



# **A-Level Chemistry**

## **Bond Enthalpies**

### **Question Paper**

**Time available: 66 minutes**

**Marks available: 63 marks**

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**1.**

This question is about enthalpy changes.

(a) Define the term enthalpy change.

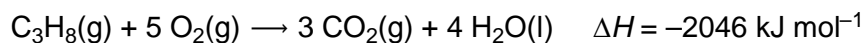
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(1)

(b) Propane undergoes complete combustion.



The table below shows some bond enthalpy data.

Bond	C–H	C=O	O–H
Mean bond enthalpy / kJ mol <sup>-1</sup>	412	743	463

The bond enthalpy for O=O is 496 kJ mol<sup>-1</sup>

For  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$   $\Delta H = +41 \text{ kJ mol}^{-1}$

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

C–C bond enthalpy \_\_\_\_\_ kJ mol<sup>-1</sup>

(4)

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

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(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.

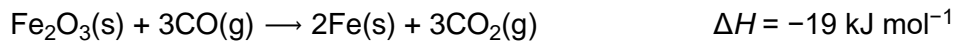
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(1)

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

**Table 1**

	CO(g)	Fe <sub>2</sub> O <sub>3</sub> (s)
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-111	-822



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.

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

(3)

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

**Table 2**

Process	$\Delta H / \text{kJ mol}^{-1}$
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$	-92
$\text{N}_2(\text{g}) \rightarrow 2\text{N}(\text{g})$	+944
$\text{H}_2(\text{g}) \rightarrow 2\text{H}(\text{g})$	+436

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

N-H bond enthalpy \_\_\_\_\_  $\text{kJ mol}^{-1}$

(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 ( $388 \text{ kJ mol}^{-1}$ ).

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(1)

(Total 8 marks)

**3.**

This question is about enthalpy changes.

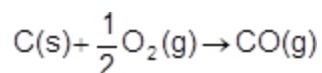
- (a) Write an equation, including state symbols, to show the reaction taking place when the standard enthalpy of combustion for ethanol is measured.

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(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.



Enthalpy change \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

(2)

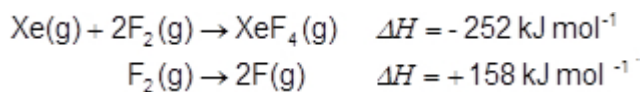
- (c) Standard enthalpies of combustion for carbon and carbon monoxide are  $-393 \text{ kJ mol}^{-1}$  and  $-283 \text{ kJ mol}^{-1}$ , respectively.

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

Enthalpy change = \_\_\_\_\_  $\text{kJ mol}^{-1}$

(2)

- (d) Use the following data to calculate a value for the Xe–F bond enthalpy in  $\text{XeF}_4$



Xe–F bond enthalpy = \_\_\_\_\_  $\text{kJ mol}^{-1}$

(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.

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(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  $\text{CF}_4(\text{g})$ .

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(1)

- (b) Explain why  $\text{CF}_4$  has a bond angle of  $109.5^\circ$ .

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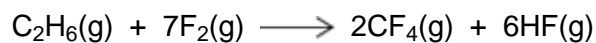
(2)

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

**Table 1**

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

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

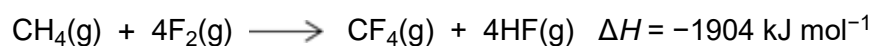


Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of  $C_2H_6(g)$ .

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

**(3)**

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



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

**Table 2**

Bond	C-H	C-F	H-F
Mean bond enthalpy / $\text{kJ mol}^{-1}$	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.

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(4)

(Total 10 marks)

5.

The table contains some bond enthalpy data.

Bond	H-H	O=O	H-O
Bond enthalpy / $\text{kJ mol}^{-1}$	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.

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(2)



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

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(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).

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(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).

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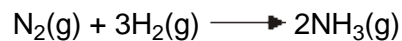
(1)

(Total 7 marks)

**6.**

Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.



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

	$\text{N} \equiv \text{N}$	$\text{H}-\text{H}$	$\text{N}-\text{H}$
Mean bond enthalpy / $\text{kJ mol}^{-1}$	944	436	388

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

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**(3)**

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

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**(1)**

- (b) The table below contains some entropy data.

	H <sub>2</sub> (g)	N <sub>2</sub> (g)	NH <sub>3</sub> (g)
S <sup>o</sup> / J K <sup>-1</sup> mol <sup>-1</sup>	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.

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(3)

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

- (i) Use the  $\Delta H$  value of  $-46 \text{ kJ mol}^{-1}$  and your answer from part (b) to calculate a value for  $\Delta G$ , 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  $-112 \text{ J K}^{-1} \text{ mol}^{-1}$ . This is not the correct answer.)

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(3)

- (ii) Use the value of  $\Delta G$  that you have obtained to comment on the feasibility of the reaction at 800 K.

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(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	$\text{N} \equiv \text{N}$	$\text{H} - \text{H}$	$\text{N} - \text{H}$
Mean bond enthalpy/ $\text{kJ mol}^{-1}$	945	436	391

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(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?

[illegible]

(8)

**(Total 11 marks)**