IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

5.3 Bond Enthalpy

Easy (4 questions)	/33
Medium (5 questions)	/43
Hard (4 questions)	/39
Total Marks	**/115**

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Easy Questions

1 (a) During chemical reactions, enthalpy changes occur as bonds are broken and formed.

i) Thermal energy is needed to overcome the attractive forces between atoms. In terms of thermal energy, name the process where bonds are broken.

ii) When bonds are formed, thermal energy is released to the surroundings. In terms of thermal energy, name the process where bonds are made.

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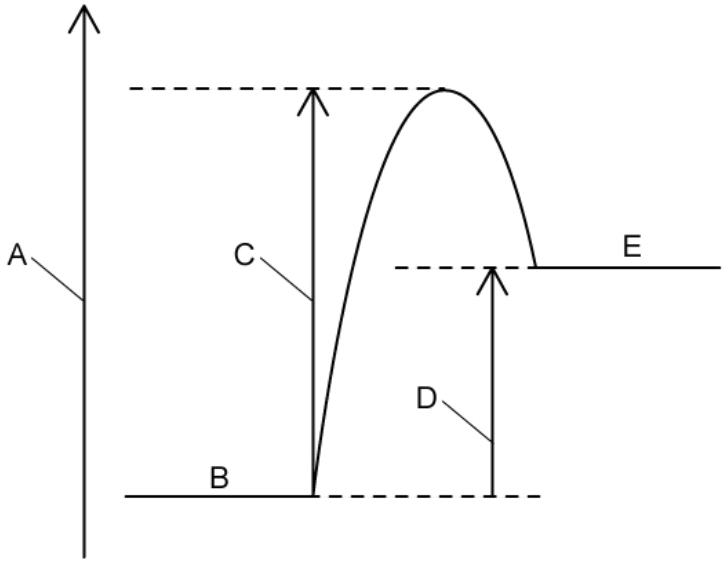
(2 marks)

(b) The energy level diagram for an endothermic reaction is shown below.



Complete the diagram by labelling parts A to E.

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(5 marks)

(c) An element **X** undergoes complete combustion according to the following equation. The enthalpy change, ΔH, and activation energy, *Ea*, for this reaction are -520 kJ mol^{-1} and +630 kJ mol^{-1} respectively. Deduce whether this reaction is exothermic or endothermic.

$$X + O_2 \rightarrow XO_2$$

(1 mark)

(d) Define the term average bond enthalpy.

(2 marks)

2 (a) State the formula for calculating the standard enthalpy change of reaction, ΔH_r, using bond energies.

(1 mark)

(b) Use section 11 of the data booklet to calculate the enthalpy change, in kJ mol^{-1}, for the following reaction.

$$Cl_2 + H_2 \rightarrow 2HCl$$

(4 marks)

(c) State whether the energy change for the reaction in part (b) is endothermic or exothermic.

(1 mark)

(d) Using section 11 of the data booklet, calculate the enthalpy change of reaction, ΔH_r, in kJ mol^{-1} for the following reaction.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

(4 marks)

3 (a) Draw the Lewis structure of an oxygen molecule, O_2.

(2 marks)

(b) State the type of energy in the stratosphere responsible for the break down of the oxygen molecule.

(1 mark)

(c) State the equation for the formation of ozone and whether this reaction is endothermic or exothermic.

(2 marks)

(d) State the name of the type of compound that is responsible for the disruption of the temperature regulation in the stratosphere.

(1 mark)

4 (a) Using displayed formulae, write the equation for the reaction of ethene with water to form ethanol.

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(2 marks)

(b) Using section 11 in the data booklet calculate the enthalpy change of reaction, ΔH_r, for the reaction of ethene with water.

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(4 marks)

(c) Define *bond dissociation energy*.

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(1 mark)

Medium Questions

1 (a) Explain what is meant by the *standard enthalpy change of reaction*.

