A-Level Chemistry

Bond Enthalpies

Question Paper

Time available: 66 minutes
Marks available: 63 marks

1. This question is about enthalpy changes.

(a) Define the term enthalpy change.

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_____

(1)

(b) Propane undergoes complete combustion.

$$C_3H_8(g) + 5\ O_2(g) \longrightarrow 3\ CO_2(g) + 4\ H_2O(l) \quad \Delta H = -2046\ kJ\ mol^{-1}$$

The table below shows some bond enthalpy data.

Bond	C–H	C=O	O–H
Mean bond enthalpy / kJ mol^{-1}	412	743	463

The bond enthalpy for O=O is 496 kJ mol^{-1}

For $H_2O(l) \longrightarrow H_2O(g)$ $\Delta H = +41$ kJ mol^{-1}

Use these data to calculate a value for the C–C bond enthalpy in propane.

C–C bond enthalpy _____ kJ mol^{-1}

(4)

(c) Explain why the value given for the O=O bond enthalpy in part (b) is **not** a mean value.

_____

_____

_____

(1)

(Total 6 marks)

2. This question is about energetics.

(a) Write an equation, including state symbols, for the reaction with an enthalpy change equal to the enthalpy of formation for iron(III) oxide.

_____

(1)

(b) **Table 1** contains some standard enthalpy of formation data.

Table 1

	$CO(g)$	$Fe_2O_3(s)$
$\Delta_f H^{\ominus}$ / kJ mol^{-1}	−111	−822

$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$ $\Delta H = -19$ kJ mol^{-1}

Use these data and the equation for the reaction of iron(III) oxide with carbon monoxide to calculate a value for the standard enthalpy of formation for carbon dioxide.

Show your working.

$\Delta_f H^{\ominus}$ _____ kJ mol^{-1}

(3)

(c) Some enthalpy data are given in **Table 2**.

Table 2

Process	**ΔH / kJ mol^{-1}**
$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$	−92
$N_2(g) \longrightarrow 2N(g)$	+944
$H_2(g) \longrightarrow 2H(g)$	+436

Use the data from **Table 2** to calculate the bond enthalpy for N−H in ammonia.

N−H bond enthalpy _____ kJ mol^{-1}

(3)

(d) Give one reason why the bond enthalpy that you calculated in part (c) is different from the mean bond enthalpy quoted in a data book (388 kJ mol^{-1}).

_____

_____

_____

(1)

(Total 8 marks)

3. This question is about enthalpy changes.

(a) Write an equation, including state symbols, to show the reaction taking place when the standard enthalpy of combustion for ethanol is measured.

_____

(2)

(b) State the name given to the enthalpy change represented by the following chemical equation.

Explain why this enthalpy change would be difficult to determine directly.

$$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$$

Enthalpy change _____

Explanation _____

_____

_____

(2)

(c) Standard enthalpies of combustion for carbon and carbon monoxide are −393 kJ mol^{-1} and −283 kJ mol^{-1}, respectively.

Use these data to calculate the enthalpy change for the reaction in part **(b)**.

Enthalpy change = _____ kJ mol^{-1}

(2)

(d) Use the following data to calculate a value for the Xe–F bond enthalpy in XeF_4

$$Xe(g) + 2F_2(g) \rightarrow XeF_4(g) \quad \Delta H = -252 \text{ kJ mol}^{-1}$$
$$F_2(g) \rightarrow 2F(g) \quad \Delta H = +158 \text{ kJ mol}^{-1}$$

Xe–F bond enthalpy = _____ kJ mol^{-1}

(3)

(e) Suggest a reason why the value calculated in part **(d)** differs from the mean Xe–F bond enthalpy quoted in a data source.

_____

_____

_____

(1)

(Total 10 marks)

4. (a) Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $CF_4(g)$.

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(1)

(b) Explain why CF_4 has a bond angle of 109.5°.

_____

_____

_____

_____

_____

(2)

(c) **Table 1** gives some values of standard enthalpies of formation ($\Delta_f H^{\ominus}$).

Table 1

Substance	$F_2(g)$	$CF_4(g)$	HF(g)
$\Delta_f H^{\ominus}$ / kJ mol^{-1}	0	−680	−269

The enthalpy change for the following reaction is −2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of $C_2H_6(g)$.

Standard enthalpy of formation of $C_2H_6(g)$ = _____ kJ mol^{-1}

(3)

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \quad \Delta H = -1904 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are given in **Table 2**.

Table 2

Bond	C−H	C−F	H−F
Mean bond enthalpy / kJ mol^{-1}	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F−F bond.

Is the student correct? Justify your answer with a calculation using these data.

(4)

(Total 10 marks)

5. The table contains some bond enthalpy data.

Bond	H−H	O=O	H−O
Bond enthalpy / kJ mol^{-1}	436	496	464

(a) The value for the H−O bond enthalpy in the table is a mean bond enthalpy.

State the meaning of the term **mean bond enthalpy** for the H−O bond.

(2)

(b) Use the bond enthalpies in the table to calculate a value for the enthalpy of formation of water in the gas phase.

(3)

(c) The standard enthalpy of combustion of hydrogen, forming water in the gas phase, is almost the same as the correct answer to part (b).

(i) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to be the same as the answer to part (b).

(1)

(ii) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to differ slightly from the answer to part (b).

(1)

(Total 7 marks)

6. Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

(a) The table below contains some bond enthalpy data.

	N ≡ N	H–H	N–H
Mean bond enthalpy / kJ mol^{-1}	944	436	388

(i) Use data from the table to calculate a value for the enthalpy of formation for one mole of ammonia.

(3)

(ii) A more accurate value for the enthalpy of formation of ammonia is –46 kJ mol^{-1}.
Suggest why your answer to part (a) (i) is different from this value.

(1)

(b) The table below contains some entropy data.

	$H_2(g)$	$N_2(g)$	$NH_3(g)$
$S^{\ominus}$ / J K^{-1} mol^{-1}	131	192	193

Use these data to calculate a value for the entropy change, with units, for the formation of one mole of ammonia from its elements.

(3)

(c) The synthesis of ammonia is usually carried out at about 800 K.

(i) Use the ΔH value of –46 kJ mol^{-1} and your answer from part (b) to calculate a value for ΔG, with units, for the synthesis at this temperature.
(If you have been unable to obtain an answer to part (b), you may assume that the entropy change is –112 J K^{-1} mol^{-1}. This is not the correct answer.)

(3)

(ii) Use the value of ΔG that you have obtained to comment on the feasibility of the reaction at 800 K.

(1)

(Total 11 marks)

7. A method of synthesising ammonia directly from nitrogen and hydrogen was developed by Fritz Haber. On an industrial scale, this synthesis requires a high temperature, a high pressure and a catalyst and is very expensive to operate.

(a) Use the data given below to calculate a value for the enthalpy of formation of ammonia

Bond	N ≡N	H – H	N – H
Mean bond enthalpy/kJ mol^{-1}	945	436	391

(3)

(b) A manager in charge of ammonia production wished to increase the daily production of ammonia and reduce the production costs. How would a chemist explain the factors that would influence the commercial efficiency of this production process?

(8)

(Total 11 marks)