Enthalpy

1. (a) The propane gas in the tank is used as a fuel in the factory. The equation for its combustion is:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) \qquad \Delta H = -2220 \text{ kJ mol}^{-1}$$

Calculate the amount of heat energy, in kJ, produced during the combustion of 30.0 kg of propane gas.

(2)

(b) (i) Explain what is meant by the term *average bond enthalpy*.

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(3)

(ii) Use the average bond enthalpy data below to calculate a value for the molar enthalpy change for the following reaction.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O\ (g)$$

Bond	C–C	C–H	O=O	C=O	H–O
Average bond enthalpy/kJ mol^{-1}	348	412	496	743	463

(3)

(iii) The value obtained in (b)(ii) is different from the standard molar enthalpy change of combustion of propane gas given in (a). State **two** reasons for this.

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(2)
(Total 10 marks)

2. (a) Define the term *standard enthalpy of formation*, $\Delta H_f^{\ominus}$

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(3)

(b) Use the data in the table to calculate the standard enthalpy of formation of liquid methylbenzene, C_7H_8

Substance	C(s)	$H_2(g)$	$C_7H_8(l)$
Standard enthalpy of combustion, $\Delta H_c^{\ominus}$ /kJ mol^{-1}	–394	–286	–3909

$7C(s) + 4H_2(g) \rightarrow C_7H_8(l)$

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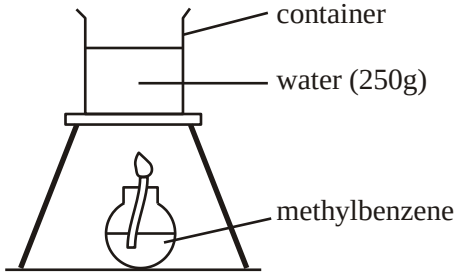
(3)

(c) An experiment was carried out to determine a value for the enthalpy of combustion of liquid methylbenzene using the apparatus shown in the diagram.



Burning 2.5 g of methylbenzene caused the temperature of 250 g of water to rise by 60°C. Use this information to calculate a value for the enthalpy of combustion of methylbenzene, C_7H_8

(The specific heat capacity of water is 4.18 J K^{-1} g^{-1}. Ignore the heat capacity of the container.)

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(4)

(d) A 25.0 cm^3 sample of 2.00 mol dm^{-3} hydrochloric acid was mixed with 50.0 cm^3 of a 1.00 mol dm^{-3} solution of sodium hydroxide. Both solutions were initially at 18.0°C.

After mixing, the temperature of the final solution was 26.5°C.

Use this information to calculate a value for the standard enthalpy change for the following reaction.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

In your calculation, assume that the density of the final solution is 1.00 g cm^{-3} and that its specific heat capacity is the same as that of water. (Ignore the heat capacity of the container.)

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(4)

(e) Give **one** reason why your answer to part (d) has a much smaller experimental error than your answer to part (c).

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(1)

(Total 15 marks)

3. (a) Define the term *standard enthalpy of combustion*, $\Delta H_c^{\ominus}$

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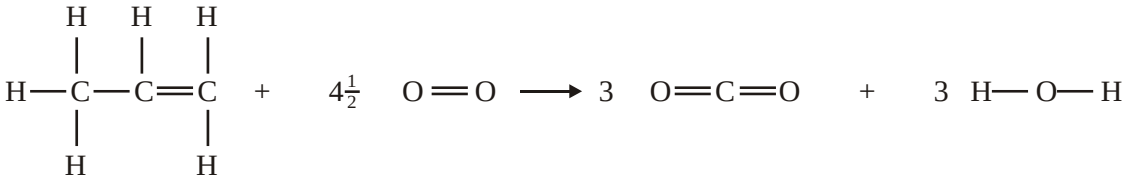
(3)

(b) Use the mean bond enthalpy data from the table and the equation given below to calculate a value for the standard enthalpy of combustion of propene. All substances are in the gaseous state.

Bond	C == C	C—C	C—H	O == O	O == C	O—H
Mean bond enthalpy/ kJ mol^{-1}	612	348	412	496	743	463



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(3)

(c) State why the standard enthalpy of formation, $\Delta H_f^{\ominus}$, of oxygen is zero.

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(1)

(d) Use the data from the table below to calculate a more accurate value for the standard enthalpy of combustion of propene.

Compound	$C_3H_6(g)$	$CO_2(g)$	$H_2O(g)$
Standard enthalpy of formation, $\Delta H_f^{\ominus}$/ kJ mol^{-1}	+20	–394	–242

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(3)

(e) Explain why your answer to part (b) is a less accurate value than your answer to part (d).

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(2)

(Total 12 marks)

4. Below are some standard enthalpy changes including the standard enthalpy of combustion of nitroglycerine, $C_3H_5N_3O_9$

$\frac{1}{2}\ N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\quad \Delta H_f^{\ominus} = +34$ kJ mol^{-1}

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H_f^{\ominus} = -394$ kJ mol^{-1}

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ $\quad \Delta H_f^{\ominus} = -242$ kJ mol^{-1}

$C_3H_5N_3O_9(l) + \frac{11}{4}\ O_2(g) \rightarrow 3CO_2(g) + \frac{5}{2}\ H_2O(g) + 3NO_2(g)$ $\quad \Delta H_c^{\ominus} = -1540$ kJ mol^{-1}

(a) Standard enthalpy of formation is defined using the term *standard state*.What does the term *standard state* mean?

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(2)

(b) Use the standard enthalpy changes given above to calculate the standard enthalpy of formation of nitroglycerine.

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(4)

(c) Calculate the enthalpy change for the following decomposition of nitroglycerine.

$$C_3H_5N_3O_9(l) \rightarrow 3CO_2(g) + \tfrac{5}{2} H_2O(g) + \tfrac{3}{2} N_2(g) + \tfrac{1}{4} O_2(g)$$

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(3)

(d) Suggest one reason why the reaction in part (c) occurs rather than combustion when a bomb containing nitroglycerine explodes on impact.

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(1)

(e) An alternative reaction for the combustion of hydrogen, leading to liquid water, is given below.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H^{\ominus} = -286 \text{ kJ mol}^{-1}$$

Calculate the enthalpy change for the process $H_2O(l) \rightarrow H_2O(g)$ and explain the sign of ΔH in your answer.

Calculation.....

Explanation for sign of ΔH.....

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(2)

(Total 12 marks)

5. A 50.0 cm^3 sample of a 0.200 mol dm^{-3} solution of silver nitrate was placed in a polystyrene beaker. An excess of powdered zinc was added to this solution and the mixture stirred. Zinc nitrate, $Zn(NO_3)_2$, and silver were formed and a rise in temperature of 3.20 °C was recorded.

(a) Write an equation for the reaction between silver nitrate and zinc.

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(1)

(b) Calculate the number of moles of silver nitrate used in the experiment.

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(2)

(c) Calculate the heat energy evolved by the reaction in this experiment assuming that all the energy evolved is used to heat only the 50.0 g of water in the mixture.
(Specific heat capacity of water is 4.18 J g^{-1} K^{-1})

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(2)

(d) Calculate the heat energy change for the reaction per mole of zinc reacted.

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(2)

(e) Explain why the experimental value for the heat energy evolved in this experiment is less than the correct value.

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(1)

(Total 8 marks)