Equilibria

Mark Scheme 6

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Mark Scheme 6

Time Allowed: **71 minutes**

Score: **/59**

Percentage: **/100**

Grade Boundaries:

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

1 **(a)** **(i)** [one chiral centre only] (1)

(ii) $C_{13}H_{18}O_2$ (1)

(iii) M_r = 206 ecf (1)

mass = 0.15 x (100/1000) x 206 = **3.1** g ecf (1)
(correct ans = (2) marks)

(iv) n(NaOH) = 0.1 x 12/100 = 1.2×10^{-3} moles (1)

n(**A**) = 0.6×10^{-3}, so M_r = 0.1/(0.6×10^{-3}) = **167** (allow 166-170) (1)
(correct ans = (2) marks)

This fits with **HO_2C-C_6H_4-CO_2H** (which has M_r = 166) (1) **[7]**

(b) (K_a =) $[H^+][A^-]/[HA]$ (1)

(ii) $[H^+] = \sqrt{K_a}.c = \sqrt{6.3 \times 10^{-6} \times 0.15} = 9.72 \times 10^{-4}$ (1)

pH = **3.0** (1)
(correct ans = (2) marks) **[3]**

(c) one that **resists/control/maintains** changes in pH (**NOT *no*** change in pH) (1)

when **small amounts** of acid/H^+ (or base/OH^-) are added. (1)

(ii) $HPO_4^{2-} + H^+ \longrightarrow H_2PO_4^-$ (1)
$H_2PO_4^- + OH^- \longrightarrow HPO_4^{2-} + H_2O$ (1)

(iii) pH = pK_a + log ([base]/[acid])
= 7.2 + log (.002/.005) = **6.8** (2)
(correct ans = (2) marks: deduct (1) for each error,
e.g. if ratio is upside down, hence pH = 7.6, answer is worth (1)) **[6]**

[Total: 16 max 15]

2 **(a)** $S + O_2 \rightarrow SO_2$ **(1)**

2 $2SO_2 + O_2 \rightleftharpoons 2SO_3$ equil **(1)** equation **(1)**

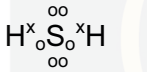
3 $SO_3 + H_2O \rightarrow H_2SO_4$ **(1)**

Allow sequences that start with SO_2
and include $H_2S_2O_7$ before H_2SO_4.

Equilibrium mark is <u>only</u> scored if $\rightleftharpoons$ <u>only</u> appears in the SO_2/SO_3 equation. **[4]**

(b) vanadium pentoxide/vanadium(V) oxide/V_2O_5 **(1)** **[1]**

(c) (i)



(1)

(ii) non-linear/bent/V-shaped **(1)**

(iii) H_2O has hydrogen bonds/H_2S does not <u>or</u>
H_2S has van der Waals' forces only **(1)**

hydrogen bonds are stronger
than van der Waals' forces <u>or</u>
H_2S has weaker intermolecular bonds
than H_2O **(1)** **[4]**

(d) (i) $2H_2S + 3O_2 \rightarrow 2H_2O + 2SO_2$ **(1)**
from -2 **(1)** to +4 **(1)**
allow e.c.f. on equation

(ii) 68.2g H_2S react with 3 x 24 dm^3 O_2 **(1)**
8.65g H_2S react with $\frac{3 \times 24 \times 8.65}{68.2} = 9.13\ dm^3$ **(1)**
allow 9.16 dm^3 if H_2S = 68 is used
allow e.c.f on **(d)(i)** **[5]**

(e) (i) an acid that is partially dissociated into ions **(1)**

(ii) $H_2S(g) + H_2O(l) \rightarrow H_3O^+(aq) + HS^-(aq)$

<u>or</u>

$H_2S(g) + aq \rightarrow H^+(aq) + HS^-(aq)$

<u>or</u>

$H_2S(aq) \rightarrow H^+(aq) + HS^-(aq)$
equation **(1)** state symbols **(1)** **[3]**

[Total: 17]

3 **(a** $K_a = [RCO_2^-][H^+]/[RCO_2H]$ **[1]**

Part (a): [1]

(b) The more chlorine atoms in the molecule, the stronger the acid, **[1]**

due to the electron-withdrawing (inductive) effect of C*l*... **[1]**
either...stabilising the anion, **or** spreading (-) charge more,
or...weakening the O-H bond in the acid, **or**...increasing ionisation,
or…facilitates H^+ donation
or…causing the equilibrium $RCO_2H \rightleftharpoons RCO_2^- + H^+$ to lie further to the right.
Mark is conditional on reference to the effect of presence of chlorine. **[1]**

