**Q1.** (a) Explain the meaning of the terms *mean bond enthalpy* and *standard enthalpy of formation*.

*Mean bond enthalpy* .....

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Standard enthalpy of formation .....

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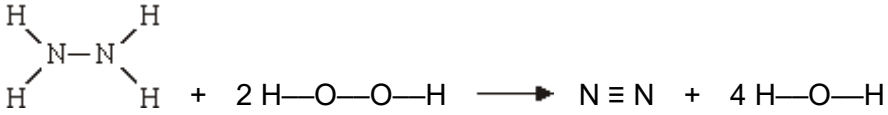
**(5)**

(b) Some mean bond enthalpies are given below.

| Bond | N–H | N–N | N≡N | H–O | O–O |
|---|---|---|---|---|---|
| Mean bond enthalpy/kJ $mol^{-1}$ | 388 | 163 | 944 | 463 | 146 |

Use these data to calculate the enthalpy change for the following gas-phase reaction between hydrazine, $N_2H_4$, and hydrogen peroxide, $H_2O_2$

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**(3)**

(c) Some standard enthalpies of formation are given below.

| | $N_2H_4(g)$ | $H_2O_2(g)$ | $H_2O(g)$ |
|---|---|---|---|

| | | | |
|---|---|---|---|
| $\Delta H_f^\ominus$ /kJ mol$^{-1}$ | +75 | –133 | –242 |

These data can be used to calculate the enthalpy change for the reaction in part (b).

$$N_2H_4(g) + 2H_2O_2(g) \rightarrow N_2(g) + 4H_2O(g)$$

(i) State the value of $\Delta H_f^\ominus$ for $N_2(g)$.

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(ii) Use the $\Delta H_f^\ominus$ values from the table to calculate the enthalpy change for this reaction.

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**(4)**

(d) Explain why the value obtained in part (b) is different from that obtained in part (c)(ii).

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**(1)**

**(Total 13 marks)**

**Q2.** When 0.10 g of propane was burned the quantity of heat evolved was 5.0 kJ. The enthalpy of combustion of propane in kJ mol$^{-1}$ is

**A** −800

**B** −1500

**C** −2200

**D** −2900

**(Total 1 mark)**

**Q3.** (a) What is the meaning of the term *enthalpy change*?

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**(2)**

(b) (i) Define the term *standard enthalpy of formation* of a compound.

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(ii) Write an equation, including state symbols, for the formation from its elements of solid sodium sulphate, $Na_2SO_4$

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**(5)**

(c) State Hess's Law.

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**(1)**

(d) Some standard enthalpy changes are difficult to measure directly but can be determined from standard enthalpies of combustion.
Maleic acid, $C_4H_4O_4$, reacts with oxygen to form carbon dioxide and water as shown

by the following equation.

$$C_4H_4O_4(s) + 3O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$$

Use the standard enthalpy of combustion data given below to calculate a value for the standard enthalpy change for the following reaction.

$$4C(s) + 2H_2(g) + 2O_2(g) \rightarrow C_4H_4O_4(s)$$

| | $C_4H_4O_4(s)$ | C(s) | $H_2(g)$ |
|---|---|---|---|
| $\Delta H_c^{\ominus}$ / kJ mol$^{-1}$ | –1356 | –393.5 | –285.8 |

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**(3)**
**(Total 11 marks)**

**Q4.** The table below contains some standard enthalpy of formation data.

| Substance | C(s) | $N_2(g)$ | $H_2O(g)$ | $CO_2(g)$ | $NH_4NO_3(s)$ |
|---|---|---|---|---|---|
| $\Delta H_f^{\ominus}$ / kJ mol$^{-1}$ | 0 | 0 | –242 | –394 | –365 |

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

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**(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.

$$NH_4NO_3(s) + \frac{1}{2}C(s) \rightarrow N_2(g) + 2H_2O(g) + \frac{1}{2}CO_2(g)$$

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**(3)**
**(Total 6 marks)**

**Q5.** (a) The table below contains some mean bond enthalpy data.

| Bond | H–O | O–O | O=O |
|---|---|---|---|
| Mean bond enthalpy/kJ $mol^{-1}$ | 463 | 146 | 496 |

The bonding in hydrogen peroxide, $H_2O_2$, can be represented by H–O–O–H. Use these data to calculate the enthalpy change for the following reaction.

$$H_2O_2(g) \rightarrow H_2O_2(g) + \tfrac{1}{2} O_2(g)$$

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**(3)**

(b) The standard enthalpy of formation, $\Delta H_f^{\ominus}$ for methane, is –74.9 kJ mol$^{-1}$. Write an equation, including state symbols, for the reaction to which this enthalpy change applies.

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**(2)**

(c) The enthalpy changes for the formation of atomic hydrogen and atomic carbon from their respective elements in their standard states are as follows.

$\tfrac{1}{2} H_2(g) \rightarrow H(g)$ $\quad \Delta H^{\ominus} = +218$ kJ mol$^{-1}$

$C(s) \rightarrow C(g)$ $\quad \Delta H^{\ominus} = +715$ kJ mol$^{-1}$

(i) By reference to its structure, suggest why a large amount of heat energy is required to produce free carbon atoms from solid carbon.

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(ii) Parts (b) and (c) give enthalpy data for the formation of $CH_4(g)$, H(g) and C(g). Use these data and Hess's Law to calculate the value of the enthalpy change for the following reaction.

$$CH_4(g) \rightarrow C(g) + 4H(g)$$

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(iii) Use your answer from part (c)(ii) to calculate a value for the mean bond enthalpy of a C–H bond in methane.

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**(5)**
**(Total 10 marks)**

**Q6.** (a) Define the term *standard enthalpy of formation*.

**(3)**

(b) State Hess's Law and use it, together with the data given in the table below, to calculate the standard enthalpy change for the following reaction.

$MgO(s) + 2HCl(g) \rightarrow MgCl_2(s) + H_2O(l)$

| | MgO | HCl(g) | $MgCl_2$ | $H_2O$ |
|---|---|---|---|---|
| $\Delta H_f^{\ominus}$/kJ mol$^{-1}$ | –602 | –92 | –642 | –286 |

**(4)**

(c) In an experiment, an excess of solid magnesium oxide was added to 50 cm$^3$ of 3.0 mol dm$^{-3}$ hydrochloric acid. The initial temperature of the solution was 21 °C. After reaction, the temperature had risen to 53 °C. (The specific heat capacity of water is 4.2 J K$^{-1}$ g$^{-1}$)

Use this information to calculate the enthalpy change for the reaction of one mole of magnesium oxide with hydrochloric acid. For your calculation you should assume that all the heat from the reaction is used to raise the temperature of 50 g of water.

**(8)**
**(Total 15 marks)**