InkChemistry

ANSWER BOOK

Enthalpy change, standard conditions and the definitions

Energetics · Unit C04

AQA 3.1.4.1 · OCR A 3.2.1

17 questions · 57 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 ECSC-Q8
B1 oxygen is an element and $O_2(g)$ is its standard state. **B1** forming $O_2(g)$ from $O_2(g)$ involves no change, so there is no enthalpy change. [2]

A2 ECSC-Q9
B1 the standard enthalpy of combustion forms water in its standard state, liquid. **B1** condensing steam to liquid water releases energy, about 44 kJ per mole, so this is not released if the water stays as steam. [2]

A3 ECSC-Q20
B1 the standard enthalpy of combustion is defined for one mole of butane, which needs 6½ moles of O_2 to form $4CO_2$ and $5H_2O$. **B1** the doubled equation burns two moles of butane, so its enthalpy change would be twice Δ_cH°. [2]

SECTION B · Standard, 3 to 5 marks

B1 ECSC-Q2
B1 the enthalpy change when one mole of the compound is formed. **B1** from its constituent elements. **B1** with all reactants and products in their standard states under standard conditions. **B1** $3C(s) + 4H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_3H_7OH(l)$, with the coefficients 3, 4 and ½ and one mole of propan-1-ol as the only product. **B1** state symbols (s) for carbon, (g) for hydrogen and oxygen and (l) for propan-1-ol; reject $O(g)$ for oxygen. [5]

B2 ECSC-Q1
B1 a pressure of 100 kPa; allow 101 kPa or one atmosphere. **B1** a stated temperature, which is usually 298 K; accept 25 °C. **B1** carbon as solid graphite, written $C(s)$; reject diamond. **B1** bromine as a liquid, $Br_2(l)$, and water as a liquid, $H_2O(l)$; both are needed for the mark. [4]

B3 ECSC-Q10
B1 axes labelled enthalpy and progress of reaction, with the reactant level higher than the product level. **B1** the line rises from the reactants to a peak before falling to the products. **B1** the activation energy is an arrow from the reactant level up to the peak; reject an arrow drawn from the axis. **B1** ΔH is an arrow from the reactant level down to the product level. [4]

B4 ECSC-Q14
B1 carbon, hydrogen and oxygen do not combine to form glucose under any conditions that can be measured in a calorimeter. **B1** any reaction between the elements gives other products, such as carbon dioxide and water, not glucose alone. **B1** the enthalpies of combustion of carbon, hydrogen and glucose can all be measured, because each burns completely in oxygen. **B1** by Hess's law, $\Delta_fH^\circ(\text{glucose}) = 6\Delta_cH^\circ(C) + 6\Delta_cH^\circ(H_2) - \Delta_cH^\circ(\text{glucose})$, since both routes end at $6CO_2(g) + 6H_2O(l)$. [4]

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B5 ECSC-Q15 **B1** A represents ΔfH° of ethene: one mole of the compound from its elements in their standard states. **B1** B starts from diamond, which is not the standard state of carbon; graphite is. **B1** C forms two moles of Fe_2O_3, so its ΔH is twice ΔfH°; accept 'not one mole of product'. **B1** D forms two moles of HBr and shows bromine as a gas, where its standard state is liquid; either reason earns the mark. [4]

B6 ECSC-Q3 **B1** the enthalpy change when one mole of the substance is burned. **B1** burned completely in oxygen; accept 'in an excess of oxygen'. **B1** with all reactants and products in their standard states under standard conditions. [3]

B7 ECSC-Q6 **B1** the products have less enthalpy than the reactants. **B1** the difference is released as heat energy to the surroundings, so the surroundings warm up. **B1** ΔH describes the change in the enthalpy of the chemicals, which has decreased, so ΔH is negative; ignore references to the beaker gaining energy. [3]

B8 ECSC-Q7 **B1** ΔfH° refers to the formation of one mole of the compound, and this equation forms two moles. **B1** ΔfH° of $H_2O(l)$ is therefore half of the value, $-286\ kJ\ mol^{-1}$. **B1** the equation as written represents ΔrH° for the reaction, which is also twice the standard enthalpy of combustion of hydrogen. [3]

B9 ECSC-Q13 **B1** ΔH is positive; dissolving ammonium nitrate is endothermic. **B1** the dissolving takes in heat energy from its surroundings, the water in the pack. **B1** so the temperature of the pack falls, and heat then flows from the skin into the pack. [3]

B10 ECSC-Q16 **B1** in an exothermic profile the products are below the reactants, whereas in an endothermic profile they are above. **B1** so the ΔH arrow points down for exothermic and up for endothermic, starting from the reactant level in both. **B1** both show a peak above the reactants for the activation energy; in the endothermic profile the activation energy is at least as large as ΔH. [3]

B11 ECSC-Q18 **M1** the equation forms two moles of NH_3, so the enthalpy change per mole of ammonia is $-92 \div 2 = -46\ kJ\ mol^{-1}$. **M1** amount of ammonia $= 85.0 \div 17.0 = 5.00$ mol. **A1** $\Delta H = 5.00 \times (-46) = -230$ kJ, that is -2.3×10^2 kJ to two significant figures; -460 kJ, from using -92 per mole, scores the second mark only. [3]

B12 ECSC-Q19 **B1** both burn completely to the same products, one mole of CO_2 and two moles of $H_2O(l)$. **B1** methanol already contains an oxygen atom bonded to its carbon, so it is partly oxidised before it burns. **B1** methanol therefore starts with less enthalpy than methane relative to those products, so less heat is released when it burns. [3]

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B13 ECSC-Q21 **B1** the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water; reject 'one mole of acid'. **B1** sulfuric acid is diprotic, so one mole of it forms two moles of water and releases about twice the heat. **B1** per mole of water the reaction in both is $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$, so the value is about −57 kJ mol^{-1} for both. [3]

SECTION C · Long, 6 marks or more

C1 ECSC-Q17 **Indicative content** [6]

B1 ΔH is the gap between the reactant and product levels on the profile, so it measures how much heat is released, not how fast it is released. **B1** the rate depends on the activation energy, which is the height of the peak above the reactant level on the same diagram. **B1** if the activation energy is high, only a tiny fraction of colliding particles have enough energy to react at room temperature, so the reaction is slow. **B1** a large negative ΔH and a high activation energy can occur together, because the depth of the products and the height of the peak are independent features of the profile. **B1** methane and oxygen, with $\Delta_c H^\circ$ = −890 kJ mol^{-1}, do not react until a spark or flame supplies the activation energy; accept paper in air or any kinetically stable mixture. **B1** the claim is therefore wrong: such a mixture is energetically unstable but kinetically stable, and ΔH alone cannot predict the rate of a reaction.

Levels

Level 3 (5–6 marks) ΔH and activation energy are both located on the profile and shown to be independent, the rate is linked to the activation energy through the fraction of particles able to react, a kinetically stable example is given, and the claim is judged wrong with the distinction between energetic and kinetic stability.

Level 2 (3–4 marks) rate is tied to activation energy rather than ΔH and an example is given; the profile is not used to show the two are independent, or the verdict is not put in terms of kinetic stability.

Level 1 (1–2 marks) the claim is accepted because a large negative ΔH means a lot of energy is released quickly, or activation energy is named with no profile and no example.

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