



## **Chemistry ACSEE**

**Past Paper Questions and  
Answers by Topic**

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### **Form VI**

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**Form VI****1.0CHEMICAL EQUILIBRIUM****2021 PAST PAPERS**

8. (a) (i) State Le Chatelier's principle. (1 mark)  
(ii) How does homogeneous equilibrium differ from heterogeneous equilibrium as applied in Chemistry? (1 mark)
- (b) Predict the direction of the net reaction for each of the following equilibrium reactions when the pressure of the system is doubled at constant temperature. Give one reason for each case.
- (i)  $2\text{Pb}(\text{s}) + 3\text{O}_2(\text{g}) \rightleftharpoons 2\text{PbO}(\text{s}) + 2\text{O}_2(\text{g})$  (1 mark)  
(ii)  $\text{PCl}_3(\text{g}) \rightleftharpoons \text{PCl}_3(\text{s}) + \text{Cl}_2(\text{g})$  (1 mark)  
(iii)  $\text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g})$  (1 mark)
- (c) Hydrogen iodide gas was synthesized from hydrogen gas and iodine vapour at  $450^\circ\text{C}$  in a 2.0 litres vessel. The value of the equilibrium constant,  $K_c$  for the reaction was found to be 50.5. If  $1.0 \times 10^{-2}$  moles of hydrogen gas,  $3.0 \times 10^{-2}$  moles of iodine vapour and  $2.0 \times 10^{-2}$  moles of hydrogen iodide were placed in a vessel at the stated temperature;
- (i) write a balanced equilibrium reaction equation for the synthesis of hydrogen iodide gas. (1 mark)  
(ii) calculate the reaction quotient ( $Q$ ) for the reaction. (3 marks)  
(iii) state whether the reaction will proceed to the right or left of the equation. Give a reason. (2 marks)  
(iv) with a reason, comment on a possible effect regarding the equilibrium position, if the pressure of the reaction system is increased. (1 mark)
- (d) Consider the reaction;  $\text{K}_2 + \text{N}_2 \rightleftharpoons 2\text{KN}$   $\Delta H = -20\text{J mol}^{-1}$  which has an equilibrium constant,  $K_c = 10$  at  $25^\circ\text{C}$ . Calculate the equilibrium constant in terms of partial pressure, ( $K_p$ ) at the same temperature. (3 marks)

Q. a) i/ Le Chatelier's principle states that "If the reaction is in equilibrium and one of the factor is altered the shift to one side the equilibrium will shift to other side in order to counteract the changes?"

ii/ Homogeneous equilibrium - is the type of equilibrium in which all reagents / species are involved in chemical reaction are in the same phase.

while

Heterogeneous equilibrium - is the type of equilibrium where two all reagents / species involved in reaction are in different phase.

b) i/ The equilibrium reaction will be more forward ie toward product side because there are large number of molecules in reactants side than product side in gaseous species.

ii/ There is no changes ie equilibrium reaction will as normal because there is same number of moles to both sides in gaseous species.

iii/ There is no changes ie equilibrium reaction will be as it is because there is the same number of moles to both sides of the equation.

g	c/.
	i/ $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$
	$\begin{array}{ccc} \text{H}_2 & + & \text{I}_2 \\ \text{---} & & \text{---} \\ 1.0 \times 10^{-2} & & 7.0 \times 10^{-2} \\ \text{---} & & \text{---} \\ 2.0 & & 2.0 \\ \text{---} & & \text{---} \\ 5 \times 10^{-3} \text{M} & 0.015 \text{M} & 0.014 \end{array}$
	Required: $KQ$
	$Q = \frac{[\text{HI}]^2}{[\text{H}_2] \times [\text{I}_2]}$
	$Q = \frac{(0.01)^2}{(5 \times 10^{-3})(0.015)}$
	$Q = 1.333$
	$\therefore$ Reaction quotient, $Q$ is 1.333.
	ii/ Since $K_c > Q$ the reaction will proceed to Right of the reaction until it will reach a point where $K_c = Q$ (at equilibrium).
	iii/ If the pressure is increased the equilibrium will start to remain as normal i.e there is no change because there is the same number of moles in both sides of the equation.
g	d) Given:
	$\text{K}_c + \text{N}_2 \rightleftharpoons 2\text{KIN} \quad \Delta H = -20 \text{ J mol}^{-1}$
	$K_c = 10 \quad \text{at} \quad 298 \text{ K}$
	$K_p = ?$
	From $K_p = K_c (RT)^{m-n}$
	$m = \text{no of moles of products}$
	$n = \text{no of moles of reactant}$
	$m-n = 2-2 = 0$
	$\therefore$
	$K_p = K_c (RT)^0 \quad (RT)^0 = 1$
	$K_p = K_c (1)$
	$K_p = K_c$
	$K_c = 10$
	$\therefore K_p = 10$
	$\therefore K_p = 10$

Extract 8.1: A sample of correct responses in question 8

## 2020 PAST PAPERS

9. (a) (i) Briefly explain the effect of change of pressure to a system at equilibrium. (2 marks)  
(ii) Why does a Coca cola soda fizz out when its bottle is opened? Give a reason. (1 mark)
- (b) Consider the following equilibrium:  
$$2\text{CrO}_4^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightleftharpoons \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$

Yellow	Orange
--------	--------

  
What would be observed when:  
(i) dilute NaOH is added to the equilibrium mixture?  
(ii) dilute HCl is added to the equilibrium mixture? (4 marks)
- (c) The following equilibrium was established during the preparation of phosphorus(V) pentachloride:  
(i) Calculate the equilibrium constant for this reaction at 127°C if the equilibrium concentrations observed at this temperature were 0.034 mol/L for ammonia, 0.85 mol/L for nitrogen and 0.031 mol/L for hydrogen.  
(ii) Using the same equilibrium concentrations in (d) (i), calculate the equilibrium constant at 127°C for the equilibrium:  
$$2\text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$$
 (6 marks)

Q9) (i) - Increasing pressure will shift the position of equilibrium to the side with fewer number of moles or less volume and more of the molecules on the side with

9a)	<p>(i) less number of moles or less volumes will be formed as those having greater volume (reacting moles) will be reduced.</p> <p>- Decreasing pressure will also shift the position of equilibrium to the side with few number of moles thus the molecules with few number of moles/volume will be found at a higher rate compared to those with greater volumes/stores.</p>
9a)	<p>(ii) Le Chatelier's principle when bottle is open because if it contains gases when closed used as preservative that escape to the surrounding when open.</p>
9b)	<p>i) Adding NaOH will reduce concentration of H<sup>+</sup> ions thus lead to the formation of more OH<sup>-</sup> ions and CrO<sub>4</sub><sup>2-</sup> ions - hence the backward reaction will be more favoured as Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup> and H<sub>2</sub>O will combine to form CrO<sub>4</sub><sup>2-</sup> and H<sup>+</sup></p> <p>ie</p> $\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-$ $\text{OH}^- + \text{H}^+ \rightarrow \text{H}_2\text{O}$ $\text{H}_2\text{O} + \text{Cr}_2\text{O}_7^{2-} \longrightarrow \text{H}^+ + \text{CrO}_4^{2-}$ <p>Therefore, yellow colour becomes dominant as more CrO<sub>4</sub><sup>2-</sup> is formed</p>

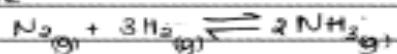
#### Extract 9.1: A sample of appropriate responses in question 9

### 2019 PAST PAPERS

6. (a) Briefly explain the following phrases, giving one example for each:
- (i) Reversible reaction. (1 mark)
  - (ii) Heterogeneous equilibrium. (1 mark)
- (b) (i) State the equilibrium law and provide the corresponding expression. (2 marks)
- (ii) List four characteristics of chemical equilibrium. (2 marks)
- (iii) Write the expression for the equilibrium constant,  $K_c$ , for the equation:  
 $\text{Cu(s)} + 2\text{Ag}^+(\text{aq}) \rightleftharpoons \text{Cu}^{2+}(\text{aq}) + 2\text{Ag(s)}$  (0.5 mark)
- (c) The equilibrium equation for the oxidation of hydrogen chloride to chlorine is:  $4\text{HCl(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{Cl}_2\text{(g)} + 2\text{H}_2\text{O(g)}$ . In a certain experiment, 0.80 moles of hydrogen chloride was mixed with 0.20 moles of oxygen in a closed vessel of capacity 10.00 dm<sup>3</sup>. At equilibrium, it was found that the mixture contained 0.20 moles of hydrogen chloride. Calculate the equilibrium constant,  $K_c$ , for the reaction. Show your work clearly including manipulations of units. (3.5 marks)

6@iv Reversible reaction

Is the type of reaction which proceed in either of the two directions  
example



iv Heterogeneous equilibrium

Is the type of chemical equilibrium in which reactants and products are in different phases.



6(b) Equilibrium law states that

"For a reversible reaction at constant temperature and pressure, the ratio of the product of the concentration of the products to the product of the concentration of the reactants each term raised to the power equal to that of stoichiometric coefficient in the balanced equation is a constant and this constant is called Equilibrium constant"

Given



$$K_c = \frac{[\text{C}]^c [\text{D}]^d}{[\text{A}]^a [\text{B}]^b}$$

where  $K_c$  = equilibrium constant

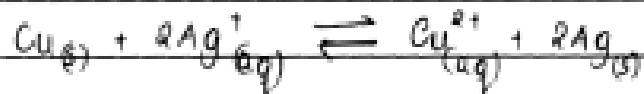
6(b) iv Four characteristics of chemical equilibrium

- The equilibrium must take place in a closed vessel
- The chemical equilibrium can be attained from any of either side of the equation

6(b)(ii) • The chemical equilibrium is always in dynamic equilibrium

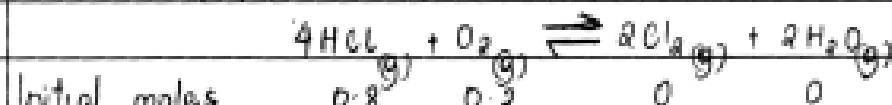
• The chemical equilibrium is independent of time of which the reaction takes place.

6(b) Given:



$$K_c = \frac{[\text{Cu}^{2+}]}{[\text{Ag}^+]^2} \quad \text{expression}$$

6(c) Given reaction:



Initial moles    0.8    0.2    0    0

Change in moles    -4x    -x    +2x    +2x

Equilibrium moles    0.8-4x    0.2-x    2x    2x

Volume, V = 10 dm<sup>3</sup>

Let "x" be number of moles reacted.

At equilibrium:

$$0.8 - 4x = 0.2 \text{ moles}$$

$$0.6 = 4x$$

$$x = 0.15 \text{ moles}$$

Then;

Equilibrium concentration

$$[\text{HCl}] = \frac{0.2}{10} = 0.02 \text{ mol dm}^{-3}$$

$$[\text{O}_2] = \frac{0.2 - 0.15}{10} = 5 \times 10^{-3} \text{ mol dm}^{-3}$$

$$[\text{Cl}_2] = \frac{2(0.15)}{10} = 0.03 \text{ mol dm}^{-3}$$

$$[\text{H}_2\text{O}] = \frac{2 \times 0.15}{10} = 0.03 \text{ mol dm}^{-3}$$

6(c)	from
	$K_c = \frac{[H_2O]^2 [Cl_2]^2}{[O_2] [HCl]^4}$
	$= \frac{(0.03)^2 (0.03)^2 \text{ mol}^4 \text{ dm}^{-12}}{(5 \times 10^{-3}) (0.02)^4 \text{ mol}^8 \text{ dm}^{-13}}$
	$K_c = 1012.5 \text{ mol}^{-4} \text{ dm}^8$
	$\therefore \text{The equilibrium constant is } 1012.5 \text{ mol}^{-4} \text{ dm}^8.$

**Extract 6.1: A sample of correct responses in question 6.**

**2018 PAST PAPERS**

9. (a) (i) State the law of mass action.  
(ii) State the Le Chatelier's principle.  
(iii) Define dynamic equilibrium.  
(iv) State three factors that change the position of the chemical equilibrium. **(2 marks)**
- (b) The equilibrium constant for the reaction  $\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$  at 986 °C is 0.63. A mixture of 1.0 mole of water vapour and 3.0 mole of CO is allowed to come to equilibrium. The equilibrium pressure is 2.0 atm.  
(i) Calculate the number of moles of H<sub>2</sub> present at equilibrium. **(4.5 marks)**  
(ii) Calculate the partial pressure of gases at equilibrium mixture. **(2 marks)**
- (c) The chief reaction used in contact process is  $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{SO}_3\text{(g)} + 4200 \text{ kJ}$ . On the basis of Le-Chatelier's principle, briefly explain three conditions that are required for the maximum yield of 2SO<sub>3</sub>(g). **(1.5 marks)**

- 9(a) (ii) law of mass action, states that "The ratio of chemical reaction is directly proportional to the molar concentration of the product divided by the molar concentration of the reactant each raised by the stoichiometric value, that appear in the balanced chemical equation."
- (iii) Le-Châtelier principle.  
 "If the system is in equilibrium and one of the factor is introduced, the position of equilibrium will change so as to overcome the change"
- (iv) Dynamic equilibrium; This is the reaction that the rate of forward reaction is equal to the rate of backward reaction.
- (v) Factors that change the position of chemical equilibrium.
- Temperature.
  - Concentration
  - Pressure.

9(b) Solution  
 Data given.



9(b)	$\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + \text{H}_2$
(i)	$K_c = 0.63$ $P_f = 2.0 \text{ atm}$ .
	$\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + \text{H}_2$ $3-x \quad 1-x \quad x \quad x$
	From $K_c = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$
	$0.63 = \frac{x^2}{(3-x)(1-x)}$
	$0.63 = \frac{x^2}{3 - 4x + x^2}$
	$1.89 - 2.52x + 0.63x^2 = x^2$ . $0.67x^2 + 2.52x - 1.89 = 0$ . $x = 0.6817$ .
	$\therefore$ The number of moles of $\text{H}_2$ at equilibrium is $0.6817$ moles.
(ii)	Resid. partial pressure of each.
	$\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + \text{H}_2$
	$0.3183 \quad 0.3183 \quad 0.6817 \quad 0.6817$
	$n_f = 4$ .

From,

partial pressure = mole fraction  $\times$  total pressure

$$P_{CO} = 2.3183 \times 2 = 1.159 \text{ atm}$$

$$P'_{H_2O} = 0.3183 \times 2 = 0.1592 \text{ atm}$$

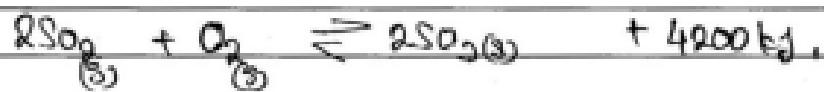
$$P'_{CO_2} = 0.6817 \times 2 = 0.341 \text{ atm}$$

$$P'_{H_2} = 0.6817 \times 2 = 0.341 \text{ atm.}$$

9(c)

Solution.

Data given,



for maximum yield of  $SO_3(g)$ .

(i) Pressure should be increased so as to favour the forward reaction hence maximum amount of  $SO_3$  will be yield.

(ii) Temperature should be increased also in order the reaction to occur more rapidly and high amount of  $SO_3$  to be produced.

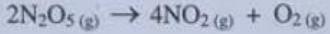
(iii) Concentration; The concentration of  $SO_2$  or Oxygen should be increased so as to favour the forward reaction, thus the production of  $SO_3$  gas.

Extract 9.1 shows correct responses (most of them) by a candidate who scored high marks. However, he/she failed to explain correctly how temperature can be adjusted to maximize the yield of  $SO_3(g)$ .

## 2017 PAST PAPERS - 2

1. (a) Distinguish between the following terms:
- Average rate and instantaneous rate.
  - Elementary step and rate-determining step.
  - Molecularity and order of reaction.
  - Activated complex and activation energy.
- (8 marks)

- (b) Determine the rate law and the rate constant,  $k$ , for the following reaction using the data provided:



Initial $[\text{N}_2\text{O}_5]$ M	Initial rate ( $\text{M s}^{-1}$ )
0.186	$9.68 \times 10^{-4}$
0.372	$19.34 \times 10^{-4}$
1.490	$77.67 \times 10^{-4}$

(6 marks)

- (c) The reaction between methane and diatomic sulphur is given by the equation



At  $550^\circ\text{C}$  the rate constant for this reaction is  $2.2 \text{ L mol}^{-1} \text{ s}^{-1}$  and at  $625^\circ\text{C}$  the rate constant is  $12.8 \text{ L mol}^{-1} \text{ s}^{-1}$ . Calculate  $E_a$  (activation energy) for the reaction.

(6 marks)

1	<p>(i) Average rate is the rate of reactant or product concentration per unit time while instantaneous rate is the rate at which concentration change over a particular period of time that is <math>\text{Average rate} = \frac{\Delta[\text{A}]}{\Delta t}</math></p> <p>Instantaneous rate <math>\frac{\Delta[\text{C}]}{\Delta t} = \frac{[\text{C}]_2 - [\text{C}]_1}{t_2 - t_1}</math></p> <p>(ii) Elementary step is the reaction of a particular step in the reaction mechanism while rate determining step is the slowest step in the reaction mechanism.</p> <p>(iii) Molecularity is the number of molecule that participate in the elementary reaction while order of reaction is the powers of reactant concentration in the rate law.</p> <p>(iv) Activated complex is the compound which has attained activation energy so as to react while activation energy is the minimum energy required by the reacting molecule to react.</p>
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Q. Solution :

First find the order of reaction

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \frac{[\text{N}_2\text{O}_5]_2}{[\text{N}_2\text{O}_5]_1}$$

$$\frac{19.34 \times 10^{-4}}{9.68 \times 10^{-4}} = \frac{(0.372)}{(0.186)}$$

$$2.00 \approx 2 = 2^n \\ 2^1 = 2^n \\ n = 1$$

Therefore the order of reaction is 1.

$$\text{Rate law} = R \propto [\text{N}_2\text{O}_5]^1$$

$$R = k [\text{N}_2\text{O}_5]^1$$

$$\therefore \text{Rate law is } R = k [\text{N}_2\text{O}_5]$$

The rate constant for rate initial rate<sub>1</sub> and concentration<sub>1</sub>

$$R = k [\text{N}_2\text{O}_5]$$

$$9.68 \times 10^{-4} = k (0.186)$$

$$k_1 = \frac{9.68 \times 10^{-4}}{0.186}$$

$$k_1 = 5.204 \times 10^{-3}$$

find  $k_2$

$$= R_2 = k_2 [\text{N}_2\text{O}_5]$$

$$19.34 \times 10^{-4} = k (0.372)$$

$$k_2 = \frac{19.34 \times 10^{-4}}{0.372}$$

	$k_2 = 5.1989 \times 10^{-3}$
	find $k_3 = R_1 = k_1 [N_2O_3]_2$
	$77.67 \times 10^{-4} = k_3 [1.490]$
	$k_3 = \frac{77.67 \times 10^{-4}}{1.490}$
	$k_3 = 5.21275 \times 10^{-3}$
	$K = \frac{k_1 + k_2 + k_3}{3}$
	$\frac{3.2040 \times 10^{-3}}{3} + 5.1989 \times 10^{-3} + 5.21275 \times 10^{-3}$
	$K = 4.205 \times 10^{-3}$
	$\therefore$ the rate constant = $4.205 \times 10^{-3} \text{ s}^{-1}$
(c)	Data given
	$T_1 = 550 + 273K = 823K$
	$T_2 = 625 + 273K = 898K$
	$k_1 = 2.2 \text{ L mol}^{-1}\text{s}^{-1}$
	$k_2 = 12.8 \text{ L mol}^{-1}\text{s}^{-1}$
	$E_a = \text{required}$
	$R = 8.314$
	from $\log \left( \frac{k_1}{k_2} \right) = \frac{E_a}{2.303R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$
	$\log \left( \frac{2.2}{12.8} \right) = \frac{E_a}{2.303 \times 8.314 \times 10^3} \left( \frac{1}{898} - \frac{1}{823} \right)$
	$\log (0.172) = \frac{E_a}{2.303 \times 8.314 \times 739054}$
	$\log (0.172) = \frac{-75 E_a}{14415077188 \times 10^6}$
	$-75 E_a = -10817862.56$
	$-75 \quad -75$
	$E_a = 144238.1675 \text{ J mol}^{-1}$
	$\therefore$ Activation energy = $144.238 \times 10^3 \text{ J mol}^{-1}$ or $144.238 \text{ kJ mol}^{-1}$

In Extract 15.1 the candidate gave clear distinctions of the terms in part (a).

In part (b), he/she applied appropriate formulae, and step by step did all necessary calculations and managed to obtain  $144.23 \text{ kJ mol}^{-1}$  as the activation energy.

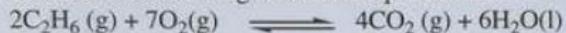
## 2017 PAST PAPERS

10. (a) Differentiate between the following:

- (i) Equilibrium constant,  $K_c$ , and rate constant,  $K$ .
- (ii) Equilibrium position and rate of reaction.

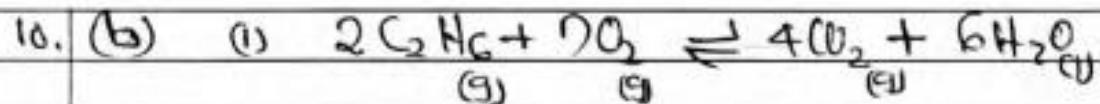
(2 marks)

(b) Consider the following reversible equilibrium:



- (i) Write down the  $K_c$  and  $K_p$  expressions. (1 mark)
- (ii) Derive the relationship between  $K_c$  and  $K_p$ . (3 marks)

(c) A  $7.52\text{ cm}^3$  of a gas H was mixed with  $7.0\text{ cm}^3$  of a gas Q in a one litre flask at  $298\text{ K}$ . At equilibrium,  $10.93\text{ cm}^3$  of gas HQ was formed. Calculate the equilibrium constant,  $K_c$  for the reaction:



$$K_c = \frac{[CO_2]^4}{[C_2H_6]^2 [O_2]^7}$$

$$K_p = \frac{(P(CO_2))^4}{(P(C_2H_6))^2 (P(O_2))^7}$$

(ii) Solution.

$$K_p = \frac{(P(CO_2))^4}{(P(C_2H_6))^2 (P(O_2))^7}$$

from

$$\frac{PV}{V} = nRT \quad \text{where } P = \text{partial pressure.}$$

$$P = [C]RT$$

$$P_{CO_2} = [CO_2]RT$$

$$P_{C_2H_6} = [C_2H_6]RT$$

$$P_{O_2} = [O_2]RT$$

10. (b) (ii)

$$K_p = \frac{([CO_2]^4)}{([C_2H_6]^2([O_2]^7)}$$

$$K_p = \frac{[CO_2]^4}{[C_2H_6]^2[O_2]^7} \times (RT)^{4-(2+7)}$$

$$\text{But } [CO_2]^4 = K_c$$
$$\frac{1}{[C_2H_6]^2[O_2]^7}$$

$$K_p = K_c (RT)^{-5}$$

$$\therefore K_p = K_c RT^{-5}$$

16. (c) Solution:

Let from Avogadro's Law.

$$V \propto n$$

$$7.52 \text{ cm}^3 \text{ of H}_2 = 7.52 \text{ moles of H}_2$$

$$7.0 \text{ cm}^3 \text{ of O}_2 = 7.0 \text{ moles of O}_2$$

$$10.93 \text{ cm}^3 \text{ of H}_2\text{O} = 10.93 \text{ moles of H}_2\text{O}$$



molecules	7.52	7.0	0
change	-x	-x	+2x

at equilibrium.

$$(7.52-x) \quad (7-x) \quad 2x$$

But

$$\frac{2x}{2} = \frac{10.93 \text{ moles of H}_2\text{O}}{2}$$

$$x = 5.465$$

$$\text{moles of H}_2 = 7.52 - 5.465$$

$$= 2.055 \text{ moles}$$

$$\text{moles of O}_2 = 7 - 5.465$$

$$= 1.535 \text{ moles}$$

$$\text{moles of H}_2\text{O} = 10.93 \text{ moles}$$

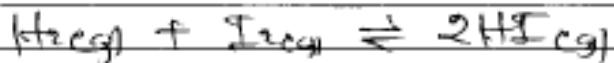
Extract 10.1 shows part (b) and (c) of the candidate's response, whereby he/she managed to write the correct  $K_c$  and  $K_p$  expressions and derived the relationship between  $K_c$  and  $K_p$ . The equilibrium constant ( $K_c$ ) for the given reaction was also calculated correctly.

## 2016 PAST PAPERS

9. (a) (i) Briefly explain the dynamic nature of equilibrium reaction.  
 (ii) Use hydrogen ( $H_2$ ) and iodine ( $I_2$ ) gases which produce hydrogen iodide ( $HI$ ) gas to illustrate the point mentioned in (a)(i). (5 marks)
- (b) (i) Mention the four common stresses explained by Le Chateliers' principle to help maximise the yield of ammonia gas in the Haber process.  
 (ii) The equation for production of ammonia gas is as follows;  
 $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$   $\Delta H^\circ = -92.6 \text{ kJ}$ . From the given equation, explain how maximum yield of ammonia can be achieved. (5 marks)

9(a)(i) The reactor is said to have dynamic nature of equilibrium reaction if the rate of forward and backward reactions are equal but there is continual constant interchange of particles between product side and reactant side.

9(a)(ii)



$$R_f = k_f [H_2][I_2]$$

$$\text{and } R_b = k_b [HI]^2$$

at equilibrium

$$R_f = R_b$$

$$k_f [H_2][I_2] = k_b [HI]^2$$

$$\frac{k_f}{k_b} = \frac{[HI]^2}{[H_2][I_2]}$$

$$K_c = \frac{[HI]^2}{[H_2][I_2]}$$

The reaction appears static externally but in reality

(a) (i) the rate of combination of  $\text{N}_2$  and  $\text{H}_2$  is equal to the rate of decomposition of  $\text{NH}_3$ , and the mixture of either of  $\text{N}_2$  and  $\text{H}_2$  is observed at equilibrium.

- 9(b) (i)
- Lowering temperature of surroundings.
  - Increasing pressure of the system.
  - Using catalyst which is finely divided iron.
  - Increasing concentration of  $\text{H}_2$  and  $\text{N}_2$ .

9(b) (ii) • Lowering temperature.

The reaction being exothermic, so lowering in temperature will favor production of more ammonia. (forward reaction will be favored).

- 9(b) (iii) • Raising pressure
- Since the reaction is accompanied by reduction of volume, increasing pressure favors forward reaction. Hence production of ammonia.
- Conclusion:
- Lower temperature decrease rate of reaction to much the will be taken to get maximum yield also construction of high pressure vessels for carrying out reaction is more expensive, so the following conditions are preferred.
- Temperature about  $450^\circ\text{C}$
  - Pressure of about 1 atm
  - and catalyst (finely divide of iron) will increase the rate of reaction despite the fact that temperature will not be too high.

In Extract 9.1, the candidate correctly explained the dynamic nature of equilibrium reaction and the concept of forward and backward reaction. The candidate mentioned the four common stresses which maximize the yield of ammonia gas in the Haber process.

## 2015 PAST PAPERS

4. (a) Write the equilibrium constant expressions ( $K_c$ ) for the following reactions:
- $2\text{NO}_{2(g)} + 7\text{H}_{2(g)} \rightleftharpoons 2\text{NH}_{3(g)} + 4\text{H}_2\text{O}_{(l)}$
  - $2\text{ZnS}_{(s)} + 3\text{O}_{2(g)} \rightleftharpoons 2\text{ZnO}_{(s)} + 2\text{SO}_{2(g)}$
  - $\text{Br}_{(l)} + \text{H}_{2(g)} \rightleftharpoons \text{HBr}_{(l)}$
  - $\frac{1}{3}\text{N}_{2(g)} + \text{H}_{2(g)} \rightleftharpoons \frac{2}{3}\text{NH}_{3(g)}$
- (4 marks)
- (b) The equilibrium constant ( $K_c$ ) for the reaction  $\text{N}_2\text{O}_4_{(g)} \rightleftharpoons 2\text{NO}_{2(g)}$  is  $4.63 \times 10^{-3}$  at  $25^\circ\text{C}$ . What is the value of  $K_p$  at this temperature? (2.5 marks)
- (c) The following equilibrium constants have been determined for hydrosulphuric acid at  $25^\circ\text{C}$ .
- $$\text{H}_2\text{S}_{(\text{aq})} \rightleftharpoons \text{H}^+_{(\text{aq})} + \text{HS}^-_{(\text{aq})}; \quad K_c = 9.5 \times 10^{-8}$$
- $$\text{HS}^-_{(\text{aq})} \rightleftharpoons \text{H}^+_{(\text{aq})} + \text{S}^{2-}_{(\text{aq})}; \quad K_c = 1.0 \times 10^{-19}$$
- Calculate the equilibrium constant for the following reaction at the same temperature:
- $$\text{H}_2\text{S}_{(\text{aq})} \rightleftharpoons 2\text{H}^+_{(\text{aq})} + \text{S}^{2-}_{(\text{aq})}$$
- (3.5 marks)

4c	$\text{H}_2\text{S}_{(\text{aq})} \rightleftharpoons \text{H}^+_{(\text{aq})} + \text{HS}^-_{(\text{aq})} \quad K_c = 9.5 \times 10^{-8}$ $\text{HS}^-_{(\text{aq})} \rightleftharpoons \text{H}^+_{(\text{aq})} + \text{S}^{2-}_{(\text{aq})} \quad K_c = 1.0 \times 10^{-19}$
----	--

4c	<p>Required to find</p> $\text{H}_2\text{S}^- \rightleftharpoons 2\text{H}^+ + \text{S}^{2-}$ $K_c = \frac{[\text{HS}^-][\text{H}^+]}{[\text{H}_2\text{S}]} \quad \dots \text{as}$ $K_{c_1} = \frac{[\text{HS}^-][\text{H}^+]}{[\text{H}_2\text{S}]} \quad \dots @$ $K_{c_2} = \frac{[\text{S}^{2-}][\text{H}^+]}{[\text{HS}^-]} \quad \dots @$ $K_{c_3} = \frac{[\text{H}^+]^2 [\text{S}^{2-}]}{[\text{H}_2\text{S}]} \quad \dots @$ <p>Multiplying the two equations (i) and (ii)</p> $K_{c_1} \times K_{c_2} = \frac{[\text{HS}^-][\text{H}^+]}{[\text{H}_2\text{S}]} \times \frac{[\text{S}^{2-}][\text{H}^+]}{[\text{HS}^-]}$ $K_{c_1} \times K_{c_2} = \frac{[\text{HS}^-][\text{H}^+] \times [\text{S}^{2-}][\text{H}^+]}{[\text{H}_2\text{S}]} \quad \dots$ $K_{c_1} \times K_{c_2} = \frac{[\text{S}^{2-}][\text{H}^+]^2}{[\text{H}_2\text{S}]} = K_{c_3}$ $K_{c_3} = K_{c_1} \times K_{c_2}$ $= 9.5 \times 10^{-8} \times 1.0 \times 10^{-19}$ $= 9.5 \times 10^{-27}$ <p><math>\therefore</math> The equilibrium constant is <math>9.5 \times 10^{-27}</math></p>
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The work of the candidate shown by Extract 4.1 is an indication that the candidate was competent in Chemical Equilibrium. He/she managed to manipulate the given equations and made appropriate substitutions to obtain the correct value of equilibrium constant.

