PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 11: EQUILIBRIUM II

SCORE	PERCENTAGE
/211	%

STEMUP

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Amount of $CH_3COOCH_2CH_3$ = ...

Amount of H_2O = ...

(Total for question = 4 marks)

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	Any one from: Catalyst / speeds up reaction / increases rate / increases rate of attainment of equilibrium / lowers activation energy	Ignore any mention of protonation or mechanism for catalysis Do not award additional incorrect types of reaction	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of moles of H^+ in 25.0 cm^3 **(1)** • calculation of moles of H^+ in 250 cm^3 flask **(1)**	Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only Example of calculation: (moles NaOH = 0.200 x $\frac{23.60}{1000}$) = 0.00472 (mol) (= mol H^+ in 25.0 cm^3) (= 10 x 0.00472) = 0.0472 (mol) (in 250 cm^3) Allow TE for M2 on moles of NaOH Correct answer with or without working scores 2 marks	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• subtracts moles of H^+ in HCl from answer to (b)(i)	Example of calculation: 0.0472 – 0.00400 = 0.0432 (mol) Allow TE on answer to part (b)(i)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	• calculation of moles of CH_3COOH that have reacted	Example of calculation: (0.105 — 0.0432) = 0.0618 Allow TE on part (b)(ii) unless negative value	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• calculation of equilibrium moles of $CH_3CH_2CH_2OH$ **(1)** • calculation of equilibrium moles of $CH_3COOCH_2CH_2CH_3$ **(1)** • calculation of equilibrium moles of H_2O **(1)**	Example of calculation: 0.0800 — 0.0618 = 0.0182 0.0618 0.111 + 0.0618 = 0.1728 Allow TE on answer to part (c)(i) unless negative value	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	$(K_c =) \frac{[CH_3COOCH_2CH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2CH_2OH]}$	IGNORE state symbols even if incorrect Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: • Same number of moles/molecules on both sides of the equation **(1)** • (so) volume / V cancels in K_c expression **(1)**	2 marks could be scored by a correct mathematical expression showing V or dm^3 cancel Allow same number of terms on top and bottom of K_c expression Allow units cancel out Allow "**all** divided by the same volume"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	• calculates value of K_c **(1)** • final value of K_c quoted to 2 or 3 SF **(1)**	Example of calculation $K_c = \frac{(0.0618) \times (0.1728)}{(0.0432) \times (0.0182)} = 13.58241758$ = 14 / 13.6 (no units) Correct answer with no working gains full marks Ignore units No TE on wrong K_c expression	2

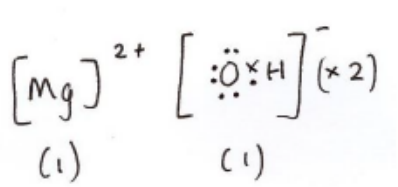
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Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • the equilibrium shifts to the left **or** the mixture absorbs carbon dioxide from the atmosphere **(1)** • so the mixture is (becoming more) acidic / the acid reforms **(1)**	Mark independently Allow no longer alkaline Do not award just "pH decreases"	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An explanation that makes reference to the following points: • carry out / repeat experiment **and** leave for longer than a week **(1)** • the titre value / K_c value will remain unchanged (if equilibrium has been established) **(1)**	Ignore pH probes / checking pH Allow repeat experiment **and** check titres within first week Allow moles / concentration are unchanged Ignore just "results unchanged"	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An answer that makes reference to the following points: • K_c value will be greater than that calculated in (d)(iii) **(1)** • because the (forward) reaction is endothermic **or** backward / reverse reaction is exothermic **(1)**	M2 depends on M1 Ignore References to the equilibrium position shifting to the right (with increasing temperature)	**(2)**

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	 (1) (1)	For Mg allow 0 or 8 electrons in outermost shell Ignore inner shell electrons	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• amount of NaOH (1) • [NaOH] (1) • $[NaF]_{eq}$ (1) • K_c expression (1) • Value of K_c (1)	Example of calculation $11.7/1000 \times 0.100 = 0.00117 / 1.17 \times 10^{-3}$ $0.00117/(25/1000) = 0.0468$ mol dm^{-3} $0.250 - 0.0468 = 0.2032$ mol dm^{-3} $K_c = [NaOH]^2 / [NaF]^2$ 0.0530 (no units)	**5**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (ii)	An answer that makes reference to the following point: • No, as temperature is likely to be different on different days and this affects value of K_c	Allow 'yes, but only if the temperature is the same'	**1**