(ii) $[H^+] = \sqrt{(0.1 \times 1.4 \times 10^{-3})}$ = 0.0118 (mol dm^{-3}) allow 0.012 **[1]**

$\therefore$ $pH = -\log_{10}(0.0118)$ = **1.93** Allow 1.9 or 1.92 e.c. **[1]**

(iii) $pK_a = -\log_{10}(5.5 \times 10^{-2})$ = **1.26** Allow 1.3 **[1]**

Part (b): [6]

(c) Cl_2(**aq**) $AlCl_3$ or UV negates **[1]**

(ii) Electrophilic substitution **or** addition-elimination **[1]**

Nucleophilic substitution **or** electrophilic substitution on OH group
If neither mark is awarded, could give "salvage" mark for substitution x2 **[1]**

(iii) **Either:** add Br_2(**aq**) phenol decolourises it, or gives a white ppt.
or: add $FeCl_3$(**aq**) phenol give a purple colour
or: add NaOH(**aq**) phenol dissolves
or: add UI solution phenol goes yellow/orange (**A** stays green)
or: add "diazonium"to solution in OH^-
phenol gives orange/red colour
(in each case, **A** give no reaction)

or: add $Cr_2O_7^{2-}/H^+$/warm **A** changes colour from orange to green
or: add MnO_4^-/H^+/warm **A** changes from purple to colourless
or: add $PCl_5/POCl_3/PCl_3/SOCl_2$ **A** gives fumes
or: add CH_3CO_2H + conc. H_2SO_4 **A** gives fruity smell

(in each case, no change with phenol)

Test + reagents **[1]** **Both** observations **[1]**

Part (c): [5]

Total: [12]

4 **(a)** $CO(NH_2)_2 + H_2O \longrightarrow 2N_3 + CO_2$ balanced equation (1)
(1) colourl

[2]

(b) **(i)** $N_2 + 3H_2 \leftrightarrow 2NH_3$

(ii) 100 ATMs or over
400 - 500°C
iron catalyst

(iii) Fertiliser, making nitric acid, explosives etc. 1 mark for each

[4]

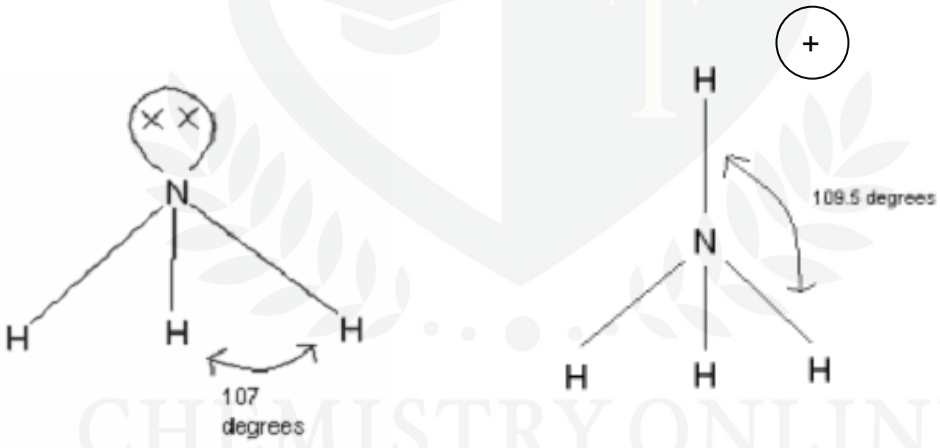
(c) **(i)** (1.2) / (2.4) = 1/20 or 0.05 mol [1]

(ii) $2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$ or equivalent [1]

(iii) 0.025 mols of H_2SO_4 are required

Vol. of 0.50 mol dm^{-3} H_2SO_4 required = (0.025 x 1000) / 0.5 = $50cm^3$ [1]

(d)



1 mark for each diagram, 1 mark for each correct bond angle
If not 3-dimensional diagram – 1 penalty.

[4]

(e) $4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O$ [1]

N goes from -3 to 0 ⟶ oxidation [1]
O goes from 0 to -2 ⟶ [1]

Total = [16]