Equilibria

Mark Scheme 1

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Mark Scheme 1

Time Allowed: **75 minutes**

Score: **/62**

Percentage: **/100**

Grade Boundaries:

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

1 **(a (i)**	$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$ reagents and formulae balancing	 [1] [1]	 [2]
(ii)	S (is oxidised) –2 to (+)4 O (is reduced) 0 to –2	[1] [1]	 [2]
(b) (i)	T = 400 – 600 °C (chosen as a compromise because) High T increases rate ora High T decreases yield / moves eqm left / makes less SO_3 as forward reaction exothermic ora	[1] [1] [1]	 [3]
(ii)	High pressure increases rate as collision frequency increases ora High pressure moves eqm right / favours forward reaction as more moles on left ora Uneconomic to use high pressures / high yield at low pressure	[1] [1] [1]	 [3]
(c) (i)	Reaction (too) exothermic / acid spray produced	[1]	[1]
(ii)	$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	[1] [1]	 [2]
(d)	Preservative owtte antimicrobial / antioxidant / reducing agent	[1] [1]	 [2]
(e) (i)	$12.35 \times 0.01 / 1000 = 1.235 \times 10^{-4}$	[1]	[1]
(ii)	$1.235 \times 10^{-4} \times 1000 / 50 = 2.47 \times 10^{-3}$	[1]	[1]
(iii)	$2.47 \times 10^{-3} \times 64.1 = 0.158327$ g = 158 (3 sf only)	[1]	[1]
			[18]

2 **(a)** **(i)** a solution that resists / minimises a change in its pH *or* **helps** maintain its pH..... **[2]**
(NOT any of: "maintains pH"; "keeps pH constant"; "no change in pH")
.....when small amounts of acid / H^+ or base / OH^- are added (**both** acid and base are needed)

(ii) HCO_3^- reacts with H^+ ions as follows: **[2]**

$$HCO3^- + H^+ \longrightarrow H_2CO_3 \text{ (or } H_2O + CO_2)$$

and with OH^- ions thus:

$$HCO_3^- + OH^- \longrightarrow CO_3^{2-} + H_2O$$

(the equation arrows can be equilibrium arrows, as long as HCO_3^- is on the left)

(iii) ($pK_a = -\log(K_a) = 7.21$) **[2]**

$pH = pK_a + \log([base]/[acid]) = 7.21 + \log(0.5/0.3)$
$= \mathbf{7.43\ (7.4)}$

(b) **(i)** $K_{sp} = [Ag^+]^3[PO_4^{3-}]$ **and** units: mol^4dm^{-12} **[1]**

(ii) call $[PO_4^{3-}] = x$, then $[Ag^+] = 3x$, and $K_{sp} = 27x^4$ **[3]**

$x = (K_{sp}/27)^{1/4} = (1.25 \times 10^{-20}/27)^{1/4} = 4.64 \times 10^{-6}$ mol dm^{-3}

$[Ag^+] = 3x = \mathbf{1.39 \times 10^{-5}}$ (mol dm^{-3}) (allow $\mathbf{1.4} \times 10^{-5}$)

(c) $H_3PO_3 + 2Fe^{3+} + H_2O \longrightarrow H_3PO_4 + 2Fe^{2+} + 2H^+$ **[2]**

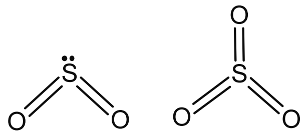
$E^{\ominus}_{cell} = 0.77 - (-0.28) = (+)\mathbf{1.05}$ V

or $3H_3PO_3 + 3H_2O + 2Fe^{3+} \longrightarrow 3H_3PO_4 + 6H^+ + 2Fe$

$E^{\ominus}_{cell} = -0.04 - (-0.28) = (+)\mathbf{0.24}$ V

[Total: 12]

3 (a (i)	(reaction between atmospheric N_2 and O_2) due to lightning / biological processes or bacteria in soil **AND** in car engines / power stations / metal refining / furnaces	(1)	[1]
(ii)	$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$ **OR** $2NO_2 + H_2O + 1/2O_2 \rightarrow 2HNO_3$ **OR** $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$	(1)	[1]
(iii)	$SO_2 + NO_2 \rightarrow SO_3 + NO$	(1)	
	$NO + 1/2O_2 \rightarrow NO_2$	(1)	
	$SO_3 + H_2O \rightarrow H_2SO_4$	(1)	[3]
(b) (i)	$K_p = pN_2O_4/(pNO_2)^2$	(1)	[1]
(ii)	moles of NO_2 = 0.32	(1)	[1]
(iii)	$x(N_2O_4) = 1.84/2.16 = 0.85$	(1)	
	$x(NO_2) = 0.32/2.16 = 0.15$ ecf from **(b)(ii)**	(1)	[2]
(iv)	$pN_2O_4 = 0.85 \times 140 = 119$ (kPa)	(1)	
	$pNO_2 = 0.15 \times 140 = 21$ (kPa) ecf from **(b)(iii)**	(1)	[2]
(v)	$K_p = 119/21^2 = 0.270$ kPa^{-1} ecf from **(b)(i)** and **(b)(iv)**	(2)	
		Total	13

Question	Scheme	Marks	T
4 **(a)**	$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$	1 1	[2]
(b) (i)	Very exothermic / gets very hot OR creates (acid / H_2SO_4) spray / mist / fog / fumes	1	1
(ii)	$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	1 1	[2]
(c) (i)	 M1 SO_2 correct M2 SO_3 correct	1+1	[2]
(ii)	115–120° bent / non-linear 120° trigonal planar	1 1	[2]
(d) (i)	Advantage = higher rate Greater KE / energy / speed / collision frequency / proportion of successful collisions / more particles with E>Ea Disadvantage – reduced yield / less product (Forward reaction) **exothermic AND** (hence in accordance with LCP) equilibrium / reaction **shifts left** (to counteract inc T) ora	1 1 1 1	[4]
(ii)	$K_p = \frac{pSO_3^{\,2}}{pSO_2^{\,2} \times pO_2}$	1	[1]

Question	Scheme	Marks	T
(iii)	$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ 2 2 0 (–1.8) (–0.9) <u>0.2 1.1</u> $xSO_3 = 1.8/3.1 = 0.581$ $xSO_2 = 0.2/3.1 = 0.065$ $xO_2 = 1.1/3.1 = 0.355$ $K_p = \dfrac{0.581^2 \times \cancel{(2 \times 10^5)^2}}{0.065^2 \times \cancel{(2 \times 10^5)^2} \times 0.355 \times 2 \times 10^5} = 1.13 \times 10^{-3}\ \text{Pa}^{-1}$	1 1 1 1+1	[5]
			[19]