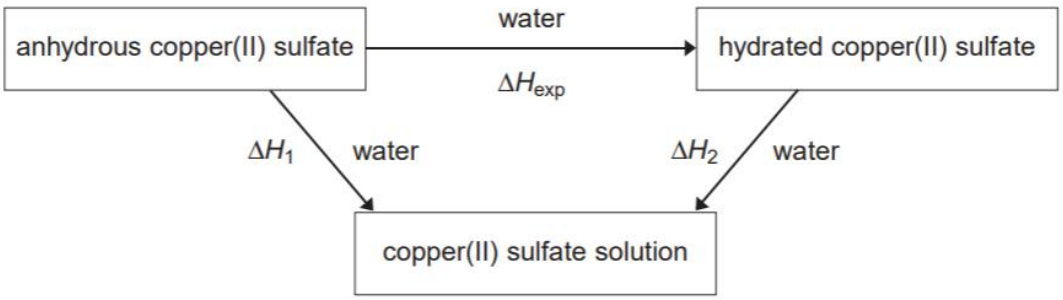
CHAPTER 4 ENERGETICS

1 A student used Hess's Law to determine a value for the enthalpy change that occurs when anhydrous copper(II) sulfate is hydrated.
This enthalpy change was labelled ΔH_{exp} by the student in a scheme of reactions.



(a) State Hess's Law.

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(1 mark)

(b) Write a mathematical expression to show how ΔH_{exp}, ΔH_1 and ΔH_2 are related to each other by Hess's Law.

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(1 mark)

(c) Use the mathematical expression that you have written in part **(b)**, and the data book values for the two enthalpy changes ΔH_1 and ΔH_2 shown, to calculate a value for ΔH_{exp}

$\Delta H_1 = -156\,kJ\,mol^{-1}$
$\Delta H_2 = +12\,kJ\,mol^{-1}$

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(1 mark)

(d) The student added 0.0210 mol of pure anhydrous copper(II) sulfate to 25.0 cm^3 of deionised water in an open polystyrene cup. An exothermic reaction occurred and the temperature of the water increased by 14.0 °C.

(i) Use these data to calculate the enthalpy change, in $kJ\,mol^{-1}$, for this reaction of copper(II) sulfate. This is the student value for ΔH_1

In this experiment, you should assume that all of the heat released is used to raise the temperature of the 25.0 g of water. The specific heat capacity of water is $4.18\,J\,K^{-1}\,g^{-1}$.

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(3 marks)

(ii) Suggest **one** reason why the student value for ΔH_1 calculated in part **(d) (i)** is less accurate than the data book value given in part **(c)**.

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(1 mark)

(e) Suggest **one** reason why the value for ΔH_{exp} **cannot** be measured directly.

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(1 mark)

2 Hydrazine (N_2H_4) decomposes in an exothermic reaction. Hydrazine also reacts exothermically with hydrogen peroxide when used as a rocket fuel.

(a) Write an equation for the decomposition of hydrazine into ammonia and nitrogen only.

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(1 mark)

(b) State the meaning of the term *mean bond enthalpy*.

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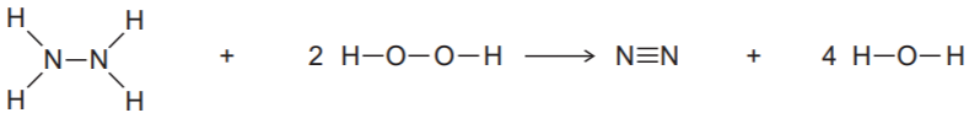
(2 marks)

(c) Some mean bond enthalpies are given in the table.

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

Use these data to calculate the enthalpy change for the gas-phase reaction between hydrazine and hydrogen peroxide.



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(3 marks)

3 Hess's Law is used to calculate the enthalpy change in reactions for which it is difficult to determine a value experimentally.

(a) State the meaning of the term *enthalpy change*.

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(1 mark)

(b) State Hess's Law.

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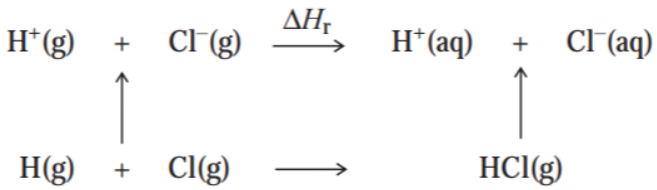
(1 mark)

(c) Consider the following table of data and the scheme of reactions.

Reaction	Enthalpy change / kJ mol^{-1}
$HCl(g) \longrightarrow H^+(aq) + Cl^-(aq)$	–75
$H(g) + Cl(g) \longrightarrow HCl(g)$	–432
$H(g) + Cl(g) \longrightarrow H^+(g) + Cl^-(g)$	+963



Use the data in the table, the scheme of reactions and Hess's Law to calculate a value for ΔH_r

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(3 marks)

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

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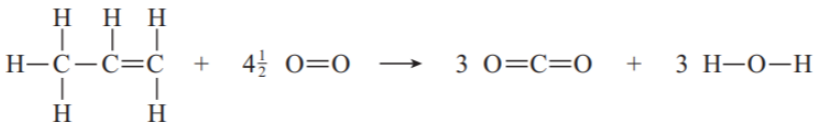
(3 marks)

(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 marks)

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

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(1 mark)

(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 marks)

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

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(2 marks)