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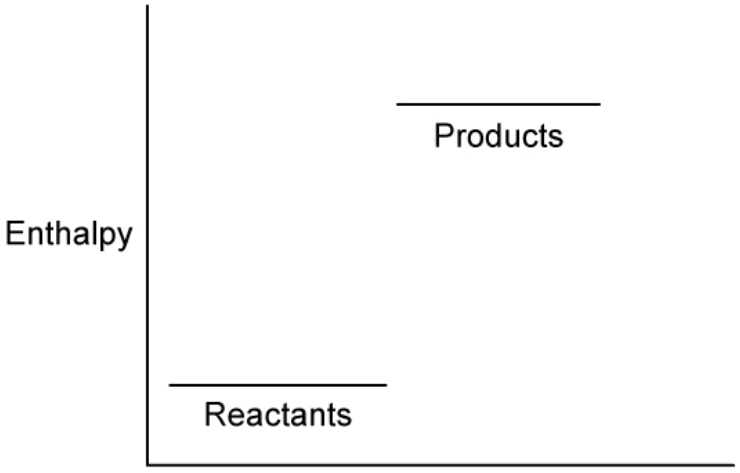
(1 mark)

(b) An enthalpy level diagram for the reaction between solid ammonium nitrate and water is shown below.

Figure 1



i) Give the sign of ΔH for the reaction and state whether the reaction is endothermic or exothermic

ii) State the relative strength of the chemical bonds in the products and in the reactants.

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(3 marks)

(c) The enthalpy of combustion for propanol is, $\Delta H_c^{\ominus}$, is -2021 kJ mol^{-1}. Draw a labelled energy level diagram for this reaction.

(3 marks)

(d) Explain why the strength of the hydrogen halide bonds decreases down the group.

(3 marks)

2 (a) Enthalpy changes can be found using bond enthalpy data. Some bond enthalpy values are shown below in **Table 1**.

Table 1

Bond	Mean Bond Enthalpy $\Delta H^{\ominus}$ (kJ mol^{-1})
C-C	346
C-H	414
H-H	436

The balanced equation for the reaction between methane and propane is

$$CH_4\,(g) + CH_3CH_2CH_3\,(g) \rightarrow CH_3CH_2CH_2CH_3\,(g) + H_2\,(g)$$

Use the equation and bond enthalpy data to calculate the enthalpy change for the above reaction.

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(3 marks)

(b) Define the term *average bond enthalpy*.

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(1 mark)

(c) Enthalpy changes can be found using bond enthalpy data. Some bond enthalpy values are shown below in **Table 2**.

Table 2

Bond	Mean Bond Enthalpy $\Delta H^{\ominus}$ (kJ mol^{-1})
C=C	614
C-H	414
O-H	463
C=O	804
O=O	498

The balanced equation for the combustion of ethene is

$$C_2H_4\,(g) + 3O_2\,(g) \rightarrow 2CO_2\,(g) + 2H_2O\,(l)$$

Use the equation and bond enthalpy data to calculate the enthalpy of combustion of ethene.

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(3 marks)

(d) Bond enthalpies can be found using Hess's Law or from experimental data.

Outline the difference between the two ways of finding bond enthalpy.

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(1 mark)

3 (a) Alkanes can be used as fuels in internal combustion engines. When sufficient oxygen is present, they undergo complete combustion reactions.

Write an equation for the enthalpy of combustion of butane.

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(1 mark)

(b) Define the term *standard enthalpy of combustion,* $\Delta H^{\ominus}_{c}$.

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(3 marks)

(c) **Table 1** below contains bond enthalpy data for the reaction shown in part (a).

Table 1

	C-C	C-H	O=O	C=O	O-H
Mean bond enthalpy (kJ mol^{-1})	346	414	498	804	463

Using the data in **Table 1** and the equation in part (a), calculate the enthalpy change of combustion of butane.

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(3 marks)

(d) In the absence of sufficient oxygen, butane will undergo incomplete combustion.

Write an equation for the incomplete combustion of butane.