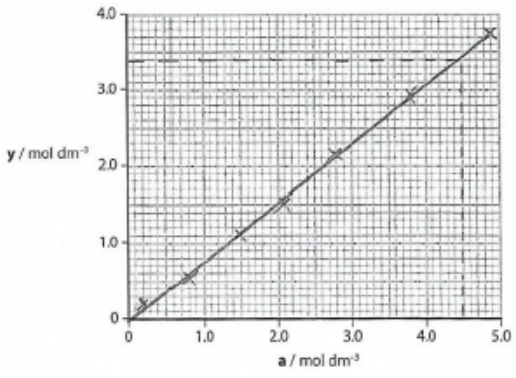
Q3.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	$(K_c =) \dfrac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$	Ignore missing state symbols or units Do not award round brackets	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	$(K_c =) \dfrac{4y^2}{(a - y)^2}$ • Numerator term correct **(1)** • Denominator term correct **(1)**	Allow square brackets Allow $(2y)^2$ Allow $(a^2 - 2ay+y^2)$ or (a-y)(a-y)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• both values correct to 2 DP	1.13 2.93	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• All 7 points plotted correctly **(1)** • Appropriate straight line of best fit, drawn through the origin **(1)**	Allow TE for incorrect values from 9(b)(i) Do not allow all points above or below the line of best fit Allow line of best fit to intersect one square either side of the origin	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• co-ordinates correctly read off the line on graph **(1)**  • gradient correctly calculated **(1)**	At least 1 line must be shown on the graph to indicate selection of co-ordinates Example of calculation 3.40 – 0.00 = gradient of 4.50 – 0.00 graph Gradient = 0.76 Ignore SF except 1SF Do not allow units for the gradient Allow a value from 0.71 to 0.81 inclusive	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	• $\frac{\sqrt{K_c}}{2+\sqrt{K_c}}$ = gradient / $\frac{y}{a}$ **(1)** • re-arrangement of expression and calculation of K_c **(1)**	Example of calculation $\frac{\sqrt{K_c}}{2+\sqrt{K_c}} = 0.76$ K_c = 40.1 /40 (no units) Allow TE on gradient from part (iii) $K_c = [(2 \times \text{grad})/(1-\text{grad})]^2$ Correct answer with no working scores (2)	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• hydrogen is flammable / explosive	Allow iodine vapour damages eyes /toxic Allow hydrogen iodide is corrosive / acidic / irritant (if qualified) / lachrymator Ignore references to high pressure Ignore references to safety precautions	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	• Faster rate of reaction / increased rate **(1)** • K_c unchanged **(1)**	Ignore references to shifting position of equilibrium	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(i)	An explanation that makes reference to the following points: • (K_c is) smaller / decreases / gets less **(1)** • (forward) reaction is exothermic **(1)**	Allow reverse/backwards reaction is endothermic MP2 dependent on MP1	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	• straight line drawn on the graph with a less steep gradient (and goes through the origin)	Do not allow if lines cross	(1)

Q4.

Question Number	Answer	Additional Guidance	Mark
	• calculation of eqm moles (1) • expressions for 3 partial pressures (1) • substitution of values into K_p expression (1) • rearrangement of K_p expression (1) • calculation of total pressure **and** answer to 1 / 2 SF	Example of calculation | | N_2 | H_2 | NH_3 | | Initial mol | 1.0 | 3.0 | - | | Eqm mol | 1.0 − 0.15 =0.85 | 3.0 − (3 x 0.15) = 2.55 | 0.30 | | Total mol at eqm | 0.85 + 2.55 + 0.30 = 3.7 | | | | Partial pressure | $\frac{0.85}{3.7} \times P$ | $\frac{2.55}{3.7} \times P$ | $\frac{0.30}{3.7} \times P$ | $K_p = 7.76 \times 10^{-5} = \frac{\left(\frac{0.30 \times P}{3.7}\right)^2}{\left(\frac{0.85 \times P}{3.7}\right)\left(\frac{2.55 \times P}{3.7}\right)^3}$ $7.76 \times 10^{-5} = \frac{0.087419}{P^2}$ $P^2 = 1126.5$ (atm^2) $P = 33.564$ $= 34 / 30$ (atm) Allow any symbol for total pressure Allow TE throughout Correct answer to 1 or 2 SF with some working scores (5) Correct answer to 1 or 2 SF with no working scores (4)	(5)

Q5.

Question Number	Answer	Additional guidance	Mark
	Correct expression for K_p (1) Calculation of mole fractions for N_2, H_2 and NH_3 (1) Calculation of partial pressures for N_2, H_2 and NH_3 (1) Substitution and evaluation of K_p (1) Units: atm^{-2} (1)	<u>Example of calculation</u> (total number of moles = 18) mf N_2 = 2.88 ÷ 18 = 0.16 mf H_2 = 8.64 ÷ 18 = 0.48 mf NH_3 = 6.48 ÷ 18 = 0.36 pN_2 = 0.16 x 200 = 32 atm pH_2 = 0.48 x 200 = 96 atm pNH_3 = 0.36 x 200 = 72 atm $K_p = \frac{p^2NH_3(g)}{pN_2(g).p^3H_2(g)}$ $K_p = \frac{72^2}{32 \times 96^3} = 1.83 \times 10^{-4}$ atm^{-2} Alternative method for calculation: $\frac{0.36^2}{0.16 \times 0.48^3}$ (= 7.32421875) $K_p = \frac{0.36^2}{0.16 \times 0.48^3} \times \frac{1}{200^2} = 1.83 \times 10^{-4}$ atm^{-2} Correct answer with no working with units scores 5 marks	5

Q6.

