_2$. The reaction absorbed heat energy from the surroundings. The temperature of the 100.0 g of water fell from 22.0 °C to 16.5 °C.

(i) Calculate the heat energy absorbed, in joules, during the reaction.

Use the equation

Heat energy absorbed (J) = mass of water × 4.2 × temperature change

(1)

(ii) Calculate the number of moles of NH_4CNS used in the experiment.

(1)

(iii) Calculate the enthalpy change of the reaction, in kJ mol^{-1}, to **two** significant figures. Include a sign in your answer.

$$2NH_4CNS(s) + Ba(OH)_2(s) \rightarrow Ba(CNS)_2(s) + 2H_2O(l) + 2NH_3(g)$$

(3)

(c) Standard enthalpy changes of reaction can also be calculated using mean bond enthalpies.

(i) What is meant by the term **mean bond enthalpy**?

(2)

(ii) Describe the bonding in a C═C double bond in terms of the different ways in which the orbitals overlap.

You may draw a diagram if you wish.

(2)

Space for diagram:

(iii) Suggest why the mean bond enthalpy of a C═C bond is less than twice the mean bond enthalpy of a C—C bond.

(1)

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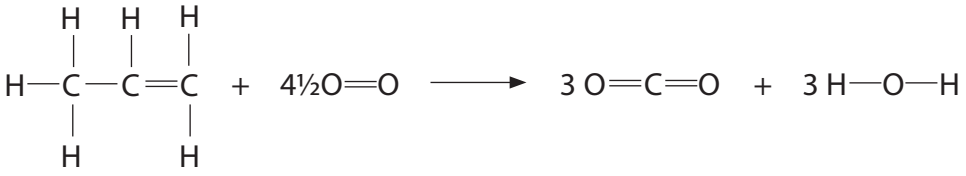
(iv) Use the mean bond enthalpy data in the table, and the equation given below, to calculate a value for the standard enthalpy change of combustion of propene.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
C═C	612
C—C	347
C—H	413
O═O	498
C═O	805
O—H	464



Answer = ... kJ mol^{-1}

*(v) The Data Booklet value for the standard enthalpy change of combustion of propene is –2058 kJ mol^{-1}.

Explain why the value calculated in (c)(iv) is less exothermic than the Data Booklet value.

(2)

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(Total for Question 1 = 17 marks)

2 Lattice energy can be used as a measure of ionic bond strength. Born-Haber cycles can be used to determine experimental values of lattice energies.

The table below shows the energy changes that are needed to determine the lattice energy of lithium fluoride, LiF.

Energy change	ΔH / kJ mol^{-1}
Enthalpy change of atomization of lithium	+159
First ionization energy of lithium	+520
Enthalpy change of atomization of fluorine, $\frac{1}{2}F_2$	+79
First electron affinity of fluorine	–328
Enthalpy change of formation of lithium fluoride	–616

(a) Define the term **lattice energy**.

(2)

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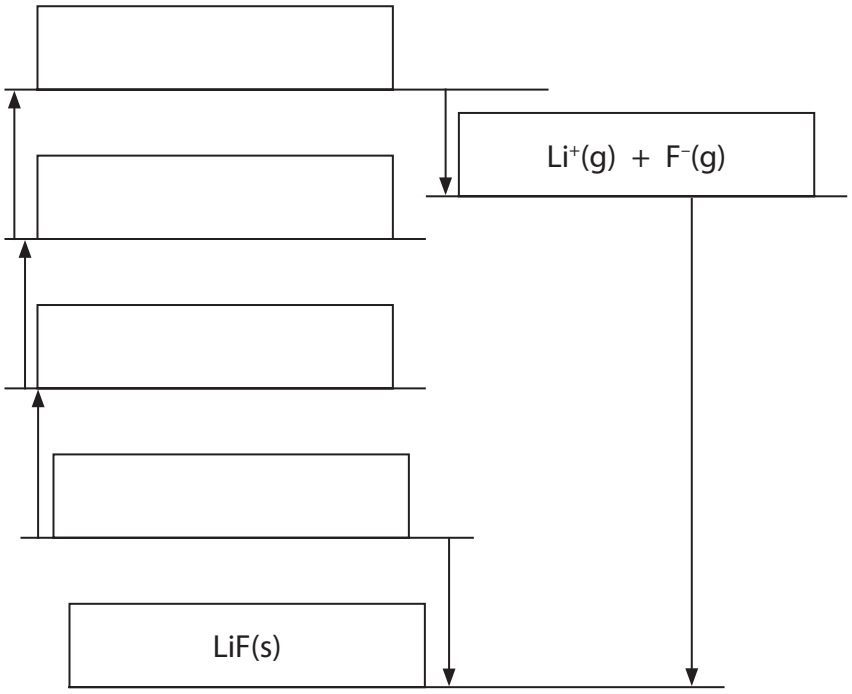
(b) The diagram below shows an incomplete Born-Haber cycle for the formation of lithium fluoride from lithium and fluorine.