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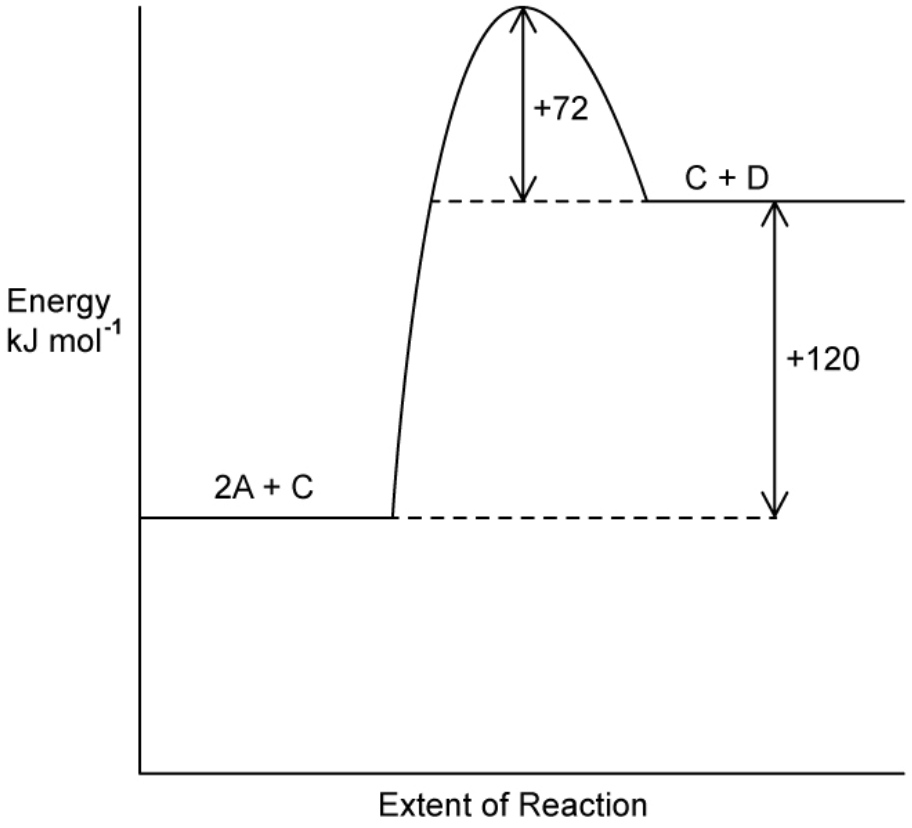
(1 mark)

4 (a) Use the energy level diagram to determine the activation energy, E_a, for the given reaction in **Figure 1**.

Figure 1



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(1 mark)

(b) Ethene can be hydrated via the following reaction:

$$C_2H_4\ (g) + H_2O\ (g) \rightarrow C_2H_5OH\ (g)$$

Table 1

Bond	C-C	C=C	C-H	C-O	O-H
Mean bond enthalpy (kJ mol^{-1})	346	614	414	358	463

Use the data in **Table 1** to calculate the enthalpy change for the hydration of ethene.

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(3 marks)

(c) Explain why the value to your answer to part (b) is different from the data book value for the hydration of ethene.

$$C_2H_4\,(g) + H_2O\,(g) \rightarrow C_2H_5OH\,(g)$$

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(2 marks)

(d) **Table 2** below has some enthalpy data for a different chemical reaction. Hydrazine, N_2H_4 can react with hydrogen peroxide in an exothermic reaction, as shown below.

$$N_2H_4(g) + 2H_2O_2 \rightarrow N_2(g) + 4H_2O(g) \qquad \Delta H^{\ominus}_r = -789\ kJ\ mol^{-1}$$

The structure of hydrazine is shown in **Figure 1**.

Figure 1

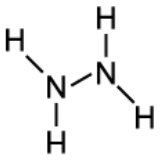

Table 2

Bond	Mean Bond Enthalpy $\Delta H^{\ominus}$ (kJ mol^{-1})
N-N	+158
N≡N	+945
O-H	+463
O-O	+144

Using the reaction equation and the data in the table above, calculate the value of the N-H bond in hydrazine.

