CHEMISTRY ONLINE
TUITION

Phone: +442081445350

www.chemistryonlinetuition.com

Email:asherrana@chemistryonlinetuition.com

CHEMISTRY
PHYSICAL CHEMISTRY

Level & Board	CIE (A-LEVEL)
TOPIC:	EQUILIBRIA
PAPER TYPE:	SOLUTION - 2
TOTAL QUESTIONS	10
TOTAL MARKS	112

ChemistryOnlineTuition Ltd reserves the right to take legal action against any individual/ company/organization involved in copyright abuse.

Equilibria - 2

1)

(a) $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$

(b) Sulphur dioxide and Nitrogen dioxide

(c) 1. Low temperature

As the forward reaction is exothermic at low temperature, the reaction will go forward to produce high yield of methanol.

2. High pressure

As the forward reaction goes to fewer gas to fewer gas molecules, the reaction will go forward at high pressure.

(d) (i) It helps to remove carbon dioxide from air which is responsible for green – house

effect and global warming.

(ii)

	CO_2	+ H_2	⇌ CO	+ H_2O
Initial moles	0.50	0.50	0.20	0.20
Equilibrium moles	(0.5 – x)	(0.50 –x)	(0.20 + x)	(0.20 + x)
Equilibrium concentration mole dm^{-3}	$\frac{0.5 - x}{1}$	$\frac{0.50 - x}{1}$	$\frac{0.20 + x}{1}$	$\frac{0.20 + x}{1}$

$$K_c = \frac{[CO][H_2O]}{[CO_2][H_2]} \quad \Rightarrow 1.44 = \frac{(0.20+x)^2}{(0.50-x)^2} \quad \Rightarrow x = 0.18$$

at equilibrium moles of (CO_2) = moles of (H_2) = 0.50 – 0.18 = 0.32

moles of (CO) = moles of (H_2O) = 0.20 + 0.18 = 0.38

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

2)

(a) Acids are species that donate protons (hydrogen ions) when dissolve in water. Bases are species that accept protons when dissolve in water.

(b) (i) When chlorine is substituted in ethanoic acid, K_a value increase and acid becomes stronger. It is due to electron withdrawing effect of chlorine making O – H bond weaker causing moles H+ ions to be free.

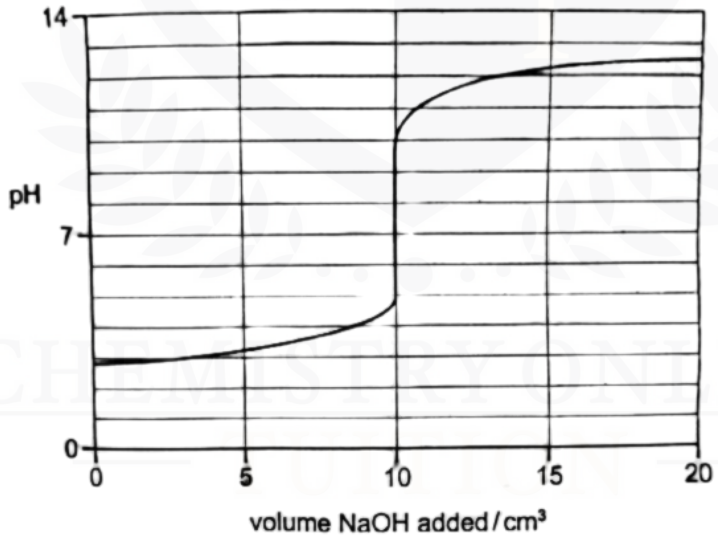
(i) $[H^+] = \sqrt{K_a[Acid]}$

$= \sqrt{(1.3 \times 10^{-3}) \times 0.1}$ = 0.0114 mol dm^{-3}

- $\log[H^+]$ = - log 0.0114

pH = 1.94

(iii)



(c) (i) $CH_3CO_2H + OH^- \rightarrow CH_3CO_2^- + H_2O$

$CH_3CO_2^- + H^+ \rightarrow CH_3CO_2HH$

(ii) $pK_a = -\log_{10}K_a = -\log_{10} 1.7 \times 10^{-5} = 4.77$

$$pH = pK_a + \log\frac{[Salt]}{[Acid]}$$

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

$= 4.77 + \log \frac{0.2}{0.1} = 4.77 + 0.30 = 5.07$

3)

(i) $K_{sp} = [Ca^{2+}][OH^-]^2$, units = $mol^3\ dm^{-9}$

(ii) Moles of acid (H^+) = $0.05 \times \frac{21}{1000} = 1.05 \times 10^{-3}$

same moles of OH^- are present in 21 cm^3 moles I 25 cm^3 of $Ca(OH)_2$.