(i) Complete the diagram by writing the formulae of the correct species, including state symbols, in the four empty boxes.

(4)



(ii) Calculate the lattice energy of lithium fluoride, in kJ mol^{-1}.

(2)

lattice energy = ... kJ mol^{-1}

*(c) The lattice energies of sodium fluoride, sodium chloride and magnesium fluoride are shown in the table below.

Compound	Lattice energy / kJ mol^{-1}
Sodium fluoride, NaF	–918
Sodium chloride, NaCl	–780
Magnesium fluoride, MgF_2	–2957

Explain, in terms of the sizes and charges of the ions involved, the differences between the lattice energy values of

(i) NaF and NaCl

(2)

(ii) NaF and MgF_2

(2)

(Total for Question 2 = 12 marks)

3 Alkanes are used as fuels in homes and in industry. It is, therefore, important that the enthalpy changes involving alkanes are known.

(a) Define the term **standard enthalpy change of formation** of a compound.

Give the conditions of temperature and pressure that are used when measuring a **standard** enthalpy change.

(3)

Definition .....

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.....

.....

Standard temperature is .....

Standard pressure is .....

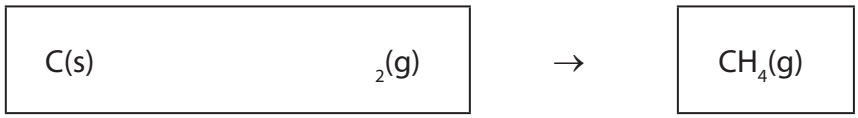
(b) Write the equation, with state symbols, that accompanies the enthalpy change of formation of hexane, $C_6H_{14}(l)$.

(2)

(c) Enthalpy changes can be calculated using enthalpy changes of combustion. Values for some standard enthalpy changes of combustion are shown in the table below.

Substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
C(s)	–394
$H_2(g)$	–286
$CH_4(g)$	–890

Use these data to complete the Hess cycle below for the reaction and then calculate the standard enthalpy change for the reaction, in kJ mol^{-1}.



(3)

Space for working

standard enthalpy change for the reaction = ... kJ mol^{-1}

(d) The equations for the combination of gaseous carbon atoms and gaseous hydrogen atoms to form methane, CH_4, and ethane, C_2H_6, are shown below.

$$C(g) + 4H(g) \rightarrow CH_4(g) \qquad \Delta H = -1652 \text{ kJ mol}^{-1}$$

$$2C(g) + 6H(g) \rightarrow C_2H_6(g) \qquad \Delta H = -2825 \text{ kJ mol}^{-1}$$

Use these data to calculate

(i) the mean bond enthalpy of a C—H bond in methane, in kJ mol^{-1}.

(1)

(ii) the bond enthalpy of a C—C bond, in kJ mol^{-1}, clearly showing your working.

(2)

(Total for Question 3 = 11 marks)

4 Barium chloride can be made by reacting solid barium carbonate with dilute hydrochloric acid in the following reaction.

$$BaCO_3(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) (i) Write the ionic equation for the reaction of solid barium carbonate with hydrogen ions from the hydrochloric acid. State symbols are not required.

(1)

(ii) State **two** observations you would make while the reaction is taking place. No change of colour occurs.

(2)

Observation 1 .....

Observation 2 .....

(b) In an experiment to prepare crystals of hydrated barium chloride, $BaCl_2.2H_2O$, a volume of 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid, HCl, was transferred to a beaker and solid barium carbonate, $BaCO_3$, was added until it was in excess.

(i) How many moles of acid were used in the reaction?

(1)

(ii) What mass of barium carbonate, in grams, reacts with this amount of acid?

The molar mass of barium carbonate is 197.3 g mol^{-1}.

(1)

(iii) Why was an **excess** of barium carbonate used in the experiment?

(1)

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(iv) How would you separate the barium chloride solution from the reaction mixture in part (iii)?

(1)

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(v) The barium chloride solution was left to crystallize. The crystals were separated and dried carefully. A sample of 5.35 g of hydrated crystals, $BaCl_2.2H_2O$, which has molar mass 244 g mol^{-1}, was obtained. Calculate the percentage yield of this reaction.

(2)

(vi) Give **one** reason why the yield of crystals is less than 100%, even when the reactants contain no impurities.

