Q1. Given the following data

$C(s) + 2H_2(g) \rightarrow CH_4(g)$ $\Delta H = -75$ kJ mol^{-1}

$H_2(g) \rightarrow 2H(g)$ $\Delta H = +436$ kJ mol^{-1}

which one of the following is the enthalpy change, in kJ mol^{-1}, of the reaction below?

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

A −947

B +511

C +797

D +947

(Total 1 mark)

Q2. Nitric acid is produced industrially from ammonia, air and water using the following sequence of reactions:

(1) $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $\Delta H = -909$ kJ mol^{-1}

(2) $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = -115$ kJ mol^{-1}

(3) $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$ $\Delta H = -117$ kJ mol^{-1}

Which is the enthalpy change (in kJ mol^{-1}) for the following reaction?

$4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(g)$

A −679

B −794

C −1024

D −1139

(Total 1 mark)

Q3. Consider the reactions

$C_2H_4(g) + 2O_2(g) \rightarrow 2CO(g) + 2H_2O(g)$ $\Delta H^{\ominus} = -758$ kJ mol^{-1}

$2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$ $\Delta H^{\ominus} = +52$ kJ mol^{-1}

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

The enthalpy of formation of carbon monoxide is

A −111 kJ mol^{-1}

B −163 kJ mol^{-1}

C −222 kJ mol^{-1}

D -464 kJ mol^{-1}

(Total 1 mark)

Q4. (a) Write an equation for the complete combustion of propanone, C_3H_6O, to form carbon dioxide and water.

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(1)

(b) In a laboratory experiment, 1.45 g of propanone were burned completely in oxygen. The heat from this combustion was used to raise the temperature of 100 g of water from 293.1 K to 351.2 K.

(i) Calculate the number of moles of propanone in the 1.45 g.

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(ii) Calculate the heat energy required to raise the temperature of 100 g of water from 293.1 K to 351.2 K.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

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(iii) Hence, calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of propanone.

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(5)

(c) In a similar experiment, the enthalpy of combustion of butanone, C_4H_8O, was found to be –1290 kJ mol^{-1}. A data book value for the same reaction is $\Delta H_c^{\ominus}$ = –2430 kJ mol^{-1}.

(i) Suggest one reason why the experimental value is very different from the data book value.

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(ii) This data book value of $\Delta H_c^{\ominus}$ for butanone (–2430 kJ mol^{-1}) refers to the formation of carbon dioxide gas and water in the gaseous state. How would this value differ if it referred to the formation of water in the liquid state? Explain your answer.

Difference .....

Explanation .....

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(3)

(d) Calculate a value for the standard enthalpy of formation for liquid ethanethiol, C_2H_5SH. Use the equation given below and enthalpy of combustion data from the following table.

Substance	$C_2H_5SH(l)$	C(s)	$H_2(g)$	S(s)
$\Delta H_c^{\ominus}$ / kJ mol^{-1}	–1170	–394	–286	–297

$2C(s) + 3H_2(g) + S(s) \rightarrow C_2H_5SH(l)$

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(3)
(Total 12 marks)

Q5. When ethanamide (CH_3CONH_2) burns in oxygen the carbon is converted into carbon dioxide, the hydrogen is converted into water and the nitrogen forms nitrogen gas.

Substance	ethanamide	carbon dioxide	water
Enthalpy of formation ($\Delta H_f^\ominus$) / kJ mol^{-1}	−320	−394	−286

Using the data above, which one of the following is a correct value for the enthalpy of combustion of ethanamide?

A −1823 kJ mol^{-1}

B −1183 kJ mol^{-1}

C −1000 kJ mol^{-1}

D −360 kJ mo1^{-1}

(Total 1 mark)

Q6. Using the data below, which is the correct value for the standard enthalpy of formation for $TiCl_4(l)$?

$C(s) + TiO_2(s) + 2Cl_2(g) \rightarrow TiCl_4(l) + CO_2(g)$ $\quad \Delta H^\ominus = -232$ kJ mol^{-1}

$Ti(s) + O_2(g) \rightarrow TiO_2(s)$ $\quad \Delta H_f^\ominus = -912$ kJ mol^{-1}

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

A −1538 kJ mol^{-1}

B −1094 kJ mol^{-1}

C −750 kJ mol^{-1}

D +286 kJ mol^{-1}

(Total 1 mark)

Q7. (a) Define the term *standard molar enthalpy of formation*, $\Delta H_f^{\ominus}$.

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(3)

(b) State Hess's law.

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(1)

(c) Propanone, CH_3COCH_3, burns in oxygen as shown by the equation

$$CH_3COCH_3(l) + 4\ O_2(g) \rightarrow 3H_2O(l) + 3CO_2(g)$$

Use the data given below to calculate the standard enthalpy of combustion of propanone.

	$CO_2(g)$	$H_2O(l)$	$CH_3COCH_3(l)$
$\Delta H_f^{\ominus}$/kJ mol^{-1}	–394	–286	–248

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(3)
(Total 7 marks)

Q8. Using the information below, answer this question.

$Fe_2O_3(s) + 3H_2(g) \rightarrow 2Fe(s) + 3H_2O(g)$ $\Delta H^{\ominus} = +96$ kJ mol^{-1}, $\Delta S^{\ominus} = +138$ J K^{-1} mol^{-1}

	$Fe_2O_3(s)$	$H_2(g)$	Fe(s)
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−822.0	0	0
$\Delta S^{\ominus}$ / J K^{-1} mol^{-1}	90.0	131.0	27.0

The standard enthalpy of formation of steam is

A +286 kJ mol^{-1}

B +242 kJ mol^{-1}

C −242 KJ mol^{-1}

D −286 kJ mol^{-1}

(Total 1 mark)

Q9. 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)

Q10. (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)