Question number	Answer	Additional guidance	Marks
(a)	B		1
(b)(i)	• calculation of n(CO) at equilibrium and n(H_2) at equilibrium (1) • converting number of moles to concentration (1) • evaluation of K_c by subst (1) • correct answer to 3.s.f (1) • units: $dm^6\ mol^{-2}$ (1)	Example of calculation n(CO) at equilibrium = 0.114 (mol) n(H_2) at equilibrium = 0.228 (mol) [CO] = 0.0950 mol dm^{-3}, [H_2] = 0.190 mol dm^{-3}, [CH_3OH] = 0.0717 mol dm^{-3} $K_c = 0.0717 \div (0.0950 \times 0.190^2) = 20.9068\ldots$ $= 20.9\ dm^6\ mol^{-2}$ Allow $mol^{-2}\ dm^6$ 3rd and 4th marks csq on answers given in 1st and 2nd marks Correct final answer to 3.s.f with units but no working scores 5 marks	5
(b)(ii)	An explanation that makes reference to the following points: • an increase in temperature shifts the equilibrium to the left (1) • an increase in pressure shifts the equilibrium to the right (1) • these changes produce opposing effects, so to predict the effect on the yield it is necessary to know the relative effects of each one (1)		3

Q7.

Question Number	Answer	Additional Guidance	Mark
	• the quotient / Q: $\frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{2 \times 2}{1 \times 1} = 4$, which is larger than K_c **or** (since $K_c = 1$) the concentrations of the products must be equal to the concentrations of the reactants at equilibrium **(1)**	Allow amounts / moles / (partial) pressures for concentrations Allow calculated K_c / the quotient / Q will be greater than 1	**(3)**
	• the concentrations of CO_2 and H_2 / products need to decrease **and** those of CO and H_2O / reactants need to increase **(1)**	Allow shift so that there is 1.5 mol of each substance	
	• so reaction shifts to the left **(1)**	M3 conditional on some explanation	

Q8.

Question Number	Correct Answer	Reject	Mark
	C		1

Q9.

Question Number	Correct Answer	Reject	Mark
(a)(i)	Mass of ethanoic acid = 0.04 x 60.1 = (2.404 g) **(1)** Volume of ethanoic acid = 2.404 ÷ 1.049 = 2.2917 = 2.3 (cm^3) **(1)** Correct answer with no working **(2)** Ignore SF except only one ALLOW 60.0 for molar mass which gives mass 2.4 and volume 2.288 = 2.3 cm^3 **(2)** OR First step 1.049 ÷ 60/60.1 to find number of moles in 1 cm^3 = 0.017 **(1)** Then volume = 0.04 ÷ 0.017 = 2.3529 (cm^3) But note, if whole calculation done on calculator, 60 gives 2.2879 and 61 gives 2.2917. **(1)** If units given, they must be correct, but penalise wrong units only once here.		**2**

Question Number	Correct Answer	Reject	Mark
(a)(ii)	Syringe ALLOW Burette Graduated/adjustable pipette	Gas syringe Biuret Just 'pipette'	**1**

Question Number	Correct Answer	Reject	Mark
(a)(iii)	To prevent... evaporation/vapour escaping water vapour entering OR To maintain a closed system OR To maintain a closed environment ALLOW To prevent: air oxidizing the alcohol reaction with air OR Due to volatility (of chemicals) IGNORE ...gas escaping ...HCl escaping		**1**

Question Number	Correct Answer	Reject	Mark
(a)(iv)	**First and second mark** Phenolphthalein **(1)** From colourless to (pale) pink/red **(1)** ALLOW Other indicators with pK_{in} in range 7.5 – 10 Some examples are: Thymol blue ((base)) (yellow to blue) Phen**ol** red (yellow to red) Thymolphthalein (colourless to blue) Second mark depends on correct indicator except bromothymol blue, which is incorrect but very close to range so allow colour yellow to blue. **Third mark** Sodium ethanoate is (slightly) alkaline OR Ethanoic acid is a weak acid OR Phenolphthalein pH range coincides with vertical section of the pH/titration curve	Litmus/universal indicator Pink to colourless Thymol blue **(acid)** Phenyl red Methyl red	**3**
	OR Titration of weak acid with strong base OR Neutralisation/equivalence point is at 8-10/ any number between 8 and 10. OR pK_{in} +/-1 lies within vertical region **(1)** Third mark is independent		

Question Number	Correct Answer	Reject	Mark
(b)(i)	$CH_3COOH+CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3+H_2O$ ALLOW Single arrow $-CO_2H$ $-C_2H_5$ Displayed formulae IGNORE state symbols even if incorrect		**1**

Question Number	Correct Answer	Reject	Mark
(b)(ii)	Volume of alkali reacting with ethanoic acid = 77.1-11.7 = 65.4 cm^3 **(1)** Moles of ethanoic acid = $\frac{65.4 \times 0.200}{1000}$ = $0.01308/1.308\times10^{-2}$ (mol) **(1)** Correct answer no working (2) Ignore SF except 1 Allow internal TE for use of Moles of ethanoic acid = $\frac{77.1 \times 0.200}{1000}$ = $0.01542/1.542\times10^{-2}$ (mol) max**(1)**		**2**

Question Number	Correct Answer	Reject	Mark
(b)(iii)	Number of moles of ethanol = $0.01308/1.308\times10^{-2}$ (mol) TE same as (ii)		**1**

Question Number	Correct Answer	Reject	Mark
(b)(iv)	Number of moles of ethyl ethanoate =0.0400−0.01308 = 0.02692 (mol) Allow TE from (ii)/(iii) for example 0.01542 gives 0.02458		**1**

