Equilibria

Mark Scheme 7

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Mark Scheme 7

Time Allowed: **74 minutes**

Score: **/61**

Percentage: **/100**

Grade Boundaries:

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

1 **(a)** $K_c = \frac{[H_2][I_2]}{[HI]^2}$ (1) **[1]**

(b) $K_c = \frac{0.274 \times 0.274}{(1.47)^2}$ = 0.035 (1) **[1]**

(c) At room temperature:

iodine is a solid/solids not K_c expression (1)

[I_2(g)] is small/concn too small to be measured (1)

it takes longer to reach equilibrium/reaction is slower (1) **[2 max]**

(d) (ΔH_{reacn} = ΔH for bonds broken – ΔH for bonds made (1)

(ii) 2H – I → H – H + I – I

2 x 299 436 151 values (1)

ΔH = 2 x 299 – (436 + 151)

= + 11 kJ mol^{-1} (1) **[3]**

(e) An acid that is completely ionised (1)

(ii) $HI + H_2O \rightarrow H_3O^+ + I^-$

(iii) I^- (1) **[3]**

[Total 10]

2 **(a) (i)** strong, because final pH is about 14 **[1]**

(ii) (pH = 0.70) ⇒ $[H^+] = 10^{-0.7}$ = 0.20 (mol dm^{-3}) **[1]**

∴ $[H_2SO_4]$ = (0.10 mol dm^{-3}) ecf **[1]**

(iii) (end point is at 34.0 cm^3 (± 0.5 cm^3), so)

amount of H^+ used = 0.2 x 25/1000 = 0.0050 mol ecf from **(ii)** **[1]**

moles of guanidine = moles of H^+ = 0.0050 mol

[guanidine] = 0.005 x 1000/34.0 = **0.147** (mol dm^{-3}) **[1]**

allow range: 0.145 – 0.149 ecf in 0.005 or 34.0

(iv) M_r = 8.68/0.147 = **59** (*allow range* 58 – 60) ecf from **(iii)** **[1]** **6**

(b) (i) ⟶ $CaSO_4$ + **3** $Ca(H_2PO_4)_2$ + **2** HF **[1]**

(ii) M_r values: $_2PO_4)_2$ = 234.1, H_2SO_4 = 98.0 **[1]**

234.1 x 3 = **702.3** 98 x 7 = **686** both **[1]**

ecf from ratios in equation, and from M_r values

∴ mass of H_2SO_4 needed = 1.0 x 686/702.3 = **0.98** kg **[1]**

(correct answer = [3] marks. accurate value is: 0.977 kg.
Allow ecf from incorrect M_r or incorrect multipliers) **4**

(c) (i) A solution that **resists** changes in pH [NOT: results in **no** pH change] **[1]**

when **small amounts** of H^+ or OH^- are added **[1]**

(ii) pH = $-\log_{10}(6.3 \times 10^{-8}) + \log_{10}(0.1/0.2)$ = **6.9** **[1]**

or $[H^+]$ = $(6.3 \times 10^{-8}) \times 0.2/0.1$ = 1.26×10^{-7}

∴ pH = $-\log_{10}(1.26 \times 10^{-7})$ = **6.9**

Total 13

3 (a) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (1) exothermic **[2]**

(b) Pr. 5O atm upwards; Temp 400-600ºC; catalyst of iron
(1 each, conditions stated) **[3]**

(c) Too high a temp and equilibrium favours LHS, less ammonia at equilibrium (1)
Too low a temp, rate too slow/not enough molecules have E_{act} (1) **[2]**

(d) (i) $K_p = \dfrac{PN\ _3{}^2}{PN_2 \times PH_2{}^3}$ (1)

(ii) $K_p = \dfrac{37.\ ^2}{44.8 \times 105.6^3}$ (1)