$[OH^-(aq)] = (1.05 \times 10^{-3}) \times \frac{1000}{25} = 4.2 \times 10^{-2}$ (mol dm^{-3})

$[Ca^{2+}(aq)] = \frac{1}{2} \times 4.2 \times 10^{-2} = 2.1 \times 10^{-2}$ (mol dm^{-3})

(iii) $Ca(OH)_2$ will be less soluble in 0.1 mol dm^{-3} NaOH because of common ion effect.

4)

(c) (i) $K_{sp} = [Pb^{2+}][Cl^-]^2$ units = $mol^3\ dm^{-9}$

(ii) Suppose $[Pb^{2+}] = x$

$\Longrightarrow [Pb^{2+}] \times [Cl^-]^2 = (x)(2x)^2$

$\Longrightarrow K_{sp} = 4x^3$

$$\Longrightarrow x = \sqrt[3]{\frac{K_{sp}}{4}} = \sqrt[3]{\frac{2.0 \times 10^{-5}}{4}} = 1.71 \times 10^{-2}$$

(iii) $[Pb^{2+}] = \frac{2 \times 10^{-5}}{(0.5)^2} = 8.0 \times 10^{-5}$ mol dm^{-3}

(iv) Solubility of $PbCl_2$ is decreased because of common ion effect.

5)

(a) (i) order with respect to $[CH_3CHO] = 1$

order with respect to $[CH_3OH] = 1$

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

order with respect to $[H^+]$ = 1

(ii) Rate of reaction = $k[CH_3CHO][CH_3OH][H^+]$

(iii) Units $mol^{-2}\ dm^6\ s^{-1}$

(iv) Rate of reaction = $\frac{0.20}{0.20} \times \frac{0.20}{0.1} \times \frac{0.20}{0.05}$

= 2 × 4 = 8 times as fast as reaction 1.

Hence relative rate of reaction = 8.

(b) (i) & (ii)

	$[CH_3CHO]$ / 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	0.10	0.05	0.00	0.00
At equilibrium	(0.20 – x)	(0.10 – 2x)	0,05	x	x
At equilibrium	0.175	0.05	0.05	0.025	0.025

(iii) $K_c = \frac{[CH_3CH(OCH_3)_2][H_2O]}{[CH_3CHO][CH_3OH]^2}$

units = $mol^{-1}dm^3$

(iv) $K_c = \frac{[CH_3CH(OCH_3)_2][H_2O]}{[CH_3CHO][CH_3OH]^2}$

$= \frac{0.025 \times 0.025}{0.175 \times (0.05)^2} = 1.4286\ mol^{-1}dm^3$

6)

(a) (i) The thermal stability decreases from HCl to Hi.

(ii) $2HX \longrightarrow H_2 + X_2$

The thermal decomposition of HX depends on the strength of the H – X bond.

Down the Group, the atomic size of X increase and its orbital, used for

bonding, becomes more diffuse. Hence, orbital overlap between H and X

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

becomes smaller and less affective causing the H – X bond to become weaker.

Therefore thermal stability of these hydrides decreases down the Group.

(b) $K_c = \frac{[HI]^2}{[H_2]\times(I_2)}$, No units.

(c) (i) As the number of moles on the right hand side and left hand side of the equation are same, increasing the pressure will have no effect on the equilibrium position.

(ii) Decreasing the temperature would favour that side of the reaction which produces more heat. As the forward reaction is exothermic, the equilibrium will move to the right hand side of the reaction

(d)

	$H_2(g)$ +	$I_2(g)$	⇌	$2HI(g)$
initial moles	0.02	0.02		0
moles at equilibrium	0.02 – x	0.02 – x		2x
concentration (in mol/dm^3) at equilibrium	$\frac{0.02-x}{1}$	$\frac{0.02-x}{1}$		$\frac{2x}{1}$

$= \frac{[HI]^2}{[H_2]\times(I_2)}$

$59 = \frac{(2x)^2}{(0.02-x)(0.02-x)}$

$59 = \frac{(2x)^2}{(0.02-x)^2}$

$\sqrt{59} = \frac{2x}{0.02-x}$

$0.02\sqrt{59} - \sqrt{59}x = 2x$

$2x + \sqrt{59}\,x = 0.02\sqrt{59} \implies x = \frac{0.02\sqrt{59}}{2+\sqrt{59}} = 0.01587 \approx 0.016$

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

∴ at equilibrium, moles of HI = 2× 0.01587

= 0.03174 ≈ 0.032 mol

moles of H_2 = moles of I_2 = 0.02 – 0.01587

= 0.00413 = 0.004 mol

(a) (i) NH_3 + HZ → NH_4^+ + Z^-

CH_3OH + HZ → $CH_3OH_2^+$ + Z^-

(ii) NH_3 + B^- → NH_2^- + BH

CH3OH + B^- → CH_3O^- + BH

(a) (i) A reaction that can go in either direction.