Question Number	Correct Answer	Reject	Mark
(b)(v)	$K_c = \frac{[CH_3CO_2CH_2CH_3][H_2O]}{[CH_3CO_2H][\ CH_3CH_2OH]}$ **(1)** $= \frac{0.02692 \times 0.02692}{0.01308 \times 0.01308}$ = 4.23579 = 4.24 **(1)** Ignore SF except one Allow TE from (ii), (iii) and (iv) for example 0.01542 etc gives 2.54 No TE for incorrect expression of K_c		**2**

Question Number	Correct Answer	Reject	Mark
(b)(vi)	The units cancel OR There are the same numbers of moles of reactants and products		**1**

Question Number	Correct Answer	Reject	Mark
(b)(vii)	(Concentrated) hydrochloric acid contains water		**1**

Question Number	Correct Answer	Reject	Mark
(c)(i)	First test tube esterification OR addition/elimination ALLOW Condensation **(1)** Second test tube (acid) hydrolysis **(1)** Two fully correct answers in wrong order **(1) max**	Alkaline hydrolysis followed by acidification	**2**

Question Number	Correct Answer	Reject	Mark
(c)(ii)	The values are the same within experimental error OR The values are concordant ALLOW The values are similar **(1)** The equilibrium can be approached from either direction OR The reaction is reversible OR Any comment relating equilibrium to reversibility IGNORE Dynamic equilibrium OR Rate of reverse reaction = rate of forward reaction **(1)**	Just...the same	**2**

Question Number	Correct Answer	Reject	Mark
(c)(iii)	(Acid) catalyst (makes it faster) OR Provides H^+ (as a catalyst) OR Protonates... OR Protonating agent... OR Donates protons OR Increases H^+ concentration	Initiates Reacts with... Protates	**1**

Q10.

Question Number	Correct Answer	Reject	Mark
(a)	A		**1**

Question Number	Correct Answer	Reject	Mark
(b)	C		**1**

Q11.

Question Number	Correct Answer	Reject	Mark
(a)	C		1

Question Number	Correct Answer	Reject	Mark
(b)	D		1

Q12.

Question Number	Correct Answer	Reject	Mark
(a)	B		**1**
(b)	D		**1**

Q13.

Question Number	Correct Answer	Reject	Mark
	A		**1**

Q14.

Question Number	Acceptable Answers	Reject	Mark
***(a)**	(A green solution) forms a yellow / orange / brown (solution) ALLOW reddish-brown **(1)** A grey / black precipitate ALLOW silver ppt ALLOW solid / crystals for precipitate **(1)**	Red 'Green(ish)' with any other colour Silver mirror silver compound	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	0.05(00) (mol dm^{-3})		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Amount of silver ion in 10 cm^3 = amount of thiocyanate = $\frac{5.6 \times 0.0200}{1000}$ = $0.000112/1.12 \times 10^{-4}$ (mol) **(1)** So concentration of silver ion = $0.000112 \times \frac{1000}{10}$ = $0.0112/1.12 \times 10^{-2}$ (mol dm^{-3}) **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	$0.0112/1.12 \times 10^{-2}$ (mol dm^{-3}) Accept TE = answer to (ii)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	$0.0500 - 0.0112 = 0.0388/3.88 \times 10^{-2}$ (mol dm^{-3}) Accept TE = 0.05 - answer to (iii) Accept answer to (i) – answer to (iii)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(v)	$K_c = \frac{[Fe^{3+}(aq)]}{[Fe^{2+}(aq)]\,[Ag^{+}(aq)]}$ ALLOW $K_c = \frac{[Fe^{3+}]}{[Fe^{2+}]\,[Ag^{+}]}$ **(1)** $= \frac{0.0388}{0.0112^2}$ $= 309.311 = 309\ dm^3\ mol^{-1}$ Value **(1)** Unit (any order) **(1)** Three SF **(1)** Accept TE from (iii) and (iv): (use of 0.1 from (i) gives 708 $dm^3\ mol^{-1}$) If [Ag] is included in the numerator and taken as $=[Fe^{3+}(aq)]$, then allow unit and SF marks ONLY, but must either state 'no units' or show working	[Ag] in numerator	**4**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	$\Delta S^{\ominus}_{total} = 8.31 \times \ln 309$ $= +47.6(4) / +47.6(5) J\ mol^{-1}\ K^{-1}$ OR $= 8.31 \times \ln 309.311 = +47.6(5)\ J\ mol^{-1}\ K^{-1}$ Accept TE : 8.31 x ln(answer from b(v)) Value **(1)** Sign **and** Unit (any order) **(1)** IGNORE sf except 1		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	First Mark: One of the products is a solid OR Two moles going to two moles but one of them is a solid OR Two moles of solution react to form one mole of solution / liquid and one mole of solid **(1)** **Second Mark** (Hence) RHS more ordered / LHS less ordered **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	$\Delta S^{\ominus}_{surroundings} = \Delta S^{\ominus}_{total} - \Delta S^{\ominus}_{system}$ $= +47.6 - (-208.3) = (+)255.9$ (J mol^{-1} K^{-1}) Accept TE on c(i) IGNORE sf except 1		**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(iv)	Because $\Delta S^{\ominus}_{surroundings} = \frac{-\Delta H^{\ominus}}{T}$ **(1)** $\Delta H = -298 \times 255.9 = -76258$ (J mol^{-1}) $= -76.258$ (kJ mol^{-1}) **(1)** Units if given must be correct Correct answer with or without working scores 2 marks IGNORE SF except 1 As T increases $\Delta S^{\ominus}_{surroundings}$ becomes less positive / decreases **therefore** ΔS_{total} becomes less positive / decreases ALLOW more negative for less positive **(1)**	$\Delta S^{\ominus}_{total} = \frac{-\Delta H^{\ominus}}{T}$	**3**

Question Number	Acceptable Answers	Reject	Mark
***(d)**	No change in the titre ALLOW No significant change Stand alone mark **(1)** (though silver solid was removed the equilibrium constant remains the same so) the equilibrium **concentration(s)** would remain the same **(1)** Second mark dependent on first IGNORE references to temperature		**2**

Q15.

