# Enthalpy, calorimetry and Hess's law

OCR A H032 and H432 · AS and A level

Answer on your own paper. Show your working where needed.

### 1. Formation of nitrogen dioxide

Write the equation for the standard enthalpy of formation of gaseous $NO_2$. Include state symbols and explain your choice of coefficients.

### 2. Energy received by a solution

A solution of mass 88.0 g warms by 12.3 K. Its specific heat capacity is 4.18 J $g^{-1}$ $K^{-1}$. Calculate the energy gained by the solution in kJ.

### 3. Mixing acid and alkali

30.0 $cm^3$ of 1.20 mol $dm^{-3}$ HCl is mixed with 40.0 $cm^3$ of 0.700 mol $dm^{-3}$ NaOH in an insulated cup. Both solutions start at the same temperature. The temperature rises by 5.35 K.

Assume density 1.00 g $cm^{-3}$ and specific heat capacity 4.18 J $g^{-1}$ $K^{-1}$. Calculate the enthalpy change per mole of water formed.

### 4. Combustion in a simple calorimeter

Burning 0.680 g of propan-1-ol warms 150.0 g of water by 19.4 K. Use M = 60.0 g $mol^{-1}$ and c = 4.18 J $g^{-1}$ $K^{-1}$. Calculate the measured molar enthalpy of combustion. Explain how heat loss affects this value.

### 5. Hydrogenation of ethene

$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

Standard enthalpies of formation for $C_2H_4(g)$ and $C_2H_6(g)$ are +52.3 and −84.7 kJ $mol^{-1}$ respectively. Calculate the standard enthalpy change for the reaction.

### 6. Hydrogenation of cyclohexene

Standard combustion enthalpies are −3753 kJ $mol^{-1}$ for cyclohexene, −286 kJ $mol^{-1}$ for hydrogen and −3920 kJ $mol^{-1}$ for cyclohexane. Calculate ΔH for cyclohexene(l) + $H_2(g)$ → cyclohexane(l).

### 7. Hydrogenation of propene

$CH_3CH{=}CH_2(g) + H_2(g) \rightarrow CH_3CH_2CH_3(g)$

Mean bond enthalpies in kJ $mol^{-1}$ are C=C 612, H-H 436, C-C 347 and C-H 413. Estimate ΔH and explain why the value is approximate.

### 8. Temperature readings after mixing

The initial temperature is 21.4 °C. Reactants are mixed at 120 s. At 180, 240 and 300 s, the mixture is cooling and its temperatures are 32.6, 32.1 and 31.6 °C.

Use the cooling readings to estimate the corrected temperature rise. Use 58.0 g of solution, c = 4.18 J $g^{-1}$ $K^{-1}$ and 0.0500 mol of product formed to estimate ΔH per mole of product.

### 9. Extra challenge · A route to an oxide

0.0200 mol each of Mg and MgO are reacted separately with excess hydrochloric acid. The corrected rises are 21.8 K and 7.30 K respectively. In each test the solution has mass 100.0 g and c = 4.18 J $g^{-1}$ $K^{-1}$.

The enthalpy of combustion of $H_2$ is −286 kJ $mol^{-1}$. Use these data to obtain ΔH for $Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$. Show the steps in your route.

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