(ii) A dynamic equilibrium occurs when the rate of the forward reaction is equal to the rate of the backward reaction.

(b) In a buffer solution at equilibrium.

$$HZ + H_2O \rightleftharpoons Z^- + H_3O^+.$$

When an acid is added, the reaction moves to the left as follows:

$$H^+ + Z^- \rightarrow HZ$$

Hence, the Buffer solution is able to maintain it's pH by shifting the equilibrium To the left or right.

(c) (i) $K_c = \frac{[CH_3CH_2COO^-][H^+]}{[CH_3CH_2COOH]}$

as $[CH_3CH_2COO^-][H^+]$

$\Longrightarrow [H^+] = \sqrt{K_a[CH_3CH_2COOH]}$

$= \sqrt{0.5 \times 1.34 \times 10^{-5}}$ = 2.588× 10^{-3} mol/dm^3

pH = - log $[H^+]$

= 2.587 ≈2.59

(ii) $CH_3CH_2CO_2H + NaOH \longrightarrow CH_3CH_2CO_2Na + H_2O$.

(iii) Total Moles of propanoic acid = 0.5 × $\frac{100}{1000}$ = 0.05.

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

Hence, the acid is in excess.

1 mole sodium hydroxide produces 1 mole of sodium propanoate.

∴ concentration of propanoate = $0.03 \div \frac{100}{1000}$ = 0.2 mol / dm^3

(iv) pH = - log10 K_a + $\log_{10}\left(\frac{[Salt]}{[Acid]}\right)$

= - $\log_{10}(1.34 \times 10^{-5})$ + $\log_{10}\left(\frac{0.3}{0.2}\right)$

= 5.049 ≈ 5.05

(d) G = CH_3CH_2COCl

H is $SOCl_2$

J is NaCl

8)

(c) (i)

- K_a is larger than that of ethanol because the $CH_3CO_2^-$ ion stabilized by charge delocalization.
- K_a is smaller than that of chloroethanoic acid because the electronegative chlorine atom in $ClCH_2CO_2H$ makes the $ClCH_2CO_2^-$ ion more stable.

(ii) $[H^+] = \sqrt{K_a \times [CH_3CO_2H]}$

$= \sqrt{1.75 \times 10^{-5} \times 0.1}$ = 0.0013229

pH = - $\log_{10}[H^+]$

= - $\log_{10}$ [0.0013229] = 2.8785 ≈ 2.88.

(d) (i) NaOH + CH_3COOH → CH_3COONa + H_2O

⟹ 1 mol of NaOH requires 1 moles of CH_3COOH.

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

moles of CH_3COOH = 0.100 × $\frac{10}{1000}$ = 0.001 moles

moles on NaOH = 0.100 × $\frac{20}{1000}$ = 0.002 moles

∴ remaining moles of NaOH at the end of addition = 0.002 – 0.001 = 0.001 moles

(ii) Total volume of solution = 30 cm^3 = 0.03 dm^3

Concentration of NaOH at the end = $\frac{0.001}{0.03}$ = 0.03333 mol/dm^3

$NaOH \rightarrow Na^+ + OH^-$

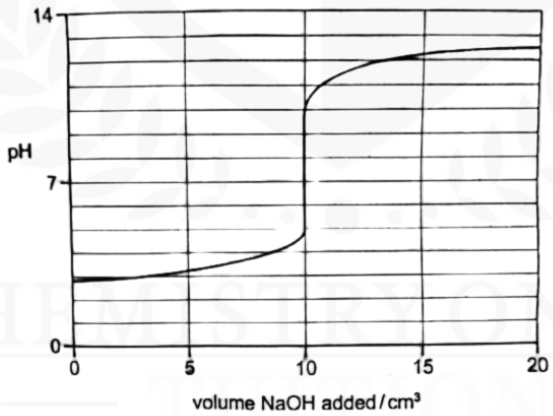
∴ [OH-] = 0.0333 mol/dm^3.

