



# **A-Level Chemistry**

## **Hess's Law**

### **Question Paper**

**Time available: 61 minutes**

**Marks available: 58 marks**

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**1.**

This question is about 1-chloropropane.

- (a) Define the term standard enthalpy of formation.

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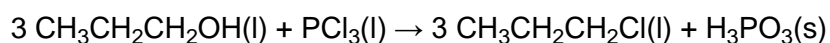
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(2)

- (b) The equation for a reaction used to manufacture 1-chloropropane is



The enthalpy change for this reaction,  $\Delta H$ , is  $-114 \text{ kJ mol}^{-1}$

The table contains some standard enthalpy of formation data.

| Substance                                 | $\text{PCl}_3(\text{l})$ | $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}(\text{l})$ | $\text{H}_3\text{PO}_3(\text{s})$ |
|---|--------------------------|--|-----------------------------------|
| $\Delta_f H^\ominus / \text{kJ mol}^{-1}$ | -339                     | -130   | -972                              |

Calculate a value for the standard enthalpy of formation of propan-1-ol using the enthalpy change for the reaction and data from the table.

Standard enthalpy of formation \_\_\_\_\_  $\text{kJ mol}^{-1}$

(3)

- (c) 1-chloropropane can also be produced by the reaction between propane and chlorine in the presence of ultraviolet light.

State why ultraviolet light is needed for this reaction to occur.

Give an equation for each propagation step in the formation of 1-chloropropane from propane.

Why ultraviolet light is needed \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Propagation step 1 \_\_\_\_\_

\_\_\_\_\_

Propagation step 2 \_\_\_\_\_

\_\_\_\_\_

(3)

- (d) The C–Cl bond in 1-chloropropane is polar because carbon and chlorine have different electronegativities.

Define the term electronegativity.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(1)

- (e) Ammonia reacts with 1-chloropropane to form propylamine.

Name and outline the mechanism for this reaction.

Name of mechanism \_\_\_\_\_

Outline of mechanism

**(5)**

**(Total 14 marks)**

**2.**

This question is about enthalpy changes.

(a) A student determined the enthalpy of combustion of cyclohexane ( $\text{C}_6\text{H}_{12}$ ).

The student

- placed a pure sample of cyclohexane in a spirit burner
- placed the spirit burner under a beaker containing 50.0 g of water and ignited the cyclohexane
- extinguished the flame after a few minutes.

The results for the experiment are shown in **Table 1**.

**Table 1**

|   |         |
|---|---------|
| Initial temperature of the water / °C             | 19.1    |
| Initial mass of spirit burner and cyclohexane / g | 192.730 |
| Final mass of spirit burner and cyclohexane / g   | 192.100 |

The student determined from this experiment that the enthalpy of combustion of cyclohexane is  $-1216 \text{ kJ mol}^{-1}$

Use the data to calculate the final temperature of the water in this experiment.

The specific heat capacity of water =  $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

The relative molecular mass ( $M_r$ ) of cyclohexane = 84.0

Final temperature of the water \_\_\_\_\_ °C

(4)

- (b) A data book value for the enthalpy of combustion of cyclohexane is  $-3920 \text{ kJ mol}^{-1}$

The student concluded that the temperature rise recorded in the experiment was smaller than it should have been.

Suggest a practical reason for this.

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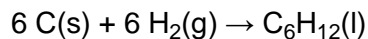
(1)

- (c) **Table 2** gives some values of standard enthalpies of combustion ( $\Delta_c H^\ominus$ ).

**Table 2**

| Substance  | C(s) | H <sub>2</sub> (g) | C <sub>6</sub> H <sub>12</sub> (l) |
|--|------|--------------------|------------------------------------|
| Standard enthalpy of combustion, $\Delta_c H^\ominus / \text{kJ mol}^{-1}$ | -394 | -286               | -3920                              |

Use the data in **Table 2** to calculate the enthalpy change for the reaction represented by this equation



Enthalpy change \_\_\_\_\_ kJ mol<sup>-1</sup>

(3)

(Total 8 marks)

3.

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.

