

2.1.3 Energy diagrams, Hess cycles and cooling correction

Name: _____ Class: _____ Date: _____

Total: 26 marks

KEY WORDS enthalpy change

Objective

Construct energy diagrams and a cooling correction, then check states, signs and the mole basis. All tasks and marking guidance are original.

1 Key knowledge and worked examples

An enthalpy change _____ belongs to the equation as written at constant pressure. Reversing the equation reverses its sign; multiplying all coefficients multiplies its value. A level diagram shows the initial and final enthalpy; it is not a graph of temperature against time.

■ Worked graphical method

A reaction is mixed at 120 s. Before mixing the temperature is 19.0 °C. The post-reaction line falls from 24.0 °C at 150 s to 23.4 °C at 210 s. Its gradient is $(23.4 - 24.0)/(210 - 150) = -0.010 \text{ °C s}^{-1}$. Extrapolating back 30 s gives 24.3 °C at mixing, so corrected $\Delta T = 24.3 - 19.0 = 5.3 \text{ °C}$. Use the before-mixing line at the same time, not an unrelated room-temperature reading.

For a Hess cycle, both routes must reach the same final substances, amounts and states. Mean bond enthalpies refer to gaseous bonds and average environments; a liquid-water product needs additional phase information.

2 Practice

2.1 At standard conditions, $2\text{C}_2\text{H}_4(\text{g}) + 6\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})$ has $\Delta H = -2822 \text{ kJ mol}^{-1}$ for the equation as written. Define the standard enthalpy change of this reaction and calculate the value for $\text{C}_2\text{H}_4(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$. [3]

2.2 Distinguish the bond enthalpy of H–H in gaseous H_2 from a tabulated mean C–H bond enthalpy. Explain why a gas-phase bond calculation cannot directly give the exact combustion enthalpy when liquid water is a product. [3]

2.3 Comparable C–Br and C–Cl bond enthalpies are 276 and 338 kJ mol^{-1} . Which is easier to break, and what tentative indication does this give about the first cleavage? Explain why these values alone do not give a numerical reaction rate. [3]

3 Exam-style questions

3.1 Draw separate labelled enthalpy-level diagrams for an exothermic and an endothermic reaction. Show reactant/product levels, the direction of the ΔH arrow and the sign. Do not add a time axis. [4]

3.2 Construct a complete combustion Hess cycle for $\text{C(s, graphite)} + 2\text{H}_2(\text{g}) \rightarrow \text{CH}_4(\text{g})$, using standard combustion enthalpies: $\text{C} -394$, $\text{H}_2 -286$ and $\text{CH}_4 -891 \text{ kJ mol}^{-1}$. Include all species, amounts, states and arrow directions, then calculate the formation enthalpy of methane. [5]

3.3 40.0 cm^3 each of 1.00 mol dm^{-3} HCl and NaOH are mixed at 120 s. Before mixing, both are at 20.0°C at 0, 60 and 120 s. After reaction, temperatures at 150, 180, 210 and 240 s are 25.2, 24.9, 24.6 and 24.3°C . Plot temperature against time, extrapolate the cooling line to mixing and find the corrected rise. Use solution density 1.00 g cm^{-3} , $c = 4.18 \text{ J g}^{-1}^\circ\text{C}^{-1}$ and negligible cup heat capacity to calculate neutralisation enthalpy. Explain why the uncorrected maximum gives a different result and state one limit of the extrapolation. [8]