Question Number	Answer	Additional Guidance	Mark
	• rearrangement of formula (1) • substitution of correct values (1) • calculation of K_c (1) • units (1)	Example of calculation $K_c = K_p \times (RT)^{\Delta n}$ $K_c = 3.55 \times 10^{-2} \times (0.0821 \times 500)^2$ $K_c = 59.821$ TE on Δn Stand alone mark $dm^6\ mol^{-2}$ or $mol^{-2}\ dm^6$ Correct value with units and no working scores (4) Ignore SF except 1 SF M1 and M2 can be in reverse order	(4)

Q16.

Question Number	Answer	Additional Guidance	Mark
	• substitution of numbers into expression (1) • evaluation of $\Delta H/R$ and $1/T_1 - 1/T_2$ (1) • rearrangement of expression (1) • evaluation of expression (1)	Example of calculation $\ln\left(\frac{K_2}{6.76 \times 10^5}\right) = \left(\frac{-92400}{8.31}\right)\left(\frac{1}{298} - \frac{1}{310}\right)$ $\ln\left(\frac{K_2}{6.76 \times 10^5}\right) = -11119.1 \times 1.299 \times 10^{-4}$ $= -1.4444$ $K_2 = 6.76 \times 10^5 \times e^{-1.4444}$ TE on M2 $K_2 = 1.59467 \times 10^5$ / 159467(atm^{-2}) TE on M3 Allow answer from earlier correct rounding to 2 or more SF Ignore SF except 1 SF Correct answer with no / some working scores (4)	(4)

Q17.

Question Number	Answer	Additional Guidance	Mark
(i)	• **(M1)** calculation of mole fractions **(1)** • **(M2)** calculation of partial pressures **(1)** • **(M3)** expression of K_p **(1)** • **(M4)** calculation of value of K_p **(1)** • **(M5)** units **(1)**	Example of calculation X_{SO_2} = 0.0160 ÷ 0.8 = 0.02(0) X_{O_2} = 0.0120 ÷ 0.8 =0.015 X_{SO_3} = 0.772 ÷ 0.8 =0.965 P_{SO_2} = 0.02(0) x 2.40 = 0.048 P_{O_2} = 0.015 x 2.40 = 0.036 P_{SO_3} = 0.965 x 2.40 =2.316 $K_p = \frac{(P_{SO_3})^2}{(P_{SO_2})^2 \times P_{O_2}}$ Do not award square brackets $K_p = \frac{2.316^2}{0.048^2 \times 0.036} =$ K_p= 64668.4..../6.46684.. x 10^4 K_p= 65000/6.5 x 10^4/64700/6.47 x 10^4 Ignore SF except 1 atm^{-1} Correct final answer without working scores	(5) (5)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of the number of molecules	Example of calculation N=(n x L = 0.0160 x 6.02 x 10^{23}) = 9.632 x 10^{21} Ignore SF except 1SF Do not award if any units are given	(1)

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • to ensure that K_p stays the same/ quotient stays the same **or** only temperature changes the value of K_p **(1)** • the number of (sulfur dioxide) molecules decreases **Either** because the equilibrium shifts to the right or because one of the denominators (oxygen) has increased so the other denominator (sulfur dioxide) has to decrease **(1)**	Standalone marks Allow concentration changes have no effect on the value of K_p Allow 'moles' for molecules	(2)

Q18.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	$(K_C =) \frac{[CH_3COOCH_2CH_3]\ [H_2O]}{[CH_3COOH]\ [CH_3CH_2OH]}$ ALLOW C_2H_5 for CH_3CH_2 State symbols are not required IGNORE any incorrect state symbols		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)			**2**

Component	$CH_3COOH(l)$	$CH_3CH_2OH(l)$	$CH_3COOCH_2CH_3(l)$	$H_2O(l)$
Equilibrium amount / mol	(0.20)	**0.10**	**0.20**	**0.35**

BOTH 0.10 AND 0.20 (1) **0.35 (1)**

0.10 **and** 0.20 scores first mark
Allow 0.1 and 0.2
0.35 scores second mark

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	Units cancel **OR** same number of **moles**/same number of **molecules** on each side **OR** volume / V cancels Ignore statements such as 'concentrations cancel' 'products and reactants cancel' 'same number of products as reactants'	Concentrations are the same	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	$K_C = \frac{(0.20) / V \times (0.35) / V}{(0.20) / V \times (0.10) / V}$ $= 3.5 / 3.50$ Correct answer with or without working scores 1 Ignore omission of V TE from values in (ii) table	$K_C = 4$	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)	• No effect on (position of) equilibrium **(1)** • Rate (of attainment of equilibrium) is faster / equilibrium reached sooner **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	**Bonds Broken** C—O **and** O—H **(1)** Ignore where these bonds are broken in the acid and alcohol molecules. **ALLOW** C—OH for C—O CO—H for O—H **Bonds Made** C—O **and** O—H **(1)** Ignore where these bonds are made in the ester and water molecules. **ALLOW** C—OC for C—O H—OH for O—H Marks can be awarded by annotating displayed or structural formulae. Comment: Max **1** if any other bonds mentioned	**Two** O—H bonds formed in H_2O molecule **ONLY** C—O bond broken and made scores **(0)** overall	**2**