## 2.0 CHEMICAL KINETICS

### 2020 PAST PAPERS - 2

2. (a) (i) What are the effects of a catalyst on the activation energy of a reaction? (2 marks)  
(ii) Describe how temperature, concentration, light, pressure and surface area can affect the rate of a chemical reaction. (5 marks)
- (b) The decomposition of a hydrogen peroxide at 25°C was studied by titrating portions of the reaction mixture with a standard potassium permanganate solution at different time intervals. The results obtained were tabulated as follows:
- | Volume of KMnO <sub>4</sub> (cm <sup>3</sup> ) | 75 | 47 | 30 | 13 | 7.20 |
|--|----|----|----|----|------|
| Time (min)                                     | 0  | 6  | 9  | 20 | 29   |
- (i) Show that the reaction is a first order.  
(ii) Without using a graph, calculate the rate constant at the given temperature. (9 marks)
- (c) The reaction, NH<sub>2</sub>NO<sub>2</sub>(aq) → N<sub>2</sub>O(g) + H<sub>2</sub>O(l) is a first order with  $k = 2.2 \times 10^{-5}\text{sec}^{-1}$ .  
(i) Find the percentage of NH<sub>2</sub>NO<sub>2</sub> that would be decomposed on heating at 310°C for 90 minutes.  
(ii) If the rate of reaction triples when the temperature is raised from 20°C to 50°C, calculate the activation energy of the reaction in kJ/mol. (4 marks)

(a) i) Positive catalyst lowers the activation energy of the reaction whereas negative catalyst raises the activation energy of the reaction.

ii. → Temperature increases the rate of chemical reaction by increasing the kinetic energy of the reactants and hence increase in their collision frequency.

- Concentration also increases the rate of reaction for, first and higher order of reaction as increase in concentration increases the number of the collisions per second.

iii. - light also increases the rate of reaction of the free radical reactions which require UV light for initiation.

- Pressure also increases the rate of reaction for gaseous reaction. However, it does not alter the rate of reaction for solid and liquid phase reactions.

- Surface area; The larger the surface area of the reactants, the higher the collision frequency and hence the higher the rate of reaction when one of the reactants is solid.

(b) i) From the equation of the first reaction:

$$\ln(A) - \ln(A_0) = -Kt$$

where  $A_0 = 45$ :

at  $t = 6$ ,

$$\ln(44) - \ln(45) = -6K$$

$$-0.467 = -6K$$

$$K_1 = 0.0778 \text{ min}^{-1}$$

When  $t = 9$ ,

$$\ln(30) - \ln(45) = -9K_1$$

$$K_2 = 0.1018 \text{ min}^{-1}$$

also  $t = 20$ :

$$\ln(15) - \ln(45) = -20K_3$$

$$K_3 = 0.0876 \text{ min}^{-1}$$

When  $t = 29$ :

$$\ln(7.40) - \ln(45) = -29K_4$$

$$K_4 = 0.0808 \text{ min}^{-1}$$

∴ Since  $K_1 = K_2 \approx K_3 \gg K_4$ , the reaction is first order.

2b	$K_{\text{cat}} = K_1 + K_2 + K_3 + K_4$
	$\therefore K_{\text{cat}} = (0.0999 + 0.103 + 0.0976 + 0.0808) \text{ min}^{-1}$
	$\therefore K_{\text{cat}} = 0.4840 \text{ min}^{-1}$
2c	From:
	$R = K [N\text{H}_3\text{NO}_3]$
	But
	$\ln A = \ln A_0 = -kt$
	$\ln \left( \frac{A}{A_0} \right) = -kt$
	$\therefore \frac{A}{A_0} = e^{-kt}$
	But $\frac{A}{A_0} = \frac{1 - \text{factor reacted}}{A_0}$
	$\therefore 1 - \text{factor reacted} = e^{-kt}$
	But $\frac{A}{A_0} = \text{factor reacted}$ .
	Fraction decomposed = $1 - \frac{A}{A_0}$
	$= 1 - 0.888$
	$= 0.112$
	% of decomposed = $0.112 \times 100\% = 11.2\%$
	$\therefore 11.2\% \text{ will be decomposed.}$

2c	From Arrhenius equation:
	$\ln K_1 = -\frac{E_A}{RT_1} \ln A \quad \dots \dots (1)$
	$\ln K_2 = -\frac{E_A}{RT_2} \ln A \quad \dots \dots (2)$
	Subtracting eqn (1) from equation (2),
	$\ln \left( \frac{K_2}{K_1} \right) = \frac{E_A}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$
	$\ln \left( \frac{K_2}{K_1} \right) = \frac{E_A}{R} \left( \frac{T_2 - T_1}{T_1 T_2} \right)$
	But,
	$K_2 = 8\text{K} \quad T_2 = 50^\circ\text{C} = 323\text{K}, \quad T_1 = 20^\circ\text{C} = 293\text{K}$

	$\text{E}_a = 2 \cdot 21 \text{ Jmol}^{-1} \text{ K}^{-1}$
	$\ln \frac{K_2}{K_1} = \frac{\text{E}_a}{2 \cdot 21 \text{ Jmol}^{-1} \text{ K}^{-1}} \left( \frac{293 \text{ K} - 273 \text{ K}}{293 \text{ K} \times 273 \text{ K}} \right)$
	$\frac{\ln \frac{K_2}{K_1}}{2 \cdot 21 \cdot 10^3} = \frac{\text{E}_a}{293 \text{ K}}$
	$\text{E}_a = 2 \cdot 21 \cdot 10^3 \text{ Jmol}^{-1} \text{ K}^{-1}$
	<del><math>\text{But } \frac{1}{K_1 \text{ mol}^{-1}} = \frac{1000 \text{ Jmol}^{-1}}{2 \cdot 21 \cdot 10^3 \text{ Jmol}^{-1}}</math></del>
	$= 2 \cdot 21 \cdot 10^3 \text{ K}^{-1} \text{ mol}^{-1}$
	$= 2 \cdot 21 \text{ K}^{-1} \text{ mol}^{-1}$
	$\therefore \text{Rate of uncatalyzed reaction} = 2 \cdot 21 \text{ K}^{-1} \text{ mol}^{-1}$

### Extract 12.1: A sample of correct responses in question 2

## 2019 PAST PAPERS - 2

2. (a) Briefly explain the following; (2 marks)
- (i) Average rate of reaction.
  - (ii) Rate constant (k).
- (b) (i) If you were in-charge of a chemical company, briefly explain why you would prefer a catalyst that works at room temperature rather than heating the reactants to 200 °C. (3 marks)
- (ii) A student defined a catalyst as "a substance that speeds up a reaction without taking part in the reaction." State what is wrong with the definition. (3 marks)
- (c) Explain the following; (6 marks)
- (i) Powdered sugar dissolves faster than crystalline sugar.
  - (ii) It takes more time to cook rice at higher altitudes than low altitudes.
  - (iii) We save fuel when we use a pressure cooker.
  - (iv) There is no difference in cooking time between sea level and higher altitude when we use a pressure cooker at both places.
- (d) Consider the reaction with  $\text{E}_a = 75 \text{ kJmol}^{-1}$  at 293 K. When a catalyst is used in the same reaction at 20 °C, its  $\text{E}_a$  is lowered to 20 kJmol<sup>-1</sup>. Calculate how fast is the catalyzed reaction with respect to uncatalyzed reaction. (9 marks)

2a i) Average rate of reaction - Is the amount of products formed per time for the completion of the reaction.  
It is dependent on temperature, concentration of reactants and surface area of reactants.

2a ii) Rate constant ( $k$ ) - Is a temperature dependant constant which is given by the ratio between the rate of a reaction and the product of concentrations each raised to their order according to the rate law.

b i) Because the catalyst would enable the reaction to take place at a lower temperature which would make the energy requirements less and the process would be more economical.

ii) She is wrong about catalysts not taking part in the reaction because they do but they just remain unchanged at the end of the reaction. Also, catalysts she is also wrong about catalysts only speeding up reactions as there are catalysts which reduce the speed of a reaction.

2c (iv) Yes, since the pressure cooker maintains the same pressure at all altitudes therefore heat used will be the same and the cooking time will also be similar at both places.

d. Given.

$$\epsilon_a = 75 \text{ kJ/mol}^{-1}$$

$$T_1 = 293 \text{ K.}$$

$$T_2 = 292 \text{ K.}$$

$$\epsilon_{a_1} = 20 \text{ kJ/mol}$$

for un-catalysed reaction,  
recall Arrhenius equation,

$$K = A e^{-\frac{\epsilon_a}{RT}}$$

$$K_1 = A e^{-\frac{\epsilon_a}{RT_1}}$$

$$\ln K_1 = \ln A + \ln e^{-\frac{\epsilon_a}{RT_1}}$$

$$\ln K_1 = \ln A - \frac{\epsilon_a}{RT_1} \quad \dots \dots \dots \textcircled{i}$$

for catalysed reaction,

$$\ln K_2 = \ln A - \frac{\epsilon_{a_1}}{RT_2} \quad \dots \dots \dots \textcircled{ii}$$

taking equation \textcircled{i} minus equation \textcircled{ii}

$$\ln K_1 - \ln K_2 = - \frac{\epsilon_a}{RT_1} + \frac{\epsilon_{a_1}}{RT_2}$$

$$\ln \frac{K_1}{K_2} = \frac{1}{RT_2} (\epsilon_{a_1} - \epsilon_a)$$

$$\ln \frac{K_1}{K_2} = 1 \left( \frac{(20 - 75) \times 10^3}{331 \times 293} \right)$$

$$\ln \frac{K_1}{K_2} = -22.59$$

$$\frac{K_1}{K_2} = e^{-22.59}$$

2d.  $\frac{K_1}{K_2} = 1.548 \times 10^{-10}$

$$K_2 = K_1$$

$$1.548 \times 10^{-10}$$

$$K_1 = 6.46 \times 10^9 \text{ K.}$$

$\therefore$  The catalysed reaction is  $6.46 \times 10^9$  times faster than the uncatalysed reaction.

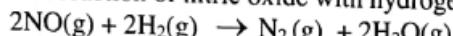
Extract 16.2: A sample of correct responses in question 2.

## 2018 PAST PAPERS - 2

I. (a) Define the following:

- |                           |                                |
|---------------------------|--------------------------------|
| (i) Rate of reaction.     | (ii) Rate constant.            |
| (iii) Reaction mechanism. | (iv) Molecularity of reaction. |
| (v) Zero order reaction.  | (vi) Half-life. (6 marks)      |

(b) The reaction of nitric oxide with hydrogen at 1280 °C is given by the equation



This reaction was studied and the following results were obtained:

Experiment	Initial [NO](M)	Initial [H <sub>2</sub> ](M)	Initial rate (M/s)
1	$5 \times 10^{-3}$	$2 \times 10^{-3}$	$1.3 \times 10^{-5}$
2	$10 \times 10^{-3}$	$2 \times 10^{-3}$	$5 \times 10^{-5}$
3	$10 \times 10^{-3}$	$4 \times 10^{-3}$	$10 \times 10^{-5}$

- (i) Determine the order with respect to each reactant and the overall order of the reaction.  
(ii) Establish the rate law for the reaction.  
(iii) Calculate the rate constant. (7 marks)

(c) The conversion of cyclopropane to propene in the gas phase is a first order reaction with a rate constant of  $6.7 \times 10^{-4} \text{ s}^{-1}$  at 500 °C.

- (i) If the initial concentration of cyclopropane is 0.25 M, what will be the concentration after 8.8 minutes?  
(ii) How long will it take for the concentration of cyclopropane to decrease from 0.25 M to 0.15 M?  
(iii) How long will it take to convert 74% of the starting material? (7 marks)

i) Rate of reaction is the change in the concentration of the reactants in a given time interval.

$$\text{Rate} = \frac{\Delta C}{\Delta t} \quad \Delta C - \text{change in concentration}$$
$$= \frac{\text{in}}{\Delta t - \text{change in time}}$$

ii) Rate constant is a temperature dependent fundamental factor which gives the relationship between the rate of reaction and the concentration of reactants.

$$\frac{R}{C} = k$$
$$k - \text{rate constant.}$$

iii) Reaction mechanism is the steps which are involved in the occurrence of a chemical reaction.

iv) Molecularity of reaction is the total number of reactant molecules taking part in a chemical reaction.

v) Zero order reaction. It is a chemical reaction whose rate is independent of the concentration of reactants.

vij Half life is the time taken half of the amount or fraction present to form product.

byjy From;  $R = k[N_0]^{x} [H_2]^y$

$$1, \quad 1.3 \times 10^{-5} = k(5 \times 10^{-3})^x (2 \times 10^{-3})^y$$

$$2, \quad 5 \times 10^{-5} = k(10 \times 10^{-3})^x (2 \times 10^{-3})^y$$

$$3, \quad 10 \times 10^{-5} = k(10 \times 10^{-3})^x (4 \times 10^{-3})^y$$

for x ; take  $2 \div 1$

$$\frac{5 \times 10^{-5}}{1.3 \times 10^{-5}} = \frac{k(10 \times 10^{-3})^x}{k(5 \times 10^{-3})^x} \cdot \frac{(2 \times 10^{-3})^y}{(2 \times 10^{-3})^y}$$

$$\frac{5}{1.3} = \left( \frac{10 \times 10^{-3}}{5 \times 10^{-3}} \right)^x$$

$$\frac{5}{1.3} = 2^x$$

$$\frac{\log \frac{5}{1.3}}{\log 2} = x \quad x = 2$$

for  $y$ , take  $2 \div 3$

$$\frac{5 \times 10^{-3}}{10 \times 10^{-3}} = k \left( \frac{10 \times 10^3}{1 \times 10^3} \right)^x \left( \frac{2 \times 10^{-3}}{4 \times 10^{-3}} \right)^y$$

$$\frac{5}{10} = \left( \frac{2}{4} \right)^y$$

$$0.5 = 0.5^y \quad y = 1$$

order of reaction with respect to  $[H_2]$   
was 2

order of reaction with respect to  $[N_2]$   
was 1

$$\text{Overall order} = 2 + 1 = 3$$

The overall order of reaction over 3

$$y = k [N_2]^x [H_2]^y$$

$$x = 2$$

$$y = 1$$

then take law

$$R = k [N_2]^2 [H_2]$$

iii)

$$R = k[N_2]^2[H_2]$$

consider experiment 3

$$10 \times 10^{-5} = k(10 \times 10^{-3})^2 \times (4 \times 10^{-1})$$

$$k = \frac{10 \times 10^{-5}}{(10 \times 10^{-3})^2 \times (4 \times 10^{-1})}$$

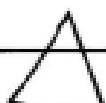
$$M^2$$

$$k = 250 \text{ m}^{-2} \text{s}^{-1}$$

$\longrightarrow$

The rate constant is  $250 \text{ m}^{-2} \text{s}^{-1}$

g)  $k = 6.7 \times 10^{-4} \text{s}^{-1}$



j)

$$a = 0.25 \text{ m}$$

$$t = 9.1 \times 60 = 529 \text{ s}$$

$$a - x = ?$$

$$\log \left( \frac{a}{a-x} \right) = \frac{kt}{2.303}$$

$$\log \left( \frac{0.25}{a-x} \right) = \frac{6.7 \times 10^{-4} \times 528}{2.303}$$

$$\log \left( \frac{0.25}{a-x} \right) = 1.5 + \left( \frac{6.7 \times 10^{-4} \times 528}{2.303} \right)$$

$$\frac{0.25}{a-x} = 1.424$$

$$a-x = 0.25$$

$$1.424$$

$$a-x = 0.1756 \text{ M}$$

The concentration of Cyclopropanes after 8.8 minutes is 0.1756 M

by  $a = 0.25 \text{ M}$   
 $a-x = 0.15 \text{ M}$

$$t = ?$$

$$k = 6.7 \times 10^{-4} \text{ s}^{-1}$$

$$\log \left( \frac{a}{a-x} \right) = \frac{kt}{2.303}$$

$$t = \frac{\log\left(\frac{a}{a-x}\right) \times 2.303}{k}$$

$$t = \frac{\log\left(\frac{0.20}{0.15}\right) \times 2.303}{6.7 \times 10^{-4}}$$

$$t = 762.56 \text{ s} \approx 12.71 \text{ minutes}$$

It will take 762.56 second or 12.71 minutes for the conversion.

(iii)  $a = 100\%$   
 $x = 74\%$

$$a-x = 100 - 74 = 26\%$$

$$t = ?$$

$$k = 6.7 \times 10^{-4} \text{ s}^{-1}$$

From

$$t = \frac{\log\left(\frac{a}{a-x}\right) \times 2.303}{k}$$

$$t = \frac{\log\left(\frac{100}{26}\right) \times 2.303}{6.7 \times 10^{-4}}$$

$$t = 2010.92 \text{ s} \approx 33.515 \text{ min}$$

Extract 15.1 is a set of responses from a candidate who correctly defined the terms and related the initial concentrations to the reaction rates. He/she correctly deduced the orders of the reactions given and finally used correct formulae to perform the required calculations.

## 2016 PAST PAPERS - 2

1. (a) Derive an expression relating  $K_c$  and  $K_p$  for the decomposition of phosphorus pentachloride.
- $$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$
- (8 marks)

(b) The equilibrium constant for the reaction  $2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$  is  $K_1 = 4.17 \times 10^{-34}$  at  $25^\circ C$  and the equilibrium constant for the reaction  $I_2(g) + Cl_2(g) \rightleftharpoons 2ICl(g)$  is  $K_2 = 2.1 \times 10^5$  at  $25^\circ C$ . Calculate the equilibrium constant for the reaction,

$$2HCl(g) + I_2(g) \rightleftharpoons 2ICl(g) + H_2(g)$$

(7 marks)

- (c) Briefly explain five factors that affect rate of chemical reaction. (5 marks)

1.	<p>(a) Required to derive an expression relating <math>K_c</math> and <math>K_p</math> for ;</p> $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g).$ <p><u>1<sup>st</sup> Case</u></p> <p>Write <math>K_c</math> expression in terms of concentration .</p> $K_c = \frac{[Products]}{[Reactants]}$ <p><u>2<sup>nd</sup> Case</u></p> <p>Find <math>K_p</math> expression in terms of partial pressure</p> $K_p = \frac{(P' PCl_3)(P' Cl_2)}{(P' PCl_5)}$ <p><u>3<sup>rd</sup> Case</u></p> <p>Relate partial pressures in terms of other variables from the Ideal gas equation .</p> $PV = nRT$ $P = \left(\frac{n}{V}\right)RT \quad \text{where } \frac{n}{V} = [ ] \text{, concentration}$ $P = [ ] RT$ <p>Introduce (iii) to (ii)</p>
----	---

1. (a)

$$k_p = \frac{([PC_3]RT)([C_6]RT)}{[PC_5]RT}$$

$$k_p = \frac{[PC_3][C_6]RT}{[PC_5]}$$

from (i)  $k_c = \frac{[PC_3][C_6]}{[PC_5]}$

Then;

$$k_p = k_c RT$$

$\therefore$  the relating equation for  $k_p$  and  $k_c$   $= k_p = k_c RT$

$$\text{or } k_c = k_p (RT)^{-1}$$

In Extract 15.1 the candidate correctly showed all the necessary steps in the process of deriving the expression relating  $K_c$  and  $K_p$ .

## 2015 PAST PAPERS - 2

3. (a) Explain four factors that can affect the rate of a chemical reaction. (4 marks)
- (b) The rate constant for the first order reaction is  $3.46 \times 10^{-2} \text{ s}^{-1}$  at 298 K. What is the rate constant at 350 K if the activation energy for the reaction is  $50.2 \text{ kJ mol}^{-1}$ ? (5 marks)
- (c) Nitrogen dioxide ( $\text{NO}_2$ ) reacts with fluorine ( $\text{F}_2$ ) to yield nitryl fluoride ( $\text{NO}_2\text{F}$ ) according to the equation  $2\text{NO}_{2(g)} + \text{F}_{2(g)} \rightarrow 2\text{NO}_{2}\text{F}_{(g)}$ . Write the reaction in terms of rate of  
 (i) formation of  $\text{NO}_2\text{F}$   
 (ii) disappearance of  $\text{F}_2$   
 (iii) disappearance of  $\text{NO}_2$ . (3 marks)
- (d) Hydrolysis of ethyl acetate by NaOH using equal concentrations of the reactants was studied by titrating  $25 \text{ cm}^3$  of the reaction mixture at different intervals against standard acid. Using data in the following table, establish that the reaction is a second order.

Time (minute)	0	5	15	25
Volume of acid used ( $\text{cm}^3$ )	16.00	10.24	6.13	4.32

(8 marks)

39 The factor affecting the rate of chemical reaction are : Concentration  
 • Temperature  
 • Catalyst  
 • Surface area of reactant.  
 • Concentration and rate of reaction.  
 The rate of chemical reaction increases or the concentration increases and decreases as the concentration decreases.  
 The rate of reaction increases as the temperature increases and decreases as temperature decreases because temperature increases the kinetic energy of the molecules to collide faster.  
 Catalyst and rate of reaction.  
 Catalyst increases the rate of reaction because it lowers the activation energy of the reaction.

• Surface area and rate of reaction  
The rate of reaction is fast to the reaction which provide large area of the reaction for take place

3b Solubus

Dg kq.

Let

$$k_1 = \text{rate constant} \quad K_1 = 3.46 \times 10^{-2} \text{ s}^{-1} \quad \text{at } T_1 = 298 \text{ K}$$

$$K_2 = ? \quad \text{at } T_2 = 350 \text{ K}$$

Let activation energy be - E

$$E = 50.2 \text{ kJ mol}^{-1}$$

$$E = 50200 \text{ J}$$

$$\text{from } k = A e^{-E/RT}$$

3b applying ln.

$$\ln k = \ln A - \frac{E}{RT} \ln f$$

$$\ln k_1 = -\frac{E}{RT_1} + \ln A$$

$$\ln k_1 = -\frac{E}{RT_1} + \ln A - (1)$$

$$\ln k_2 = -\frac{E}{RT_2} + \ln A - (2)$$

equation (1) - (2)

$$\ln k_2 - \ln k_1 = -\frac{E}{RT_2} + \frac{E}{RT_1}$$

$$\ln \left( \frac{k_2}{k_1} \right) = \frac{E}{R} \left[ \frac{1}{T_1} - \frac{1}{T_2} \right]$$

$$\ln \left( \frac{k_2}{3.46 \times 10^{-2}} \right) = \frac{50200}{8.31} \left[ \frac{1}{298} - \frac{1}{350} \right]$$

$$\ln \left( \frac{k_2}{3.46 \times 10^{-2}} \right) = 3.011769484$$

$$K_2 = 2.3233299 \times 10^{-2}$$

$$\therefore K_2 = 0.3031872155^{-1}$$

Q.C. 5 cm



Q.C.i Rate in terms of formation of  $\text{NO}_2f$  =  $\frac{1}{2} \frac{d[\text{NO}_2f]}{dt}$

Q.C.ii Rate in terms of disappearance of  $f_2$

IS  
Rate =  $-\frac{d[f_2]}{dt}$

Q.C.iii Rate in terms of disappearance of  $\text{NO}_2$

IS  
Rate =  $-\frac{1}{2} \frac{d[\text{NO}_2]}{dt}$

Q.d - Solution

if A be amount from second order.

$$\frac{dA}{dt} = -k A^2$$

$$\int_{A_0}^A \frac{dA}{(A)^2} = -k \int_{t_0}^t dt$$

$$\frac{1}{A} - \frac{1}{A_0} = -kt$$

$$\frac{1}{A} = kt + \frac{1}{A_0}$$

but A = V

$$\frac{1}{V} = kt + \frac{1}{V_0}$$

Table of results		
Time (s)	$\nu$ (mol)	$\nu/v$ ( $\text{m}^{-3}$ )
0	16	0.0625
5	10.24	0.0977
15	6.17	0.1631
25	4.02	0.2315
<u>Since the graph is the straight line hence the reaction is the second order</u>		

In Extract 3.1, the candidate gave correct factors that affect the rate of a chemical reaction, calculated correctly the rate constant and wrote properly the rate expressions and established that, the hydrolysis of ethyl acetate by NaOH is a second order.

### 3.0 ELECTRO CHEMISTRY

#### 2021 PAST PAPERS- 2

1. (a) (i) Distinguish between an electrolytic cell and a galvanic cell. (1 mark)
- (ii) Lead rods are placed in each of the following solutions:  $\text{AgNO}_3$ ,  $\text{CuSO}_4$ ,  $\text{FeSO}_4$  and  $\text{ZnSO}_4$ . In which solution would you expect a coating of one metal on lead rod? Give a reason. (Given  $\epsilon^\circ \text{ Zn}^{2+}/\text{Zn} = -0.76 \text{ V}$ ,  $\epsilon^\circ \text{ Pb}^{2+}/\text{Pb} = -0.13 \text{ V}$ ,  $\epsilon^\circ \text{ Cu}^{2+}/\text{Cu} = +0.34 \text{ V}$ ,  $\epsilon^\circ \text{ Ag}^+/\text{Ag} = +0.81 \text{ V}$  and  $\epsilon^\circ \text{ Fe}^{2+}/\text{Fe} = -0.44 \text{ V}$ ). (3 marks)
- (b) Why the Kohlrausch's law of independent migration of ions applies at infinite dilution of electrolytes? Briefly explain. (1 mark)
- (c) Show that for the cell reaction  
 $\text{Zn(s)} + \text{Cu}^{2+}(\text{aq}) \longrightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu(s)}$  with different cell concentrations and the temperature 298 K, the cell potential is given by;  $\epsilon = \epsilon^\circ_{\text{cell}} - 0.0295 \log \frac{[\text{Zn}^{2+}(\text{aq})]}{[\text{Cu}^{2+}(\text{aq})]}$  (7 marks)
- (d) A galvanic cell consists of metallic zinc and lead plates immersed in 0.1 M  $\text{Zn}(\text{NO}_3)_2$  and 0.02 M  $\text{Pb}(\text{NO}_3)_2$  solution.  
(i) Write the chemical equations for the electrode reactions.  
(ii) Write the cell notation for the reaction.  
(iii) Calculate the e.m.f of the cell. (8 marks)

1a) Electrolytic cell is one which uses electricity for occurrence of spontaneous chemical reaction while galvanic cell is a cell which uses chemical reactions to produce electricity.

1b) This is because at infinite dilution there is higher molar conductivity of the electrolyte due to ions of the metal electrode being comparatively lighter than those of the solution in which the metal electrode is contained, thus easily migration of ions due to its high molar conductivity.

1c) So,  
Consider the cell reaction  
 $\text{Zinc} + \text{Cu}^{2+}(\text{aq}) \longrightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu(s)}$

From Gibbs free energy

$$\Delta G = -RT \log Q \quad \text{(1)}$$

Whereas

- $\Delta G$  is Gibbs free energy
- $T$  is Temperature of 298K or 298.15
- $R$  is Number of mole transfers in chemical reaction
- $F$  is Faraday's Constant
- $Q$  is Reaction Quotient.

But,

$$\Delta G = E_{\text{cell}} - E_{\text{cell}}^\circ \quad \text{(2)}$$

Substitute eqn (1) into (2)

$$E_{\text{cell}} - E_{\text{cell}}^\circ = -\frac{RT}{F} \log Q \quad \text{(3)}$$

But,

$$Q = \frac{[\text{Zn}^{2+}]_{\text{final}}}{[\text{Zn}^{2+}]_{\text{initial}}} \quad \text{(4)}$$

So,

$$Q = \frac{[\text{Cu}^{2+}]_{\text{final}}}{[\text{Cu}^{2+}]_{\text{initial}}} \quad \text{(5)}$$

1c) Substit. (i) into (ii)

So,

$$E_{\text{cell}} - E^{\circ}_{\text{cell}} = \frac{-RT}{nF} \log \frac{[Zn^{2+}_{\text{cath}}]}{[Cu^{2+}_{\text{cath}}]}$$

So,

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{-RT}{nF} \log \frac{[Zn^{2+}_{\text{cath}}]}{[Cu^{2+}_{\text{cath}}]}$$

$$\text{But, } R = 8.315 \text{ J/mole}$$

$$F = 96500 \text{ C/mole}$$

$$T = 298 \text{ K}$$

So,

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{8.31 \times 298}{96500} \log \frac{[Zn^{2+}_{\text{cath}}]}{[Cu^{2+}_{\text{cath}}]}$$

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{0.0591}{n} \log \frac{[Zn^{2+}_{\text{cath}}]}{[Cu^{2+}_{\text{cath}}]}$$

But,  $E^{\circ}_{\text{cell}}$  = Reduction Reaction  
Oxidation Half Reaction

$Zn(s) +$



Also, Reduction Half Reaction

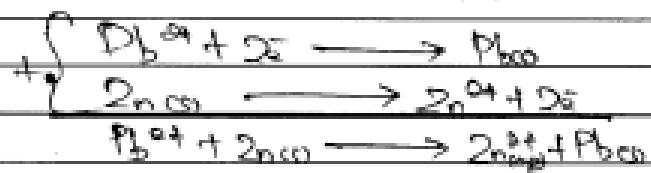


Overall equation



$E_c$	$E_{\text{cell}}$
	$n=2$
	So, From eqn ⑦ Substitute The Value Of $n$
	$E_{\text{cell}}$
	$E_{\text{cell}} = E^{\circ}_{\text{cell}} - 0.0591 \log \frac{[Zn^{2+}]_{\text{cell}}}{[Cu^{2+}]_{\text{cell}}}$
	$E_{\text{cell}} = E^{\circ}_{\text{cell}} - 0.0295 \log \frac{[Zn^{2+}]_{\text{cell}}}{[Cu^{2+}]_{\text{cell}}}$
	$\therefore E_{\text{cell}} = E^{\circ}_{\text{cell}} - 0.0295 \log \frac{[Zn^{2+}]_{\text{cell}}}{[Cu^{2+}]_{\text{cell}}} \rightarrow \text{Hence shown}$
d) i)	$\text{Q.}$
	Given
	$E^{\circ} [Zn^{2+}] = 0.1 \text{ V}$ Also $E^{\circ} Zn^{2+}/Zn = 0.76 \text{ V}$
	$[Pb^{2+}] = 0.02 \text{ M}$ $E^{\circ} Pb^{2+}/Pb = -0.13 \text{ V}$
	For chemical equations:
	Cathodic (Reduction) half-cell Reaction:
	$Pb^{2+}_{\text{cell}} + 2e^- \longrightarrow Pb_{\text{cell}}$
	Also,
	Oxidation (Anode) half-cell Reaction
	$Zn_{\text{cell}} \longrightarrow Zn^{2+}_{\text{cell}} + 2e^-$

i) The Overall Cell equation



ii) The Cell notation for the reaction is



iii)

Required:  $E_{\text{cell}}$

From Given data:

$$[\text{Zn}^{2+}] = 0.14$$

$$[\text{Pb}^{2+}] = 0.02M$$

$$E^{\circ} \text{Zn}^{2+}/\text{Zn} = -0.76V$$

$$E^{\circ} \text{Pb}^{2+}/\text{Pb} = -0.13V$$

$$E_{\text{cell}} = \text{Required}$$

From Formula:

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{0.0591}{n} \log \frac{[\text{Oxidation}]}{[\text{Reduction}]}$$

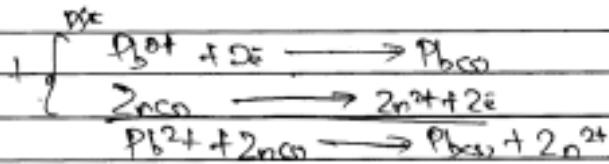
Reqd?

$$\begin{aligned}
 E^{\circ}_{\text{cell}} &= E^{\circ}_{\text{cathode}} + E^{\circ}_{\text{anode}} \\
 &= (-0.13 - -0.76)V \\
 &= 0.63V
 \end{aligned}$$

$$E^{\circ}_{\text{cell}} = 0.63V$$

1)  $\text{PbO}_2$

From Chemical Reaction in d(i)



Thus,

$$n = 2$$

$$\text{A.G. } [\text{Oxidation}] = [2\text{N}^{2+}] = 0.1 \text{ M}$$

$$[\text{Reduction}] = [\text{Pb}^{2+}] = 0.002 \text{ M}$$

∴ Recall from formula...

$$E_{\text{cell}} = \text{---}$$

$$E_{\text{cell}} = 0.63 - 0.0591 \log \left( \frac{0.1}{0.002} \right)$$

$$E_{\text{cell}} = 0.609 \text{ V}$$

$$\therefore E_{\text{m.f. of the cell}} = 0.609 \text{ V}$$

#### Extract 11.1 A sample of correct responses in question 1

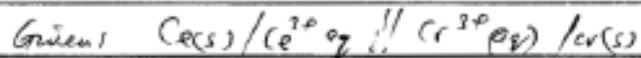
### 2019 PAST PAPERS- 2

3. (a) Describe the following;  
(i) The standard electrode potential. (3 marks)  
(ii) Electrochemical series.
- (b) (i) Write the equation showing how the electromotive force(e.m.f) of the following cell changes with their ions concentration.  
 $\text{Ce(s)} \mid \text{Ce}^{3+}(\text{aq}) \parallel \text{Cr}^{3+}(\text{aq}) \mid \text{Cr(s)}$ .  
(ii) Calculate the value of the equilibrium constant for the following reaction given that;  
 $E^\circ \text{Ce}^{3+}/\text{Ce} = -2.33 \text{ V}$  and  $E^\circ \text{Cr}^{3+}/\text{Cr} = -0.41 \text{ V}$ .  
 $\text{Ce(s)} + \text{Cr}^{3+}(\text{aq}) \rightleftharpoons \text{Ce}^{3+}(\text{aq}) + \text{Cr(s)}$ . (9 marks)
- (c) (i) Write down the expression for the cell e.m.f for the reaction below;  
 $\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{s})$ .  
(ii) State why the oxidizing power of manganate (VII) ions in (i) is quite sensitive to the concentration of hydrogen ions. (4 marks)
- (d) Briefly explain any four methods for rusting prevention. (4 marks)

3) Standard electrode potential is the electric potential generated on the electrode when it is in contact with 1M (1molar) solution of its ions at standard conditions of temperature and pressure i.e.  $25^{\circ}\text{C}$  and 1 atm.

