

## 2.1.1 Calorimetry: sign, amount and uncertainty

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 19 marks

**KEY WORDS** enthalpy change

### Objective

Calculate molar enthalpy from an observed energy transfer and evaluate the measurement. All questions and marking guidance are original.

### 1 Key knowledge and worked examples

The reaction and the heated surroundings have opposite energy changes. At constant pressure, use  $q = mc\Delta T$  for the solution, then  $\Delta H = -q/n$  for an exothermic reaction. Convert J to kJ and identify the amount specified by the balanced reaction. Use total solution mass, not just the mass of one reactant.

#### ■ Worked method

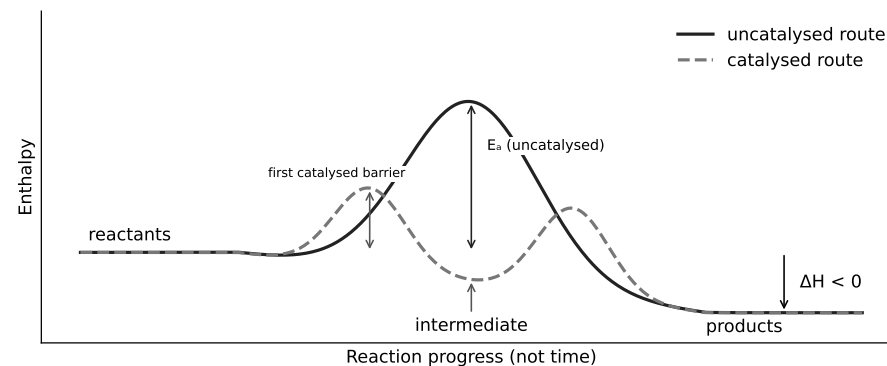
40.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> acid reacts with excess alkali. Total solution mass is 80.0 g; corrected rise is 3.4 °C;  $c = 4.18 \text{ J g}^{-1} \text{ °C}^{-1}$ . One mole of acid forms one mole of water.

$$q = mc\Delta T = 80.0 \times 4.18 \times 3.4 = 1137 \text{ J} = 1.137 \text{ kJ}$$

$$n = cV = 0.500 \times 0.0400 = 0.0200 \text{ mol}$$

$$\Delta H = -q/n = -1.137/0.0200 = -56.8 \text{ kJ mol}^{-1}$$

Heat loss makes the measured rise too small. Stirring, insulation, a lid and a justified cooling correction improve the estimate. Repeats do not remove heat loss.



### 2 Practice

**2.1** State standard pressure and the usual stated temperature for standard enthalpy data. [2]

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**2.2** A reaction warms 100.0 g of solution by 4.0 °C. Use  $c = 4.18 \text{ J g}^{-1} \text{ °C}^{-1}$ . Calculate energy gained by the solution. [2]

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**2.3** The reaction in the previous item forms 0.0300 mol of water. Calculate the molar enthalpy of neutralisation. [2]

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### 3 Exam-style questions

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**3.1** 0.460 g of ethanol ( $M = 46.0 \text{ g mol}^{-1}$ ) burns and warms 200 g water by  $12.0^\circ\text{C}$ . Use  $c = 4.18 \text{ J g}^{-1}^\circ\text{C}^{-1}$ . Calculate the experimental combustion enthalpy, then explain why it can be less negative than the standard value. [5]

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**3.2** A thermometer has  $\pm 0.1^\circ\text{C}$  uncertainty per reading. A measured rise is  $2.0^\circ\text{C}$ . Estimate the maximum percentage uncertainty in the rise and explain one way to lower it without claiming repeats correct the thermometer. [3]

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**3.3** State what one mole refers to in each standard enthalpy definition: formation, combustion, neutralisation and atomisation. Write a correctly scaled atomisation equation for chlorine. [5]

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## Solutions

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Original marking guidance: M1 method, A1 accuracy, B1 explanation.

**2.1** 100 kPa, usually 298 K. Temperature must be specified; standard does not mean room conditions chosen without a value.

**2.2**  $q = mc\Delta T = 100.0 \times 4.18 \times 4.0 = 1672 \text{ J}$ , or 1.67 kJ.

**2.3**  $\Delta H = -q/n = -1.672 \text{ kJ}/0.0300 \text{ mol} = -55.7 \text{ kJ mol}^{-1}$ .

**3.1**  $q = mc\Delta T = 200 \times 4.18 \times 12.0 = 10032 \text{ J} = 10.032 \text{ kJ}$ .  $n = m/M = 0.460/46.0 = 0.0100 \text{ mol}$ .  $\Delta H = -q/n = -1003 \text{ kJ mol}^{-1}$ . Heat loss, incomplete burning or fuel evaporation makes energy received per measured mole too small.

**3.2** Two readings give  $\pm 0.2 \text{ }^{\circ}\text{C}$ ;  $100(0.2/2.0) = 10\%$ . A safely larger rise reduces relative reading uncertainty, or use a more precise thermometer.

**3.3** Formation: one mole of compound; combustion: one mole of substance completely burned; neutralisation: one mole of water formed; atomisation: one mole of gaseous atoms formed.  $\frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{Cl}(\text{g})$ . Each process is under specified standard conditions.