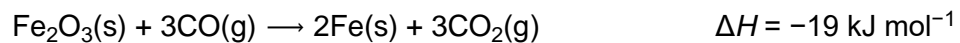
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(1)

- (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)

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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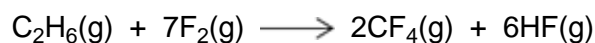
(2)

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

**Table 1**

| Substance                                 | $\text{F}_2(\text{g})$ | $\text{CF}_4(\text{g})$ | $\text{HF}(\text{g})$ |
|---|------------------------|-------------------------|-----------------------|
| $\Delta_f H^\ominus / \text{kJ mol}^{-1}$ | 0                      | -680                    | -269                  |

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

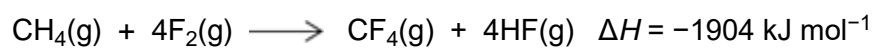


Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of  $\text{C}_2\text{H}_6(\text{g})$ .

Standard enthalpy of formation of  $\text{C}_2\text{H}_6(\text{g}) =$  \_\_\_\_\_  $\text{kJ mol}^{-1}$

(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 / kJ mol <sup>-1</sup> | 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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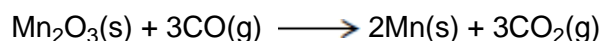
(4)  
(Total 10 marks)

**5.**

This question is about the extraction of metals.

- (a) Manganese can be extracted from  $\text{Mn}_2\text{O}_3$  by reduction with carbon monoxide at high temperature.
- (i) Use the standard enthalpy of formation data from the table and the equation for the extraction of manganese to calculate a value for the standard enthalpy change of this extraction.

|   | $\text{Mn}_2\text{O}_3(\text{s})$ | $\text{CO}(\text{g})$ | $\text{Mn}(\text{s})$ | $\text{CO}_2(\text{g})$ |
|---|-----------------------------------|-----------------------|-----------------------|-------------------------|
| $\Delta H_f^\ominus / \text{kJ mol}^{-1}$ | -971                              | -111                  | 0                     | -394                    |




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**(3)**

- (ii) State why the value for the standard enthalpy of formation of  $\text{Mn}(\text{s})$  is zero.

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**(1)**

- (b) Titanium is extracted in industry from titanium(IV) oxide in a two-stage process.

- (i) Write an equation for the first stage of this extraction in which titanium(IV) oxide is converted into titanium(IV) chloride.

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**(2)**

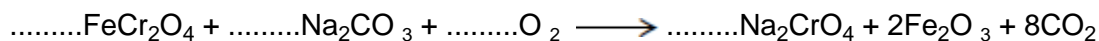
- (ii) Write an equation for the second stage of this extraction in which titanium(IV) chloride is converted into titanium.

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**(2)**

(c) Chromium is extracted in industry from chromite ( $\text{FeCr}_2\text{O}_4$ ).

- (i) In the first stage of this extraction, the  $\text{FeCr}_2\text{O}_4$  is converted into  $\text{Na}_2\text{CrO}_4$ . Balance the equation for this reaction.



(1)

- (ii) In the final stage, chromium is extracted from  $\text{Cr}_2\text{O}_3$  by reduction with aluminium.

Write an equation for this reaction.

\_\_\_\_\_

(1)

(Total 10 marks)

6.

The table below contains some standard enthalpy of formation data.

| Substance                                 | C(s) | N <sub>2</sub> (g) | H <sub>2</sub> O(g) | CO <sub>2</sub> (g) | NH <sub>4</sub> NO <sub>3</sub> (s) |
|---|------|--------------------|---------------------|---------------------|-------------------------------------|
| $\Delta H_f^\ominus / \text{kJ mol}^{-1}$ | 0    | 0                  | -242                | -394                | -365                                |

- (a) Why are the values of the standard enthalpy of formation for carbon and nitrogen zero?

\_\_\_\_\_

(1)

- (b) State Hess's Law.

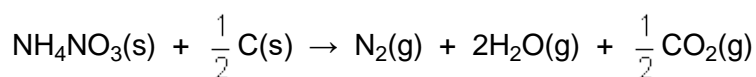
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(2)

- (c) Use  $\Delta H_f^\ominus$  data from the table to calculate a value for the enthalpy change for the following reaction.



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\_\_\_\_\_

(3)

(Total 6 marks)