(1)

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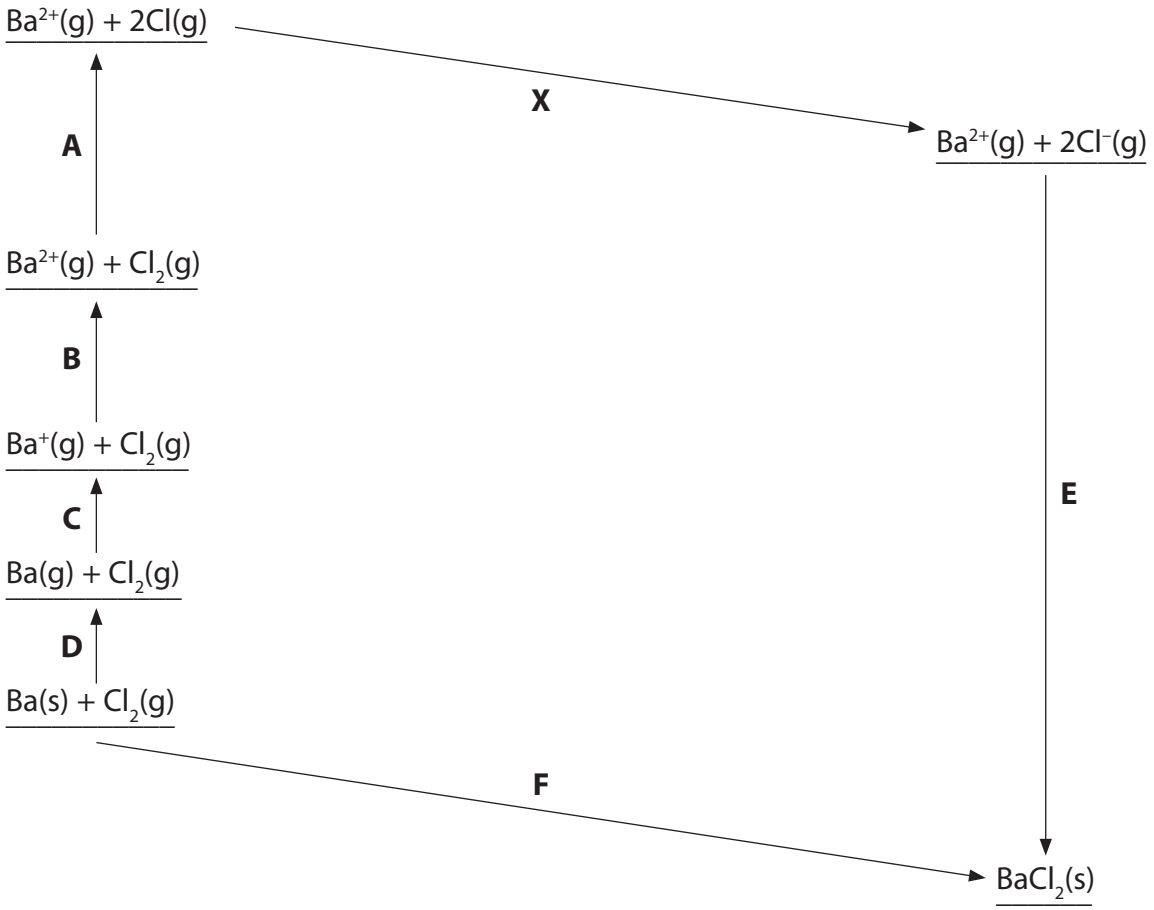
(c) The diagram below, which is not drawn to scale, shows how the lattice energy of barium chloride can be calculated using the Born-Haber cycle.



(i) Using the letters **A** to **F**, complete the table below by matching each letter to its corresponding energy change.

(3)

(ii) The energy change **X** is –697.6 kJ mol^{-1}.

In the table, add the name of the enthalpy change which is occurring in this stage of the cycle.

(1)

Energy change	Letter	ΔH / kJ mol^{-1}
Lattice energy of barium chloride		
Enthalpy change of atomization of barium		180.0
Enthalpy change of atomization of $Cl_2(g)$ to 2Cl(g)		243.4
First ionization energy of barium		503
Second ionization energy of barium		965
	X	2 × (–348.8) = –697.6
Enthalpy change of formation of barium chloride		–858.6

(iii) Use the data to calculate the lattice energy of barium chloride.

(2)

Answer = ... kJ mol^{-1}

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

What can you deduce from the fact that the experimental and theoretical values for the lattice energy of barium chloride are very close?

(2)

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(Total for Question 4 = 18 marks)