5.3 Bond Enthalpy

Question Paper

Course	DP IB Chemistry
Section	5. Energetics / Thermochemistry
Topic	5.3 Bond Enthalpy
Difficulty	Medium

Time allowed: 60

Score: /43

Percentage: /100
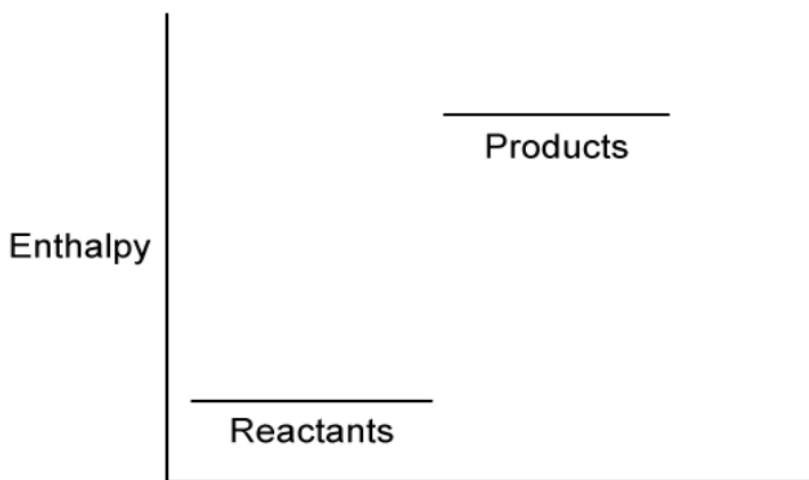
Question 1a

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

[1 mark]

Question 1b

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

Figure 1

i)   Give the sign of Δ*H* 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.

[3 marks]

Question 1c

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]

Question 1d

d)   Explain why the strength of the hydrogen halide bonds decreases down the group.
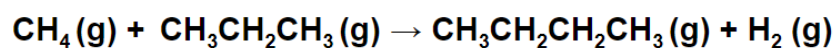
[3 marks]

Question 2a

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.

[3 marks]

Question 2b

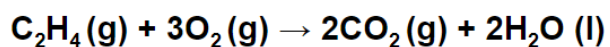b)   Define the term *average bond enthalpy*.

[1 mark]

Question 2c

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.

[3 marks]

Question 2d

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.

[1 mark]

Question 3a

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.

[1 mark]

Question 3b

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

[3 marks]

Question 3c

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.
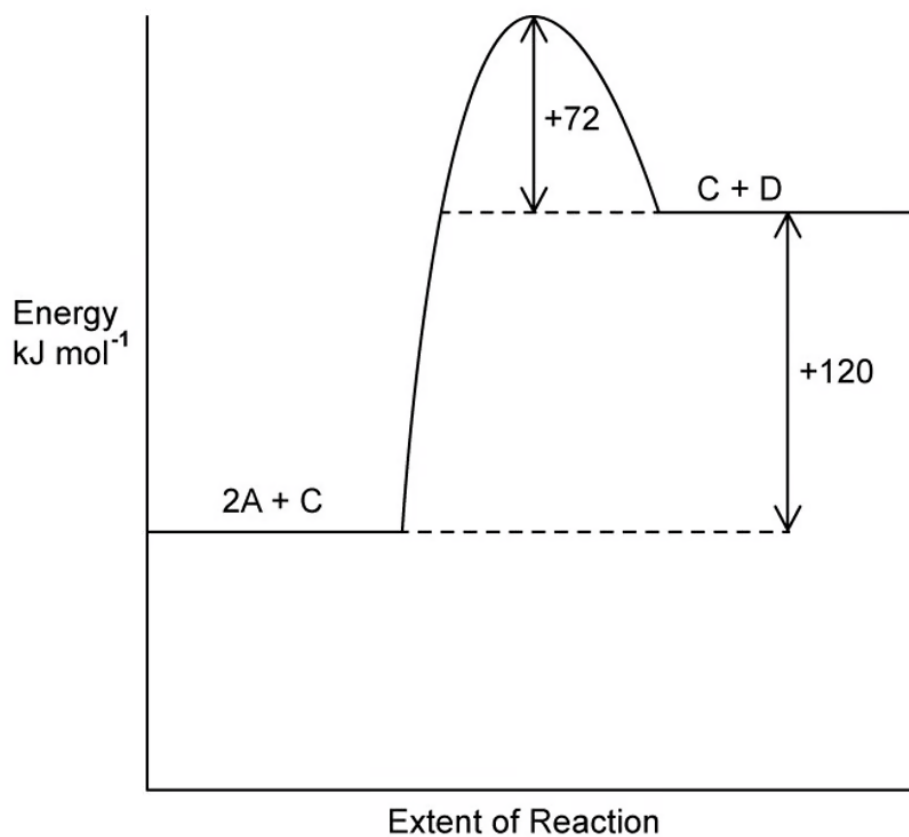
[3 marks]

Question 3d

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

Write an equation for the incomplete combustion of butane.

[1 mark]

Question 4a

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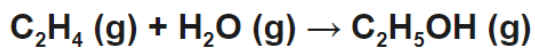
Figure 1

[1 mark]

Question 4b

b)   Ethene can be hydrated via the following reaction:

$$C_2H_4 \text{ (g)} + H_2O \text{ (g)} \rightarrow C_2H_5OH \text{ (g)}$$

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.
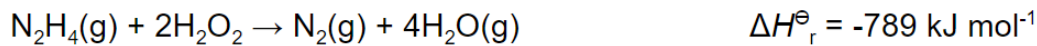
[3 marks]

Question 4c

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

$$C_2H_4 \text{ (g)} + H_2O \text{ (g)} \rightarrow C_2H_5OH \text{ (g)}$$
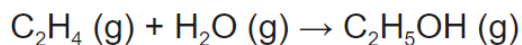
[2 marks]

Question 4d

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.

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

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

Figure 1
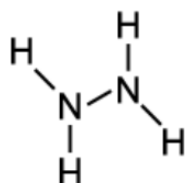
Table 2

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.

[3 marks]

Question 5a

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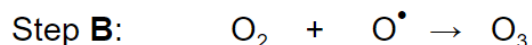
Table 1

O=O	O-O
498	144

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

[2 marks]

Question 5b

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**: $O_3 \rightarrow O_2 \; + \; O^\bullet$
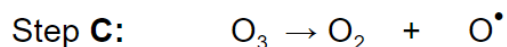
i)   Identify, with a reason, which of the three steps is exothermic.

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

[2 marks]

Question 5c

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.

[2 marks]

Question 5d

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?

[2 marks]