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(3 marks)

5 (a) The bond enthalpies, in $kJmol^{-1}$, of oxygen-oxygen single and double bonds are shown below in **Table 1.**

Table 1

O=O	O-O
498	144

Predict, with a reason, the bond enthalpy of the oxygen-oxygen bond in ozone, O_3.

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(2 marks)

(b) Ozone is formed in the upper atmosphere in a two-step process as shown below:

Step **A**: $O_2 \rightarrow 2O^{\bullet}$

Step **B**: $O_2 + O^{\bullet} \rightarrow O_3$

Ozone is naturally lost through the decomposition of ozone:

Step **C:** $O_3 \rightarrow O_2 + O^{\bullet}$

i) Identify, with a reason, which of the three steps is exothermic.

ii) Identify which of the steps is endothermic. Explain with reference to the bonding

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(2 marks)

(c) Draw an enthalpy level diagram to represent the three steps **A**, **B** and **C** shown in part (b). Clearly label the position of oxygen, ozone, and the oxygen radical.

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(2 marks)

(d) What can be deduced from the fact that ozone absorbs UV radiation in the region of 340 nm and molecular oxygen in the region of 242 nm?

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(2 marks)

Hard Questions

1 (a) Define the term *average bond enthalpy*.

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(2 marks)

(b) Determine the bond dissociation energy, in kJ mol^{-1}, for one mole of O–F bonds using the following equation and section 11 of the data booklet. Give your answer to 3 significant figures.

$$F_2(g) + \frac{1}{2}O_2(g) \rightarrow OF_2(g) \quad \Delta H_r = +28 \text{ kJ mol}^{-1}$$

[3]

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(3 marks)

(c) The reaction of ethanoyl chloride, CH_3COCl , and ethanol form an ester. State the equation for this reaction.

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(2 marks)

(d) Use section 11 in the data booklet to deduce the energy required, in kJ mol^{-1}, to break the bonds.

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(2 marks)

(e) Deduce the energy released, in kJ mol^{-1}, when the bonds are formed and therefore the enthalpy change for the reaction.

(3 marks)

2 (a) Methane reacts violently with fluorine to form carbon tetrafluoride and hydrogen fluoride

Formulate the equation for this reaction.

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(2 marks)

(b) Use your answer to part a) and section 10 of the data booklet to calculate the following:

i) The energy required, in kJ, to break the bonds for the reaction between methane and fluorine.

[1]

ii) The energy released, in kJ, to form the bonds for the reaction between methane and fluorine.

[1]

iii) The enthalpy change, ΔH_r, in kJ mol^{-1} for this reaction.

[2]

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(4 marks)

(c) A student suggested that one reason for the high reactivity of fluorine is a weak F–F bond. State whether the student is correct. Justify your answer.

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(2 marks)

(d) Sketch a labelled energy diagram for the reaction of methane and fluorine.

(3 marks)

3 (a) Hydrazine has the formula N_2H_4 and is used as a rocket fuel (e.g. for the Apollo moon rockets). It burns in the following reaction for which the enthalpy change is -583 kJ mol^{-1}.

$$N_2H_4\ (g) + O_2\ (g) \rightarrow N_2\ (g) + 2H_2O\ (g)$$

Sketch the Lewis structure of hydrazine, N_2H_4.

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(2 marks)

(b) Use section 11 of the Data booklet and the information in part a) to deduce the bond enthalpy, in kJ mol^{-1}, for the N-N bond.

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(3 marks)

(c) Outline why the value of enthalpy of reaction calculated from bond enthalpies is less accurate.

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(1 mark)

4 (a) Ozone prevents UV radiation emitted from the Sun reaching the surface of the Earth. Draw the resonance Lewis structures of ozone.

(3 marks)

(b) By using equations, state the environmental impact of CFCs on the ozone layer.

(4 marks)

(c) The destruction of ozone is a significant environmental issue as ozone can absorb frequencies of ultraviolet radiation that oxygen can not.

Explain with reference to the structure and bonding of oxygen and ozone why this occurs.

(3 marks)