

5.2 Hess's Law

Question Paper

Course	DPIB Chemistry
Section	5. Energetics / Thermochemistry
Topic	5.2 Hess's Law
Difficulty	Medium

Time allowed: 70
Score: /51
Percentage: /100

Question 1a

- a) Define the term *standard enthalpy of formation*, ΔH_f^\ominus .

[3 marks]

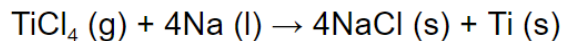
Question 1b

- b) State Hess's Law.

[2 marks]

Question 1c

- c) The following equation represents the second step in the extraction of titanium, using the Kroll process:



Use the standard formation data shown in **Table 1** to calculate the enthalpy change for the reaction, ΔH_r^\ominus .

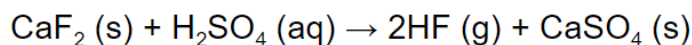
Table 1

	$\text{TiCl}_4 (\text{g})$	$\text{Na} (\text{l})$	$\text{NaCl} (\text{s})$	$\text{Ti} (\text{s})$
$\Delta H_f^\ominus (\text{kJ mol}^{-1})$	-720	+3	-411	0

[2 marks]

Question 1d

- d) Construct a Hess's Law cycle for the reaction of calcium fluoride, $\text{CaF}_2 (\text{s})$, and sulfuric acid, $\text{H}_2\text{SO}_4 (\text{aq})$.



[3 marks]

Question 2a

- a) Define the term *standard enthalpy of combustion*, ΔH_c^\ominus .

[3 marks]

Question 2b

- b) Write an equation for the complete combustion of propanol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ (l).

[2 marks]

Question 2c

- c) Construct a Hess's Law cycle for the complete combustion of propanol.

Table 1

	$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ (l)	O_2 (g)	CO_2 (g)	H_2O (l)
ΔH_f^\ominus (kJ mol ⁻¹)	-303	0	-393.5	-285.8

[3 marks]

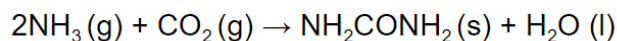
Question 2d

- d) Use the data given in **Table 1** in part (d) to calculate the enthalpy change of the reaction, ΔH_r^\ominus .

[3 marks]

Question 3a

- a) Urea can be used as a fertiliser and is manufactured by the reaction of ammonia and carbon dioxide via the following equation.



Using the data in **Table 1** calculate the enthalpy change for the formation of urea, ΔH_f^\ominus .

Table 1

	$\text{NH}_3(\text{g})$	$\text{NH}_2\text{CONH}_2(\text{s})$	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$
$\Delta H_f^\ominus (\text{kJ mol}^{-1})$	-46.2	-333.2	-393.5	-285.8

[2 marks]

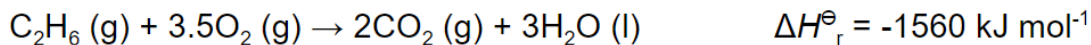
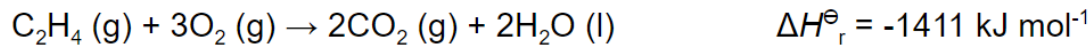
Question 3b

- b) Ammonia reacts with oxygen to produce steam and nitrogen(II) oxide. Draw a Hess's Law cycle which could be used to calculate the enthalpy change of the reaction using formation data.

[3 marks]

Question 3c

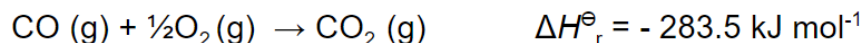
- c) Use Hess's Law and the information below to calculate the enthalpy change, ΔH_r^\ominus , for the conversion of one mole of ethene and one mole of hydrogen to one mole of ethane.



[3 marks]

Question 3d

- d) Use Hess's Law and the information below to calculate the enthalpy change for the conversion of one mole of solid carbon into carbon monoxide.



[3 marks]

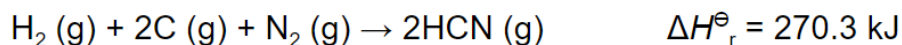
Question 4a

- a) Define the term *standard enthalpy of reaction*, ΔH_r^\ominus .

[2 marks]

Question 4b

- b) Use Hess's Law and the information below to calculate the enthalpy change, ΔH_r^\ominus , for the conversion of methane and ammonia to form hydrogen cyanide and hydrogen.



[4 marks]

Question 4c

- c) Using your answer to part (b) draw a reaction profile diagram for the reaction outlined.

[3 marks]

Question 4d

- d) Draw the Lewis structure for hydrogen cyanide, HCN.

[1 mark]

Question 5a

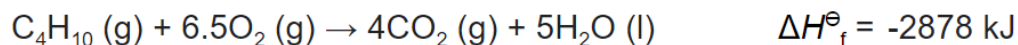
- a) Butane, C_4H_{10} , is typically used as fuel for cigarette lighters and portable stoves, a propellant in aerosols, a heating fuel, a refrigerant, and in the manufacture of a wide range of products.

Write an equation for the complete combustion of butane.

[1 mark]

Question 5b

- b) Determine the enthalpy of formation of butane, C_4H_{10} , using the enthalpy of combustion data below.



[4 marks]

Question 5c

- c) Butane can be formed from the hydrogenation of butene. Using the data in **Table 1**, determine a value for the enthalpy of formation.

Table 1

Bond	Mean Bond Enthalpy ΔH^\ominus (kJ mol ⁻¹)
C-C	346
C-H	414
H-H	436
C=C	614

[3 marks]

Question 5d

- d) The data book value for the hydrogenation of butene is -126 kJ mol⁻¹. Suggest why your answer to part (c) may be different to this value.

[1 mark]