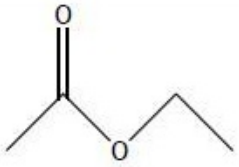
Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(C–O and O–H) bond enthalpies differ in: different environments /different molecules /different compounds OR Bond enthalpies/bond energies are average values **ALLOW** Bonds being broken and made are attached to different atoms	'Heat loss'	**1**

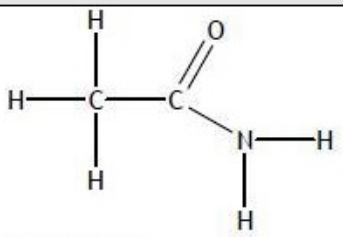
Question Number	Acceptable Answers	Reject	Mark
(d)(i)	$\Delta S_{total} = R \ln K$ Allow ΔS_{total} is proportional to **<u>ln</u>***K* ALLOW K_c or K_p instead of K	log instead of ln ΔS_{total} is proportional to K / ΔS_{total} increases as K increases	**1**

Question Number	Acceptable Answers	Reject	Mark
* **(d)(ii)**	**First mark:** (ΔH = 0 so) $\Delta S_{surroundings} = 0$ OR $-\frac{\Delta H}{T} = 0$ **(1)** IGNORE "$\Delta S_{surroundings}$ stays the same". **Second mark:** (so) ΔS_{total} does not change OR (so) $\Delta S_{total} = \Delta S_{system}$ **(1)** **Third mark:** (As $\Delta S_{total} = R \ln K$) ***K*** does not alter **(1)** **ALLOW** "it does not alter" to assume K does not alter. ALLOW use of K_c or K_p instead of K **Each point is stand alone** **IGNORE** justifications in terms of Le Chatelier's Principle **NOTE:** **Can award max (1) (i.e. the third scoring point) if the effect on *K* stated follows on CQ from a change to ΔS_{total}**	If only mentions 'no effect on position of equilibrium' rather than the equilibrium constant	**3**

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Question Number	Acceptable Answers	Reject	Mark
(e)(i)	$CH_3COCl + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + HCl$ Allow C_2H_5 for CH_3CH_2 Allow $CH_3CO_2CH_2CH_3$ for $CH_3COOCH_2CH_3$ IGNORE missing or incorrect state symbols	CH_3CClO/ CH_2CH_3OH	**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	 **IGNORE** Bond angles and length of the lines.		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iii)	 **IGNORE** Other products of the reaction if the above structure has been correctly drawn.	NH_2 or CH_3	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(i)	$(CH_3COOCH_2CH_3 + NaOH \rightarrow)$ $CH_3COONa + CH_3CH_2OH$ /C_2H_5OH Allow ionic representations of the sodium salt $CH_3COO^-Na^+$ IGNORE missing or incorrect state symbols	CH_2CH_3OH for ethanol	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(ii)	(Reaction with sodium hydroxide is) **not** an equilibrium / **not** reversible / goes to completion OR Reverse argument for acid hydrolysis		**1**

Q19.

Question Number	Correct Answer	Reject	Mark
(a)(i)	Purple gas/ gas turns colourless **(1)** to (silver/shiny) grey/black solid **(1)** **Just** gas to solid OR solid forming **(1)max**	Purple liquid/solid	2

Question Number	Correct Answer	Reject	Mark
(a)(ii)	**First mark** Heat for different lengths of time OR After more time/specified time eg 2 days .... OR Use a colorimeter OR Set up reverse reaction **(1)** **Second mark** Measure the concentration of a reactant or product of two tubes, which should be the same OR Colour does not change /is same **(1)**		2

Question Number	Correct Answer	Reject	Mark
***(b)(i)**	Equilibrium moles HI $\frac{30 \times 0.00353}{1000} = 0.0001059$ **(1)** H_2 and I_2 $\frac{30 \times 0.00048}{1000} = 0.0000144$ **(1)** Initial amount of HI = 0.0001059 + 2 x 0.0000144 = 0.0001347 (mol) ALLOW TE from wrong moles of either or both entity **(1)** Mass of 1 mol of HI = 127.9 **(1)** Mass of HI = 0.0001347 x 127.9 = 0.0172 g **(1)** Correct answer with or without working **(5)** All marks stand alone Last two marks are available for **any** amount in moles x 127.9correctly calculated		5

Question Number	Correct Answer	Reject	Mark
(b)(ii)	$K_c = \frac{[H_2][I_2]}{[HI]^2}$ Ignore state symbols unless (aq) or (s) Ignore eq or eqm	p H_2 etc (K_p)	1

Question Number	Correct Answer	Reject	Mark
(b)(iii)	$K_c = \frac{0.00048 \times 0.00048}{0.00353^2}$ $= 0.018489$ $= 0.0185$ Allow all SF except 1		1