4) Electrochemical series is the arrangement of elements in order of increasing reduction potential.

Ex)  $\text{Ce}^{3+}/\text{Ce}^{2+}$



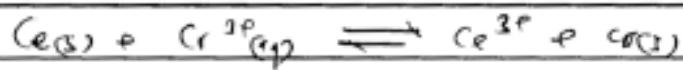
$$\text{Emf of cell} = E_{\text{cell}}^{\circ} - \frac{0.0591}{3} \log \frac{[\text{Ce}^{2+}]}{[\text{Cr}^{3+}]}$$

$$\therefore E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{3} \log \frac{[\text{Ce}^{2+}]}{[\text{Cr}^{3+}]}$$

At equilibrium  $E_{\text{cell}} = 0$ .

$$\therefore 0 = E_{\text{cell}}^{\circ} - \frac{0.0591}{3} \log \frac{[\text{Ce}^{2+}]}{[\text{Cr}^{3+}]}$$

$$E_{\text{cell}} = \frac{0.0591 \log \left[ \frac{\text{Ce}^{3+}}{\text{Ce}^{2+}} \right]}{3}$$



$$k_c = \frac{[\text{Ce}^{3+}]}{[\text{Cr}^{3+}]}$$

$$\therefore E_{\text{cell}}^{\circ} = \frac{0.0591 \log k_c}{3}$$

$$\begin{aligned} E_{\text{cell}}^{\circ} &= E^{\ell} - E^{\text{i}} \\ &= -0.41 \text{ V} - -2.33 \text{ V} \\ &\approx 1.92 \text{ V.} \end{aligned}$$

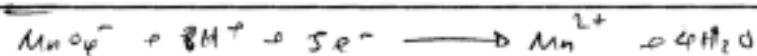
$$\therefore 1.92 = \frac{0.0591 \log k_c}{3}$$

$$\therefore \log^{-1} \left( \frac{3 \times 1.92}{0.0591} \right) = 10c$$

$$10c = 2.897 \times 10^{97}$$

$$\therefore \text{Equilibrium constant} = 2.897 \times 10^{97}$$

17/17 Given



$$3 \text{ c) } E_{\text{cell}} = E_{\text{mox}} - \frac{0.0591}{5} \log \frac{P_{\text{O}_2}}{P_{\text{O}_2^{\text{ref}}}}$$

$$E_{\text{cell}} = E_{\text{mox}} - \frac{0.0591}{5} \log \frac{[\text{Mn}^{2+}]}{[\text{Mn}^{4+}] [\text{H}^+]^8}$$

iv) The oxidising power of manganese (ii) ions is sensitive to concentration of hydrogen ions because the effect of concentration of hydrogen ions is eight times the effect of concentration of other components.

d) Methods of rusting prevention:-

i) Coating metal with zinc (zinc plating) This is the method which involves coating the metal with a thin sheet of zinc. It is more effective but cannot be used for food storage appliances.

ii) Tin plating - This involves coating the metal (iron) with tin. Tin prevents the contact of water and air thus prevent the process of rusting.

iii) Painting - This involves covering an iron (metal) with several layers of rust resisting paints which prevent the contact of iron with water and air.

iv) Using plastics covers to cover the metal surface.

**Extract 17.1:** A sample of correct responses in question 3.

## 2018 PAST PAPERS- 2

2. (a) (i) Briefly explain the term oxidation-reduction reaction. (2 marks)
- (ii) The reaction between dichromate (VI) ions and chloride ions in acidic solution yields chlorine and chromium (III) ions as shown in the following unbalanced equation:  
 $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{Cr}^{3+}(\text{aq}) + \text{Cl}_2(\text{g})$

Derive the balanced half-reaction equations and overall net equation for this redox reaction.

(3 marks)

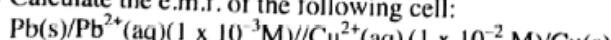
- (b) State which of the following are oxidation-reduction reactions:

- (i)  $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$   
(ii)  $\text{Zn}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{ZnCl}_2(\text{aq}) + \text{H}_2(\text{g})$   
(iii)  $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow 2\text{CrO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
(iv)  $\text{O}_3(\text{g}) + \text{NO}(\text{g}) \rightarrow \text{O}_2(\text{g}) + \text{NO}_2(\text{g})$

(2 marks)

- (c) Identify the oxidizing agent, the reducing agent, the substance being oxidized and the substance being reduced in 2(b) (i - iv). (6 marks)

- (d) Calculate the e.m.f. of the following cell:

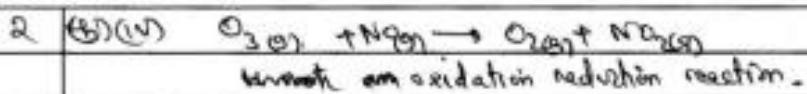


Given the following standard reduction potentials:

$$\text{Pb}^{2+}/\text{Pb}, E^\circ = -0.126 \text{ V}; \quad \text{Cu}^{2+}/\text{Cu}, E^\circ = 0.34 \text{ V}$$

(7 marks)

2 (a) (i)	Oxidation half equation  $2\text{Cl}^-(\text{aq}) \longrightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$
	Reduction half equation  <del><math>\text{Cr}_2\text{O}_7^{2-}(\text{aq}) \longrightarrow \text{Cr}^{3+}(\text{aq})</math></del> $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) \longrightarrow 2\text{Cr}^{3+}(\text{aq})$
	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$
	Adding the two half equations: $3 \left[ 2\text{Cl}^-(\text{aq}) \longrightarrow \text{Cl}_2(\text{g}) + 2\text{e}^- \right]$ $1 \left[ \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) \right]$ $+ \left[ \begin{array}{l} \text{Cr}^{3+}(\text{aq}) \longrightarrow 3\text{Cl}_2(\text{g}) + 6\text{e}^- \\ \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) \end{array} \right]$
	Overall equation: $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 6\text{Cl}^-(\text{aq}) + 14\text{H}^+(\text{aq}) \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) + 3\text{Cl}_2(\text{g})$
	$\therefore$ Overall net equation $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 6\text{Cl}^-(\text{aq}) + 14\text{H}^+(\text{aq}) \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) + 3\text{Cl}_2(\text{g})$
(b) (i)	$\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$ - oxidation-reduction reaction
(ii)	$2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\text{g})$ oxidation-reduction reaction
(iii)	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 2\text{OH}^-(\text{aq}) \longrightarrow 2\text{CrO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$ , oxidation-reduction reaction



(c)

(i) oxidizing agent:  $O_2(g)$

Reducing agent:  $CH_4(g)$

Substance oxidized:  $CH_4(g)$  to  $CO_2(g)$

Substance reduced:  $O_2(g)$  to  $H_2O(g)$

(ii) Oxidizing agent: Zinc Helium

Reducing agent: Hot  $Zn(s)$

Substance oxidized:  $Zn(s)$  to  $ZnCl_2(aq)$

Substance reduced:  $He(g)$  to  $H_2(g)$

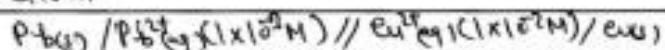
(iii) Oxidizing agent:  $O_3(g)$

Reducing agent:  $NO(g)$

Substance oxidized:  $NO(g)$  to  $NO_2(g)$

Substance reduced:  $O_2(g)$  to  $O_2(g)$

(d) Given:



$$Pb^{2+}/Pb E^\circ = -0.126V \quad Cu^{2+}/Cu E^\circ = 0.34V$$

$$\text{E}_{\text{cell}} = \text{E}_{\text{cathode}} - \text{E}_{\text{anode}}$$

Cathode  $\rightarrow Cu^{2+}/Cu$ .

Anode  $Pb^{2+}/Pb$ .

$$\text{E}_{\text{cell}} = \text{E}_{\text{cathode}} - \text{E}_{\text{anode}}$$

but

$$\text{E} = \text{E}^\circ \pm \frac{RT \ln C}{nF}$$

2	(Q) $E_{\text{cell}} = \frac{E_{\text{Cu}}^{\circ} - E_{\text{Pb}}^{\circ}}{nF}$
	$n=2 \quad F = 96500 \text{ C mol}^{-1}$
	$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
	$T = 25^\circ\text{C} = 298 \text{ K}, \quad c = 1 \times 10^2 \text{ M.}$
	$E_{\text{Cu}} = 0.34 \text{ V} + \frac{8.31 \times 298 \ln(1 \times 10^2)}{2 \times 96500 \text{ C mol}^{-1}}$
	$E_{\text{Cu}} = 0.34 \text{ V} - 0.089 \text{ V}$
	$E_{\text{Cu}} = 0.251 \text{ V.}$
	Also $E_{\text{Pb}} = \frac{E_{\text{Pb}}^{\circ} + RT \ln c}{nF}$
	$n=2 \quad c = 1 \times 10^2 \text{ M.} \quad E_{\text{Pb}}^{\circ} = -0.126 \text{ V}$
	$E_{\text{Pb}} = -0.126 \text{ V} + \frac{8.31 \times 298 \ln(1 \times 10^2)}{2 \times 96500 \text{ C mol}^{-1}}$
	$E_{\text{Pb}} = -0.126 \text{ V} - 0.0886 \text{ V}$
	$E_{\text{Pb}} = -0.2146 \text{ V.}$
	Now, $E_{\text{cell}} = E_{\text{Cu}} - E_{\text{Pb}} = 0.251 \text{ V} - (-0.2146 \text{ V})$
	$E_{\text{cell}} = 0.4656 \text{ V}$
	$\therefore$ e.m.f of the cell is $0.4656 \text{ V.}$

2	(a)(i) Oxidation-Reduction reaction
	In the chemical reaction in which oxidation and reduction occurs at the same time. It involves loss or gainning of electrons, loss of oxygen or gainning of oxygen, removal of hydrogen, addition of hydrogen, increase or decrease in oxidation state.
	Example: $\text{MnO}_4^- + 5\text{Fe}^{2+} + 8\text{H}^+ \rightarrow \text{Mn}^{2+} + 5\text{Fe}^{3+} + 4\text{H}_2\text{O}$
	- $\text{MnO}_4^-$ is an oxidizing agent and it has reduced to $\text{Mn}^{2+}$
	- $\text{Fe}^{2+}$ is a reducing agent and it has oxidized to $\text{Fe}^{3+}$ .

Extract 16.1 shows that the candidate correctly applied the concept of oxidation-reduction to derive the overall net equation and succeed to point out both the oxidizing agents and reducing agents as required. Furthermore, he/she calculated the exact value of e.m.f of the cell which was 0.4955 V.

## 2017 PAST PAPERS- 2

2. (a) Give the oxidation numbers of all atoms in the following compounds:

- (i) Cl<sub>2</sub>
- (ii) Cl<sub>2</sub>O<sub>7</sub>
- (iii) Na<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>.

(3 marks)

(b) Balance the following equations for redox reactions:

- (i) Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>(aq) + Br<sup>-</sup>(aq) + H<sup>+</sup>(aq) → Cr<sup>3+</sup>(aq) + H<sub>2</sub>O(l) + Br<sub>2</sub>(s)
- (ii) MnO<sub>4</sub><sup>-</sup>(aq) + I<sup>-</sup>(aq) → MnO<sub>2</sub>(s) + I<sub>2</sub>(s) in basic medium.

(5 marks)

(c) 25 cm<sup>3</sup> containing 3.16 g per litre of KMnO<sub>4</sub> were acidified and mixed with 20 cm<sup>3</sup> of KI solution. The liberated iodine was titrated against Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.10H<sub>2</sub>O solution containing 31.64 g/L.

- (i) Write balanced ionic equations representing the reactions described.
- (ii) Calculate the molarity of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.10H<sub>2</sub>O if 26.70 cm<sup>3</sup> of it were required to reach the end point.

(6 marks)

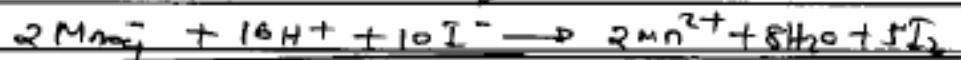
(d) The molar conductivities at infinite dilution at 25 °C of NH<sub>4</sub>Cl, NaOH and NaCl are 129.8, 217.4 and 108.9 S cm<sup>2</sup> mol<sup>-1</sup>, respectively. For 0.01 M NH<sub>4</sub>OH molar conductance is 9.33 S cm<sup>2</sup> mol<sup>-1</sup>. Calculate the ionization constant of NH<sub>4</sub>OH.

(6 marks)

Page 2 of 7

02.	<p>(e) (i) MnO<sub>4</sub><sup>-</sup> + I<sup>-</sup> <math>\xrightarrow{H^+}</math> Mn<sup>2+</sup> + I<sub>2</sub></p> <p>Consider, reduction half reaction</p> <p>MnO<sub>4</sub><sup>-</sup> <math>\longrightarrow</math> Mn<sup>2+</sup> + 4H<sub>2</sub>O,</p> <p>MnO<sub>4</sub><sup>-</sup> + 8H<sup>+</sup> <math>\longrightarrow</math> Mn<sup>2+</sup> + 4H<sub>2</sub>O.</p> <p>MnO<sub>4</sub><sup>-</sup> + 8H<sup>+</sup> + 5e<sup>-</sup> <math>\longrightarrow</math> Mn<sup>2+</sup> + 4H<sub>2</sub>O — (i)</p> <p>Also,</p> <p>Consider, oxidation half reaction,</p> <p>I<sup>-</sup> <math>\longrightarrow</math> I<sub>2</sub></p> <p>2I<sup>-</sup> <math>\longrightarrow</math> I<sub>2</sub> + 2e<sup>-</sup> — (ii)</p> <p>Add eqn (i) and (ii) in such a way that number of electrons are eliminated,</p> <p>2 { MnO<sub>4</sub><sup>-</sup> + 8H<sup>+</sup> + 5e<sup>-</sup> <math>\longrightarrow</math> Mn<sup>2+</sup> + 4H<sub>2</sub>O</p> <p>5 { 2I<sup>-</sup> <math>\longrightarrow</math> I<sub>2</sub> + 2e<sup>-</sup></p> <p>2MnO<sub>4</sub><sup>-</sup> + 16H<sup>+</sup> + 10I<sup>-</sup> <math>\longrightarrow</math> 2Mn<sup>2+</sup> + 8H<sub>2</sub>O + 5I<sub>2</sub>.</p>
-----	--

$\therefore$  The first ionic equation is



Also, second reaction is,

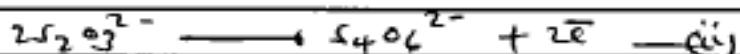
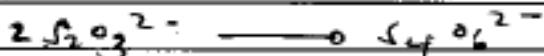


Consider reduction half reaction.

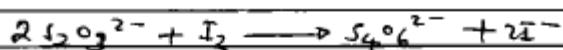
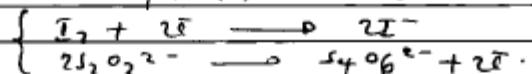


Also,

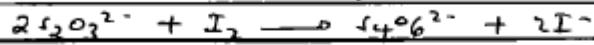
Consider, the oxidation half reaction.



Q2. (c) (i) Add eqn (i) and (ii)



$\therefore$  The second ionic equation is



Q2. (c) (ii) given:-

$$\text{Concentration of KMnO}_4 = 3.16\text{ g/l}$$

$$\text{Volume of KMnO}_4 = 25\text{ cm}^3$$

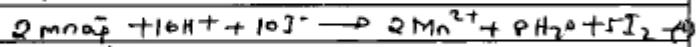
$$\text{Volume of Na}_2\text{S}_2\text{O}_3 = 26.70\text{ cm}^3$$

Asked:-

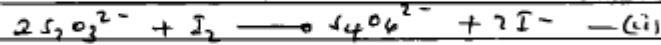
The molarity of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 10\text{H}_2\text{O}$

From,

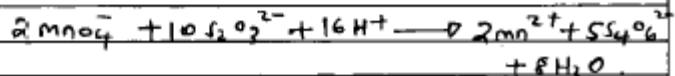
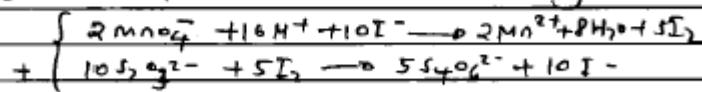
1st reaction,



and 2nd reaction,



Multiply eqn (ii) by 5 then add to eqn (i)  
in order to eliminate iodine gas.



$\therefore$  From the overall reaction, mole Ratio

$$\text{KMnO}_4 : \text{Na}_2\text{S}_2\text{O}_3 = 2 : 10$$

Q2. (c) (ii) From,

$$\text{Molar mass of } \text{KMnO}_4 = 39 + 55 + (4 \times 16) \\ = 158 \text{ g/mol}$$

So,

$$\text{Molarity of } \text{KMnO}_4 = \frac{\text{Concentration}}{\text{molar mass}} \\ = \frac{2.16 \text{ g/litre}}{158 \text{ g/mol}}$$

$$\text{Molarity of } \text{KMnO}_4, M_1 = 0.02 \text{ M}$$

$$\text{Volume of } \text{KMnO}_4, V_1 = 25 \text{ cm}^3$$

$$\text{Volume of } \text{Na}_2\text{S}_2\text{O}_3 \cdot 10\text{H}_2\text{O}, V_2 = 26.7 \text{ cm}^3$$

From,

$$\frac{M_1 V_1}{M_2 V_2} = \frac{n_1}{n_2}$$

$$M_2 = \frac{M_1 V_1 n_2}{V_2 \cdot n_1}$$

$$M_2 = \frac{0.02 \times 25 \times 10}{26.7 \times 2}$$

$$M_2 = 0.0936 \text{ M.}$$

Where,  $M_2$  = Molarity of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 10\text{H}_2\text{O}$

∴ The molarity of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 10\text{H}_2\text{O}$  is  
0.0936 M.

Q2. (d) Given,

Molar conductivity at infinite dilution

$$\text{of, NH}_4\text{Cl} = 129.8 \text{ S cm}^2 \text{ mol}^{-1}$$

$$\text{NaOH} = 217.4 \text{ S cm}^2 \text{ mol}^{-1}$$

$$Q2. (d) \lambda_{NaCl} = 108.9 \text{ } S \text{ cm}^2 \text{ mol}^{-1}$$

Also,

$$\text{Concentration of NH}_4\text{OH} = 0.01 \text{ M.}$$

$$\text{molar conductance of NH}_4\text{OH} = 9.335 \text{ } S \text{ cm}^2 \text{ mol}^{-1}.$$

Asked:-

Fornization constant of NH<sub>4</sub>OH ( $K_b$ )

from,

Kohlrausch's law of mobility,

$$\lambda_{AB} = \lambda_{A^+} + \lambda_{B^-}$$

$$\therefore \lambda_{NH_4OH} = \lambda_{NH_4^+} + \lambda_{OH^-} - \lambda_{Na^+}$$

$$\lambda_{\infty} = (129.8 + 217.4 - 108.9) \text{ } S \text{ cm}^2 \text{ mol}^{-1}$$

$$\lambda_{\infty} \text{NH}_4\text{OH} = 238.3 \text{ } S \text{ cm}^2 \text{ mol}^{-1}$$

$\therefore$  Molar conductivities of NH<sub>4</sub>OH at infinite dilution is 238.3  $S \text{ cm}^2 \text{ mol}^{-1}$ .

From,

$$\text{degree of dissociation, } \alpha = \frac{\lambda_m}{\lambda_\infty}$$

$$= 9.33 \text{ } S \text{ cm}^2 \text{ mol}^{-1}$$

$$238 \text{ } S \text{ cm}^2 \text{ mol}^{-1}$$

$$\alpha = 0.0392$$

also, from, Ostwald's dilution law,

$$\alpha = \sqrt{\frac{k_b}{c}}$$

$$\alpha^2 = \frac{k_b}{c}$$

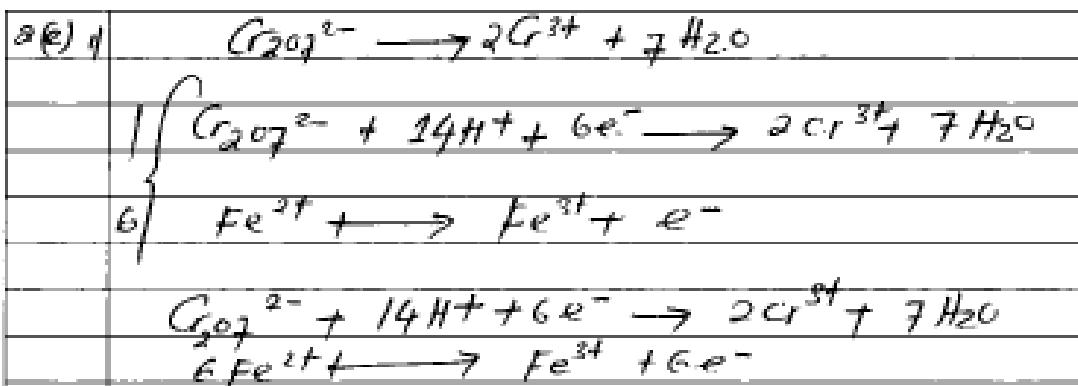
02.	(d) So,
	$k_b = \alpha^2 \cdot c$
	$k_b = (0.039)^2 \times 0.01$
	$k_b = 1.5329 \times 10^{-5}$
	$\therefore$ ionization constant of $\text{NH}_4\text{OH}$ is $1.53 \times 10^{-5}$ .

Extract 16.1 shows part (c) and (d) of a candidate's response. The candidate used the appropriate formula to calculate the molarity of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 10\text{H}_2\text{O}$  and ionization constant of  $\text{NH}_4\text{OH}$ .

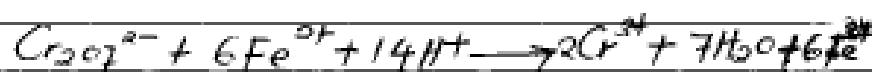
## 2016 PAST PAPERS- 2

2. (a) Define the following terms:  
 (i) Standard electrode potential.  
 (ii) Redox reaction.  
 (iii) Corrosion. (3 marks)
- (b) Briefly explain how voltaic cells differ from electrolytic cells. (2 marks)
- (c) Write a balanced ionic equation and identify the oxidants and reductants in each of the following chemical reactions:  
 (i) Iron (II) sulphate solution reacts with an acidified potassium dichromate solution.  
 (ii) Iodine and sodium thiosulphate solution react together.  
 (iii) Copper (II) sulphate solution and potassium iodide solution react together. (9 marks)
- (d) Explain the function of moisture in the rusting process. (1 mark)
- (e) Using the following half reactions,  
 $\text{Au}^{3+} + 3\text{e}^- \rightarrow \text{Au}$   $E^\circ = 1.50 \text{ v}$   
 $\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{NO} + 2\text{H}_2\text{O}$   $E^\circ = 0.96 \text{ v}$   
 predict whether 1 M  $\text{HNO}_3$  will dissolve gold metal to form a 1 M  $\text{Au}^{3+}$  solution. (5 marks)

2(c)	<p style="text-align: center;"><u>Solution</u></p>
i)	<p>Standard electrode potential <math>\rightarrow</math> It is the potential difference of the electrode relative to the standard hydrogen electrode at the concentration of 1M, Pressure of 1 atm and temperature of 25°C.</p>
ii)	<p>Pedox reaction <math>\rightarrow</math> It is the chemical reaction in which both oxidation and reduction reaction occurs simultaneously.</p>
iii)	<p>Corrosion <math>\rightarrow</math> It is the deteriorating/decay of the metal surface due to the chemical reaction occurring on its surface.</p>
iv)	<p>Voltaic cells <math>\rightarrow</math> These are the cells which use the chemical reaction of the chemical solution to generate the electric power example the galvanic cell but;</p>
	<p>Electrolytic cells <math>\rightarrow</math> These are the cell which use the electric power to allow the chemical reaction to take place.</p>
v)	<p>Iron (II) sulphate and <math>K_2Cr_2O_7</math> half reactions</p>
	$Fe^{2+} \longrightarrow Fe^{3+} + e^-$
	$Cr_2O_7^{2-} \longrightarrow Cr^{3+}$



Overall reaction



Oxidant from Potassium dichromate ( $\text{Cr}_2\text{O}_7^{2-}$ )

Reductant from Iron (ii) sulphate ( $\text{Fe}^{2+}$ )

2(f) ii) Iodine and Sodium thiosulphate

$\text{I}_2$  and  $\text{Na}_2\text{S}_2\text{O}_3$

Hall reaction



Overall reaction

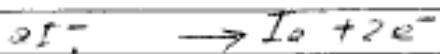
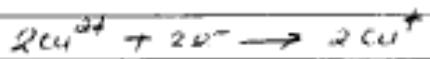
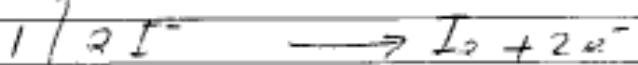
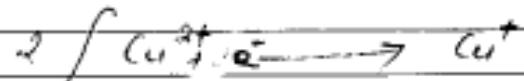


Oxidant : Iodine ( $\text{I}_2$ )

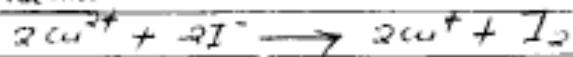
Reductant from Sodium thiosulphate ( $\text{S}_2\text{O}_3^{2-}$ )

a(c) iii) Copper (II) sulphate and Potassium iodide

$\text{CuSO}_4 (\text{Cu}^{2+})$  and  $\text{KI} (\text{I}^-)$   
Half reaction



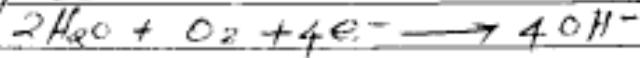
Overall reaction



Oxidant; from Copper(II)sulphate ( $\text{Cu}^{2+}$  ion)

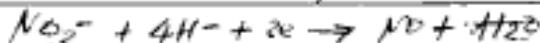
Reductant from Potassium iodide ( $\text{I}^-$  ion)

2(d) The Function of Moisture in the rusting process  
is to provide the water and oxygen which  
are the major components taking chemical  
reaction at the cathode reaction during  
rusting process



2(e)

Cathode;  $\text{Au}^{3+} + 3\text{e}^- \rightarrow \text{Au} E^\circ = 1.5 \text{V}$



2(e)	<u>solution</u>
	reverse the reaction $\text{Au}^{3+} + 3\text{e}^- \rightarrow \text{Au}$
	$\text{Au} \rightarrow \text{Au}^{3+} + 3\text{e}^- \quad E^\circ = -1.5 \text{ V}$
	$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{NO} + 2\text{H}_2\text{O} \quad E^\circ = 0.96 \text{ V}$
	adding the two half reactions
	$\text{NO}_3^- + 4\text{H}^+ + \text{Au} \rightarrow \text{Au}^{3+} + \text{NO} + 2\text{H}_2\text{O} \quad E^\circ = -0.54$
	Since the $E^\circ_{\text{red}}$ of the reaction is negative ( $-0.54$ ) 1M of $\text{HNO}_3$ will not dissolve gold metal Because: Gold is the strong reducing agent than $\text{HNO}_3$ (weak reducing agent). that during chemical reaction they would react.

In Extract 16.2, the candidate correctly responded to all the parts of the question. She/he gave correct definitions and formulated the required equations and then substituted the appropriate data, and finally obtain the required solution.

## 2015 PAST PAPERS- 2

(8 marks)

4. (a) Define the following terms:

- (i) Electric double layer
- (ii) Electrode potential
- (iii) Standard electrode potential.

