InkChemistry

ANSWER BOOK

The equilibrium constant Kc

Chemical equilibria · Unit C06

AQA 3.1.6.2 · OCR A 3.2.3 (f) and (g), 5.1.2

15 questions · 58 marks

NAVY EDITION

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SECTION B · Standard, 3 to 5 marks

B1 ECK-Q26 [5]

M1 one 40.0 cm³ portion: (m ÷ 40.0) ÷ ((1.00 - m) ÷ 50.0) = 9.00, so 50.0m = 360(1.00 - m). **A1** m = 360 ÷ 410 = 0.878 g extracted by one portion. **M1** first 20.0 cm³ portion: 50.0m = 180(1.00 - m), so m = 0.783 g, leaving 0.217 g in the water. **M1** second 20.0 cm³ portion takes the same fraction, 180 ÷ 230, of the 0.217 g left, which is 0.170 g. **A1** two portions extract 0.953 g in total, more than the 0.878 g from one portion; error carried forward from M2.

B2 ECK-Q1 [4]

B1 Kc = $[SO_3]^2 \div ([SO_2]^2[O_2])$; square brackets are required. **B1** units: $(\text{mol dm}^{-3})^2 \div (\text{mol dm}^{-3})^3 = \text{mol}^{-1}\,\text{dm}^3$; accept $\text{dm}^3\,\text{mol}^{-1}$. **B1** Kc = $[NH_3]^2 \div ([N_2][H_2]^3)$. **B1** units: $(\text{mol dm}^{-3})^2 \div (\text{mol dm}^{-3})^4 = \text{mol}^{-2}\,\text{dm}^6$; accept $\text{dm}^6\,\text{mol}^{-2}$.

B3 ECK-Q6 [4]

M1 acid reacted = 1.00 - 0.230 = 0.770 mol, so 0.770 mol each of ester and water form. **M1** ethanol at equilibrium = 1.50 - 0.770 = 0.730 mol. **M1** the volume cancels, so Kc = (0.770 × 0.770) ÷ (0.230 × 0.730). **A1** Kc = 3.53, with no units; error carried forward from M2.

B4 ECK-Q8 [4]

M1 at equilibrium PCl_3 = 0.0950 mol, Cl_2 = 0.0950 mol and PCl_5 = 0.250 - 0.0950 = 0.155 mol. **M1** concentrations, dividing by 5.00 dm³: $[PCl_3] = [Cl_2] = 0.0190\ \text{mol dm}^{-3}$ and $[PCl_5] = 0.0310\ \text{mol dm}^{-3}$. **M1** Kc = $[PCl_3][Cl_2] \div [PCl_5] = 0.0190^2 \div 0.0310$. **A1** Kc = $0.0116\ \text{mol dm}^{-3}$, to three significant figures; an answer of 0.0582 from amounts in moles scores M1 only.

B5 ECK-Q9 [4]

M1 if y mol of H_2 reacts, equilibrium amounts are H_2 (0.500 - y), I_2 (0.500 - y) and HI 2y mol. **M1** the volume cancels: $(2y)^2 \div (0.500 - y)^2 = 49.0$. **M1** taking square roots, $2y \div (0.500 - y) = 7.00$, so 9.00y = 3.50 and y = 0.389. **A1** amount of HI = 2y = 0.778 mol, to three significant figures.

B6 ECK-Q13 [4]

B1 each concentration is the amount divided by the same volume V, and for the ester there are two terms on top and two on the bottom, so V cancels. **B1** for PCl_5 there are two terms on top and one below, so one factor of V remains and the amounts must be divided by the volume. **B1** doubling the volume halves every concentration, and with two powers on top and two on the bottom for HI the ratio is unchanged. **B1** the ratio still equals Kc, so there is no shift and the amount of HI stays the same.

B7 ECK-Q18 [4]

B1 Kc is defined for the equation as written, even though the equilibrium mixture is the same. **B1** reversing the equation inverts the expression, so Kc for $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ is $1 \div 46.0 = 0.0217$. **B1** halving every coefficient takes the square root of Kc, not half of it, so Kc for the third equation is $\sqrt{0.0217} = 0.147$. **B1** both of the student's values are wrong.

