InkChemistry

ANSWER BOOK

Hess's law and enthalpy cycles

Energetics · Unit C04

AQA 3.1.4.3 · OCR A 3.2.1

16 questions · 51 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 HSL-Q1
B1 the enthalpy change for a reaction is independent of the route taken. **B1** provided the initial and final conditions are the same. [2]

A2 HSL-Q12
B1 $O_2(g)$ and C(graphite), the standard states of oxygen and carbon. **B1** $Br_2(l)$, because bromine is a liquid at 298 K and 100 kPa; $Br_2(g)$, O_3 and diamond are not standard states. [2]

A3 HSL-Q13
B1 almost all organic compounds burn completely in oxygen, so their enthalpies of combustion can be measured directly. **B1** organic compounds cannot be made directly from their elements, so their enthalpies of formation are not measured directly. [2]

SECTION B · Standard, 3 to 5 marks

B1 HSL-Q11
B1 $3C(s) + 4H_2(g) \rightarrow C_3H_8(g)$ across the top, with the arrow labelled ΔfH°. **B1** $3CO_2(g) + 4H_2O(l)$ in a box underneath, the combustion products; allow $+ 5O_2(g)$ shown on the down arrows. **B1** arrows pointing down from both the elements and propane to the box, labelled $3\Delta cH^\circ(C) + 4\Delta cH^\circ(H_2)$ and $\Delta cH^\circ(C_3H_8)$; arrows pointing up lose this mark. **M1** $\Delta fH^\circ = 3(-394) + 4(-286) - (-2220) = -1182 - 1144 + 2220$. **A1** $\Delta fH^\circ = -106$ kJ mol^{-1} to three significant figures. [5]

B2 HSL-Q17
B1 the measured enthalpy change for the hydrogencarbonate is per mole of $KHCO_3$. **B1** the target equation starts with two moles of $KHCO_3$, so two moles react with acid on the indirect route and that step contributes twice the measured value. **M1** both routes end at $2KCl(aq) + 2CO_2(g) + 2H_2O(l)$, so $\Delta H = 2\Delta H(KHCO_3$ with acid$) - \Delta H(K_2CO_3$ with acid$)$. **M1** $\Delta H = 2 \times (+27.0) - (-34.0) = 54.0 + 34.0$. **A1** $\Delta H = +88.0$ kJ mol^{-1} to three significant figures; reject +61.0 kJ mol^{-1}, which leaves out the factor of two. [5]

B3 HSL-Q3
M1 $\Delta rH^\circ = \Sigma\Delta fH^\circ$(products) $- \Sigma\Delta fH^\circ$(reactants), with ΔfH° of $O_2(g) = 0$ as an element in its standard state. **M1** products: $4(+90) + 6(-242) = 360 - 1452 = -1092$. **M1** reactants: $4(-46) + 5(0) = -184$; a coefficient left out of either sum loses that mark only. **A1** $\Delta rH^\circ = -1092 - (-184) = -908$ kJ mol^{-1}, to three significant figures. [4]

B4 HSL-Q5
M1 a combustion cycle: $\Delta fH^\circ = \Sigma\Delta cH^\circ$(reactants) $- \Sigma\Delta cH^\circ$(products). **M1** reactants: $2(-394) + 3(-286) = -788 - 858 = -1646$. **M1** $\Delta fH^\circ = -1646 - (-1367)$. **A1** $\Delta fH^\circ = -279$ kJ mol^{-1}, to three significant figures. [4]

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B5 HSL-Q2 **M1** $\Delta_r H^\circ = \Sigma \Delta_f H^\circ(\text{products}) - \Sigma \Delta_f H^\circ(\text{reactants})$, with $\Delta_f H^\circ$ of $O_2 = 0$. **M1** products: $2(-394) + 3(-286) = -1646$; reactants: -277. **A1** $\Delta_r H^\circ = -1646 - (-277) = -1369$ kJ mol^{-1}, to four significant figures as the data are given. [3]

B6 HSL-Q6 **M1** $\Delta_r H^\circ = \Sigma \Delta_c H^\circ(\text{reactants}) - \Sigma \Delta_c H^\circ(\text{products})$, because the data are enthalpies of combustion. **M1** $= (-1411 + -286) - (-1560) = -1697 + 1560$. **A1** $\Delta_r H^\circ = -137$ kJ mol^{-1}, to three significant figures; +137 kJ mol^{-1}, from products minus reactants, scores the second mark only. [3]

B7 HSL-Q8 **B1** burning carbon in a limited supply of oxygen gives a mixture of CO, CO_2 and unburned carbon, never pure CO. **B1** the enthalpies of combustion of carbon and of carbon monoxide can both be measured. **B1** by Hess's law, $\Delta_f H^\circ(CO) = \Delta_c H^\circ(C) - \Delta_c H^\circ(CO) = -394 - (-283) = -111$ kJ mol^{-1}. [3]

B8 HSL-Q9 **B1** water added to the solid cannot be made to react in exactly a 5:1 ratio. **B1** some of the salt dissolves in the water added, while some stays anhydrous inside lumps. **B1** the reaction does not go cleanly to completion, so the heat measured is not that of the hydration alone. [3]

B9 HSL-Q10 **B1** enthalpy depends only on the state of the substances, not on how they reached it. **B1** if two routes between the same start and finish had different enthalpy changes, going out by one and back by the other would release energy on every cycle. **B1** that would create energy from nothing, which the law of conservation of energy forbids, so the two routes must have the same enthalpy change. [3]

B10 HSL-Q14 **B1** the temperature rise measured would be too small. **B1** so ΔH_1 for dissolving the anhydrous salt would be less negative than its true value. **B1** $\Delta H(\text{hydration}) = \Delta H_1 - \Delta H_2$, so the hydration would come out less exothermic than its true value. [3]

B11 HSL-Q15 **B1** the formation cycle has the elements in the box at the bottom, while the combustion cycle has CO_2 and H_2O. **B1** in the formation cycle the arrows point up, out of the box, while in the combustion cycle they point down, into it. **B1** so $\Delta_r H^\circ$ is Σ products $-$ Σ reactants for formation but Σ reactants $-$ Σ products for combustion. [3]

B12 HSL-Q16 **B1** the formula used, products minus reactants, is correct for formation data, and leaving out O_2 is correct. **B1** the enthalpy of formation of water has not been multiplied by 2, its coefficient in the equation. **B1** the correct working is $(-394 + 2 \times -286) - (-75) = -891$ kJ mol^{-1}. [3]

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B13
HSL-Q19

B1 the hydrogencarbonate reaction cools the acid below room temperature, so heat flows in, the fall is too small and its ΔH is too small. **B1** the carbonate reaction warms the acid, heat is lost, the rise is too small and its ΔH is not negative enough. **B1** $\Delta H = 2\Delta H_1 - \Delta H_2$, so both errors make the calculated decomposition less endothermic. [3]

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