(3 marks)

- (b) Given that  $Zn^{2+}/Zn E^\ominus = -0.76 \text{ V}$  and  $Cu^{2+}/Cu E^\ominus = 0.337 \text{ V}$ ;

- (i) Calculate the e.m.f. of the cell.
- (ii) Briefly explain what would be the effects on the e.m.f. if the  $[Zn^{2+}]$  or  $[Cu^{2+}]$  is altered.
- (iii) What will be the e.m.f. of the cell if zinc electrode system is replaced by silver electrode system given that  $Ag^+/Ag E^\ominus = 0.80 \text{ V}$ ?

(9 marks)

- (c) (i) State Faraday's laws of electrolysis.

- (ii) List at least two importance of the second law of electrolysis.

- (iii) An electric current is passed through three cells in series containing solutions of copper sulphate, silver nitrate and potassium iodide respectively. What weights of silver and iodine will be liberated when 2 g of copper is being deposited?

(8 marks)

Qn 4g) v. Electric double layer :- Is the layer formed between negative ions formed by the electrode and the positive ions aligned on the surface of the electrode.

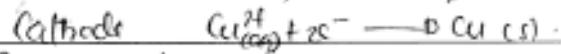
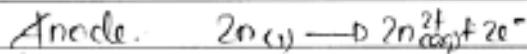
Qn 4a) ii) Electrode potential :- Is the emf produced in the electrodes containing its hydrated ion.

Qn 4g) iii) Standard pot. electrode potential :- Is the emf produced when 1 mole of electrodes are dipped into 1 mole of concentrated electrolyte solution at 25°C and standard temperature and pressure.

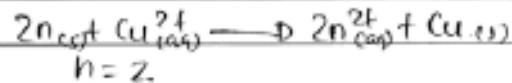
Qn 4b). v. soln.

From

$$E_{\text{cell}} = \frac{\varepsilon^{\theta}_{\text{cell}}}{n} - 0.059 \log Q.$$



Overall reaction.



$$n=2$$

$$\text{But } E^{\theta}_{\text{cell}} = E^{\theta}_{\text{cathode}} - E^{\theta}_{\text{anode}}$$

$$= E^{\theta}_{\text{Cu}} - E^{\theta}_{\text{Zn}}$$

$$= 0.337 - -0.76$$

$$E^{\theta}_{\text{cell}} = 1.097 \text{ V}$$

Qn 4b) vi. From

$$E_{\text{cell}} = \frac{\varepsilon^{\theta}_{\text{cell}}}{n} - 0.059 \log \frac{(\text{oxidation})}{(\text{reduction})}$$

Therefore  $\varepsilon^{\theta}_{\text{cell}} = 1.097$  and  $n=2$ .

$$E_{\text{cell}} = 1.097 - \frac{0.059}{2} \log \frac{[2n^{2+}]}{[\text{Cu}^{2+}]}$$

$$E_{\text{cell}} = 1.097 - 0.0295 \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

NOTE: The concentration of  $[Zn^{2+}]$  and  $[Cu^{2+}]$  are not provided

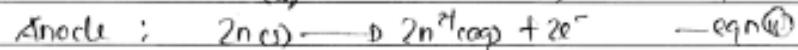
$$\therefore E^{\circ}_{\text{cell}} = 1.097 \text{ V}$$

$$\text{and } E_{\text{cell}} = 1.097 - 0.0295 \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

NOTE:

There is a difference between emf of the cell and standard emf of a cell.

Qn4b) If the  $[Zn^{2+}]$  or  $[Cu^{2+}]$  is altered from the cathodic and anodic equation,



Consider Anodic reaction

If the concentration of  $Zn^{2+}$  is increased the reaction at anode will favour backward reaction and hence emf of the cell will be lowered but when  $[Zn^{2+}]$  is reduced the reaction will shift more forward to produce enough  $Zn^{2+}$  and hence emf of the cell is increased.

Also

Consider Cathodic reaction

If the concentration of  $Cu^{2+}$  is increased the reaction will shift more forward and hence the emf of the cell will

Qn4b) If the  $[Cu^{2+}]$  is decreased the reaction will shift more backward and hence the emf of the cell will be lowered

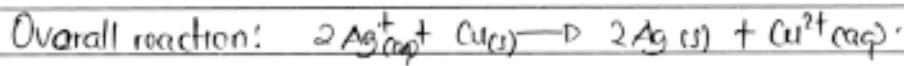
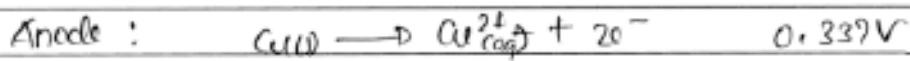
Qn4b) soln.

When  $Zn$  electrode is replaced with  $Ag$  electrode the galvanic cell will change and copper electrode will be at anode and silver at cathode since copper is more reactive than silver.

Hence

$$E^{\circ}_{\text{cell}} = E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}}$$

Consider reactions:



$$E^\theta_{\text{cell}} = (0.80 - 0.337)V$$

$$E^\theta_{\text{cell.}} = 0.463V$$

$$\therefore E^\theta_{\text{cell}} = 0.463V$$

$$E_{\text{cell}} = E^\theta_{\text{cell}} - \frac{0.059}{n} \log \frac{[\text{Cu}^{2+}]}{[\text{Ag}^+]^2}$$

$$n = 2$$

$$= 0.4630 - \frac{0.059}{2} \log \frac{[\text{Cu}^{2+}]}{[\text{Ag}^+]^2}$$

$$E_{\text{cell.}} = 0.463 - 0.0295 \log \frac{[\text{Cu}^{2+}]}{[\text{Ag}^+]^2}$$

NOTE: There is a difference between  $E_{\text{cell}}$  of the cell and standard  $E^\theta_{\text{cell}}$  of the cell.  $[\text{Cu}^{2+}]$  and  $[\text{Ag}^+]$  are not 1

Qn4c) ✓ 1<sup>st</sup> Faraday's law of electrolysis states that,  
"The amount of mass liberated during electrolysis process is directly proportional to the quantity of electricity passed"

$$\text{i.e. } m \propto Q.$$

$$m \propto It$$

2<sup>nd</sup> Faraday's law of electrolysis states that,  
When the same quantity of electricity is passed through the same electrodes but different electrolytes, the amount of substance mass liberated is directly proportional to its equivalent weight

$$\text{i.e. } m \propto E$$

Ques 11 Two importance of the 2<sup>nd</sup> law of electrolysis.

- It helps to determine the amount of substance liberated when its equivalent is known.
- It gives the amount of quantity liberated by using Faraday's constant.

Ques 12 soln.

Given  $M_{\text{copper}} = 2\text{g}$ .

Solution:

$\text{CuSO}_4$ ,  $\text{AgNO}_3$  and  $\text{KI}$ .

From 2<sup>nd</sup> law of Faraday's electrolysis.

$$m \propto E$$

$$m = KE$$

$$\frac{m}{E} = K \text{ (constant of proportionality)}$$

$$\frac{M_{\text{copper}}}{E_{\text{copper}}} = \frac{M_{\text{silver}}}{E_{\text{silver}}}$$

$$\frac{M_{\text{copper}}}{M_{\text{silver}}} = \frac{E_{\text{copper}}}{E_{\text{silver}}}$$

$$\text{But } E_{\text{copper}} = \frac{Mr}{\text{charge}} = \frac{63.5}{2} = 31.75$$

$$E_{\text{silver}} = \frac{Mr}{\text{charge}} = \frac{108}{1} = 108$$

$$M_{\text{copper}} = 2$$

$$M_{\text{silver}} = \frac{M_{\text{copper}} \cdot E_{\text{silver}}}{E_{\text{copper}}}$$

$$= \frac{2 \times 108}{31.75}$$

$$M_{\text{silver}} = 6.8\text{g.}$$

∴ The mass of silver is 6.8g.

Qn 2(c), iii.

From,

$$\frac{E_{\text{copper}}}{E_{\text{iodine}}} = \frac{M_{\text{copper}}}{M_{\text{iodine}}}$$

$$E_{\text{iodine}} = \frac{129}{1} = 129$$

$$E_{\text{copper}} = 31.75$$

$$M_{\text{copper}} = 29$$

$$M_{\text{iodine}} = \frac{M_{\text{copper}} \cdot E_{\text{iodine}}}{E_{\text{copper}}}$$

$$= \frac{29 \times 129}{31.75}$$

$$M_{\text{iodine}} = 89$$

∴ The mass of iodine is 89.

- i. The weight of silver and iodine liberated  
is 6.8g and 8g respectively.

The answer in Extract 4.1 is an indication that the candidate had clear knowledge on Electrochemistry, since all parts of the question are presented accurate answers clearly according to the requirement of the question.

## 4.0 ACIDS, BASES, AND SALTS

### 2020 PAST PAPERS - 2

3. (a) Calculate the pH of a solution obtained when:
- 1.0 cm<sup>3</sup> of 0.10 M NaOH is added to 100 cm of 0.001 M HCl.
  - 1.0 cm<sup>3</sup> of 1.0 M HCl is added to 1000 cm<sup>3</sup> of a solution mixture prepared by dissolving 0.04 moles of CH<sub>3</sub>COOH. Use  $K_a(\text{CH}_3\text{COOH}) = 1.84 \times 10^{-5}$ . (10 marks)
- (b) How does Bronsted-Lowry concept account for the relative strength of acid-base conjugate pairs? (4 marks)
- (c) Indicate the acid-base conjugate pairs in each of the following equilibria:
- $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$
  - $\text{H}_2\text{SO}_4 + \text{H}_2\text{O} \rightleftharpoons \text{HSO}_4^- + \text{H}_3\text{O}^+$
  - $\text{AH} + \text{H}_2\text{O} \rightleftharpoons \text{A}^- + \text{H}_3\text{O}^+$
- (6 marks)

3(a)	<p>Details:</p> <p>molarity of NaOH (<math>M_b</math>) = 0.10M</p> <p>① Volume of 100% NaOH (<math>V_{NaOH}</math>) = 100 cm<sup>3</sup>.</p> <p>Volume of acid (<math>V_{HCl}</math>) = 100 cm<sup>3</sup> (100 cm<sup>3</sup>)</p> <p>molarity of acid (<math>M_a</math>) = 0.001 M.</p> <p><math>\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}</math></p> <p>(1 : 1)</p> <p>number of moles of NaOH = molarity <math>\times</math> volume of NaOH  <math>= 0.10 \times \frac{1}{1000}</math>  <math>= 1 \times 10^{-4}</math> moles.</p> <p>number of moles of HCl = molarity of HCl <math>\times</math> volume of HCl  <math>= 0.001 \times \frac{1}{1000}</math>  <math>= 1 \times 10^{-4}</math> moles.</p> <p>Since number of moles of HCl = number of moles of NaOH  <math>\therefore [\text{H}^+] = [\text{OH}^-] = 10^{-7} \text{ mol/dm}^3</math></p> <p><math>\text{pH} = -\log(10^{-7})</math>  <math>\text{pH} = 7</math>  <math>\therefore \text{pH of solution is } 7</math></p> <p>② <math>\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+</math></p> <p>At t=0      1.0      0      0</p> <p>At            1 - <math>\alpha</math>      <math>\alpha</math>      <math>\alpha</math></p> <p>equilibrium;</p> <p>concentration    <math>(1 - \alpha)c</math>      <math>\alpha c</math>      <math>\alpha c</math></p> <p>at equilibrium;</p> <p><math>[\text{H}^+] = \alpha c</math></p> <p>But <math>\alpha = \sqrt{\frac{k_a}{c}}</math></p> <p><math>[\text{H}^+] = \sqrt{k_a c}</math></p> <p>But concentration is = <math>\frac{\text{number of moles}}{\text{volume of solution}}</math></p> <p>Concentration (<math>c</math>) = <math>0.04</math>  <math>1</math></p> <p>3(a)</p> <p><math>c = 0.04 \text{ M}</math></p> <p><math>[\text{H}^+] = \sqrt{1.84 \times 10^{-5} \times 0.04}</math></p> <p><math>[\text{H}^+] = 8.579 \times 10^{-4} \text{ M}</math></p>
------	--

2b)	<p><u>Bronsted-Lowry acids;</u></p> <p>Acid; <u>any hydrogen containing species that is capable of donating proton to <math>H^+</math> to bases</u></p> <p>Bases <u>are any species that are capable of accepting <math>H^+</math> protons donated by acids.</u></p> <p>According to Bronsted-Lowry theory to account for relative strengths of acid-base conjugate pair as follows:</p> <ul style="list-style-type: none"> <li>⇒ If the acid is strong, its conjugate base is weak.</li> </ul> <p>Example:</p> $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$ <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;">strong acid</td> <td style="text-align: center;">weak conjugate base</td> </tr> </table> <ul style="list-style-type: none"> <li>⇒ If the acid is weak, its conjugate base is strong.</li> </ul> <p>Example:</p> $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;">weak acid</td> <td style="text-align: center;">strong conjugate base</td> </tr> </table> <ul style="list-style-type: none"> <li>⇒ If the base is strong its conjugate acid is weak.</li> </ul> <ul style="list-style-type: none"> <li>⇒ If the base is weak its conjugate acid is strong.</li> </ul> <p>Example:</p> $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;">weak base</td> <td style="text-align: center;">strong conjugate acid</td> </tr> </table>	strong acid	weak conjugate base	weak acid	strong conjugate base	weak base	strong conjugate acid
strong acid	weak conjugate base						
weak acid	strong conjugate base						
weak base	strong conjugate acid						
2c)	$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ <p style="text-align: center;"><u>conjugate pair</u></p>						
	<p><u><math>NH_4^+/NH_3</math> and <math>H_3O^+/H_2O</math> - conjugate acid-base pairs.</u></p>						
2d)	$H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$ <p style="text-align: center;"><u>conjugate pair</u></p>						
	<p><u><math>H_2CO_3/HCO_3^-</math> and <math>H_3O^+/H_2O</math> - conjugate acid-base pair</u></p>						
2e)	$A^- + H_2O \rightleftharpoons AH + OH^-$ <p style="text-align: center;"><u>conjugate pair</u></p>						
	<p><u><math>AH/A^-</math> and <math>H_3O^+/H_2O</math> - conjugate acid-base pair</u></p>						

Extract 13.1: A sample of correct responses in question 3

2019 PAST PAPERS - 2

1. (a) Define the following terms giving one example in each;

  - A conjugate base.
  - A conjugate acid base pair.
  - A conjugate acid.
  - Arrhenius acid.

(4 marks)

(b) Label the conjugate acids and bases in these reactions;

  - $\text{S}^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \rightleftharpoons \text{HS}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$
  - $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
  - $\text{NH}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{OH}^-(\text{aq})$
  - $\text{CH}_3\text{COOH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$

(4 marks)

(c) Calculate the concentration of hydrogen ions and hydroxide ions in 0.01 M solution of

  - hydrochloric acid.
  - acetic acid ( $\alpha$  for  $\text{CH}_3\text{COOH}$  is 5%).

(4 marks)

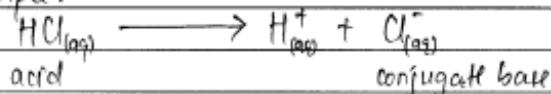
(d) The  $K_w$  of water at 25 °C and 65 °C are  $10^{-14} \text{ mol}^2\text{dm}^{-6}$  and  $2.92 \times 10^{-14} \text{ mol}^2\text{dm}^{-6}$  respectively.

  - State the effect of temperature in the dissociation of water.
  - Calculate the  $[\text{H}^+]$  at 65 °C.
  - Find the pH of water at 65 °C.
  - Calculate the pH of water under neutral condition at 65 °C.

(8 marks)

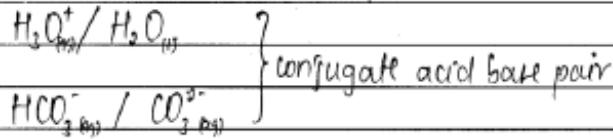
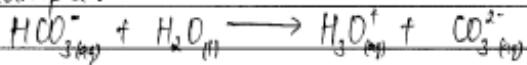
Q1. A conjugate base is the anion of an acid formed acid dissociates to form:

Example:



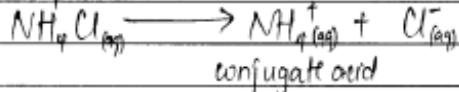
ii) A conjugate acid base pair is a pair of cation and anion formed when ions dissociate in water.

Example:



vii) A conjugate acid is a cation formed when a base dissociates into its ions when dissolved in water.

Example:



Q1.	<p>iv) Arrhenius acid is the substance that gives hydrogen proton as the only positive ion when dissolved in water.</p> <p>Example:</p>
	$\text{HND}_3 \xrightarrow{\text{(aq)}} \text{H}^+_{\text{(aq)}} + \text{ND}_2^-_{\text{(aq)}}$
b)	$\text{HS}^{2-} + \text{H}_3\text{O}^+ \rightleftharpoons \text{HS}^- + \text{H}_2\text{O}_{\text{(l)}}$ conjugate acid      conjugate base
i)	$\text{NH}_4^+ + \text{H}_2\text{O}_{\text{(l)}} \rightleftharpoons \text{NH}_3 \text{ }_{\text{(aq)}} + \text{H}_3\text{O}^+_{\text{(aq)}}$ conjugate base      conjugate acid
ii)	$\text{NH}_3 \text{ }_{\text{(aq)}} + \text{H}_2\text{O}_{\text{(l)}} \rightleftharpoons \text{NH}_2 \text{ }_{\text{(aq)}} + \text{OH}^-_{\text{(aq)}}$ conjugate acid      conjugate base
iv)	$\text{CH}_3\text{COOH} \text{ }_{\text{(aq)}} + \text{H}_2\text{O}_{\text{(l)}} \rightleftharpoons \text{CH}_3\text{COO}^-_{\text{(aq)}} + \text{H}_3\text{O}^+_{\text{(aq)}}$ conjugate base      conjugate acid
c)	$\text{HCl} \xrightarrow{\text{(aq)}} \text{H}^+_{\text{(aq)}} + \text{Cl}^-_{\text{(aq)}}$ $0.07 \text{ M} \qquad \qquad \qquad 0.07 \text{ M}$
	$[\text{H}^+] = [\text{HCl}] = 0.07 \text{ M}$
	$\text{pH} = -\log [\text{H}^+]$
	$\text{pH} = -\log (0.07)$
	$\text{pH} = 2$

$$01^c \Rightarrow pH + pOH = pK_w$$

$$pOH = pK_w - pH$$

$$pOH = 14 - 2$$

$$pOH = 12$$

but,

$$pOH = -\log [OH^-]$$

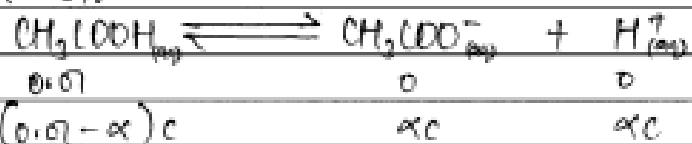
$$[OH^-] = 10^{-pOH}$$

$$= 10^{-12}$$

$$[OH^-] = 1 \times 10^{-12} M$$

$$\therefore [H^+] = 0.01 M \quad \text{and} \quad [OH^-] = 1 \times 10^{-12} M$$

$$\therefore \alpha = 5\%$$



$$[H^+] = \alpha c$$

$$= \frac{5}{100} \times 0.01 M$$

$$[H^+] = 5 \times 10^{-4} M$$

$$\text{from } pH = -\log [H^+]$$

$$= -\log (5 \times 10^{-4})$$

$$pH = 3.3$$

$$pH + pOH = pK_w$$

$$pOH = pK_w - pH$$

Q1. *i*)  $pOH = 14 - 3.3$   
 $pOH = 10.7$

$$pOH = -\log [OH^-]$$

$$10.7 = -\log [OH^-]$$

$$[OH^-] = 10^{-10.7}$$

$$[OH^-] = 2 \times 10^{-11} M$$

$$\therefore [H^+] = 5 \times 10^{-4} M \text{ and } [OH^-] = 2 \times 10^{-11} M$$

d)  $K_w = 10^{-14} \text{ mol}^2/\text{dm}^3$  at  $25^\circ\text{C}$   
 $K_w = 2.92 \times 10^{-14} \text{ mol}^2/\text{dm}^3$  at  $65^\circ\text{C}$

D) Increase in temperature increases the extent of dissociation of water.



$$K_w = [H^+][OH^-]$$

but

$$[H^+] = [OH^-]$$

$$K_w = [H^+]^2$$

$$2.92 \times 10^{-14} = [H^+]^2$$

$$[H^+] = 1.7088 \times 10^{-7} M$$

$$\therefore [H^+] = 1.7088 \times 10^{-7} M$$

$$Q1. d) \text{ by } \text{pH} = -\log [\text{H}^+]$$

$$= -\log (1.7088 \times 10^{-7})$$

$$\text{pH} = 6.967$$

$$\therefore \text{pH} = 6.967$$



$$K_w = [\text{H}^+][\text{OH}^-]$$

but,

$$[\text{H}^+] = [\text{OH}^-]$$

$$K_w = [\text{H}^+]^2$$

$$1.7088 \times 10^{-14} = [\text{H}^+]^2$$

$$[\text{H}^+] = 1.7088 \times 10^{-7} \text{ M}$$

$$\text{pH} = -\log [\text{H}^+]$$

$$= -\log (1.7088 \times 10^{-7})$$

$$\text{pH} = 6.967$$

$$\therefore \text{pH} = 6.967$$

Extract 15.1: A sample of correct responses in question 1.

## 2018 PAST PAPERS - 2

3. (a) Define the following:
- Conjugate base.
  - Conjugate acid.
  - Conjugate acid-base pair.
- (3 marks)

(b) Identify the acid, base and acid-base conjugates for each of the following equations:

- $\text{H}_2\text{O} + \text{HCl} \longrightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$
  - $\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CH}_3\text{COO}^-$
  - $\text{CH}_3\text{COOH} + \text{H}_2\text{SO}_4 \rightleftharpoons \text{CH}_3\text{COOH}_2^+ + \text{HSO}_4^-$
  - $\text{C}_6\text{H}_5\text{NH}_2 + \text{-NH}_2 \rightleftharpoons \text{C}_6\text{H}_5\text{NH}^+ + \text{NH}_3$
- (8 marks)

(c) Calculate the concentration of sodium propanoate ( $\text{CH}_3\text{CH}_2\text{COONa}$ ) that must be present in a 0.01 M solution of propanoic acid ( $\text{CH}_3\text{CH}_2\text{COOH}$ ) to produce a pH of 4.30 if  $K_a$  for propanoic acid is  $1.3 \times 10^{-5}$ .

(d) Calculate the pH of 0.02 M acetic acid ( $\text{CH}_3\text{COOH}$ ). The dissociation constant ( $K_a$ ) of acetic acid is  $1.8 \times 10^{-5}$ .

3	<p>(i) Conjugate base = Is an acid after losing proton  <math>\text{Chlorine atom}</math> or          Is a base formed when the acid donates a proton</p> <p>(ii) Conjugate acid = Is a base after accepting proton  <math>\text{Chlorine atom}</math> or          Is an acid formed after the base has accepted a proton</p> <p>(iii) Conjugate acid-base pair = Is a pair of acid with          its corresponding conjugate base and base with</p>																												
4	<p>(i) its corresponding conjugate acid.</p>																												
	<table border="1"> <thead> <tr> <th></th> <th>Acid</th> <th>Base</th> <th>Conjugate Acid</th> <th>Conjugate Base</th> </tr> </thead> <tbody> <tr> <td>(i)</td> <td>HCl</td> <td>H<sub>2</sub>O</td> <td>H<sub>3</sub>O<sup>+</sup></td> <td>Cl<sup>-</sup></td> </tr> <tr> <td>(ii)</td> <td>CH<sub>3</sub>COOH</td> <td>H<sub>2</sub>O</td> <td>H<sub>3</sub>O<sup>+</sup></td> <td>CH<sub>3</sub>COO<sup>-</sup></td> </tr> <tr> <td>(iii)</td> <td>H<sub>2</sub>SO<sub>4</sub></td> <td>CH<sub>3</sub>COO<sup>-</sup></td> <td>CH<sub>3</sub>COO<sup>-</sup>H<sub>3</sub></td> <td>H<sub>2</sub>SO<sub>4</sub><sup>-</sup></td> </tr> <tr> <td>(iv)</td> <td>C<sub>6</sub>H<sub>5</sub>NH<sub>2</sub></td> <td>-NH<sub>2</sub></td> <td>NH<sub>3</sub></td> <td>C<sub>6</sub>H<sub>5</sub>NH<sup>+</sup></td> </tr> </tbody> </table>					Acid	Base	Conjugate Acid	Conjugate Base	(i)	HCl	H <sub>2</sub> O	H <sub>3</sub> O <sup>+</sup>	Cl <sup>-</sup>	(ii)	CH <sub>3</sub> COOH	H <sub>2</sub> O	H <sub>3</sub> O <sup>+</sup>	CH <sub>3</sub> COO <sup>-</sup>	(iii)	H <sub>2</sub> SO <sub>4</sub>	CH <sub>3</sub> COO <sup>-</sup>	CH <sub>3</sub> COO <sup>-</sup> H <sub>3</sub>	H <sub>2</sub> SO <sub>4</sub> <sup>-</sup>	(iv)	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	-NH <sub>2</sub>	NH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub> NH <sup>+</sup>
	Acid	Base	Conjugate Acid	Conjugate Base																									
(i)	HCl	H <sub>2</sub> O	H <sub>3</sub> O <sup>+</sup>	Cl <sup>-</sup>																									
(ii)	CH <sub>3</sub> COOH	H <sub>2</sub> O	H <sub>3</sub> O <sup>+</sup>	CH <sub>3</sub> COO <sup>-</sup>																									
(iii)	H <sub>2</sub> SO <sub>4</sub>	CH <sub>3</sub> COO <sup>-</sup>	CH <sub>3</sub> COO <sup>-</sup> H <sub>3</sub>	H <sub>2</sub> SO <sub>4</sub> <sup>-</sup>																									
(iv)	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	-NH <sub>2</sub>	NH <sub>3</sub>	C <sub>6</sub> H <sub>5</sub> NH <sup>+</sup>																									
	<p>(e) Required: Concentration of sodium propanoate (<math>\text{CH}_3\text{CH}_2\text{COONa}</math>)          Given <math>\text{CH}_3\text{CH}_2\text{COOH} = 0.01 \text{ M}</math>.  <math>\text{pH} = 4.30</math>  <math>K_a = 1.3 \times 10^{-5}</math></p> <p>From  <math>\text{pH} = \text{pka} + \log \frac{[\text{salt}]}{[\text{acid}]}</math></p> <p><math>\text{pka} = -\log K_a</math>  <math>= 4.89</math></p> <p>Then  <math>4.30 = 4.89 + \log \frac{[\text{CH}_3\text{CH}_2\text{COONa}]}{[0.01]}</math></p> <p><math>\log \frac{[\text{CH}_3\text{CH}_2\text{COONa}]}{[0.01]} = 4.30 - 4.89</math>.</p>																												

$$3. (c) \log \frac{[\text{CH}_3\text{CH}_2\text{COO}^-]}{[\alpha+1]} = -0.59,$$

$$\frac{[\alpha+1]}{[\alpha+1]} = 1$$

$$\frac{[\text{CH}_3\text{CH}_2\text{COO}^-]}{[\alpha+1]} = \log^{-1}(-0.59)$$

$$[\text{CH}_3\text{CH}_2\text{COO}^-] = 0.259 \times 0.01$$

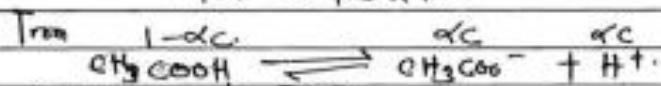
$$[\text{CH}_3\text{CH}_2\text{COO}^-] = 2.59 \times 10^{-3} \text{ M}$$

$\therefore$  Concentration of sodium propanoate =  $2.59 \times 10^{-3} \text{ M}$ .

(d) Required: pH

Given: 0.02 M acetic acid ( $\text{CH}_3\text{COOH}$ )

$$K_a = 1.8 \times 10^{-5}$$



$$\text{pH} = -\log [\text{H}^+]$$

But from Ostwald Law

$$\begin{aligned} \alpha &= \sqrt{\frac{K_a}{c}} \\ &= \sqrt{\frac{1.8 \times 10^{-5}}{0.02}} = 0.03 \end{aligned}$$

$$\text{But } [\text{H}^+] = \alpha c$$

$$= 0.03 \times 0.02$$

$$= 6 \times 10^{-4}$$

$$\text{Then } \text{pH} = -\log(6.0 \times 10^{-4}) = 3.2$$

$$\therefore \text{pH} = 3.2$$

Extract 17.1 shows responses where by the candidate provided correct definitions, and identified the acid and bases with their conjugate pairs. He/she also applied the Ostwald law of dilution properly to calculate the required pH.

## **2017 PAST PAPERS - 2**

3. (a) Define the following:  
(i) Common ion effect.  
(ii) Buffer solutions.  
(iii) Ionic product of water.  
(iv) Salt hydrolysis. **(4 marks)**
- (b) Briefly explain each of the following observations:  
(i) Ammonia ( $\text{NH}_3$ ) is one of the Lowry-Brønsted bases.  
(ii)  $\text{Al}^{3+}$  ion behaves as a Lewis acid when it is in water.  
(iii) Lead (II) chloride is soluble in concentrated HCl solution.  
(iv) Aqueous aluminium nitrate solution turns blue litmus paper red. **(6 marks)**
- (c) For each of the following pairs, write an equation to show how the pair reacts to form a conjugate acid and a conjugate base. For each reaction, identify the acid, base, conjugate acid and conjugate base.  
(i) Bicarbonate ion and water.  
(ii) Ammonia and water.  
(iii) Nitrous ion and hydroxonium ion.  
(iv) Ammonium ion and carbonate ion. **(6 marks)**
- (d) Briefly explain how an acidic buffer solution works to maintain its pH value when a small amount of acid is added to it. **(4 marks)**

### 3 (a) (i) Common ion Effect

This is the effect which arises when a strong salt is introduced into a solution of a weak salt which contains the same ions (either cations or anions) as the ions present in the strong salt, hence destabilizing the equilibrium system of the weak salt.

### 3 (a) (ii) Buffer solutions.

These are solutions which can maintain the pH values on addition of small amount of acid or base.

### (a) (iii) Ion product of water.

This is the product of concentrations of Hydroxonium ions and hydroxyl ions in the solution, that is  $K_w = [H^+][OH^-]$ .

### (a) (iv) Salt hydrolysis

This is the chemical reaction of a salt to give either acidic solution (Cationic salt hydrolysis) or basic solution (Anionic salt hydrolysis).

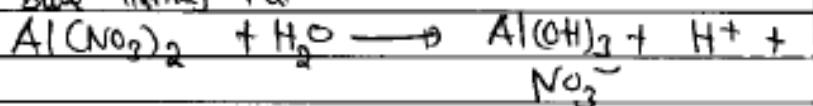
### 3 (b) (i) Brønsted-Lowry bases accept hydrogen proton ( $H^+$ ) from the Brønsted-Lowry acids. $NH_3$ normally accepts $H^+$ from acids to give $NH_4^+$ (ammonium ion), hence it is a Brønsted-Lowry base.

