Equilibria

Mark Scheme 5

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Mark Scheme 5

Time Allowed: **64 minutes**

Score: **/53**

Percentage: **/100**

Grade Boundaries:

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

1 **(a** $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ (1) [1]

(b) SO_2 (1)

NO_x / NO_2 / NO – **not** N_2O (1
Pb compounds – **not** Pb ((any 2)

If more than two answers are given any wrong ones will be penalised. [2]

(c) low temperature (1)
because forward reaction is exothermic (1)

high pressure (1)
because forward reaction goes to fewer molecules (1)
or shows a reduction in volume

increase [CO] **or** [H_2]
or remove CH_3OH (

correct explanation in terms of the effect of the change
on the position of equilibrium or on the rate of reaction (1)
(any two pairs) [4]

(d) **(** removes CO_2 (1)
which causes greenhouse effect/global warming (1)

(ii)

	CO_2	+	H_2	$\rightleftharpoons$	CO	+	$_2O$	
initial moles	0.50		0				0.20	
equil. moles	(0.50-x)		(0.5					(1)
equil. concn.	$\frac{(0.50-x)}{1}$		$\frac{(0.50-x)}{1}$		$\frac{(0.20+x)}{1}$		$\frac{(0.20+x)}{1}$	

$K_c = \frac{[CO][H_2O]}{[CO_2][H_2]}$ (1)

$K_c = \frac{(0.20+x)^2}{(0.50-x)^2} = 1.44$ (1)

gives x = 0.18 (1)

at equilibrium,
$n(CO_2) = n(H_2) = 0.32$ **and**
$n(CO) = n(H_2O) = 0.38$ (1)

Allow ecf on wrong values of x that are less than 0.5. [7]

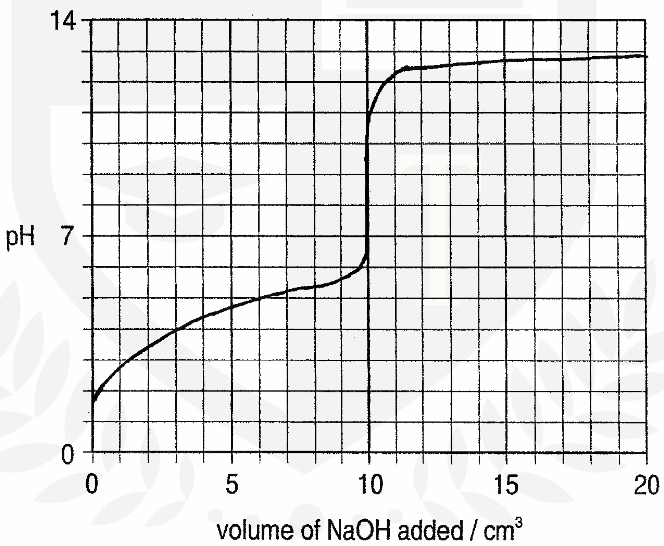
[Total: 13 max]

2 **(a)** acids are proton/H^+ donors [1]
bases are proton/H^+ acceptors [1] **[2]**

(b) more C*l* atoms produce a **stronger acid** *or* the larger the K_a the **stronger the acid**
(NOT just "the more C*l* atoms, the larger the K_a" – must refer to acid strength) [1]
because the anion/RCO_2^- is more stable *or* the O-H bond is weaker/polarised [1]
due to the electronegativity/electron-withdrawing effect of C*l* [1]

(ii) $[H^+] = \sqrt{(K_a.c)}$ = 0.0114 (mol dm^{-3}) [1]
pH = **1.94** (allow 1.9) ecf from $[H^+]$ [1
(correct answer = [2])

(iii)



start at pH = 1.94 (ecf from **(ii)** and goes up > 2 pH units before steep portion) [1]
steep portion (over at least 3 pH units) at V = 10 cm^3 [1]
flattens off at pH 12–13 [1] **[8]**

(c) $CH_3CO_2H + OH^- \longrightarrow CH_3CO_2^- + H_2O$ [1]