(iii) $K_w = [H^+][OH^-] \implies [H^+] = \frac{K_w}{[OH^-]}$

$= \frac{1\times10^{-14}}{0.0333} = 3.0 \times 10^{-13}$ mol/dm^3

∴ pH = $-\log_{10}[H^+]$

$= -\log_{10}(3.0 \times 10^{-13}) = 12.52$



(v)

Indicator	pH at which colour changes	Place one tick only in this column
malachite green	0 – 1	
thymol blue	1 – 2	
bromophenol	3 – 4	
thymolphthalein	9 - 10	

Copyright © ChemistryOnlineTuition Ltd - All rights reserved

9)

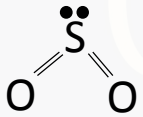
(a) (i) $4FeS_2 + 11O_2 \longrightarrow 2FeO_3 + 8SO_2$

(b) (i) The reaction of sulfur trioxide with water is very exothermic and produces harmful acid mist.

(ii) $SO_3 + H_2SO_4 \longrightarrow 2H_2SO_4$

(c) (i)

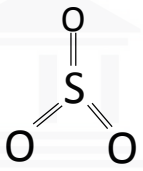
SO_2



(ii) SO_2 shape: Bent

SO_2 bond angle: 117.5

SO_3



SO_2 shape: Trigonal planar

SO_3 bond angle: 120

(d) (i) Advantage: Reaction rate is high.

Explanation: More molecules have energy greater then activation energy and therefore there will be more fruitful collisions between particles.

Disadvantage: As the forward reaction is exothermic, increasing the temperature will favour that side of the reaction which absorbs heat i.e. the left hand side of the reaction.

(ii) $K_p = \frac{P_{SO_3^2}}{P_{SO_3^2} \times P_{O_2}}$

Copyright © ChemistryOnlineTuition Ltd - All rights reserved

(iii)

	$2SO_2(g)$	$+ O_2(g) \rightleftharpoons$	$2SO_3(g)$
Initial number of moles:	2	2	0
	(- 1.80)	(- 0.9)	
moles of equilibrium:	0.2	1.1	0

sum of moles at equilibrium = 0.2 + 1.1 + 1.80 = 3.1

mole fraction of SO_3 = $\frac{1.8}{3.1}$ = 0.581

mole fraction of SO_2 = $\frac{0.2}{3.1}$ = 0.065

mole fraction of O_2 = $\frac{1.1}{3.1}$ = 0.355

$$\therefore K_p = \frac{(0.581\times(2\times10^5))^2}{(0.065\times(2\times10^5))^2\times(0.355\times(2\times10^5))}$$

units = Pa^{-1}

10)

(d) (i) $K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$

(ii) $Ca_3(PO_4)_2 \longrightarrow 3Ca^{2+} + 2PO_4^{3-}$

$[Ca^{2+}] = 3 \times (2.50 \times 10^{-6}) = 7.6 \times 10^{-6}$ mol/dm^3

$[PO_4^{3-}] = 2\times (2.50 \times 10^{-6})\ 5 \times 10^{-6}$ mol/dm^3

$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$

$= [7.5\times 10^{-6}]^3[5\times 10^{-6}]^2 = 1.05 \times 10^{-26}$ mol^{5}dm^{-15}.

(e) (i) The enthalpy change when 1 mole of an ionic compound is formed from it's gaseous ions.

(ii) Mg^{2+} has a smaller ionic radius than Ca^{2+}

 Copyright © ChemistryOnlineTuition Ltd - All rights reserved

DR. ASHAR RANA

M.B.B.S / MS. CHEMISTRY

CHEMISTRY ONLINE TUITION

Phone: +442081445350
www.chemistryonlinetuition.com
Email: asherrana@chemistryonlinetuition.com

- Founder & CEO of Chemistry Online Tuition Ltd.
- Completed Medicine (M.B.B.S) in 2007
- Tutoring students in UK and worldwide since 2008
- CIE & EDEXCEL Examiner since 2015
- Chemistry, Physics, Math's and Biology Tutor

CONTACT INFORMATION FOR **CHEMISTRY ONLINE TUITION**

- UK Contact: 02081445350
- International Phone/WhatsApp: 00442081445350
- Website: www.chemistryonlinetuition.com
- Email: asherrana@chemistryonlinetuition.com

Address: 210-Old Brompton Road, London SW5 OBS, UK