3 (b) When in water  $\text{Al}^{3+}$  hydron reacts to give  $\text{Al}(\text{OH})_3$ . The  $\text{Al}(\text{OH})_3$  has empty orbitals in its structure hence it is capable of sharing its empty orbitals w/ with Lewis bases (accepting lone pairs) thus acting as a Lewis acid.

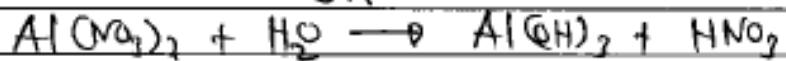
5 (ii) In concentrated HCl solution, Lead(II) chloride reacts to give a complex  $[\text{Pb}(\text{Cl})_4]^{2-}$  which is soluble in water. This is one of the common im effects.



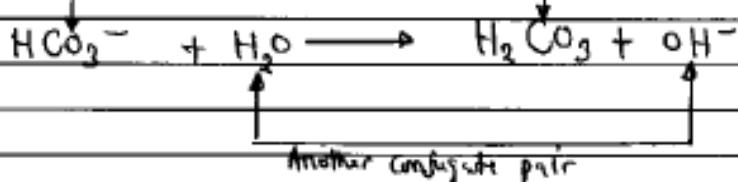
(b) (v) In solution aluminium nitrate having some degree of covalent character, it hydrolyses to give acidic solution ( $\text{H}^+$ ). Hence it is this acidic solution that turns blue litmus red.



OR



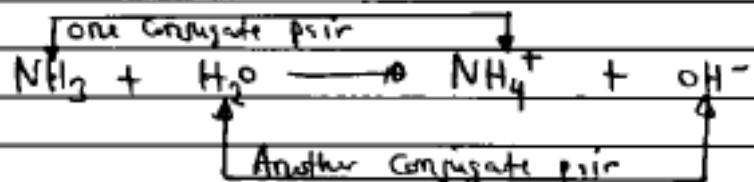
3 (c) (i)



Whereas  $\text{HCO}_3^-$  is a conjugate base of  $\text{H}_2\text{CO}_3$  which is a conjugate acid.

or  $\text{H}_2\text{O}$  is a conjugate acid of  $\text{OH}^-$  which is a conjugate base.

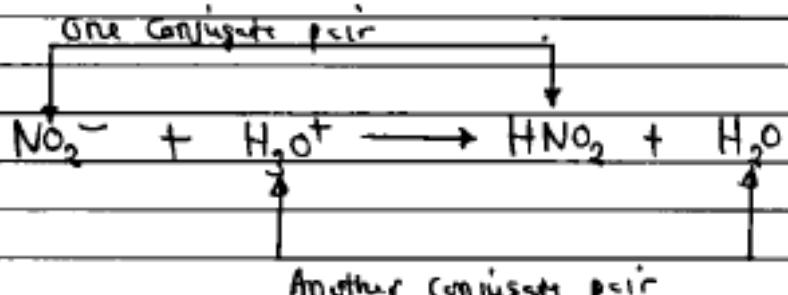
3 (c) (i)



Where:

- ①  $\text{NH}_3$  is a conjugate base of  $\text{NH}_4^+$  which is a conjugate acid
- ②  $\text{H}_2\text{O}$  is a conjugate acid of  $\text{OH}^-$  which is a conjugate base.

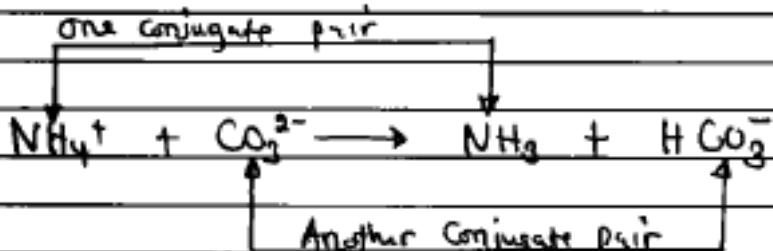
3 (c) (ii)



Where:

- ①  $\text{NO}_2^-$  is a conjugate base of  $\text{HNO}_2$  which is a conjugate acid
- ②  $\text{H}_3\text{O}^+$  is a conjugate acid of  $\text{H}_2\text{O}$  which is a conjugate base.

3 (c) (iii)



Where:

- ①  $\text{NH}_4^+$  is a conjugate acid of  $\text{NH}_3$  which is a conjugate base
- ②  $\text{CO}_3^{2-}$  is a conjugate base of  $\text{HCO}_3^-$  which is a conjugate acid.

3 (d)	Consider	$\text{CH}_3\text{COOH}/\text{CH}_3\text{COONa}$
	Buffer system. Before addition of strong salt ( $\text{NaCl}$ )	
	the $\text{CH}_3\text{COOH}$ ionises as follows:	
	$\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^-(aq) + \text{H}^+(aq) \quad \text{---(i)}$	
	② On the addition of strong salt, $\text{CH}_3\text{COONa}$ , the salt dissociates completely as follows:	
	$\text{CH}_3\text{COONa} \longrightarrow \text{CH}_3\text{COO}^-(aq) + \text{Na}^+$	
	③ The addition of $\text{CH}_3\text{COO}^-$ from strong salt causes common ion effect which disrupts the equilibrium established in eqn (i) hence more of $\text{H}^+$ must react with the added $\text{CH}_3\text{COO}^-$ to restore equilibrium.	
	④ Since there are no enough $\text{H}^+$ from $\text{CH}_3\text{COOH}$ to react with $\text{CH}_3\text{COO}^-$ from strong salt, the equilibrium remains disturbed.	
	⑤ (i) Addition of strong base such as $\text{NaOH}$ :	
	$\text{NaOH} \longrightarrow \text{Na}^+ + \text{OH}^-$	
	⑥ The added $\text{OH}^-$ eliminates $\text{H}^+$ from equilibrium system of $\text{CH}_3\text{COOH}$ . Hence the $\text{CH}_3\text{COO}^-$ from strong acid	

In Extract 17.1 the candidate correctly responded to all the parts of the question. All work is clearly shown.

## 2016 PAST PAPERS - 2

3. (a) Calculate the values of  $[H^+]$  and  $[OH^-]$  in a 0.005 M solution of NaOH. (4 marks)
- (b) The pH of a 0.1 M solution of a weak base is 10.6. Calculate the ionization constant of the base. (4 marks)
- (c) Calculate the number of grams of sodium acetate ( $CH_3COONa$ ) which are to be added to 500 cm<sup>3</sup> of 0.12 M acetic acid ( $CH_3COOH$ ) to give a buffer solution of pH = 4.60, given that  $k_a(CH_3COOH) = 1.8 \times 10^{-5}$ . (4 marks)
- (d) The solubility product of lead (II) chloride,  $PbCl_2$  has a value of  $1.6 \times 10^{-5} \text{ Mol}^3 \text{dm}^{-9}$  at 298 K. Calculate the solubility of lead (II) chloride at 298 K. (4 marks)
- (e) Give the difference between the following terms:  
 (i) Solubility and solubility product.  
 (ii) Reaction quotient and equilibrium constant. (4 marks)

(a)	<p>they given that  <math>NaOH \rightarrow Na^+ + OH^-</math> (strong base)</p> <p>The mole ratio is <math>NaOH : OH^-</math> is the same.</p> $pNaOH = pOH^-$
	$pOH^- = 0.005 \text{ M}$
	$pOH^- = 0.005 \text{ M}$
	<p>From the relation that. <math>pH = -\log[H^+]</math>,      also <math>pOH = -\log[OH^-]</math></p> $-\log[OH^-] = pOH$
	$pOH = -\log[0.005]$ ,
	$pOH = 2.3$
	$pH = 14 - pOH$
	$pH = 11.699$
	<p>But <math>pH = -\log[H^+]</math>,</p> $-\log[H^+] = 11.699$

3a

$$pH^+ = -pH$$

$$pH^+ = 1.3 + (-pH)$$

$$\log_{10} \frac{1}{1.3} = 1.6997$$

$$\text{then } pH^+ = 2 \times 10^{-12} \text{ M}$$

3b Given the molality of the weak base  
 $= 0.1 \text{ M}$ ,  
 $pH = 10.6$

then the ionisation constant of the base

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

Also

$$pOH = -\log_{10} [OH^-]$$

$$pH + pOH = 14.$$

$$pOH = 14 - pH$$

$$= 14 - 10.6$$

$$pOH = 3.4$$

$$-\log_{10} [OH^-] = 3.4,$$

$$[OH^-] = 10^{-3.4} \text{ M}$$

$$3(b) \text{ Then } pOH^{-} = 9.92 \times 10^{-4} M$$

From the relation that

$K_b$

$$K_b [Base] = [OH^{-}]^2$$

[Base]      [Base]

$$K_b = \frac{(9.92 \times 10^{-4})^2}{[0.8]}$$

$$K_b \approx 1.585 \times 10^{-6} \text{ mol/l dm}^3$$

$$\text{Then the value of } K_b = 1.585 \times 10^{-6} \text{ mol/l dm}^3$$

q.e Data given:

$$pH = 4.6$$

$$[HCO_3^-] = 1.8 \times 10^{-5}$$

$$\text{Molarity of the acid} = 0.12 \text{ M}$$

from the relationship that

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

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

$$\frac{[Salt]}{[Acid]} = 10^{-(pH - pK_a)}$$

$$P_{\text{salt}} = K_{\text{eq}} \times 10^{-1} [pH - pK_a]$$

$$pK_a = -\log K_a$$

$$= 4.745$$

$$P_{\text{salt}} = 0.12 \times 10^{-1} [4.6 - 4.745]$$

$$P_{\text{salt}} = 0.026 \text{ M}$$

then Molar concentration:

$$= 0.086 \text{ M}$$

$$\text{Mass Concentration} = \text{Molarity} \times \text{Molar Mass}$$

$$= 0.086 \times 88$$

$$= 7.052 \text{ g/dm}^3$$

$$\frac{\text{then } 7.052}{x} = \frac{100}{500}$$

$$= \frac{500 \times 7.052}{1000}$$

$$= 3.526 \text{ g}$$

then the mass required

$$= 3.526 \text{ g}$$

Q(d) Data solubility product =  $1.6 \times 10^{-5}$  mol<sup>3</sup> dm<sup>-6</sup>  
then to calculate the solubility of  
 $\text{PbCl}_2$  at 298:

Qd then  $\text{PbCl}_2 \rightleftharpoons \text{Pb}^{2+} + 2\text{Cl}^-$

$$K_{sp} = [\text{Pb}^{2+}] [\text{Cl}^-]^2 \quad \textcircled{1}$$

$$K_{sp} = [\text{Pb}^{2+}] [\text{Cl}^-]^2$$

upt that the solubility of  
lead is equal to  $x$ .

$$K_{sp} = [x] [2x]^2$$

$$K_{sp} = \frac{4x^3}{27}$$

$$x = \sqrt[3]{\frac{K_{sp}}{4}}$$

$$\sqrt[3]{\frac{1.6 \times 10^{-5}}{4}}$$

$$x = 0.016 \text{ M}$$

Solubility of  $\text{Pb}(\text{II}) \text{ PbCl}_2 = 0.016 \text{ M}$

3(e) Solubility is the ability of the substances to dissolve in a given solvent while

Solubility product is the equilibrium constant obtained as the product of the concentrations of the ions present in the saturated solution raised to their powers.

3(e)(i) Reaction quotient is the ratio of the product of the concentration of the reactant each raised to its stoichiometric coefficient obtained in a balanced chemical equation at any time.

Equilibrium constant is the ratio of product of the concentration of product to the product of concentration of the reactant each raised to the stoichiometric coefficient obtained in a balanced chemical equation when the reaction is at equilibrium.

In extract 17.1, the candidate used correct formulae and data to all calculation parts of the question. He/she appropriately manipulated the data and eventually obtained the required solution. Finally, the candidate correctly differentiated the terms asked in part 3(e).

## 2015 PAST PAPERS - 2

1. (a) According to Brönsted-Lowry theory,  $\text{HSO}_3^-$  ion behaves as an acid in the following reaction:
- $$\text{HSO}_3^- \rightleftharpoons \text{H}^+ + \text{SO}_3^{2-}$$
- (i) Explain in terms of Brönsted-Lowry theory how  $\text{HSO}_3^-$  is acting as an acid.  
(ii) Write the formula for the conjugate base.  
(iii) Illustrate with an equation how  $\text{HSO}_3^-$  ion can also act as a base. (4 marks)
- (b) Calculate the pH at the neutralization point for the reaction between 0.01 M  $\text{NH}_4\text{OH}$  and 0.01 M HCl solutions given that  $K_a(\text{NH}_4^+) = 5.7 \times 10^{-10} \text{ mol/dm}^3$ . (8 marks)
- (c) An ethanoic acid/sodium ethanoate buffer containing 1.00 M  $\text{CH}_3\text{COOH}$  has a pH = 4.742. Calculate the following given that,  $K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5} \text{ mol/dm}^3$ .
- (i) Concentration of sodium ethanoate in the given buffer.  
(ii) pH of the resulting solution after 0.01 mole  $\text{HCl}_{(\text{aq})}$  has been added in  $1\text{dm}^3$  of the buffer solution.  
(iii) pH of the resulting solution after 0.01 mole NaOH solution is added in  $1\text{dm}^3$  of the buffer solution.  
(iv) pH when 0.01 mole of NaOH is added to  $1.0 \text{ dm}^3$  of pure water. (8 marks)

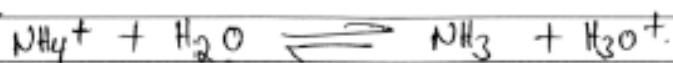
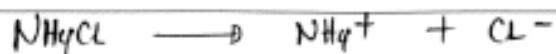
1.	(a)	<p>(i) According to Brönsted-Lowry theory.      Acid is a substance that donate proton to another substance.      Therefore in equation</p> $\text{HSO}_3^- \rightleftharpoons \text{H}^+ + \text{SO}_3^{2-}$ <p><math>\text{HSO}_3^-</math> donate its <math>\text{H}^+</math> to the surrounding while itself becoming <math>\text{SO}_3^{2-}</math></p> $\text{HSO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{SO}_3^{2-} + \text{H}_3\text{O}^+$ <p>(ii) Conjugate base is <math>\text{SO}_3^{2-}</math></p> <p>(iii)</p> $\text{HSO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{SO}_3 + \text{OH}^-$															
	(b)	<p>Given,      Concentration of <math>\text{NH}_4\text{OH}</math> = <math>0.01\text{M}</math>      Concentration of <math>\text{HCl}</math> = <math>0.01\text{M}</math>  <math>K_a(\text{NH}_4^+) = 5.7 \times 10^{-10} \text{ mol/dm}^3</math>.      Required, pH at neutralisation point, pH=?</p> <p>From,</p> $\text{NH}_4\text{OH} + \text{HCl} \longrightarrow \text{NH}_4\text{Cl} + \text{H}_2\text{O}$ <table style="margin-left: auto; margin-right: auto;"> <tr> <td><math>0.01\text{M}</math></td> <td><math>0.01\text{M}</math></td> <td><math>-</math></td> <td><math>-</math></td> <td><math>t=0</math></td> </tr> <tr> <td><math>- \alpha</math></td> <td><math>- \alpha</math></td> <td><math>\alpha</math></td> <td><math>\alpha</math></td> <td><math>t=t</math></td> </tr> <tr> <td><math>0.01 - \alpha</math></td> <td><math>0.01 - \alpha</math></td> <td><math>\alpha</math></td> <td><math>\alpha</math></td> <td><math>t</math></td> </tr> </table>	$0.01\text{M}$	$0.01\text{M}$	$-$	$-$	$t=0$	$- \alpha$	$- \alpha$	$\alpha$	$\alpha$	$t=t$	$0.01 - \alpha$	$0.01 - \alpha$	$\alpha$	$\alpha$	$t$
$0.01\text{M}$	$0.01\text{M}$	$-$	$-$	$t=0$													
$- \alpha$	$- \alpha$	$\alpha$	$\alpha$	$t=t$													
$0.01 - \alpha$	$0.01 - \alpha$	$\alpha$	$\alpha$	$t$													

$$1(5) \text{ but } 0.01 - \alpha = 0$$

$$\alpha = 0.01 \text{ M}$$

$$\therefore [\text{NH}_4\text{Cl}] = 0.01 \text{ M}$$

∴



1 C	-	-	t=0
(1 - α) C	α C	α C	t=t

$$K_a = \frac{[\text{NH}_3][\text{H}_3\text{O}^+]}{[\text{NH}_4^+]}$$

$$K_a = \frac{\alpha^2 C}{1 - \alpha}$$

$$\alpha^2 C = K_a - \alpha K_a$$

$$C\alpha^2 + K_a\alpha - K_a = 0$$

$$0.01\alpha^2 + 5.7 \times 10^{-10}\alpha - 5.7 \times 10^{-10} = 0$$

$$\alpha = 2.39 \times 10^{-4}$$

but

$$\text{pH} = -\log [\text{H}_3\text{O}^+] \quad \text{--- (1)}$$

$$[\text{H}_3\text{O}^+] = \alpha C$$

$$[\text{H}_3\text{O}^+] = 2.39 \times 10^{-4} \times 0.01$$

$$[\text{H}_3\text{O}^+] = 2.39 \times 10^{-6}$$

1)b From equation (1) above  
 $\text{pH} = -\log [\text{H}_3\text{O}^+]$ .

$$\text{pH} = -\log (2.39 \times 10^{-6})$$

$$\text{pH} = 5.62$$

∴ The pH at neutralization point is  
 $\text{pH} = 5.62$ .

(c)

Given;

Concentration of ethanoic acid,  $[\text{CH}_3\text{COOH}] = 1 \text{ M}$ .

pH of a buffer,  $\text{pH} = 4.742$ .

acid dissociation constant,  $K_a = 1.8 \times 10^{-5} \text{ mol/dm}^3$ .

Required;

(i) Concentration of Sodium ethanoate in the given buffer,  $[\text{CH}_3\text{COONa}] = ?$

From;

$$\text{pH} = \text{p}K_a + \log \frac{[\text{CH}_3\text{COONa}]}{[\text{CH}_3\text{COOH}]}$$

$$\log \frac{[\text{CH}_3\text{COONa}]}{[\text{CH}_3\text{COOH}]} = \text{pH} - \text{p}K_a$$

$$\log \frac{[\text{CH}_3\text{COONa}]}{[\text{CH}_3\text{COOH}]} = \log \frac{1}{[\text{CH}_3\text{COOH}]} = -(\text{pH} - \text{p}K_a)$$

but

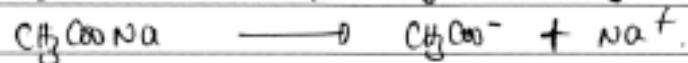
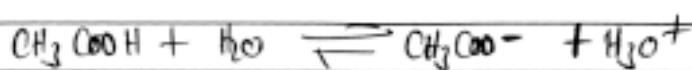
$$\text{p}K_a = -\log K_a = -\log 1.8 \times 10^{-5} = 4.745$$

$$[\text{CH}_3\text{COO}^-] = \log - (4.742 - 4.745)$$

$$[\text{CH}_3\text{COO}^-] = 0.993 \text{ mol/dm}^3.$$

∴ Concentration of Sodium ethanoate is  
0.993 moles/dm<sup>3</sup>.

(ii) From;



Addition of HCl.

number of moles of ethanoic acid.

$$= 1 \text{ mol/dm}^3 \times 1 \text{ dm}^3$$

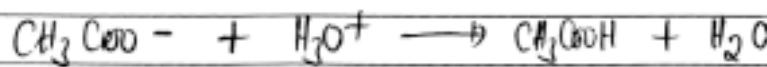
$$= 1 \text{ moles.}$$

number of moles of sodium acetate.

$$= 0.993 \text{ mol/dm}^3 \times 1 \text{ dm}^3$$

$$= 0.993 \text{ mole}$$

HCl reacts with Sodium ethanoate according to the equation.



$$0.993 \text{ moles} \quad 0.01 \text{ moles} \quad 1 \text{ moles} \quad \text{to}$$

$$0.993 - 0.01 \quad 0.01 - 0.01 \quad 1 + 0.01 \quad \text{tot}$$

$$0.983 \text{ moles} \quad - \quad 1.01 \text{ moles}$$

1. (C) From,

$$pH = pK_a + \log \frac{[CH_3COO^-]}{[CH_3COOH]}$$

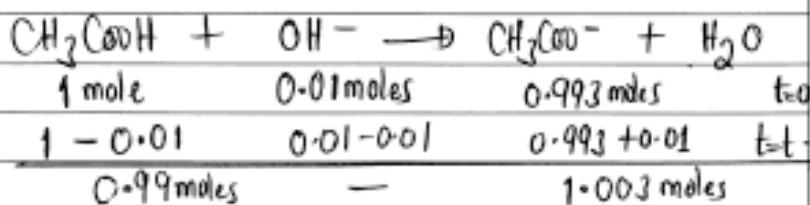
$$pH = -\log(1.8 \times 10^{-5}) + \log \frac{0.983}{1.01}$$

$$pH = 4.73$$

∴ The pH of a buffer will be 4.73.

(III) on addition of NaOH

NaOH reacts with ethanoic acid according to the equation.



From,

$$pH = pK_a + \log \frac{[CH_3COO^-]}{[CH_3COOH]}$$

$$pH = -\log(1.8 \times 10^{-5}) + \log \frac{1.003}{0.99}$$

$$pH = 4.75$$

∴ The pH will be 4.75.

Extract 1.1 shows a well presented answer with correct calculation procedures given by the candidate.

## 5.0 SOLUBILITY, SOLUBILITY PRODUCT AND IONIC PRODUCT

### 2021 PAST PAPERS- 2

3. (a) To a solution containing 0.1 M  $\text{Cl}^-$  and 0.01 M  $\text{CrO}_4^{2-}$ , a solution of  $\text{AgNO}_3$  is added slowly.
- Which salt will precipitate first between  $\text{AgCl}$  and  $\text{Ag}_2\text{CrO}_4$ ? Show clearly how you arrived to your answer.
  - Find the concentration of the ion that will precipitate first at the time the second ion will start precipitating. Use  $K_{sp}(\text{AgCl}) = 2.72 \times 10^{-10}$  and  $K_{sp}(\text{Ag}_2\text{CrO}_4) = 2.4 \times 10^{-12}$ .
- (8 marks)

(b) Calculate the solubility of  $\text{Ag}_2\text{CrO}_4$  in water if the value of solubility product  $K_{sp}$  is  $1.3 \times 10^{-11}$  (mol/L)<sup>3</sup>.

(c) A standard solution of  $\text{AgCl}(\text{aq})$  at 36 °C has a conductivity of  $1.32 \times 10^{-6} \Omega^{-1} \text{cm}^{-1} \text{mol}^{-1}$ . If its molar conductivity at infinite dilution is  $120 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$ , calculate;

- the solubility of  $\text{AgCl}$  in g/dm<sup>3</sup>.
- the solubility product of  $\text{AgCl}$  at the given temperature.

(8 marks)

Q3.	<p><u>Q3. @ Given</u></p> <p><math>[\text{Cl}^-] = 0.1 \text{M}</math></p> <p><math>[\text{CrO}_4^{2-}] = 0.01 \text{M}</math></p> <p><math>K_{sp} (\text{AgCl}) = 2.72 \times 10^{-10}</math></p> <p><math>K_{sp} (\text{Ag}_2\text{CrO}_4) = 2.4 \times 10^{-12}</math></p> <p><u>① From</u></p> <p><math>\text{AgCl}(\text{aq}) \xrightleftharpoons{\text{H}_2\text{O}} \text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq})</math></p> <p><math>K_{sp} = [\text{Ag}^+] [\text{Cl}^-]</math></p> <p><math>K_{sp} = [\text{Ag}^+] \times 0.1 \text{M}</math></p> <p><math>[\text{Ag}^+] = \frac{K_{sp}}{0.1 \text{M}}</math></p> <p><math>= \frac{2.72 \times 10^{-10}}{0.1}</math></p> <p><math>[\text{Ag}^+] = 2.72 \times 10^{-9} \text{M}</math></p> <p><u>But also</u></p> <p><math>\text{Ag}_2\text{CrO}_4(\text{s}) \xrightleftharpoons{\text{H}_2\text{O}} 2\text{Ag}^+(\text{aq}) + \text{CrO}_4^{2-}(\text{aq})</math></p> <p><math>K_{sp} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]</math></p> <p><math>[\text{Ag}^+] = \sqrt{\frac{K_{sp}}{[\text{CrO}_4^{2-}]}}</math></p> <p><math>[\text{Ag}^+] = \sqrt{\frac{2.4 \times 10^{-12}}{0.01}}</math></p> <p><math>[\text{Ag}^+] = 1.549 \times 10^{-5} \text{M}</math></p>
-----	--

Q3 Since the solubility of  $\text{Ag}^{+}$  in  $\text{AgCl}$  is smaller than the solubility of  $\text{Ag}^{+}$  in  $\text{Ag}_2\text{CrO}_4$  then  $\text{AgCl}$  will precipitate first and then  $\text{Ag}_2\text{CrO}_4$ .

(ii) Given:

$$K_{sp} \text{ Ag}_2\text{CrO}_4 = 2.4 \times 10^{-12}$$

$$K_{sp} \text{ AgCl} = 1.77 \times 10^{-10}$$

When the second ion will precipitate first it means that the concentration of  $\text{Ag}^{+}$  present is equal  $= 1.549 \times 10^{-5} \text{ M}$

From



$$K_{sp} = [\text{Ag}^{+}][\text{Cl}^{-}]$$

$$[\text{Cl}^{-}] = \frac{K_{sp}}{[\text{Ag}^{+}]}$$

$$[\text{Cl}^{-}] = \frac{1.77 \times 10^{-10}}{1.549 \times 10^{-5}}$$

$$[\text{Cl}^{-}] = 1.1756 \times 10^{-5} \text{ M}$$

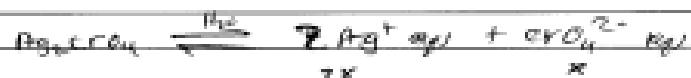
$\therefore$  The concentration of  $\text{Cl}^{-}$  is  $1.1756 \times 10^{-5} \text{ M}$

Q3 (ii) Given:

$$K_{sp} = 1.7 \times 10^{-10} \text{ mol/l}^2$$

Concentration of  $\text{Ag}_2\text{CrO}_4 =$

From



$$K_{sp} = [\text{Ag}^{+}]^2 [\text{CrO}_4^{2-}]$$

$$x^2 = 4x^2 \cdot x$$

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

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

$$x^3 = \frac{1.7 \times 10^{-10} \text{ M}^3}{4}$$

$$x = \sqrt[3]{\frac{1.7 \times 10^{-10} \text{ M}^3}{4}}$$

$$x = 1.021 \times 10^{-4} \text{ mol/l}^{1/3}$$

$\therefore$  The solubility of  $\text{Ag}_2\text{CrO}_4$  is  $1.021 \times 10^{-4} \text{ mol/l}^{1/3}$

$$0.7 \quad (c) K = 1.32 \times 10^{-2} \text{ mol}^{-1} \text{ mol}^{-1}$$

$$K_a = 1.20 \text{ mol}^{-1} \text{ mol}^{-1} \quad M_r \text{ of } \text{AgCl} = 107.5 \text{ g/mol}$$

0.8 bar

$$K_{\text{eq}} = \frac{K}{C_m}$$

but  $C_m = \text{Molarity}$

$$C_m = \frac{K}{K_{\text{eq}}}$$

$$= \frac{1.32 \times 10^{-2} \text{ mol}^{-1} \text{ mol}^{-1}}{1.20 \text{ mol}^{-1} \text{ mol}^{-1}}$$

$$= 1.1 \times 10^{-2} \text{ mol/l cm}^3$$

$$\text{but } 1 \text{ dm}^3 = 1000 \text{ cm}^3$$

$$\Rightarrow 1 \text{ cm}^3 = 10^{-3} \text{ dm}^3$$

$$C_m = \frac{1.1 \times 10^{-2} \text{ mol}}{10^{-3} \text{ dm}^3}$$

$$C_m = 1.1 \times 10^{-2} \times 1000 \text{ mol/dm}^3$$

$$C_m = 1.1 \times 10^{-2} \text{ mol/l dm}^3$$

i. The molar solubility of AgCl is

Conc = molarity  $\times$  molar mass

$$= 1.1 \times 10^{-2} \text{ mol/l dm}^3 \times 107.5 \text{ g/mol/l}$$

$$= 1.1885 \times 10^{-2} \text{ g/dm}^3$$

ii. The solubility of AgCl is  $1.1885 \times 10^{-2} \text{ g/dm}^3$ .