$CH_3CO_2^- + H^+ \longrightarrow CH_3CO_2H$ [1]

(ii) $pK_a = -\log_{10}(1.7 \times 10^{-5}) = 4.77$ *or* $[H^+] = 8.5 \times 10^{-6}$ (mol dm^{-3}) [1]
pH = $pK_a + \log_{10}(0.2/0.1)$ = **5.07** (allow 5.1) [1]
(correct answer = [2]) **[4]**

[Total: 14]

3 **(a** high temperature (and/or pressure) provide enough energy (1)

to break N≡N bond
or to provide E_a for N_2/O_2 reaction (1) [2]

(b) **(i)** **two** from C, CO, hydrocarbon, SO_2, H_2S, NO_2/NO_x (1 + 1)

not CO_2, H_2, H_2O, SO_3, NO

(ii) Pt **or** Pd **or** Pt/Rh **or** Pt/Pd/Rh (1)

(iii) $2NO + 2CO \rightarrow 2CO_2 + N_2$
or $2NO + C \rightarrow CO_2 + N_2$ (1) [4]

(c) **(i)** $K_c = \frac{[NO]^2[Cl_2]}{[NOCl]^2}$ (1)

units are mol dm^{-3} (1)

(ii) at 230 °C $K_c = \frac{(1.46 \times 10^{-3})^2 \times 1.15 \times 10^{-2}}{(2.33 \times 10^{-3})^2}$

$= 4.5 \times 10^{-3}$ mol dm^{-3} (1)

at 465 °C $K_c = \frac{(7.63 \times 10^{-3})^2 \times 2.14 \times 10^{-4}}{(3.68 \times 10^{-4})^2}$

$= 9.2 \times 10^{-2}$ mol dm^{-3} (1)

allow ecf on answer to part **(i)**

(iii) endothermic **because** K_c increases with temperature
mark is for explanation
allow ecf on answer to part **(ii)** (1) [5]

(d) **(i)** equilibrium moves to RHS (1)

more moles on RHS (1)

(ii) no change to equilibrium position (1)

[NOC*l*] and [NO] change by same amount (1) [4]

[Total: 15]

4 **(a** rate of forward reaction equals
rate of backward reaction
or equilibrium concentrations remain constant
while reaction is occurring [1] **[1]**

(b) $K_c = \dfrac{[CH_3CO_2C_2H_5][H_2O]}{[CH_3CO_2H][C_2H_5OH]}$ [1] **[1]**

(c) $CH_3CO_2H + C_2H_5OH \rightleftharpoons CH_3CO_2C_2H_5 + H_2O$

initial moles	0.5	0.5	0.1	0.1	
equil. moles	$(0.5 - x)$	$(0.5 - x)$	$(0.1 + x)$	$(0.1 + x)$	[1]
equil. concn./ mol dm^{-3}	$\dfrac{(0.5-x)}{V}$	$\dfrac{(0.5-x)}{V}$	$\dfrac{(0.1+x)}{V}$	$\dfrac{(0.1+x)}{V}$	

$K_c = \dfrac{(0.1+x)^2}{(0.5-x)^2} = 4$ [1]

gives $x = 0.3$ [1]

$n(CH_3CO_2H) = n(C_2H_5OH) = 0.2$ **and**

$n(CH_3CO_2C_2H_5) = n(H_2O) = 0.4$ [1]

allow ecf on wrong equil. moles subject to $x < 0.5$ **[4]**

(d)

reagent(s) and conditions \ alcohol	$CH_3CH_2CH_2CH_2OH$	$_3CH_2CH(OH)CH_3$	$(CH_3)_3COH$	
red phosphorus and iodine heat under reflux	X	$CH_3CH_2CHCH_3$ | I [1]	X	
concentrated H_2SO_4 heat	X	X	CH_3—$C=CH_2$ | CH_3 [1]	
$Cr_2O_7^{2-}/H^+$ heat under reflux	$CH_3CH_2CH_2CO_2H$ [1]	$CH_3CH_2COCH_3$ [1]	no reaction [1]	**[5]**

[Total: 11]