$= 2.62 \times 10^{-5}\ atm^{-2}$ (1) calculation and un **[3]**

(e) Excess (hence uncontrolled) nitrates leach out of fields into streams, seas (1)
Bacteria or algae grow fast/use oxygen/clog up water (1)
Balance destroyed/fish unable to live (1) **[3]**
Process called eutrification (1) any 3

[Total: 13]

4 **(a (i)**	use restriction enzymes ***or*** using an enzyme to break (the DNA) down into smaller fragments	**1**
(ii)	use the polymerase chain reaction ***or*** use DNA polymerase to replicate / copy (the sample of DNA)	**1**
(iii)	• amino acids have different charges due to their side-chain / R group / pH / CO_2^- **and** NH_3^+ groups • DNA fragments have negatively-charge phosphates(or PO_4) ***or*** DNA has PO_4^{3-} groups	**1** **1**
(iv)	A piece of leather from an Egyptian tomb — A sample of skin from a mummified body — A fragment of ancient pottery — **X** A piece of wood from a Roman chariot —	**1**
(b) (i)	the electron density in the molecule ***or*** positions of atoms ***or*** interatomic distance / spacing between the atoms	**1**
(ii)	phosphorus has the most electrons ***or*** phosphorus has the highest electron density	**1**
(c) (i)	equilibrium constant (for the solution) of a solute between two (immiscible) solvents ***or*** ratio of the concentration of the solute in (each of the) two solvents ***or*** ratio of the solubility of the solute in (each of the) two solvents	**1**
(ii)	$\frac{x/(25/1000)}{(0.0042-x)/(25/1000)}$ x = 0.0252 – 6x x = **0.0036g**	 **1** **1**
		[Total: 10]

5 **(a** **(i)** **B** and **D** [1] + [1]

(ii) **D** [1]

3

(b) heat with dilute $H^+(aq)$ *or* $H_2SO_4(aq)$ [1]

1

(c) K_a larger than that for ethanol because
the ethanoate ion / $CH_3CO_2^-$ is stabilised by charge delocalisation
or
the O–H bond is weakened due to its proximity to C=O / carbonyl group *or* the second electronegative / oxygen atom [1]

K_a smaller than that for chloroethanoic acid because
electron-withdrawing / electronegative chlorine (atom) makes the anion more stable *or* O–H bond weaker *or* H more easily lost [1]

(ii) $[H^+] = \sqrt{([CH_3CO_2H] \times K_a)} = \sqrt{(0.1 \times 1.75 \times 10^{-5})} = \mathbf{1.32(3) \times 10^{-3}}$ (mol dm^{-3}) [1]

$pH = -\log_{10}[H^+] =$ **2.88** (**2.9**) [1]

4

(d) $n(NaOH)$ at start $= 0.1 \times 20/1000 = 2.0 \times 10^{-3}$ mol
$n(NaOH)$ at finish $= \mathbf{1.0 \times 10^{-3}}$ mol

(ii) this is in $30\,\text{cm}^3$ of solution,
so $[NaOH]$ at finish $= 1.0 \times 10^{-3} / 0.030 = \mathbf{3.3(3) \times 10^{-2}}\,\text{mol dm}^{-3}$ ($\geqslant$2 s.f.) ecf from **(i)** [1]

(iii) $[H^+] = K_w / [OH^-] = 1 \times 10^{-14} / 3.33 \times 10^{-2} = 3.0 \times 10^{-13}\,\text{mol dm}^{-3}$
$pH = -\log_{10}[H^+] =$ **12.5(2)** [1]

or $pOH = -\log_{10}(3.33 \times 10^{-2}) = 1.48$
$pH = pK_w - pOH = 14 - 1.48 =$ **12.5(2)** [1]

(iv) pH / vol curve: start at pH 2.88 (2.9) ecf [1]

vertical (over at least 2 pH units) portion at $V = 10\,\text{cm}^3$ [1]

levels off at pH 12.5 $\pm$ 0.3 ecf [1]

(v) indicator is thymolphthalein [1]

7

[Total: 15]