03	@ ⑩
	From $\text{AgCl}_{(s)} \xrightleftharpoons{H_2O} \text{Ag}^+_{(aq)} + \text{Cl}^-_{(aq)}$
	$K_{sp} = [\text{Ag}^+] [\text{Cl}^-]$
	$[\text{Ag}^+] = [\text{Cl}^-] \phi^{-1}$
	but molar solubility of $\text{AgCl}$ from chart is $1.1 \times 10^{-5} \text{ mol dm}^{-3}$
	$[\text{Ag}^+] = [\text{Cl}^-] = 1.1 \times 10^{-5} \text{ mol dm}^{-3}$
	$K_{sp} = [1.1 \times 10^{-5} \times 1.1 \times 10^{-5}] (\text{Mol/L})^2$
	$K_{sp} = 1.21 \times 10^{-10} \text{ M}^2$
	$\therefore$ The solubility product of $\text{AgCl}$ is $1.21 \times 10^{-10} \text{ M}^2$

**Extract 13.1: A sample of correct responses in question 3**

## 2018 PAST PAPERS- 2

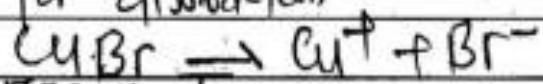
4. (a) Write the solubility product constant ( $K_{sp}$ ) expressions for the solubility equilibria of each of the following compounds:
  - (i) Copper (I) bromide.
  - (ii) Bismuth sulphide, ( $\text{Bi}_2\text{S}_3$ ).
  - (iii) Copper (II) iodate,  $\text{Cu}(\text{IO}_3)_2$ .
  - (iv) Silver chromate,  $\text{Ag}_2\text{CrO}_4$ . (4 marks)
- (b) The  $[\text{Ag}^+]$  of a solution is  $4 \times 10^{-3}$ . Calculate the  $[\text{Cl}^-]$  that must be exceeded before  $\text{AgCl}$  can precipitate. The  $K_{sp}$  of  $\text{AgCl}$  is  $1.0 \times 10^{-10}$ . (4 marks)
- (c)  $25 \text{ cm}^3$  of  $0.001 \text{ M}$   $\text{BaCl}_2$  solution were mixed with  $40 \text{ cm}^3$  of  $0.002 \text{ M}$   $\text{Na}_2\text{SO}_4$  solution. Will  $\text{BaSO}_4$  precipitate from this solution? Support your answer by calculation. The  $K_{sp}$  of  $\text{BaSO}_4$  at  $25^\circ\text{C}$  is  $1.12 \times 10^{-10} \text{ mol}^2\text{dm}^{-6}$ . (6 marks)
- (d) (i) Outline four factors which affect the solubility of sparingly soluble salts.  
 (ii) Calculate the solubility of  $\text{AgCl}$  in  $0.20 \text{ M}$   $\text{AgNO}_3$  solution.  $K_{sp}(\text{AgCl}) = 1.0 \times 10^{-10}$ . (6 marks)

(4) (a) (i)

Copper(I) Bromide

Formula:  $\text{CuBr}$

Equation for dissociation

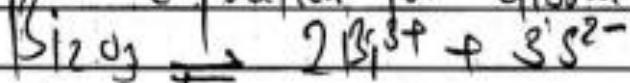


$$\therefore K_{\text{sp}} = [\text{Cu}^+] [\text{Br}^-]$$

Then  $K_{\text{sp}} = x^2$

(ii) Bismuth sulphide,  $\text{Bi}_2\text{S}_3$

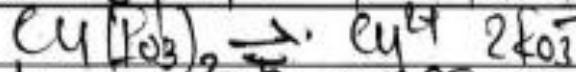
Equation for dissociation



$$\therefore K_{\text{sp}} = [\text{Bi}^{3+}]^2 [\text{S}^{2-}]^3$$

(iii) Copper(II) iodate,  $\text{Cu}(\text{IO}_3)_2$

Equation for dissociation



$$\therefore K_{\text{sp}} = [\text{Cu}^{2+}] [\text{IO}_3^-]^2$$

4(i)(iv) Silver chromate ( $\text{Ag}_3\text{CrO}_4$ ),  
Equation for dissociation  
 $\text{Ag}_3\text{CrO}_4 \rightleftharpoons 2\text{Ag}^+ + \text{CrO}_4^{2-}$

$$\therefore K_{\text{sp}} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]$$

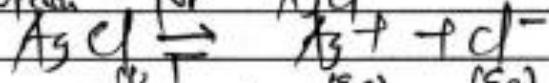
(b) Data provided.

$$\text{Concentration of } \text{Ag}^+ \text{ in } \text{AgCl} = 4 \times 10^{-3}$$

$$[\text{CrO}_4^{2-}] \text{ in } \text{AgCl} = 1.6 \times 10^{-6}$$

$$\text{Required is } [\text{Cl}^-]$$

Equation for  $\text{AgCl}$



$$K_{\text{sp}} = [\text{Ag}^+][\text{Cl}^-]$$

$$[\text{Cl}^-] = \frac{K_{\text{sp}}}{[\text{Ag}^+]}$$

$$[\text{Cl}^-] = \frac{1.0 \times 10^{-10}}{4 \times 10^{-3}} = 2.5 \times 10^{-8}$$

$$[\text{Cl}^-] = 2.5 \times 10^{-8}$$

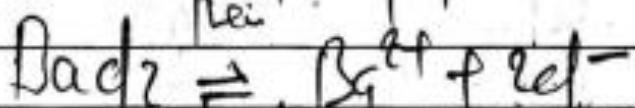
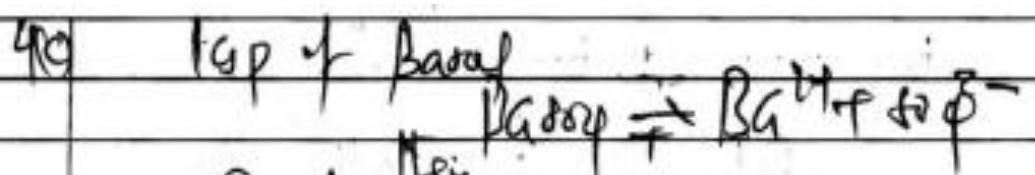
∴ the  $[\text{Cl}^-]$  that must be exceeded before  $\text{AgCl}$  can precipitate is  $2.5 \times 10^{-8}$ .

(v) Data provided

$$25\text{cm}^3 \text{ of } 0.001 \text{ M BaCl}_2$$

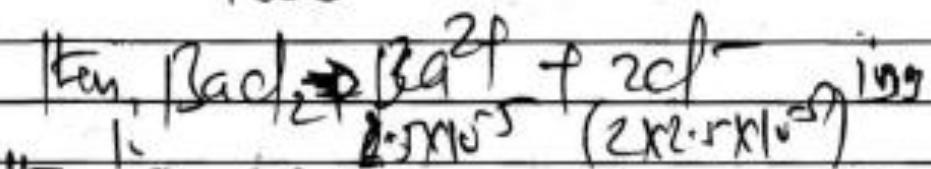
$$40\text{cm}^3 \text{ of } 0.002 \text{ M Na}_2\text{SO}_4$$

$$K_{\text{sp}} \text{ of BaSO}_4 \text{ is } 1.12 \times 10^{-10}$$



Number of moles of  $\text{Ba}^{2+}$  in BaCl<sub>2</sub>  
before mixing

$$= \frac{2.5 \text{ mol}}{1000} \times 0.001 = 2.5 \times 10^{-5}$$



But the volume after mixing baro

$$\text{Total } 40 \text{ cm}^3 + 25 \text{ cm}^3 = 65 \text{ cm}^3$$

$$\text{In dm}^3 = 65 / 1000 = 0.065 \text{ dm}^3$$

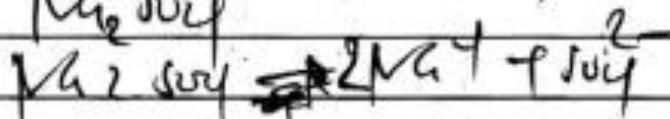
$\therefore$  Concentration of  $\text{Ba}^{2+}, \text{Ba}^{2+}$  after mixing

$$n = 2.5 \times 10^{-5} /$$

$$0.065 \text{ dm}^3$$

$$= 3.85 \times 10^{-6} \mu$$

For MgSO<sub>4</sub>



Number of moles before mixing

$$= \frac{4 \text{ mol}}{1000} \times 0.001 = 8 \times 10^{-5}$$

(c) Then  $\text{Na}_2\text{SO}_4 \rightarrow \text{Na}^+$  &  $\text{SO}_4^{2-}$

The concentration of  $\text{SO}_4^{2-}$  after mixing because  $\text{Ba}^{2+} \text{ & } \text{SO}_4^{2-}$  both  
 $= 0.065 \times 10^{-3} \text{ M}$

$$\text{But } Q_{\text{sp}} = [\text{Ba}^{2+}][\text{SO}_4^{2-}]$$

$$Q_{\text{sp}} = 3.85 \times 10^{-4} \times 1.23 \times 10^{-3} \text{ M}$$

$$Q_{\text{sp}} = 4.74 \times 10^{-7} \text{ M}^2 \text{ dm}^{-6}$$

Since  $Q_{\text{sp}} > K_{\text{sp}}$   
then the precipitate will occur

(d) (i) - Common ion effect which decreases solubility

- Complex formation this increases solubility

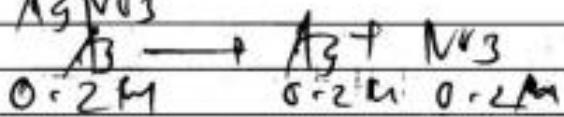
- Temperature - it affects depending on nature of reaction with whether exothermic or endothermic

- Concentration,

(ii) Data provided,  
 $K_{\text{sp}}$  of  $(\text{AgCl}) = 1.0 \times 10^{-10}$   
concentration of  $\text{AgNO}_3 = 0.2 \text{ M}$ .

$K_{\text{sp}}$  is given by dissociation of  
 $\text{AgCl} \rightleftharpoons \text{Ag}^+ + \text{Cl}^-$

Q3(iii) Rev  $\text{AgNO}_3$



$0.2\text{M}$   $0.2\text{M}$   $0.2\text{M}$

$$\text{then } K_{\text{sp}} \text{ for AgCl} = (\text{Ag}^+)(\text{Cl}^-)$$

$$1.0 \times 10^{-10} = 0.2y$$

where  $y$  is the solubility  
for  $\text{AgCl}$ .

$$\frac{1.0 \times 10^{-10}}{0.2} = \frac{0.2y}{0.2}$$

$$\text{Solubility (y)} = 5 \times 10^{-10}$$

$\therefore$  the solubility for  $\text{AgCl}$   
is  $5 \times 10^{-10} \text{ M}$

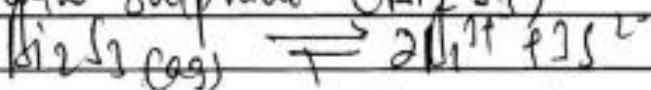
(a) Solubility product expressions

(b) Copper (II) bromide ( $\text{CuBr}_2$ )



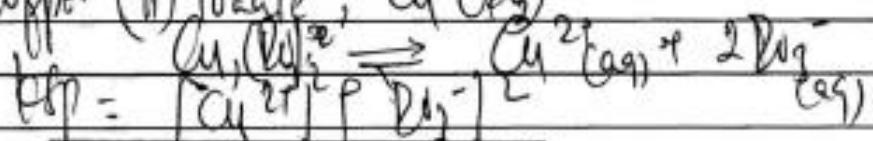
$$K_{\text{sp}} = [\text{Cu}^{2+}]P[\text{Br}^-]^2$$

(c) Bismuth sulphide ( $\text{Bi}_2\text{S}_3$ )



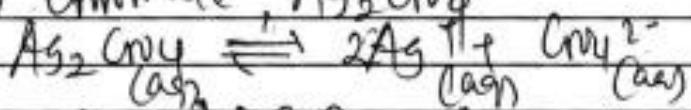
$$K_{\text{sp}} = [\text{Bi}^{3+}]^2[\text{S}^{2-}]^3$$

(d) Copper (II) iodide,  $\text{Cu}(\text{I}_2)^2$



$$K_{\text{sp}} = [\text{Cu}^{2+}]P[\text{I}^-]^2$$

(a)

silver chromate,  $\text{Ag}_2\text{CrO}_4$ 

$$K_{\text{sp}} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]$$

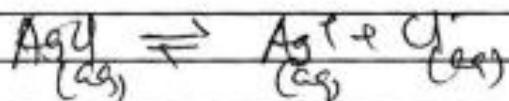
(b) Data given:

$$\text{Concentration of } [\text{Ag}^+] = 4.0 \times 10^{-3} \text{ M}$$

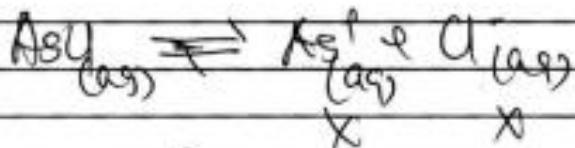
$$K_{\text{sp}} \text{, solubility product} = 1.0 \times 10^{-10}$$

$$[\text{Ag}^+] [\text{Cl}^-] = 1.0$$

from:



thus:



$$K_{\text{sp}} = x^2$$

$$K_{\text{sp}} = [\text{Ag}^+] [\text{Cl}^-]$$

$$[\text{Cl}^-] = \frac{K_{\text{sp}}}{[\text{Ag}^+]}$$

$$= \frac{1.0 \times 10^{-10}}{4.0 \times 10^{-3}}$$

$$= 2.5 \times 10^{-8}$$

Thus for precipitation to occur, the  $\text{FeCl}_3$  must exceed  $2.5 \times 10^{-8}$

(c) Data given:

$$\text{Volume of salt, } [V_1] = 25 \text{ cm}^3$$

$$\text{Volume of } \text{Na}_2\text{SO}_4, [V_2] = 40 \text{ cm}^3$$

$$\text{Concentration of salt, } [\text{Mg}^{2+}] = 0.80 \text{ M}$$

$$\text{Concentration of } \text{Na}_2\text{SO}_4 [\text{M}_N] = 0.80 \text{ M}$$

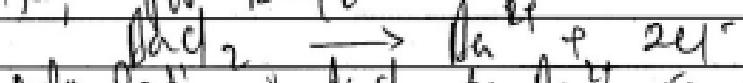
$$q) \text{ Ksp of } \text{BaSO}_4 = 1.12 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$$

thus, for BaSO<sub>4</sub>:



$$\text{thus, Ksp} = [\text{Ba}^{2+}] [\text{SO}_4^{2-}]^2$$

Also, for BaCl<sub>2</sub>



Molar ratio of BaCl<sub>2</sub> to BaSO<sub>4</sub> is 1.

Thus

Amounts of moles of Ba<sup>2+</sup> obtained.

$$n_B = \sqrt{\text{Volume} \times \text{Molarity}} \\ = \sqrt{V \times M}$$

$$n_B = \frac{0.25}{1000} \times 0.001$$

$$= 2.5 \times 10^{-5} \text{ moles}$$

thus Moles

$$[\text{Ba}^{2+}] = \frac{n_B}{V_f}$$

$$= \frac{2.5 \times 10^{-5} \times 1000}{(2.25 + 40)}$$

$$= 3.846 \times 10^{-4} \text{ M}$$

for Na<sub>2</sub>SO<sub>4</sub>



thus Moles = Molarity  $\times$  Volume

$$= M_{\text{Na}_2\text{SO}_4} V_N$$

$$= 0.602 \times \frac{40}{1000}$$

$$= 8 \times 10^{-5} \text{ moles}$$

Molarities of SO<sub>4</sub><sup>2-</sup>, [SO<sub>4</sub><sup>2-</sup>] =  $\frac{1}{V_f}$

40) New concentration of  $\text{Ba}^{2+}$

$$[\text{Ba}^{2+}] = \frac{11 \times 100}{\sqrt{F}} \\ = \frac{9 \times 10^{-1} \times 100}{6} \\ = 1.23 \times 10^{-1} \text{ M}$$

there

$$\text{Q}_{\text{sp}} = [\text{Ag}^{+}] [\text{Ba}^{2+}] \\ = [1.23 \times 10^{-1}] [1.23 \times 10^{-1}] \\ = 4.73 \times 10^{-2} \text{ M}^2 \text{ dm}^{-6}$$

Since,  $\text{Q}_{\text{sp}} > \text{K}_{\text{sp}}$ , thus  $\text{BaSO}_4$  will precipitate in this filtration.

(c) Factors which affect the solubility of sparingly soluble salts:

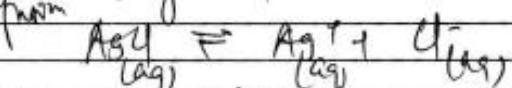
- Common ion effect
- Temperature
- Complex compound formation
- Nature of the solute in salt

(ii) Data given:

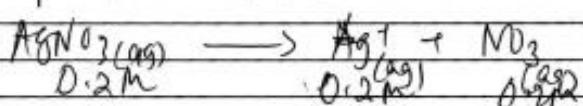
$$\text{Solubility product } \text{K}_{\text{sp}} = 1.8 \times 10^{-10}$$

$$\text{Concentration of } \text{AgNO}_3 \text{, c} = 0.2 \text{ M}$$

Solubility of  $\text{AgCl}$ ,



$$\text{At } 0^\circ \text{C, } \text{K}_{\text{sp}} = [\text{Ag}^{+}] [\text{Cl}^{-}]$$



∴

$$\text{Thus, } [\text{Ag}^{+}] = 0.2 \text{ M}$$

From

$$\text{K}_{\text{sp}} = [\text{Ag}^{+}] [\text{Cl}^{-}]$$

$$[\text{Cl}^{-}] = \frac{\text{K}_{\text{sp}}}{[\text{Ag}^{+}]}$$

$$= 1.8 \times 10^{-10}$$

$$\therefore \text{The solubility of AgCl} \\ = \frac{8 \times 10^{-10}}{5 \times 10^{-10}} \text{ M}$$

In Extract 18.1, the candidate appropriately calculated  $\text{K}_{\text{sp}}$  and  $\text{Q}_{\text{sp}}$  values and managed to rule out correctly that  $\text{BaSO}_4$  would be precipitated. He/she also stated the factors affecting solubility properly and calculated the solubility of  $\text{AgCl}$  correctly.

## 2017 PAST PAPERS- 2

4. (a) Silver chloride has a measured solubility of  $1.024 \times 10^{-4}$  mol/dm<sup>3</sup> at 18 °C. Calculate its K<sub>sp</sub> value. (4 marks)
- (b) (i) Briefly describe the term "common ion effect". (2 marks)  
(ii) Calculate the solubility of solid CaF<sub>2</sub> in a 0.05 M NaF solution. The K<sub>sp</sub> of CaF<sub>2</sub> is  $4.0 \times 10^{-11}$ . (8 marks)
- (c) Should a precipitate of barium fluoride be obtained when 100 mL (millilitres) of 0.25 M NaF and 100 mL of 0.015 M Ba(NO<sub>3</sub>)<sub>2</sub> are mixed? Support your answer by calculations. The K<sub>sp</sub> of BaF<sub>2</sub> is  $1.7 \times 10^{-6}$ . (6 marks)

4	(a) When silver chloride dissolves it gives Ag <sup>+</sup> and Cl <sup>-</sup>
	$\text{AgCl} \rightleftharpoons \text{Ag}^+ + \text{Cl}^-$
	But $x = \text{solubility in water}$ $= 1.024 \times 10^{-4} \text{ mol dm}^{-3}$
	Then
	$K_{\text{sp}} = [\text{Ag}^+][\text{Cl}^-]$

$$K_{sp} = [1.024 \times 10^{-4}] [1.024 \times 10^{-4}]$$

$$K_{sp} = [1.024 \times 10^{-4}]^2$$

$$= 1.048576 \times 10^{-8} \text{ mol}^2 \text{ dm}^{-4}$$

$\therefore$  The  $K_{sp}$  value of silver chloride is

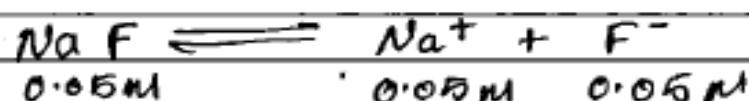
$$1.04857 \times 10^{-8} \text{ mol}^2 \text{ dm}^{-4}$$

(b) (ii) Common ion effect the shifting of equilibrium position of sparingly soluble salt by lowering its solubility due to the addition of ion similar to the one present in the solution. For example the addition of NaF in  $\text{CaF}_2$  because  $\text{F}^-$  which already present in  $\text{CaF}_2$ .

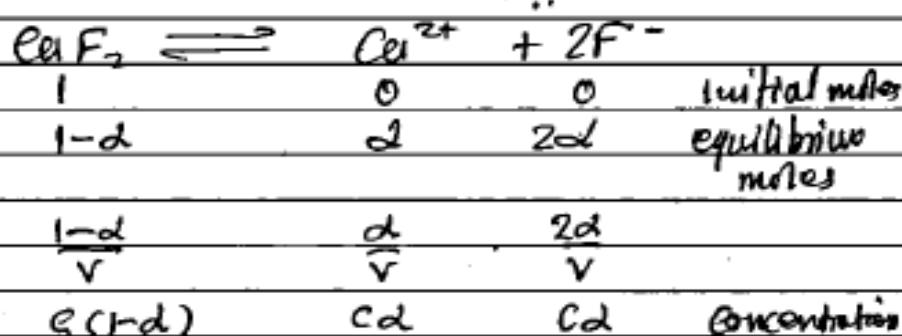
(ii) Given,

$$K_{sp} \text{ of } \text{CaF}_2 = 4.0 \times 10^{-11}$$

concentration of NaF =  $0.05 \text{ M}$   
when NaF dissociates gives  $\text{Na}^+$  and  $\text{F}^-$



For the dissociation of  $\text{CaF}_2$



Now,

$$K_{sp} = \frac{[Ca^{2+}][F^-]^2}{[CaF_3]}$$

$$K_{sp} = \frac{[Ca][Cd]^2}{[Ca(Cd)]}$$

$$\Rightarrow K_{sp} = \frac{(Cd)^2}{c(1-d)}$$

$$K_{sp} = \frac{Cd^2}{1-d}$$

Assuming  $d$  is very small and  
 $1-d \approx 1$

$$K_{sp} = Cd^2$$

$$d = \sqrt{\frac{K_{sp}}{c}}$$

$$= \sqrt{\frac{4.0 \times 10^{-11}}{0.05}}$$

$$= 2.828 \times 10^{-5} \text{ M}$$

Then:

$$Cd = 2.828 \times 10^{-5} \times 0.05 \\ = 1.414 \times 10^{-6} \text{ M}$$

Now

$$K_{sp} = [Ca^+][F^-]^2 \\ = [d][d + 0.05]^2$$

If  $d$  is very small and  $d + 0.05 \approx 0.05$

$$K_{sp} = [d][0.05]^2$$

$$d = \frac{K_{sp}}{[0.05]^2}$$

$$\Rightarrow K_s = \frac{4.0 \times 10^{-11}}{(0.05)^2}$$

$$= 1.6 \times 10^{-8} \text{ M}$$

$\therefore$  the solubility of  $\text{CaF}_2$  is  $1.6 \times 10^{-8}$ .

A (c) for  $\text{NaF}$

$$\text{Initial concentration } M_1 = 0.25 \text{ M}$$

$$\text{Initial volume } V_1 = 100 \text{ ml}$$

$$\text{Final volume } V_2 = (100 + 100) \text{ ml} \\ = 200 \text{ ml}$$

Final concentration is

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{0.25 \times 100}{200} \\ = 0.125 \text{ M}$$

For  $\text{Ba}(\text{NO}_3)_2$

$$\text{Initial concentration } M_1 = 0.015 \text{ M}$$

$$\text{Initial volume } V_1 = 100 \text{ ml}$$

$$\text{Final volume } V_2 = 200 \text{ ml}$$

Final concentration is

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{0.015 \times 100}{200} \\ = 7.5 \times 10^{-3} \text{ M}$$

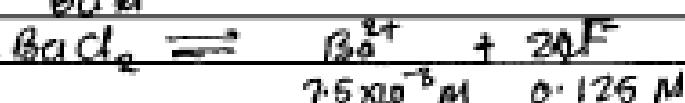
points



and



For  $\text{BaF}_2$



$\text{By finding } Q_{sp} \text{ of } \text{BaF}_2$ $\Rightarrow Q_{sp} = [\text{Ba}^{2+}][\text{F}^-]^2$ $= [7.8 \times 10^{-3}] [0.125]^2$ $Q_{sp} = 1.1718 \times 10^{-4}$
$\therefore \text{Since } Q_{sp} \text{ is greater than } K_{sp}$ $\text{the precipitate of } \text{BaF}_2 \text{ will occur.}$

In Extract 18.1 the candidate applied correct formulae to all parts, correctly substituted the given data and finally made correct calculations.

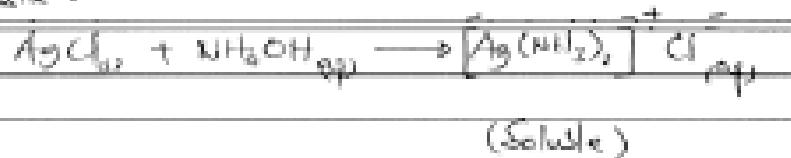
## 2015 PAST PAPERS- 2

2. (a) Explain the following chemical phenomena with the aid of chemical reaction(s):
- (i) Addition of aqueous solution of silver nitrate into dilute HCl produces a white precipitate which dissolves in aqueous ammonia solution.
  - (ii) Zinc sulphide is not precipitated when hydrogen sulphide is passed through a solution to which dilute HCl is added.
  - (iii) The passage of carbondioxide through calcium hydroxide solution changes the latter into a precipitate which dissolves into a clear solution in excess carbondioxide. (6 marks)
- (b) (i) State whether a precipitate will form when  $0.5 \text{ dm}^3$  of  $2 \times 10^{-3} \text{ M BaCl}_2$  is mixed with  $1 \text{ dm}^3$  of  $2 \times 10^{-4} \text{ M Na}_2\text{SO}_4$  given that  $K_{sp}(\text{BaSO}_4) = 1 \times 10^{-10} \text{ mol}^2 \text{dm}^{-6}$ .
- (ii) Calculate the mass of  $\text{Ca}(\text{OH})_2$  which is precipitated at  $25^\circ\text{C}$  when  $500 \text{ cm}^3$  of saturated solution of  $\text{Ca}(\text{OH})_2$  is mixed with equal volume of  $0.4 \text{ M NaOH}$ .  $K_{sp}(\text{Ca}(\text{OH})_2) \text{ at } 25^\circ\text{C} = 4.42 \times 10^{-5} \text{ mol}^3 \text{dm}^{-9}$ . (8 marks)
- (c) The solubility product of lead (II) chloride ( $\text{PbCl}_2$ ) has a value of  $1.6 \times 10^{-5} \text{ mol}^3 \text{dm}^{-9}$  at  $298 \text{ K}$ .
- (i) Explain what is meant by this statement.
  - (ii) Calculate the solubility of lead (II) chloride in water at  $298 \text{ K}$ .
  - (iii) Calculate the solubility of the above compound in a  $0.1 \text{ M}$  solution of lead (II) nitrate at the same conditions. (6 marks)

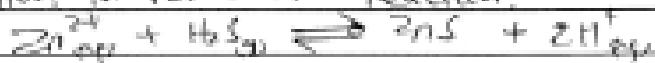
2 a) i) When Silver nitrate solution is added in to dilute  $\text{Zn}^{2+}$  white precipitate forms due to formation of soluble silver chloride



And when aqueous ammonia ( $\text{NH}_3\text{H}_2\text{O}$ ) is added in the solution there is loss of ammonia coordinate bond with silver ion  $\text{Ag}^{+}$  to  $\text{AgCl}$  to form a complex ion and then complexed. The complex compound so formed is soluble -



ii) In absence of dilute HCl, hydrogen sulphide reacts with  $\text{Zn}^{2+}$  ions to give zinc sulphide as following in reversible reaction:

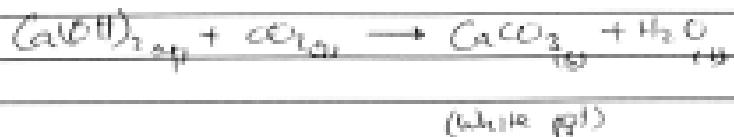


But on adding dilute HCl, the acid dissociates completely to yield  $\text{H}^+$  ions and  $\text{Cl}^-$  ions.



This increases the concentration of hydrogen ions ( $\text{H}^+$ ) and thus shifts the equilibrium to the left, favoring dissociation of  $\text{ZnS}$ .

2 a) iii) When Carbon dioxide ( $\text{CO}_2$ ) is passed through a solution of  $\text{Ca(OH)}_2$ , White insoluble Calcium carbonate is formed as per equation:



But when  $\text{CO}_2$  is present in excess, the product above reacts to form soluble, colorless solution of calcium bicarbonate



Q) Data given.

$$\text{Volume of BaCl}_2 (V_1) = 0.5 \text{ dm}^3$$

$$\text{Molarity of BaCl}_2 (M_1) = 2 \times 10^{-3} \text{ M}$$

$$\text{Volume of Na}_2\text{SO}_4 (V_2) = 1 \text{ dm}^3$$

$$\text{Molarity of Na}_2\text{SO}_4 (M_2) = 2 \times 10^{-3} \text{ M}$$

$$K_{sp}(\text{BaSO}_4) = 1 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$$

From,



where  $x$  is the solubility (concentration) of ions.

Let  $Q_{sp}$  be the solubility product for reaction.

$$Q_{sp} = [\text{Ba}^{2+}] [\text{Cl}^-]^2$$

$$Q_{sp} = x \cdot x^2$$

Now,

$$\text{Concentration of } \text{Ba}^{2+} (\text{Ba}^{2+}) = ?$$

$$[\text{Ba}^{2+}] = \frac{n_{\text{Ba}^{2+}}}{V_{\text{soln}}}$$

from,

$$n_{\text{Ba}^{2+}} = M_{\text{Ba}^{2+}} \times V_{\text{soln}}$$

thus,



$$2 \times 10^{-3} \text{ M} \quad 4 \times 10^{-3} \text{ M}$$

So,

$$n_{\text{Ba}^{2+}} = 2 \times 10^{-3} \text{ M} \times 0.5 \text{ dm}^3$$

$$= 1 \times 10^{-3} \text{ mole}$$

$$\therefore n_{\text{Ba}^{2+}} = n_1 + n_2 = 0.5 + 0.5 = 1 \text{ dm}^3$$

Q.	Balanced
	$[Ba^{2+}] = \frac{1 \times 10^{-2} \text{ mol}}{1.5 \text{ dm}^3}$
	$= 6.67 \times 10^{-4} \text{ M}$
	Concentration of $SO_4^{2-}$ ( $[SO_4^{2-}]$ ) = ?
	From $[SO_4^{2-}] = \frac{n_{SO_4^{2-}}}{V_{\text{dm}^3}} = \frac{\text{Moles} \times V_2}{V_{\text{dm}^3}}$
	From $K_{sp, BaSO_4} = 10^{-4} \rightarrow [SO_4^{2-}]$ $2 \times 10^{-4} \quad \square \quad \square$ $\square \quad 4 \times 10^{-4} \quad 2 \times 10^{-4} \text{ M}$
	$Q_s$ $[Ba^{2+}] = 2 \times 10^{-4} \text{ M} \times [SO_4^{2-}]$ $\quad \quad \quad 1.5 \text{ dm}^3$ $\quad \quad \quad \times 1.33 \times 10^{-4}$
	Thus, $Q_{sp} = [Ba^{2+}] \times [SO_4^{2-}]$ $= 6.67 \times 10^{-4} \text{ M} \times 1.33 \times 10^{-4} \text{ M}$ $= 8.87 \times 10^{-8} \text{ mol}^2 \text{ dm}^{-4}$
	Now, Since $Q_{sp} > K_{sp}$ for $BaSO_4$ , then the precipitate will form.

Extract 2.1 shows one of the candidates' responses who provided good responses in part (a) and (b). This illustrates a mastery of solubility product.

## 6.0 EXTRACTION OF METALS

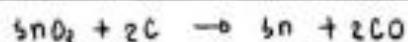
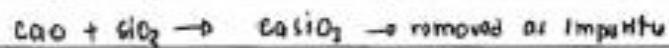
### 2018 PAST PAPERS -2

6. (a) Briefly describe the extraction process of tin from its chief ore. (8 marks)
- (b) Briefly describe the chemical extraction of aluminium from its chief ore. (12 marks)

Ques	The extraction of tin from its chief ore.
	Steps involved in extraction of Tin
i:	chief ore of Tin Since Tin is more reactive it exists in a combined state to form an oxide - Cassiterite (Tin stone) - $\text{SnO}_2$
ii:	concentration of the ore The concentration of ore is done by separation the earth impurities from Tin. This involves grinding of the Tin ore into smaller pieces then separating them from the lighter impurities.
iii:	washing The powdered ore contains earth impurities which become separated from Tin by gravity separation whereby the lighter siliceous impurities are washed away by the current of water. i.e silicon containing impurities are washed away.
iv:	Roasting The impurities in the Tin ore include iron and arsenic which tend to react to form the oxides which are more volatile and tend to escape like vapour. i.e $4 \text{ As} + 3 \text{ O}_2 \rightarrow 2 \text{ As}_2 \text{ O}_3$ $3 \text{ Fe} + \text{ O}_2 \rightarrow 2 \text{ FeO}$
v:	Leaching and washing This is done to remove the sulphates of copper and iron that act as impurities in extraction of Tin and the Tin obtained is black Tin.

