Enthalpy, calorimetry and Hess’s law

AQA 7404 and 7405 · 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 · Compare the two temperature rises

25.0 cm^3 of 1.00 mol dm^{-3} NaOH is separately mixed with 25.0 cm^3 of 1.00 mol dm^{-3} HCl and with the same volume and concentration of ethanoic acid. The corrected rises are 6.80 K for HCl and 6.10 K for ethanoic acid.

Each run forms 0.0250 mol of water. Use 50.0 g of solution and c = 4.18 J g^{-1} K^{-1} for both. Calculate both molar enthalpies of neutralisation. Use the difference to estimate the enthalpy change for $CH_3COOH(aq) \rightarrow H^+(aq) + CH_3COO^-(aq)$.

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