Question Number	Correct Answer	Reject	Mark
(b)(iv)	The units cancel OR There are the same numbers of moles of reactants and products		1

Question Number	Correct Answer	Reject	Mark
(c)(i)	$K_c' = \frac{[H_2]^{½}[I_2]^{½}}{[HI]}$ Ignore state symbols unless (aq) or (s) Ignore eq or eqm	p H_2 etc (K_p) but not if already penalised	1

Question Number	Correct Answer	Reject	Mark
(c)(ii)	$K_c' = \frac{[0.00048]^{½}[0.00048]^{½}}{[0.00353]}$ $= 0.136$ Allow all SF except 1 **(1)** Which is the square root of the previous value OR $K_c = (K_c')^2$ OR $0.136^2 = 0.0185$ **(1)**		2

Question Number	Correct Answer	Reject	Mark
(d)	**Frist mark** K_p remains unchanged/constant **(1)** **Second mark** (when pressure is increased) the quotient/ratio p_{H2}: $(p_{HI})^2$ becomes less than *K*p OR Ratio decreases OR Ratio proportional to 1/P (P is total pressure change) ALLOW K_p proportional to 1/P **(1)**	K_p decreases for this mark only	3
	Third mark To restore the value of the quotient/ratio to *K*p ALLOW To restore *K*p **And** EITHER p_{H2} increases / p_{HI} decreases **(1)** OR Equilibrium shifts to the right **(1)**		

Q20.

Question number	Answer	Additional Guidance	Marks
(a)	**B** $\left(\frac{p_{SO_3}}{p_{SO_2} . p_{O_2}^{\frac{1}{2}}} \right)$		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(b)	An answer that makes reference to the following point: • the amount of SO_3 is much greater than the amounts of SO_2 and O_2 **or** • as K_p greater than 1 x 10^{10} the equilibrium lies completely to the right / reaction goes to completion		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(c)	An explanation that makes reference to the following points: • the yield of sulfur trioxide decreases because the forward reaction is exothermic (1) • because as the temperature increases K_p decreases (1)		**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(d)	• calculating $\Delta_r G^\ominus$ (1) • since $\Delta_r G^\ominus$ is negative this confirms the reaction is thermodynamically feasible (1)	$\Delta_r G^\ominus$ = − 8.31 x 298 x ln 2.00 x 10^{12} = − 70 100 J mol^{-1} accept any number of significant figures e.g. 70 141	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(e)	• the rate of the reaction is increased (even though the yield is less)		**1**

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • the concentration of a solid / $Mg(OH)_2$ is constant / unchanged / changes very little	Allow magnesium hydroxide is in a different phase / state (from the aqueous ions) Ignore solids do not appear in K_c expressions / just 'it is solid' Ignore solid does not affect the concentration of the solution Ignore it is a heterogeneous equilibrium Ignore it is difficult to measure the concentration of a solid Do not award the solid does not have a concentration	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
6(b)(ii)	• $mol^3\ dm^{-9}$	Allow $dm^{-9}\ mol^3$ mol^3/dm^9 Ignore any working before the answer	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• use of $\Delta_{sol}H = \Delta_{hyd}H[Mg^{2+}(aq)] + 2\Delta_{hyd}H[OH^-(aq)] - \Delta_{latt}H[Mg(OH)_2(s)]$ **(1)** • calculation of $\Delta_{sol}H$ **(1)**	Example of calculation $\Delta_{sol}H = -1920 + 2(-460) - (-2842)$ Allow this shown on a Hess cycle $\Delta_{sol}H$ = (+)2 (kJ mol^{-1}) Allow 2000 J mol^{-1} Correct answer with no working scores 2	(2)

Question Number	Answer	Mark
(iv)	**The only correct answer is D** ***A*** *is not correct because it should not be linear and should level off* ***B*** *is not correct because it should not increase in that way and should level off* ***C*** *is not correct because it should not be horizontal*	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(v)	An answer that makes reference to the following points: Addition of magnesium sulfate solution: • equilibrium position shifts to the left / in the backwards direction **(1)** • because increased concentration / amount of magnesium ions / $Mg^{2+}((aq))$ **(1)** Addition of dilute hydrochloric acid: • equilibrium shifts to the right / in the forwards direction **(1)** • because the hydrogen ions / $H^+((aq))$ react with / neutralise / removes the hydroxide ions / $OH^-((aq))$ **(1)**	Mark independently Allow more magnesium hydroxide precipitates / forms Allow more Mg^{2+} ions present Allow more magnesium hydroxide dissolves / dissociates Allow $H^+((aq)) + OH^-((aq))$ $\rightarrow H_2O((l))$ Allow magnesium hydroxide reacts with / is neutralised by acid / equation to show this Allow acid / HCl reacts with / neutralises / removes hydroxide ions Penalise reference to K_c changing once only	**(4)**

Q22.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	A		1

Q23.