6(a) vi: Smelting

This is done in the reverberatory furnace in which tin ore is reduced to tin and the impurities of silicate are removed.



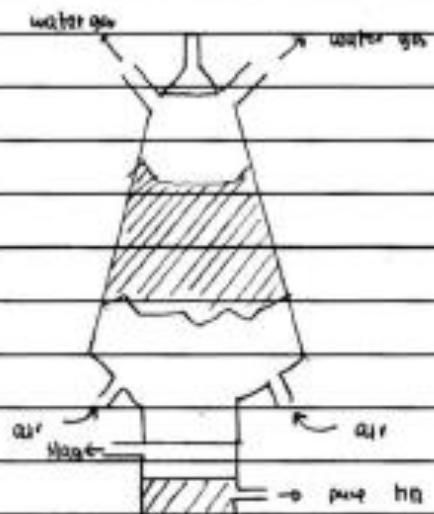
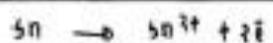
vii: Purification of tin:

This can be done through liquation and electrolysis whereby in electrolysis within electrolytic cell the electrolyte is  $\text{H}_2\text{SO}_4$  and  $\text{CuSO}_4$  whereby pure tin is collected at cathode and impure at anode.

At Cathode:



At anode:



Reverberatory furnace

Q(b)	The chemical extraction of aluminium from the ore.
	Step in extraction
i: chief ore	<ul style="list-style-type: none"> <li>- Gossite <math>\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}</math></li> </ul>
ii: other ores	<ul style="list-style-type: none"> <li>- Kaolin</li> <li>- Felspar</li> <li>- Cryolite - <math>\text{Na}_3[\text{AlF}_6]</math></li> </ul>
iii: impurities	<ul style="list-style-type: none"> <li>- <math>\text{TiO}_2</math></li> <li>- <math>\text{FeO}</math></li> <li>- <math>\text{SiO}_2</math></li> </ul>
iv: concentration of the ore	<p>The chief ore of aluminium is crushed to smaller pieces      then treated with concentrated NaOH at higher pressure      whereby the ore and <math>\text{SiO}_2</math> react:</p> $\text{NaOH} + \text{Al}_2\text{O}_3 + \text{H}_2\text{O} \xrightarrow[\Delta]{\text{high pressure}} \text{Na}[\text{Al}(\text{OH})_4]$
	$\text{NaOH} + \text{SiO}_2 \rightarrow \text{Na}_2\text{SiO}_3$
	$\text{TiO}_2 + \text{NaOH} \text{NaOH} \rightarrow \text{no reaction}$
	$\text{FeO} + \text{NaOH} \rightarrow \text{no reaction}$
v: Filtration and separation	
	On filtration and separation the $\text{Na}[\text{Al}(\text{OH})_4]$ and $\text{Na}_2\text{SiO}_3$ are the filtrate while $\text{TiO}_2$ and $\text{FeO}$ are moved as the residue.

Ques	iv) The reaction with carbondioxide
	Only $\text{Na}[\text{Al}(\text{OH})_4]$ reacts with carbondioxide to form
	$\text{Al}(\text{OH})_3$ while $\text{Na}_2\text{AlO}_2$ does not react with carbondioxide
	$\text{Na}[\text{Al}(\text{OH})_4] + \text{CO}_2 \rightarrow \text{Al}(\text{OH})_3 + \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$
	$\text{Na}_2\text{CO}_3 + \text{CO}_2 \rightarrow$ no reaction
v) Separation and filtration	
	On separation $\text{Al}(\text{OH})_3$ will be the residue while $\text{Na}_2\text{AlO}_2$ will be the filtrate
	$\text{Al}(\text{OH})_3 \rightarrow$ residue
	$\text{Na}_2\text{AlO}_2 \rightarrow$ filtrate
vi) Formation of aluminum ( $\text{Al}_2\text{O}_3$ )	
	This is done through decomposition reaction by heating
	$\text{Al}(\text{OH})_3$ in intense heat to form $\text{Al}_2\text{O}_3$ and $\text{H}_2\text{O}$
	$\text{Al}(\text{OH})_3 \xrightarrow{\Delta} \text{Al}_2\text{O}_3 + \text{H}_2\text{O}$
vii) Electrolysis	
	During electrolysis the pure aluminum is collected at the cathode in the electrolytic cell. There is the use of
	cryolite that helps in increasing conductivity of aluminum
	and lowers melting point of aluminum
	Al collected
	$\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$
	Al anode
	$\text{O}_2 + 4\text{e}^- \rightarrow \text{O}^{2-}$

(a)	The carbon electrode used is replaced frequently because the liberated oxygen oxidises it to carbon dioxide.

Extract 20.1 shows a set of correct responses from a candidate who explained correctly, with the support of illustrations, the basic stages involved in extraction process of tin and aluminium from their chief ores.

## 2017 PAST PAPERS -2

6. (a) Identify four general principles or steps which are followed during metal extraction. (2 marks)
- (b) With the aid of chemical equation(s), analyse the process of extracting tin (Sn) from its ore cassiterite under the following subheadings:
- (i) Thermal reduction of the ore
  - (ii) Purification of the ore from the impurities.
  - (iii) Its two uses in real life. (8 marks)
- (c) Extraction of aluminium and its purification from bauxite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) can be represented by sequence of steps of events using boxes with relevant information. Design and formulate the major events sequentially to summarise the extraction which eventually leads to purification of this metal. (Diagram of the electrolytic cell and details of chemical reactions involved are not required). (10 marks)

6  
C

Aluminium ore is treated with sodium hydroxide at 140 - 240°C and pressure of 25 atm.

The aluminium ore form  $\text{Na}[\text{Al(OH)}_4]$  and silicate impurities react with sodium hydroxide to form silicic dioxide either impurities do not react.

The mixture is filtered and  $\text{NaAl(OH)}_4$  and  $\text{SiO}_2$  obtained as filtrate while other impurities obtained as residue.

The filtrate obtained is treated with carbon dioxide. Then the  $\text{NaAl(OH)}_4$  react with carbon dioxide to form white precipitate of  $\text{Al(OH)}_3$  while the silicic acid  $\text{SiO}_2$  do not react with carbon dioxide.

The mixture is filtered again, and aluminium hydroxide

(Q)  $\text{Al(OH)}_3$  is obtained as residue precipitate and  $\text{SiO}_2$  a precipitate.

The  $\text{Al(OH)}_3$  is heated to obtain  $\text{Al}_2\text{O}_3$  which is introduced into electrolytic cell together with cryolite  $\text{NaAlF}_6$ .

The molten aluminium is collected at the lining cathode.

Extract 20.2 shows a response to part 6 (c) of the question. The candidate adhered to the questions demand by designing and

formulating block diagrams to show the major events from the extraction to purification of aluminium.

## 2016 PAST PAPERS -2

7. Briefly explain the following:

- (a) (i) Metals do not occur as nitrate in nature.  
(ii) Activity series of metals.  
(iii) A metal A is found in free state in nature while metal B is found in the form of its compound. Which of the two metals will be nearer to the top of the activity series of metals?  
(iv) Aluminium cannot be extracted by reducing alumina with carbon.  
(v) Limestone is added to the blast furnace in the extraction of iron from haematite. Support with equations.

(10 marks)

(b) Describe methods that are applied in extracting metals which are

- (i) very reactive  
(ii) less reactive.

(10 marks)

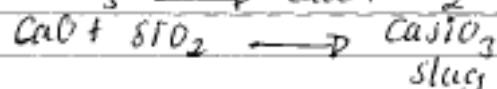
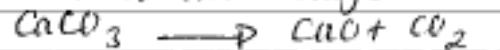
7a (i) Metal do not occur as nitrate in nature  
This is because nitrates are unstable  
such that can not exist under ordinary  
conditions.

(ii) Activity series of metal  
Is the arrangement of metal in order of  
increasing or decreasing reducing power.

(iii) Metal B will be nearer to the top of the  
activity series since it is more reactive.

(iv) Aluminium can not be extracted by reducing  
alumina with carbon this is because  
Aluminium is very reactive thus reacts with  
Carbon to form aluminium carbide instead  
of aluminium metal.

(v) Limestone is added in the blast furnace  
in order to form  $\text{CaO}$  which will then  
used to form slag ie  $\text{CaSiO}_3$ .



b Extraction of metal is the process of obtaining  
pure metal from its ore, the choice of  
method of extraction depends on the position  
of the metal in activity series. This is  
explained as follows

7b

(i) very reactive metal

Very reactive metals such as Na, ca and aluminium are extracted from their chief ores by electrolysis method. The method is used because normal reducing agent can not reduce metals from their oxides. For example

Aluminium Oxide can not be reduced by Carbon or Carbonmonoxide because Aluminium reacts with Carbon to form Aluminium Carbide.



Hence Electrolysis become the best option.

(ii) Less reactive metal

The less reactive metal such as Iron, copper silver and gold can be extracted from their chief ores by Chemical Reduction and purification. For example Gold and silver being least reactive can only be extracted by Purification.

Ores which occurs as sulphides eg Copper is first converted to oxide which can be easily reduced to metal. For example Iron Haematite is reduced to iron by Carbonmonoxide.



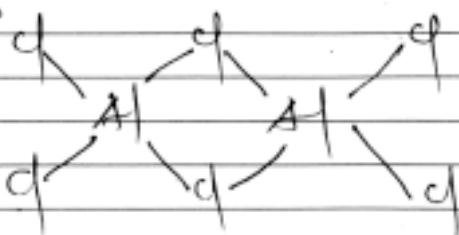
In Extract 21.2, the candidate correctly responded to all the items in part (a) except item (i). Similarly, he/she gave correct descriptions of the methods that are applied in extracting metals which are very reactive and less reactive.

## 2015 PAST PAPERS -2

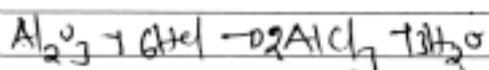
5. (a) Explain the following phenomena with the aid of chemical equation(s) where possible  
(i) Common reductants are useless in the manufacture of aluminium from its ore.  
(ii) Aluminium chloride is a good Lewis acid.  
(iii) Molecular mass of  $\text{AlCl}_3$  in vapour state is twice the expected value.  
(iv) Aluminium oxide shows basic properties by reacting with HCl. (6 marks)
- (b) Describe the process of aluminium extraction starting with bauxite under the following stages:  
(i) Purification of the ore from impurities.  
(ii) Electrolysis of aluminium. (10 marks)
- (c) Evaluate any four uses of aluminium which reflect its physical and chemical properties. (4 marks)

5	<p>(a) (i) Because aluminium can act as the reducing agent itself.</p> <p>(ii) Aluminium chloride is Lewis acid because it can accept lone pair since it has an empty orbital.</p> $\text{AlCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{Al(OH)}_3 + 3\text{HCl}$

(iii) Molecular mass of  $\text{AlCl}_3$  in vapour state is twice of the expected because in the vapour state  $\text{AlCl}_3$  undergoes dimerization which results in the increase of its mass.



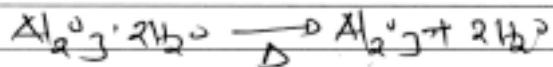
5 (a) (iv) Aluminium oxide shows basic properties by reacting with NaOH because Aluminium oxide reacts with NaOH to produce salt and water



5 (b) Aluminium extraction by using bauxite

(i) Purification of the ore from Impurities

(a) Removal of water from the ore. The ore is heated to remove water

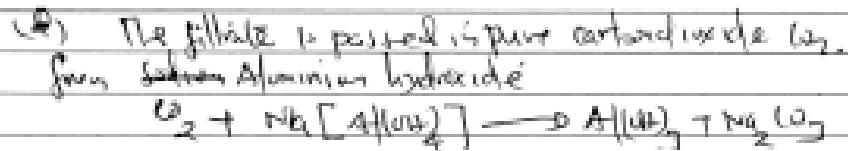


(b) The ore is reacted with concentrated Sodium hydroxide (NaOH) to form Sodium tetrahydroxo aluminate



but silicon and ferric which are impurities of Al Bauxite doesn't react with conc. NaOH

(c) The mixture of  $\text{Na}[\text{Al}(\text{OH})_4]$  was filtered to obtain the filtrate the  $\text{SiO}_4^{4-}$  and  $\text{Fe}^{3+}$  remain as residue



5 (diss) The aluminium hydroxide is heated to produce solid aluminium oxide.



### 8 (diss) Electrolysis of aluminium

The molten aluminium oxide introduced into electric furnace needs to melt. The aluminium oxide melts at the temperature of  $900^\circ\text{C}$ . In order to decrease the temperature of  $\text{Al}_2\text{O}_3$  cryolite is added.

The electrolytic cell's temperature should not exceed  $900^\circ\text{C}$ . If the temperature will exceed cryolite can melt the cryolite. Lower the temperature to about  $700^\circ\text{C}$ . This cause the aluminium oxide to decompose.



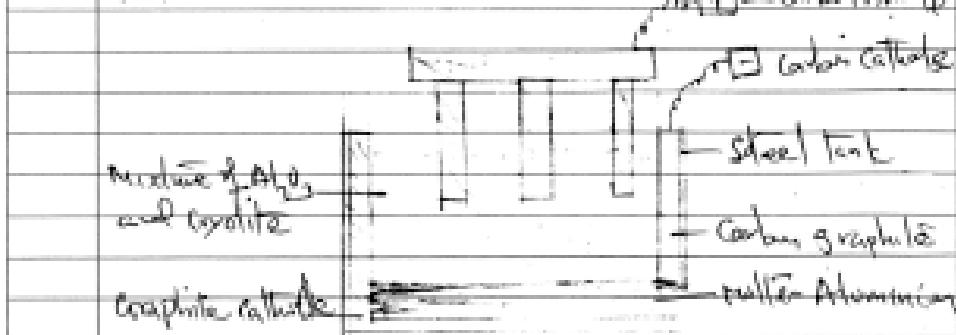
- Reaction at the cathode



- Reaction at the anode



Diagram of electrolytic cell (Bayard cell) of Aluminium.



5	(a) Four uses of aluminium.
	(i) It used in transportation of nitric acid (litres) because it form protective layer.
	(ii) It used in manufacturing of electronic devices because it is good conductor of electricity.
	(iii) It used in Manufacturing domestic utensils because it is good conductor of heat.
	(iv) It used in Manufacturing of Aluminium sheets which used in Building and construction of vehicle.

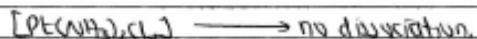
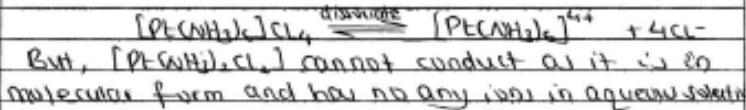
Extract 5.1 shows a sample of responses of candidate who managed to perform well all parts of the question.

## 7.0 TRANSITION ELEMENTS

### 2019 PAST PAPERS - 2

6. (a) (i) Explain how do  $[\text{PtCl}_2(\text{NH}_3)_2]$  and  $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$  differ in electrolytic conductance.  
(ii) Write the hybridization states of Pt in compounds at 6 (a) (i). (5 marks)
- (b) Identify the coloured complexes from the following and give one reason for each compound of your selection.  
(i)  $[\text{Ti}(\text{NO}_3)_4]$ .  
(ii)  $[\text{Cu}(\text{NH}_3)_4]\text{BF}_4^-$ .  
(iii)  $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$ .  
(iv)  $\text{K}_3[\text{VF}_6]$ . (5 marks)
- (c) (i) Distinguish paramagnetism from diamagnetism.  
(ii) With reasons, identify the paramagnetic and diamagnetic compound in  $[\text{Fe}(\text{CN})_6]^{4-}$  and  $[\text{FeF}_6]^{6-}$ . (4 marks)
- (d) An element X with common oxidation state of +2 is obtained as a white gelatinous precipitate when sodium hydroxide is added to its ionic solution. When excess amount of the alkali is used, the precipitate dissolves. The precipitate also dissolves when an aqueous solution of ammonia is added in excess amount. Deduce element X using proper chemical equations from the given information. (6 marks)

6(a) vii  $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$  is very conducting in aqueous solution and hence has higher electrolytic conductivity compared to  $[\text{Pt}(\text{Cl}_2(\text{NH}_3)_2]$ . This is because,  $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$  tends to dissociate to form ions in the aqueous solution and these ions allow it to conduct electricity much faster and easily.



6(a) viii

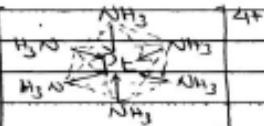
Hybridisation in  $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$

Oxidation state in the compound

$$x + (\text{CN})_6 = +4$$

$$x = +4$$

Pt - The shape of the molecule is thus octahedral



Thus, hybridisation state of Pt in  $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$  is  $s p^3 d^2$  hybridisation

Hybridisation in  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$

Oxidation state in the compound

$$x + (\text{CN})_2 + (\text{Cl})_2 = 0$$

$$x - 2 = 0$$

$$x = +2$$

Extract 20.2: A sample of correct responses in question 6.

## 2016 PAST PAPERS - 2

4. (a) Write the chemical formulae for the compounds; potassium hexacyanocobaltate (III) and potassium hexacyanoferrate (II). **(2 marks)**
- (b) Observe the complex ion  $[\text{Co}(\text{NH}_3)_3(\text{H}_2\text{O})_2\text{Cl}]^+$ , then answer the following questions:
- Identify the ligands and the charge on each of them.
  - Write the geometry of the complex ion. **(3 marks)**
- (c) Briefly explain why bivalent titanium ion  $[\text{Ti}^{2+}]$  is paramagnetic. **(1.5 marks)**
- (d) Give the IUPAC names of the following compounds:
- $\text{Cu}_2[\text{Fe}(\text{CN})_6]^{2-}$
  - $[\text{Cu}(\text{NH}_3)_4\text{SO}_4]$
  - $\text{Ag}(\text{NH}_3)_2\text{Cl}$
  - $[\text{Ni}(\text{NH}_3)_6]\text{Cl}_2$
  - $[\text{Cr}(\text{en})_2\text{Cl}_2]^+\text{NO}_3^-$ . **(7.5 marks)**
- (e) Find oxidation state of the central metal ion or atom in the following compounds:
- $\text{KMnO}_4$
  - $[\text{Pt}(\text{NH}_3)_4][\text{PtCl}_4]$
  - $[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]_2(\text{SO}_4)_3$
  - $[\text{Co}(\text{NH}_3)_4\text{Br}_2]_2\text{SO}_4$ . **(6 marks)**

4a)	The formulae for the named compounds are
i)	K Potassium hexacyanocobaltate (III) = $\text{K}_3 [\text{Co}(\text{CN})_6]$ .
ii)	Potassium hexacyano ferate (II) = $\text{K}_4 [\text{Fe}(\text{CN})_6]$ .
b)	Given: $[\text{Co}(\text{NH}_3)_3(\text{H}_2\text{O})_2\text{Cl}]^+$
i.	The ligands are: $\text{NH}_3$ , $\text{H}_2\text{O}$ and $\text{Cl}^-$ The charges are for $\text{NH}_3$ it is $0$ , for $\text{H}_2\text{O}$ it is $0$ and for $\text{Cl}^-$ it is $-1$
ii.	The complex is an octahedral complex.
iii.	Required: To explain why $[\text{Ti}^{2+}]$ is paramagnetic. $\Rightarrow$ paramagnetic substance is a substance which can be attracted by a magnet. for a sub-atom $\Rightarrow$ be paramagnetic if must have at least

a) One unpaired electron in one of its orbitals. This is paramagnetic as it has two unpaired electrons in its d orbital as indicated by its electronic configuration given below.

$$[Ar] 3d^2$$

The electrons in d orbital are unpaired as shown in the orbital diagram below:



-The two unpaired electrons make  $Ti^{2+}$  paramagnetic.

b) The IUPAC names for the given compounds are as follows:

i) Copper (II) hexacyano ferrate (III).

ii) Tetraammine sulphato copper (III).

iii) Diammine silver Diammine silver(II) chloride.

iv) Hexaammine nickel (II) chloride.

v) Dichloro bis (ethylenediamine) chromium (III) nitrate.

g) Oxidation state.

$K_2MnO_4$

The compound has two ions  $K^+$  and  $MnO_4^-$ .

The oxidation state of  $K^+$  is +1

For Mn in  $MnO_4^-$  can be found as per

$$x + (y - 2) = -1$$

4e)	$x = +7$ ∴ The oxidation state of Mn is +7
i.	$[\text{Pt}(\text{NH}_3)_4] \text{Cl}_4$ Let the oxidation state of Pt in the compound be x $x + (6 \times 4) + 4 + -1 \times 4 = 0$ $2x = 4 - 8$ $2x = -4$ $\frac{2x}{2} = \frac{-4}{2}$ ∴ The oxidation state of Pt is +2.
ii.	The compound has two ions $[\text{Co}(\text{C}_5\text{H}_5\text{NHC}_5\text{H}_5)_2]^{\frac{+}{2}}$ and $\text{SO}_4^{2-}$ Let the oxidation state of Co be x $x + 3 \times 0 = +3$ $x = +3$ ∴ The oxidation state of Co is +3.
iii.	$[\text{Co}(\text{PPh}_3)_4 \text{Br}_2]$ , SO <sub>4</sub> <sup>2-</sup> , the compound has two ions $[\text{Co}(\text{PPh}_3)_4 \text{Br}_2]^+$ and $\text{SO}_4^{2-}$ Let x be the oxidation state of Co $x + 4 \times 0 + 2 \times -1 = +1$ $x = +3$ ∴ The oxidation state of Co is +3.

In Extract 18.1, the candidate wrote correct chemical formulae of the asked compounds, identified the ligands and their charges, correctly explained why  $[\text{Ti}^{2+}]$  is paramagnetic, gave correct IUPAC names of compounds and finally computed the correct oxidation states of the central metal ion as required.

## 2015 PAST PAPERS - 2

6. (a) (i) Write the electronic configurations of the following species:  $Mn^{2+}$ ,  $V^{3+}$  and  $Fe^{3+}$ .  
(ii) Give reason(s) why in manganese the oxidation state of +2 is more stable than the oxidation state of +3.

(4 marks)

- (b) Briefly explain each of the following phenomena:

- (i) The radii of Fe, Co and Ni show a much smaller variation in size than those of Na, Mg and Al.
- (ii) Cadmium has two electrons in the outermost shell as does magnesium but they are not classified in the same group.
- (iii) Iron element exhibits magnetic properties while zinc element does not.

(6 marks)

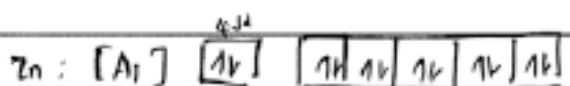
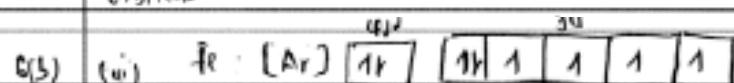
- (c) (i) Account for the different coordination numbers between  $[FeCl_4]^{2-}$  and  $[FeF_6]^+$ .  
(ii) What are the origins of magnetism in transition elements?  
(iii) Use the 3d electron configuration in cobalt (III) ions to explain why  $[CoF_6]^{3-}$  is paramagnetic while  $[Co(CN)_6]^{3-}$  is diamagnetic.  
(iv) Briefly explain why  $[Fe(CN)_6]^{4-}$  is said to be an inner orbital complex while  $[CoF_6]^{3-}$  is said to be an outer orbital complex. Determine the type of hybridization exhibited by each of the two complexes.

(10 marks)

(a)	$Mn^{2+} : [Ar] 4s^2 3d^5$
	$V^{3+} : [Ar] 4s^2 3d^2$
	$Fe^{3+} : [Ar] 4s^2 3d^5$
(b)	$Mn^{2+} : [Ar] 4s^2 3d^5$
	$Mn^{3+} : [Ar] 4s^2 3d^4$
	Manganese oxidation state of +2 is more stable because the d-orbital is half-filled in comparison with the rest of half-filled orbital. Due to this half-filled d-orbital it makes it to be stable but for
	Manganese oxidation state of +3 is not stable because the d-orbital in it is not half-filled due to this it
	makes it to be unstable

(b) (i) The radii of Fe, Co and Ni show small variation because first these elements are transitional elements due to this the difference in atomic number (<sup>charge</sup>) in them is compensated by the effect of screening effect since electrons are added in the same d-orbital hence making their radii not to vary much but for Na, Mg and Al are elements in group three and in each element the outermost electron is in different orbital as a result the effect of increase in atomic number (charge) is not compensated hence making their radii to vary much because of different factors affecting it.

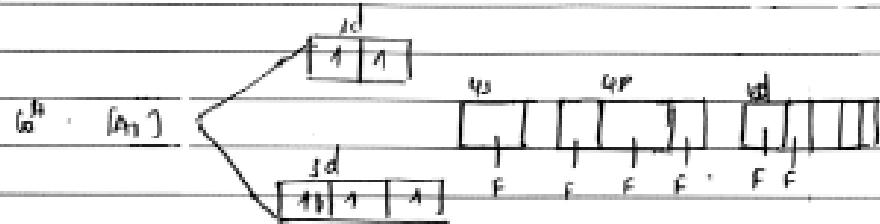
(ii) Sodium is not classified in the same group as magnesium despite of having same number of electrons in the valence shell it is because magnesium has large metallic character as group 2 elements but sodium has low metallic character due to these it makes it not to belong to group 2 and this is as a result of strong octet pair effect it experiences hence it cannot remove its electrons and f electrons cannot participate in a reaction due to poor screening effect caused by presence of d and f orbital.



Iron element exhibit magnetic properties due to presence of unpaired electrons due to this induces magnetic effect (field) but for Zn the d orbitals are fully paired as a result it makes it not have magnetic properties.

Q(1)	<p><math>[\text{Fe}(\text{Cl}_6)]^{2-}</math> and <math>[\text{FeF}_6]^{4-}</math> have different coordination number due to the factor of steric hindrance caused by bulkiness of a ligand. For <math>[\text{FeCl}_6]^{2-}</math> the ligand chloro has high molecular weight due to this it uses coordination number of 6 to try to reduce bulkiness hence avoiding steric hindrance but for <math>[\text{FeF}_6]^{4-}</math> fluorine is a light ligand hence uses high coordination number and it</p>
Q(2)	<p>definite effect the central metal atom has on steric hindrance and bulkiness hence as a result making it stable</p>
Q(3)	<p>All transition elements are elements with partially filled electrons in the d-orbitals due to this most elements in their d-orbitals consist of unpaired electrons hence creating magnetic field so the result is makes it to have magnetic properties with exception to zinc</p>
Q(4)	<p>(i) <math>[\text{Co}(\text{A}_1)]^{4+} \text{sd}^1</math>  <math>[\text{Co}(\text{T})]^{4+} \text{sd}^1</math></p>
(ii) $[\text{CoF}_6]^{3-}$	<p>In addition of a ligand the d orbital splits to form triplet and doublet group depending whether a strong ligand or weak ligand is added. In presence of weak ligand the two groups will have equivalent energy but for strong ligand two groups formed will have different energy      for <math>[\text{CoF}_6]^{3-}</math></p>
	<p>Ligand added is fluorine which is a weak ligand hence d orbital will split to form triplet and doublet group which will have equivalent energy hence adding of electrons will follow Mnd's rule</p>

(e) (ii)

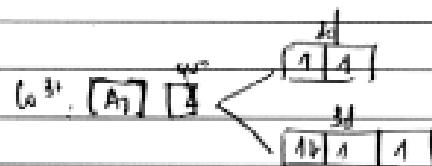


Hence forming unpaired electrons as the result it is paramagnetic.

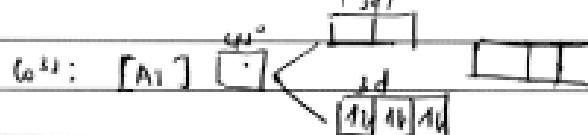
(f) (i) For  $[\text{Co}(\text{CN})_6]^{3-}$

Cyano is a strong ligand hence making the d-orbital to split and form double and triple group of different energies.

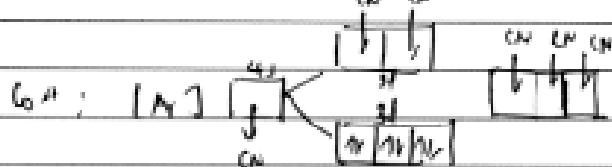
In CN cyano is a strong ligand it makes unpaired electrons to pair up and hence filling begins.



In addition of cyano electrons pair up



Hence ligands occupy empty orbital



Due to huge, there is no unpaired electrons hence making it diamagnetic.

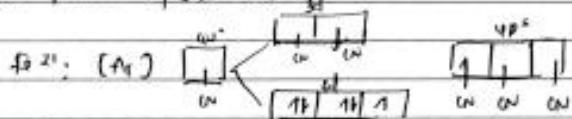
(a) (i)  $[\text{Fe}(\text{CN})_6]^{4-}$  consist of strong ligand due to this it will force the unpaired electrons in d orbital to pair up and hence  $\text{Fe}^{2+}$  occupy the empty d orbital left first then the s orbital due to this it makes it an inner orbital complex but for  $[\text{Fe}(\text{CN})_6]^{3-}$  consist of weak ligand and it cannot force unpaired electrons to pair up hence no empty orbital will be present as a result it will occupy the s orbital then followed by other orbitals which are empty due to this it makes it outer orbital (empty)

$\text{Fe}^{2+} [\text{Tr}(\text{CN})_6]^{4-}$

$\text{Fe} : (\text{Ar}) 4s^2 3d^6$

$\text{Fe}^{2+} : (\text{Ar}) 4s^2 3d^5$

On addition of ligand if split then a strong ligand is added follows Aufbau rule



Hence d orbital is filled first followed by orbital

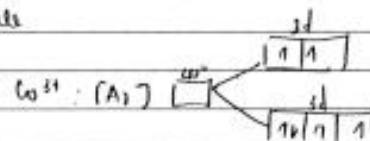
Hence hybridization is  $d^5sp^3$  hybridization

for  $[\text{CoF}_6]^{3-}$

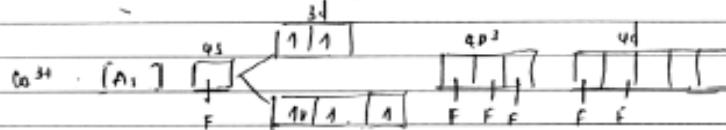
(a)  $[\text{Ar}] 4s^2 3d^7$  at ground state

(a)  $[\text{Ar}] 4s^2 3d^6$  at excited state

On addition of fluorine (weak ligand) it splits and addition of electrons will follows Hund's rule



(a) On addition of fluorine it will occupy the empty orbitals and 4s orbital will be occupied first, then followed by 4p and finally for 3d orbital



$sp^3d^2$

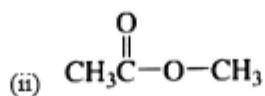
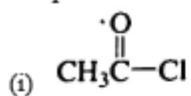
∴ the hybridization prohibited by  $[\text{CoF}_6]^{3-}$  -  $sp^3d^2$  hybridization.

