Equilibria

Mark Scheme 3

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Mark Scheme 3

Time Allowed: **68 minutes**

Score: **/56**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 **(a) (i)** $NH_3 + HZ \longrightarrow NH_4^+ + Z^-$ [1]
$CH_3OH + HZ \longrightarrow CH_3OH_2^+ + Z^-$ [1]

(ii) $NH_3 + B^- \longrightarrow NH_2^- + BH$ [1]
$CH_3OH + B^- \longrightarrow CH_3O^- + BH$ [1]

[4]

(b) (i) a reaction that can go in either direction [1]

(ii) of forward = **rate** of backward reaction
or forward/back reactions occurring but concentrations of all species do not change [1]

[2]

(c) (i) a solution that resists changes in pH [1]

when small quantities of acid or base/alkali are added [1]

(ii) in the equilibrium system $HZ + H_2O \rightleftharpoons Z^- + H_3O^+$ [1]

addition of acid: reaction moves to the left
or H^+ combines with Z^- **and** forms HZ [1]

addition of base: the reaction moves to the right
or H^+ combines with OH^- **and** more Z^- formed [1]

[5 max 4]

(d) (i) $[H^+] = \sqrt{(0.5 \times 1.34 \times 10^{-5})} = 2.59 \times 10^{-3}$ (mol dm^{-3}) [1

pH = **2.59/2.6** (min 1 d.p) ecf [1]

(ii) $CH_3CH_2CO_2H + NaOH \longrightarrow CH_3CH_2CO_2Na + H_2O$ [1]

(iii) n(acid) in 100 cm^3 = 0.5 × 100/1000 = 0.05 mol
n(acid) remaining = 0.05 – 0.03 = 0.02 mol
[acid remaining] = **0.2** (mol dm^{-3}) [1

likewise, n(salt) = 0.03 mol
[salt] + **0.3** (mol dm^{-3}) [1

(iv) pH = 4.87 + log(0.3/0.2) = **5.04–5.05** ecf [

[6]

(e) **G** is CH_3CH_2COCl
H is $SOCl_2$ *or* PCl_5
J is $NaCl$ [2]
(or corresponding Br compounds for **G**, **H** and **J**; CH_3CH_2COBr, $SOBr_2$, NaBr)

[Total: 18]

2 **(a** $K_c = \dfrac{[CH_3CH_2R][H_20]}{[CH_3CH_2H][ROH]}$ (1)

no units (1) [2]

(b) **(** $n(NaOH) = \dfrac{22.5 \times 2.00}{1000} = 0.045$ (1)

(ii) $n(NaOH) = n(HCl) = 0.005$ (1)

(iii) $CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O$ (1)

(iv) $n(NaOH) = 0.045 - 0.005 = 0.04$
allow ecf on **(i)** and/or **(ii)** (1) [4]

(c) **(** $n(NaOH)$ **and** $n(CH_3CO_2H) = 0.04$ (1)
$n(CH_3CO_2R)$ **and** $n(H_2O) = 0.06$ (1)

(ii) $K_c = \dfrac{0.06 \times 0.06}{0.04 \times 0.04} = 2.25$

allow ecf on wrong values in **(b)(i)**
allow ecf on wrong expression in **(a)** (1)

(d) E_a for reaction with ester is high **or**
E_a for reaction with acid is low
or
reaction with ester is slow **or**
reaction with acid is fast (1) [1]

(e) equilibrium moves to RHS/more ester would be formed (1)
to maintain value of K_c **or**
to restore system to equilibrium (1) [2]

[Total: 12]

3 **(a) (i)** One that can go in either direction. [1]

(ii) both forward & reverse reactions are going on at the same time, but the concentrations of all species do not change (owtte)
or rate of forward = rate of backward reaction [1]

(b) (i) $K_c = [H^+][OH^-]/[H_2O]$ [

(ii) $K_w = [H^+][OH^-]$ [1]
rearrangement of equation in **(i)** gives $K_c[H_2O] = [H^+][OH^-]$ & $K_w = K_c[H_2O]$ (owtte)
or the $[H_2O]$ is contained within K_w [1]

(iii) K_w will be higher in hot water **because** reaction is endothermic [1]

(c) (i) $[OH^-] = 5 \times 10^{-2}$; $[H^+] = (1 \times 10^{-14})/ 5 \times 10^{-2}$ = **2×10^{-13}** [1]
pH = $-\log_{10}[H^+]$ = **12.7** (correct ans = [2]) ecf [1]

(ii) $[NH_4^+] = [OH^-]$ (= x) [1
$x^2 = 1.8 \times 10^{-5} \times 0.05 \Rightarrow x$ (= $[OH^-]$) = **9.49×10^{-4}** (mol dm^{-3}) (correct ans = [2]) [1]

(iii) $[H^+] = K_w/[OH^-] = (1 \times 10^{-14})/ 9.49 \times 10^{-4}$ = **1.05×10^{-11}**(mol dm^{-3}) ecf [1]

(iv) pH = **11.0** ecf [1]

[Total: 12 max 11]

4 **(a) (i)** Order w.r.t. $[CH_3CHO] = 1$ [1]
Order w.r.t. $[CH_3OH] = 1$ [1]
Order w.r.t. $[H^+] = 1$ [1]

(ii) rate = $k[CH_3CHO][CH_3OH][H^+]$ [1]

(iii) units = $mol^{-2}\ dm^6\ s^{-1}$ [1]

(iv) rate will be 2 × 4 = 8 times as fast as reaction 1 (relative rate = 8) [1]
[6]

(b)

	$[CH_3CHO]$ /mol dm^{-3}	$[CH_3OH]$ /mol dm^{-3}	$[H^+]$ /mol dm^{-3}	[acetal **A**] /mol dm^{-3}	$[H_2O]$ /mol dm^{-3}
at start	0.20			0.00	
at equilibrium	(0.20 – x)	***(0.10 – 2x)***	***0.05***	x	***x***
at equilibrium	***0.175***		***0.05***	0.025	***0.025***

(i) 3 values in second row 3 x [1]

(ii) 4 values in third row 4 x [1]

(iii) $K_c = \{[\text{acetal } \mathbf{A}][H_2O]\}/\{[CH_3CHO][CH_3OH]^2\}$ [1]
units = $mol^{-1}dm^3$ [1]

(iv) $K_c = 0.025^2/(0.175 \times 0.05^2) =$ **1.4(3)** ($mol^{-1}\ dm^3$) [1]
[max 9]

[Total: 15]