

5.2 Hess's Law

Question Paper

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|------------|---------------------------------|
| 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]

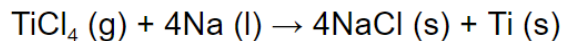
Question 1b

- 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 .

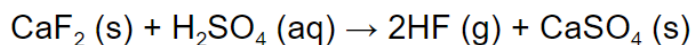
Table 1

| | $\text{TiCl}_4 (\text{g})$ | $\text{Na} (\text{l})$ | $\text{NaCl} (\text{s})$ | $\text{Ti} (\text{s})$ |
|---|----------------------------|------------------------|--------------------------|------------------------|
| $\Delta H_f^\ominus (\text{kJ mol}^{-1})$ | -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]

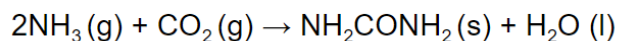
Question 2d

- 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]

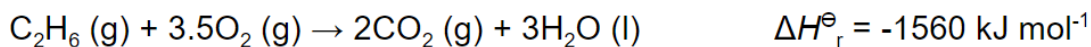
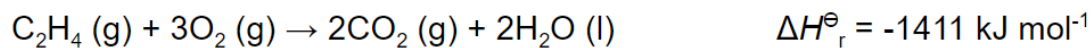
Question 3b

- 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

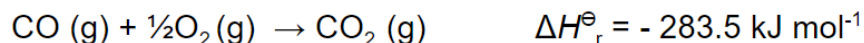
- c) Use Hess's Law and the information below to calculate the enthalpy change, ΔH_r^\ominus , for the conversion of one mole of ethene and one mole of hydrogen to one mole of ethane.



[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]

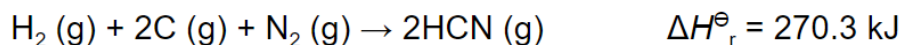
Question 4a

- 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

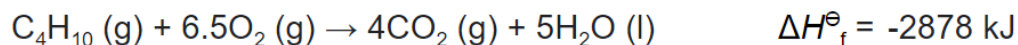
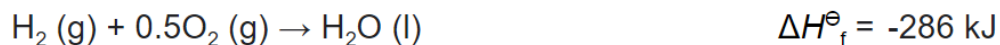
- a) Butane, C_4H_{10} , is typically used as fuel for cigarette lighters and portable stoves, a propellant in aerosols, a heating fuel, a refrigerant, and in the manufacture of a wide range of products.

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]