Question Number	Correct Answer	Mark
(a)	C	**1**

Question Number	Correct Answer	Mark
(b)	B	**1**

Question Number	Correct Answer	Mark
(c)	D	**1**

Q24.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • carbon / solid has no (vapour / partial) pressure **or** (partial) pressure of carbon / solid is constant **or** carbon does not contribute to the overall pressure (of the system)	Allow the reaction is heterogeneous **and** (partial) pressure of a pure solid is not included (in K_p expression) Do not allow just 'because carbon is a solid' or 'carbon is not a gas'	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • there are fewer moles / molecules / particles of **gas** on the left / reactant side **(1)** • so equilibrium position/ it moves / shifts to the left / reactant side **(1)**	Allow 2 moles / molecules of **gas** on right and 1 mole / molecule on left M2 is conditional on M1 **or** the idea of fewer particles on the left / decreasing the value of the quotient / Q Do not allow any indication of K_p changing	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points: • (forward) reaction is endothermic **and** so equilibrium constant / K_p increases as temperature increases **(1)** • so equilibrium position / it moves / shifts to the right / product side **(1)**	Ignore references to ΔG and ΔS M2 is conditional on M1 **or** endothermic or equilibrium constant increases	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iv)	• calculation of moles of each substance at equilibrium **(1)** • calculation of partial pressure of each substance **(1)** • calculation of K_p **(1)** • units (stand alone mark) **(1)**	Example of calculation: $K_p = \frac{0.895 \times 0.895}{0.20994}$ = 3.815 / 3.82 / 3.8 atm 3.8144 / 3.814 / 3.81 / 3.8 atm from 0.105 and 0.210 Correct answer with units but no working scores (4) Allow TE for M2 and M3 Ignore SF except 1 SF	**(4)**

	$H_2O(g)$	$H_2(g)$	$CO(g)$
Initial moles	1.00	0	0
Eqm moles	1.00 − 0.81 = 0.19	0.81	0.81
Total moles = 0.19 + 0.81 + 0.81 = 1.81			
Mole fraction	0.19/1.81 = 0.10497	0.81/1.81 = 0.4475	0.81/1.81 = 0.4475
Partial pressure /atm	0.10497 x 2.0 =0.20994	0.4475 x 2.0 = 0.895	0.4475 x 2.0 =0.895

Q25.

Question Number	Answer	Additional Guidance	Mark
(i)	• square root of K_w at 310K to get $[H^+]$ **(1)** • calculation of pH to 2 decimal places **(1)**	Example of calculation: $[H^+] = (\sqrt{2.40 \times 10^{-14}}) = 1.549..\times10^{-7}$ (mol dm^{-3}) pH = (–log $1.549..\times10^{-7}$) = (6.809894379) = 6.81 Correct answer with no working scores (2) Allow TE from incorrect $[H^+]$ as long as answer is in the pH range 6.00 – 7.00 inclusive	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • **(M1)** neutral **(1)** • **(M2)** because $[H^+(aq)] = [OH^-(aq)]$ /equal amounts of H^+ and OH^- ions **(1)**	Acidic or alkaline scores (0) Allow both $[H^+]$ and $[OH^-]$ have increased equally (from 298 K to 310 K) M2 dependent on M1	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following point: • positive / + sign because K_w increases as the temperature increases	Allow 'positive because' bond breaking requires energy or equilibrium shifts to the right or there is greater/more ionisation/dissociation Ignore 'endothermic'	**(1)**

Q26.

Question Number	Answer	Mark
(i)	**The only correct answer is C** (120° and 109.5°) ***A*** *is incorrect because both angles are incorrect* ***B*** *is incorrect because 90° is incorrect* ***D*** *is incorrect because 109.5° is incorrect for the left hand O–C–H angle*	**(1)**

Question Number	Answer	Mark
(ii)	**The only correct answer is D** (atm^{-1}) ***A*** *is incorrect because it is the inverse of the units for* K_C ***B*** *is incorrect because it is the units for* K_C ***C*** *is incorrect because it is the inverse of the units for* K_p	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points • K_p will remain unchanged **(1)** • equilibrium moves to right-hand side (to keep K_p constant) / only temperature affects K_p **(1)**	Allow answers in terms of quotient Do not award M2 if K_p is described as changing Ignore comments related to rate	**(2)**

Q27.

Question Number	Answer	Additional Guidance	Mark
(i)	• $K_c = \frac{[CH_3COOCH_2CH_3(l)][H_2O(l)]}{[CH_3COOH(l)][CH_3CH_2OH(l)]}$	Ignore omission of state symbols Do not award round brackets	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• expression for equilibrium amounts in terms of x **(1)** • use equilibrium amounts in K_c expression and rearrangement to find amount of product / express as correct quadratic expression **(1)** • calculation of amount of product **(1)**	Example of calculation Amounts $CH_3CH_2OH = 1.2 - x$; $CH_3COOH = 1.2 - x$; $CH_3COOCH_2CH_3 = x$; $H_2O = x$ $K_c = \frac{(x \div vol)^2}{[(1.2-x) \div vol]^2}$ $K_c = (x^2 \div vol^2) \div ((1.2-x)^2 \div vol^2)$ $K_c = x^2 \div (1.2-x)^2$ so $x^2 = K_c \times (1.2-x)^2$ $x = \sqrt{K_c} \times (1.2-x)$ $x = 0.63498 \div 1.52915$; $x = 0.41525 = 0.42$ (So amounts of each product = 0.42 (mol)) Allow use of quadratic equation for M2 Allow M2 for expression without inclusion of volume Correct answer with no working scores 3 marks Ignore SF except 1 SF Ignore negative amounts Allow alternative methods Allow TE throughout (a)(ii) for use of $x / (1.2-x)^2$ in K_c expression	**(3)**

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