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B8 ECK-Q19

B1 $K_c = [Fe^{3+}] \div ([Fe^{2+}][Ag^+])$, with units of $mol^{-1}\ dm^3$. **B1** silver is left out because the concentration of a solid is fixed by its density and does not change, so it is folded into the constant. **B1** the titration removes silver ions, so with silver present the reverse reaction of Ag with Fe^{3+} would replace them during the titration. **B1** the titre would then be larger than the amount of Ag^+ at equilibrium; without the solid the reverse reaction cannot happen. [4]

B9 ECK-Q22

B1 in dilute solution water is the solvent in vast excess, so its concentration is effectively constant and is left out. **B1** in the ester mixture water is one of four liquids in similar amounts, and its concentration changes significantly as the reaction proceeds, so it is included. **B1** $K_c = [Cr_2O_7^{2-}] \div ([CrO_4^{2-}]^2[H^+]^2)$. **B1** units: $mol\ dm^{-3} \div (mol\ dm^{-3})^4 = mol^{-3}\ dm^9$. [4]

B10 ECK-Q4

B1 A: the position lies far to the right and the mixture is almost all products, so the reaction goes virtually to completion. **B1** B: the mixture contains substantial amounts of both reactants and products. **B1** C: the position lies far to the left and almost none of the reactants has reacted. [3]

B11 ECK-Q5

M1 $K_c = [NO_2]^2 \div [N_2O_4]$. **M1** $K_c = 0.0300^2 \div 0.0450 = 0.000900 \div 0.0450$. **A1** $K_c = 0.0200\ mol\ dm^{-3}$, to three significant figures; accept $0.02\ mol\ dm^{-3}$. [3]

B12 ECK-Q11

B1 Kc depends only on temperature, which has not changed. **B1** the added ethanol makes the denominator larger, so the ratio of concentrations falls below Kc. **B1** the forward reaction runs faster than the reverse until the ratio equals Kc again, which forms more ester. [3]

B13 ECK-Q14

B1 cooling and diluting slows the reaction almost to a stop; accept 'quenches the reaction'. **B1** so the position of equilibrium does not shift while the alkali removes ethanoic acid during the titration. **B1** the alkali also neutralises the sulfuric acid, so the titre for the catalyst alone is subtracted to leave the titre for the ethanoic acid. [3]

B14 ECK-Q27

M1 at equilibrium: ester 0.667 mol, water 0.667 mol, acid 1.00 - 0.667 = 0.333 mol and ethanol 0.333 mol, since the equation is 1 : 1 : 1 : 1. **M1** $K_c = [CH_3COOC_2H_5][H_2O] \div ([CH_3COOH][C_2H_5OH]) = (0.667 \times 0.667) \div (0.333 \times 0.333)$; the volume cancels because there are two terms above the line and two below. **A1** $K_c = 0.445 \div 0.111 = 4.0$, with no units; allow 4.01. [3]

SECTION C · Long, 6 marks or more

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C1 ECK-Q23 **Indicative content** [6]

B1 adding oxygen raises $[O_2]$, so the ratio $[SO_3]^2 \div ([SO_2]^2[O_2])$ falls below Kc and the forward reaction runs faster than the reverse. **B1** the position shifts to the right until the ratio equals Kc again, so more SO_3 forms while Kc itself is unchanged. **B1** raising the pressure raises every concentration by the same factor, and with three moles of gas on the left and two on the right the ratio falls below Kc. **B1** the position shifts right, towards fewer moles of gas, but Kc is unchanged because only a change of temperature changes Kc. **B1** a catalyst increases the forward and reverse rates equally, so neither the position nor Kc changes and equilibrium is only reached sooner. **B1** raising the temperature decreases Kc because the forward reaction is exothermic, so the ratio is now above the new Kc and the position shifts left, lowering the yield of SO_3.

Levels

Level 3 (5–6 marks) all four changes are explained, each with its effect on the position and on Kc stated separately and correctly, and the reasoning uses the ratio compared with Kc rather than Le Chatelier's principle alone; the answer says that only temperature changes Kc and explains why in terms of the exothermic forward reaction.

Level 2 (3–4 marks) three of the four changes are right for both position and Kc, or all four are covered and Kc goes wrong for one of them.

Level 1 (1–2 marks) the shift in position is given for one or two changes, with Kc said to rise when oxygen is added or the pressure raised.

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