Extract 6.1 shows a sample of a response of a candidate who had sufficient knowledge in transitional elements. The candidate gave proper and clear explanations according to the requirement of the question. However, the candidate failed to give concrete explanation why  $\text{Mn}^{2+}$  is more stable than  $\text{Mn}^{3+}$  which led to failure to score full marks.

## 8.0 AMINES

### 2020 PAST PAPERS – 2

5. (a) With the aid of chemical equations, show how dimethylamine reacts with the following compounds:



(3 marks)

- (b) Give the structural formula of the following compounds:

(i) tripropylamine

(ii) dipentylamine

(iii) 2,4-dimethyl-3-hexanamine.

(3 marks)

- (c) (i) Show how you can carry out the conversion starting from propanoylchloride to dipropylamine.

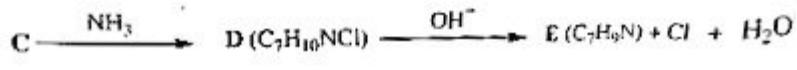
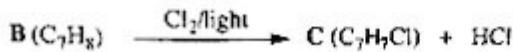
(ii) Write the equation to show the reaction between benzaldehyde ( $\text{C}_6\text{H}_5\text{CHO}$ ) and warm phenylamine.

(iii) Write the general formula and functional group of secondary amine and tertiary amine.

(iv) Write the equation for the equilibrium that exists when diethylamine dissolves in water.

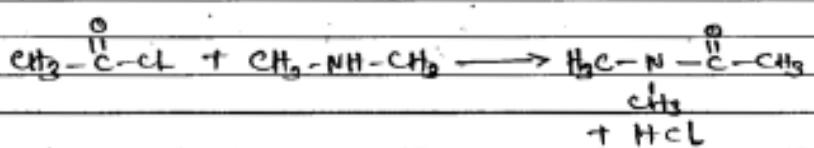
(8 marks)

- (d) Give the structural formula for compounds B through E, which undergo the following sequence of reactions:

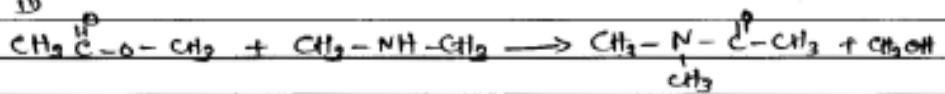


(6 marks)

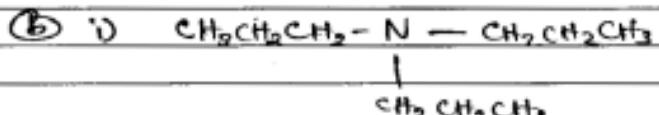
5 a) i)



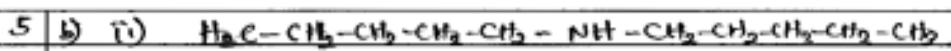
ii)



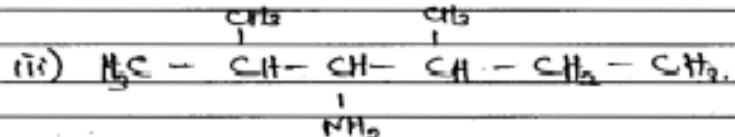
b) i)



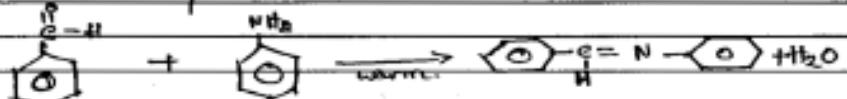
b) ii)



iii)

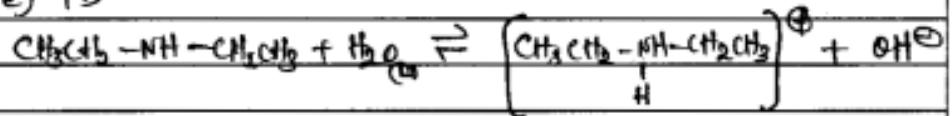


c) ii) The equation is:

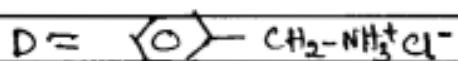
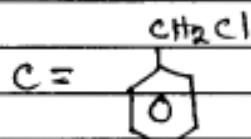
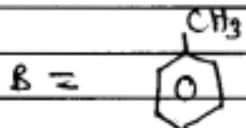
iv) - The general formula for secondary amine is  $\text{R}-\text{NH}-\text{R}'$ .The functional group is  $-\text{NH}-$  $\Rightarrow$  Also for tertiary amine the general formula- The functional group is  $-\text{N}-$ 

iv) Dimethylamine dissolves in water to form a fish smell odour. The reaction for the equilibrium is as follows.

5 e) i)

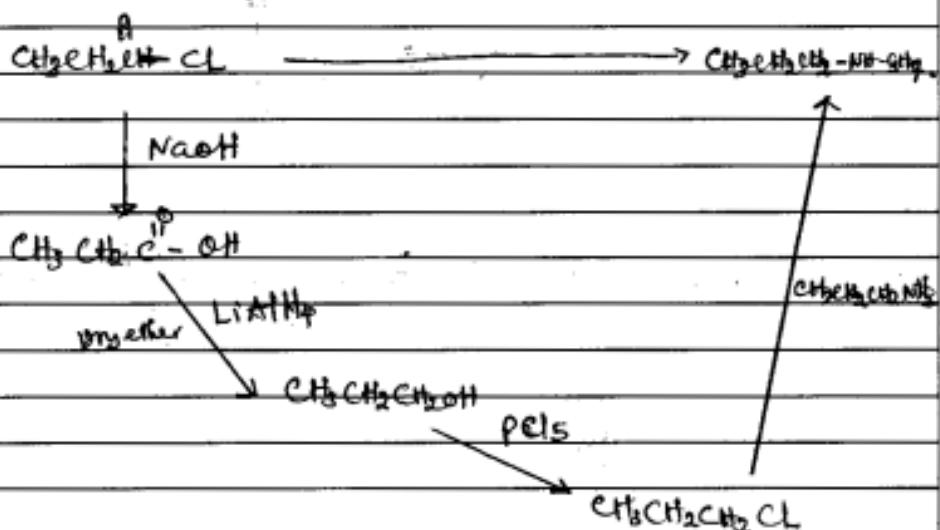


d)



5 c) i) The conversion is carried as follows.

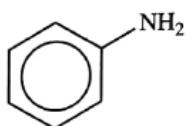
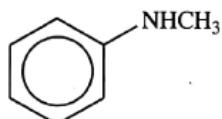
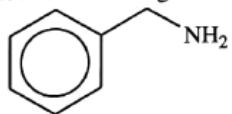
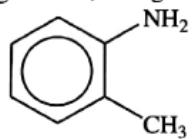
5 c) ii)



Extract 15.1: A sample of correct responses in question 5

## 2018 PAST PAPERS – 2

9. (a) Giving reasons, arrange the following amines in order of increasing basic strength:



(4 marks)

- (b) Show how *n*-propylamine could be prepared from each of the following compounds:

- (i) *n*-Propylbromide.
- (ii) *n*-Propylalcohol.
- (iii) *n*-Butylalcohol.
- (iv) Propanitrile.

(8 marks)

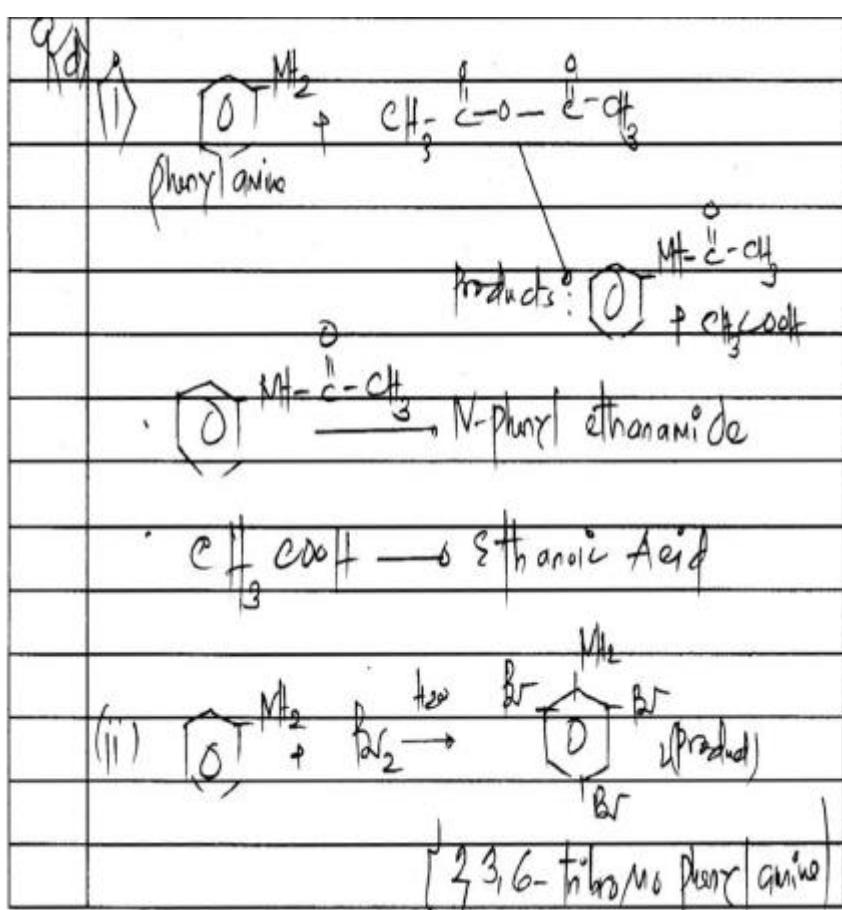
- (c) In two steps, describe how you would convert benzene into aniline (phenylamine)

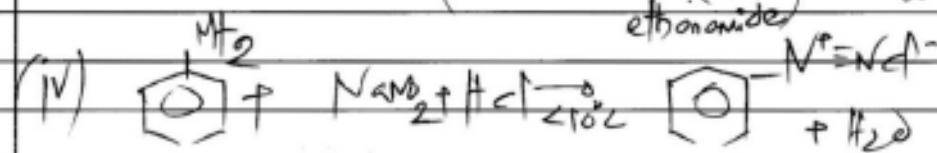
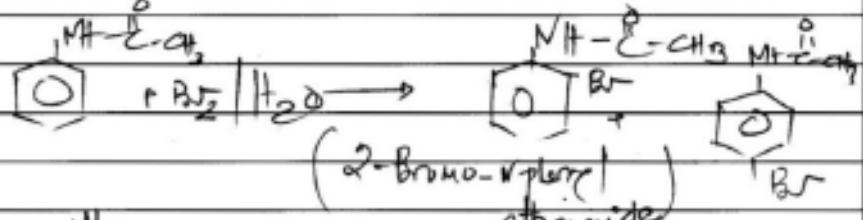
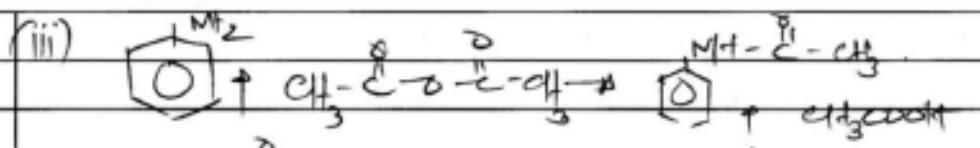
(3 marks)

- (d) Give the structures and names of the organic products formed when phenylamine reacts with the following:

- (i) Ethanoic anhydride.
- (ii) Aqueous bromine.
- (iii) Ethanoic anhydride followed by bromine water.
- (iv) Sodium nitrite and hydrochloric acid below 10 °C.

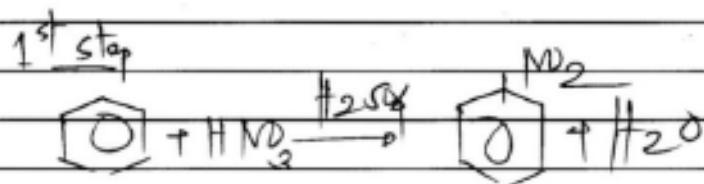
(5 marks)





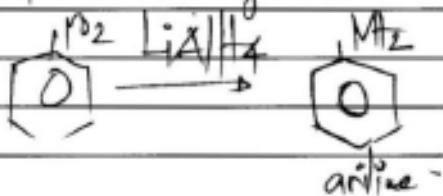
Product:  $\text{N}^{\bullet}\text{H}-\text{C}(\text{Cl})-\text{C}_6\text{H}_5$ , Benzene diazonium chloride

Ques - with the detailed conversion.  
Benzene  $\xrightarrow{\text{Oxidation}}$  into aniline.



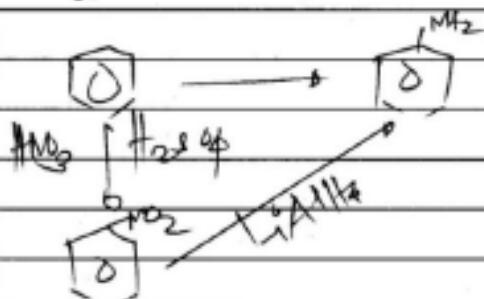
2<sup>nd</sup> step

Reduction of  $\text{N}^{\bullet}\text{O}_2$  benzene

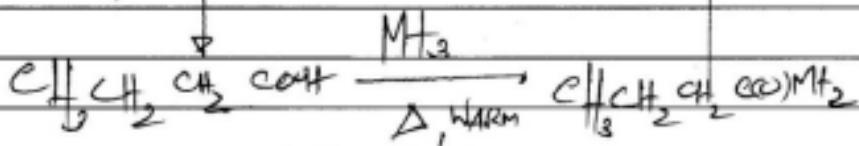
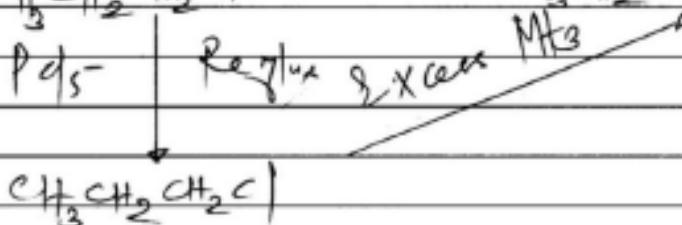
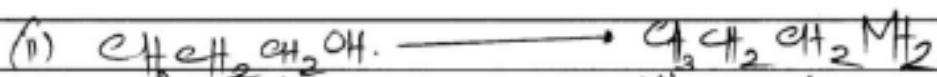
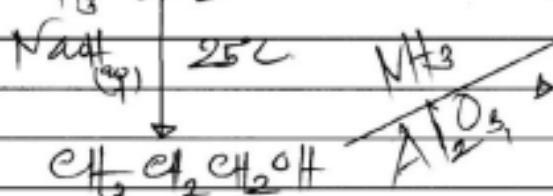
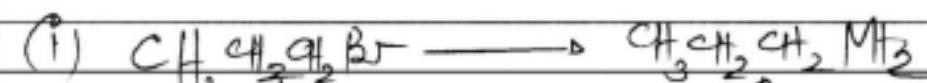


q(c)

or



q(b)

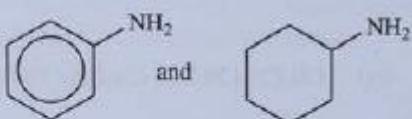


Extract 23.1 gives responses from one of the candidates who demonstrated a good understanding on the topic of amines by supplying correct reactions and names of the products in most parts of the question.

## 2017 PAST PAPERS – 2

9. (a) For the following pairs of organic compounds, briefly explain which compound in each pair is more basic than the other.

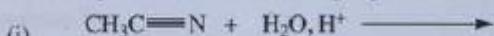
(i)



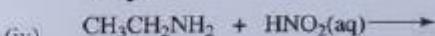
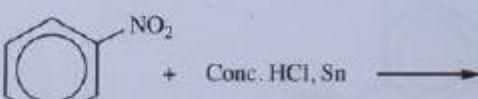
(ii) CH<sub>3</sub>-NH<sub>2</sub> and CH<sub>3</sub>-NH-CH<sub>3</sub>.

(4 marks)

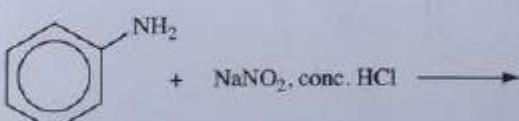
- (b) Give the products of the following organic reactions:



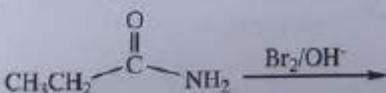
(iii)



(v)



(vi)



(6 marks)

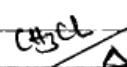
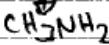
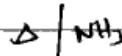
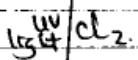
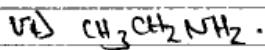
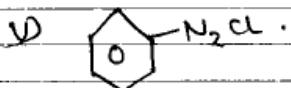
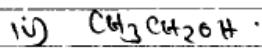
Page 5 of 7

- (c) Briefly describe the laboratory preparation of dimethylamine from methane. (2 marks)

- (d) An organic compound A was treated with nitrous acid and yielded compound B and nitrogen gas was evolved. Compound B has a composition of 60% C, 13.33% H and 26.67% O. Compound B has a vapour density of 30. When compound B was oxidized using H<sub>2</sub>CrO<sub>4</sub> it yielded compound C. Compound C forms oxime with hydroxylamine. Compound C also reacts with Fehling's solution to form brick red precipitate.

(i) Work out to suggest the structures of compounds A, B and C. (6 marks)

(ii) Give the chemical equations for the reactions mentioned. (2 marks)



Q. d) solution

Symbol	C	H	O
90% Composition	60	43.33	26.67
98% Composition	60	42.33	26.67
P.A.M	12	4	16
	= 5	= 13.33	= 1.67
divide by the smallest	5	13.33	1.67
	3	8	1.

Empirical formula C<sub>3</sub>H<sub>8</sub>O.

Molecular formula:

$$\text{Molecular weight} = 2 \times \text{M.U.} \cdot n$$

$$= 2 \times 30$$

$$= 60.$$

$$n(C_3H_8O) = 60$$

$$n(2 \times 30 + 16) = 60$$

$$60n = 60$$

$$n = 1$$

$$\text{Molecular formula} = n(C_3H_8O)$$

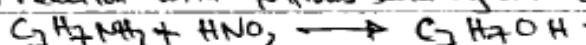
$$= 1(C_3H_8O)$$

$$= C_3H_8O.$$

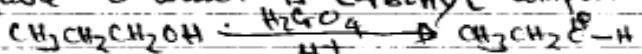
Then compound B was C<sub>3</sub>H<sub>8</sub>O.

Then compound A was C<sub>3</sub>H<sub>7</sub>NOH<sub>2</sub>.

On reaction with Nitrous acid gave B.

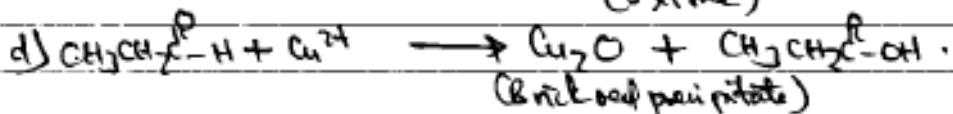
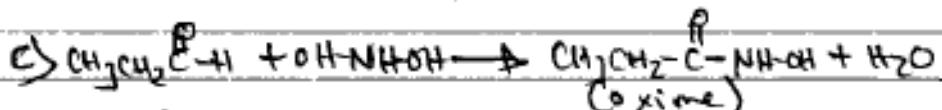
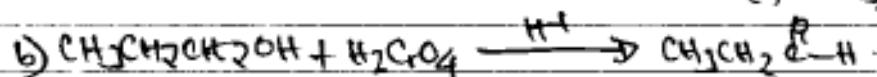
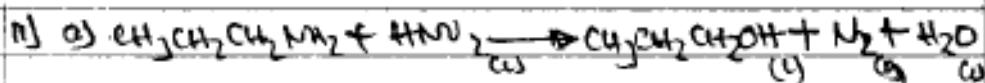
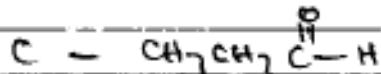
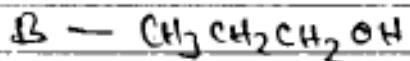
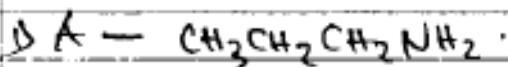


When B oxidized with H<sub>2</sub>CrO<sub>4</sub> (weak oxidizing agent) gave C which is carbonyl compound.



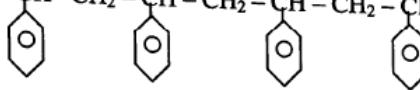
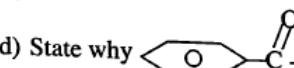
Q. - Compound C is the aldehyde because it can react with hydroxylamine to give Oxime. Aldehyde reacts with Fehling's solution to form brick red precipitate.

Then structures of compounds A, B and C are



Extract 23.1 is a response of a candidate who managed to perform well in parts (b), (c) and (d) of the question.

## 2016 PAST PAPERS – 2

9. (a) Arrange the following compounds in the order of decreasing basic strength:  
 $\text{NH}_3$ ,  $\text{C}_6\text{H}_5\text{NH}_2$ ,  $\text{CH}_3\text{CH}_2\text{NH}_2$ ,  $\text{CH}_3\text{-N-CH}_3$  and  $\text{CH}_3\text{-N-CH}_3$ . (4 marks)
- $\text{CH}_3 \qquad \qquad \qquad \qquad \qquad \text{H}$
- (b) (i) Give the structural formulae of hexane-1,6-dioic acid and 1,6-diaminohexane.  
(ii) Explain why the pair of molecules in (i) is suitable for polymerization.  
(iii) Give the structure of the polymer which might be formed by the pair of molecules in (i).  
(iv) Show the repeating unit of the polymer formed by this pair of compounds. (8 marks)
- (c) Indicate the monomer and the polymerization method which are likely to be used in making each of the following commercial polymers:  
(i)  $\text{CF}_2 - \text{CF}_2 - \text{CF}_2 - \text{CF}_2 - \text{CF}_2 - \text{CF}_2$   
(ii)  $\text{CH} - \text{CH}_2 - \text{CH} - \text{CH}_2 - \text{CH} - \text{CH}_2 - \text{CH} - \text{CH}_2$   

- (iii)  $\text{NH} - (\text{CH}_2)_5 - \text{CO} - \text{NH} - (\text{CH}_2)_5 - \text{CO} - \text{NH}(\text{CH}_2)_5\text{CO}_2$ . (6 marks)
- (d) State why  and  $\text{HOCH}_2\text{CH}_2\text{OH}$  cannot form a polymer. (2 marks)

	(a)
Q79.	<p><math>\text{CH}_3 - \text{F} - \text{CH}_3 &gt; \text{CH}_2 - \text{N} - \text{CH}_3 &gt; \text{CH}_3\text{CH}_2\text{NH}_2 &gt; \text{NH}_3 &gt; \text{C}_2\text{H}_5\text{NH}_2</math>.</p> <p style="text-align: center;"><math>\text{CN}_3</math>                  H</p> <p style="text-align: center;">decreasing basic strength.</p>
	(b)
	<p>(i) Acetone-1,1-difluoro acid = <math>\text{H}-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{CH}_2\text{CH}(\text{F})\text{CH}_2-\text{F}-\text{OH}</math>.</p> <p>1,6-diaminohexane = <math>\text{H}_2\text{N}-\text{CH}_2\text{CH}(\text{NH}_2)\text{CH}_2\text{CH}(\text{NH}_2)\text{CH}_2-\text{NH}_2</math>.</p> <p>(ii) The pairs of molecules above are suitable for polymerization because both of the monomers have bifunctional groups, this favours the condensation polymerization.</p> <p>(iii) A polymer from the two monomers:</p> $\left[ \text{H}-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{CH}_2\text{CH}(\text{F})\text{CH}_2-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{CH}_2\text{CH}(\text{F})\text{CH}_2-\text{CH}_2-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{CH}_2\text{CH}(\text{F})\text{CH}_2-\right] - \text{H}$
	(iv) Repeating unit is
	$\left[ \overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{(CH}_2)_5-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{N}-(\text{CH}_2)_6-\text{N}-\right] - \text{H}_2\text{O}$
	(c)
	<p>(i) The monomer is <math>\text{C}=\text{C}'\text{F}</math></p> <p>Method: By addition polymerization.</p>

	(a) The monomer is $\text{HC}=\text{CH}_2$
	<p>Method: Addition polymerization.</p>
	<p>(ii) The monomer is <math>\text{NH}_2-(\text{CH}_2)_5-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}-\text{OH}</math>.</p> <p>Method: Condensation polymerization.</p>
	<p>(iii) They can not form a polymer because <math>\text{C}(=\text{O})-\text{Cl}</math> has only one functional group thus to form a polymer the two should have bifunctional groups, such that more than one.</p>

The work in Extract 23.1 indicates that the candidate had adequate knowledge of amines and polymers as he/she accurately answered all the items.

## 9.0 POLYMERS

### 2020 PAST PAPERS - 2

6. (a) Briefly, explain the following and give one example for each:
- (i) Thermoplastic polymers
  - (ii) Thermosetting polymers
  - (iii) Natural polymers
- (4 marks)
- (b) Write the monomers used in synthesis of the following polymers:
- (i) Polyvinylchloride (PVC)
  - (ii) Teflon
  - (iii) Bakelite
- (3 marks)
- (c) (i) Why cationic polymerization is more favored than anionic polymerization when vinylic monomers contain an electron donating group?  
(ii) Why styrene undergo anionic polymerization easily? Briefly explain.  
(iii) Differentiate addition from condensation polymers basing on the mode of polymerization. Give one example for each type.
- ( 7 marks)
- (d) With reasons, write down the use of each of the following polymers:
- (i) Butyl-rubber
  - (ii) Polyacrylonitriles
  - (iii) Polyhaloalkene
- (6 marks)

06(a)	<p>i) Thermoplastic polymers.          Are the polymers which can be melted without decomposition when heated.          Example is polyethylene.</p> <p>ii) Thermosetting polymers.          Are the polymers which are hard and can be melted with decomposition when heated.          Examples are bakelite and melamine.</p> <p>iii) Natural polymers.          Are the polymers which are found naturally in plants and animals.          Example is cellulose and protein.</p>
(b)	<p>i) <math>\text{CH}_2 = \text{CHCl}</math></p> <p>ii) <math>\text{CF}_2 = \text{CF}_2</math></p> <p>iii) <math>\text{HCHO}</math> and <math>\text{HO}-\text{OH}</math></p>
c)	<p>i) Cationic polymerization is more favored than anionic polymerization when vinylic monomers contains the electron donating group because there is the formation of stable carbocation (<math>\text{R}^+</math>) in which the electron donating groups increase the stability by donating the electron pairs to the positive carbon by the inductive effect.</p>

Q6(c) (ii) Styrene undergoes anionic polymerization easily due to the formation of stable carbocation in the carbon of the intermediate state due to the stabilization brought about by the phenyl group by the negative inductive effect in which phenyl group attract the electrons of the carbon with negative charge hence stable.

(iv) Addition polymers are the polymers which are formed by the combination of the unsaturated monomers through addition reaction example is the polyvinyl chloride  $\left( \text{CH}_2-\text{CH}=\text{Cl} \right)_n$  white.

Condensation polymer is the polymer which is formed by combination of small molecules or monomers with the evolution of small molecules such as  $\text{H}_2\text{O}$  and  $\text{H}_2\text{S}$ . Example is Nylon, which is  $\left[ \text{HO}-\text{C}\left(\text{CH}_2\right)_4-\text{CO}-\text{NH}-\text{C}\left(\text{CH}_2\right)_6-\text{NH} \right]_n$

- Q6(d) i) Butyl rubber is used in the manufacturing of car tyres, because
- It possess the few cross links in its chains which can makes them to be retain their shapes and size after force acting on them.
  - They have considerable elasticity.
  - They can withstand higher temperature during operation since they are of higher boiling point and melting point.
  - They are non-reactive hence not attacked easily.

Q6(c) ii) Styrene undergoes anionic polymerization easily due to the formation of stable carbocation in the carbon of the intermediate state due to the stabilization brought about by the phenyl group by the negative inductive effect in which phenyl group attract the electrons of the carbon with negative charge hence stable.

iii) Addition polymers are the polymers which are formed by the combination of the unsaturated monomers through addition reaction example is the polyvinyl chloride  $\left(-\text{CH}_2-\overset{\text{Cl}}{\underset{\text{C}}{\text{CH}_2}}\right)_n$  white.

Condensation polymer is the polymer which is formed by combination of of small molecules or monomers with the evolution of small molecules such as  $\text{H}_2\text{O}$  and  $\text{H}_2\text{S}$ . Example is Nylon, So its  $\text{L}=\left(-\overset{\text{C}}{\underset{\text{C}}{\text{H}_2}}-\text{CH}_2-\overset{\text{C}}{\underset{\text{C}}{\text{H}_2}}-\text{CH}_2-\text{NH}-\text{CH}_2-\text{CO}-\text{CH}_2\right)_n$

Q6(d) i) Butyl rubber is used in the manufacturing of car tyres, because

- It possess the few cross links in its chains which can makes them to be restore their shape and size after force acting on them.
- They have considerably elasticity.

- They can withstand higher temperature during operation since they are of higher boiling point and melting point.

- They are non-reactive hence not attacked easily.

(ii) polyacrylonitrile

- They are used in the manufacture of the carpets because of the following reasons:
  - They are non reactive hence does not attacked easily by the chemicals.
  - They are hard hence cannot change their shapes much during operation.

(iii) Polyhaloalkane

(a) They are used in the manufacturing of plastic products such as crates, bottles and strings because

- They are not reactive hence not not easily attacked by the chemicals or water.
- They can be moulded and formed in to different shapes when heated.
- They have not very large or very low melting point.
- can be recycled for manufacturing of tea facilities or vessels.

(b) They can be used in manufacturing of fishing nets, because they are insoluble in water.

(c) They can be used in manufacturing of clothes, in the mixture with other elements and polymer such as fibres.

Extract 16.1: A sample of correct responses in question 6

## 2019 PAST PAPERS - 2

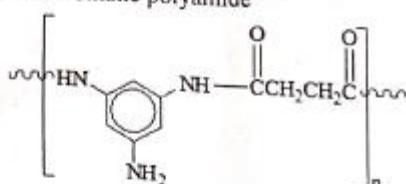
(5 marks)

10. (a) Show the initiation step and propagation step for the following polymerization types for Polytetrafluoroethylene (PTFE) polymer:
- Free radical polymerization.
  - Cationic polymerization.
  - Anionic polymerization.

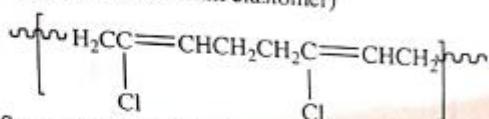
(7.5 marks)

- (b) Give the IUPAC names of monomers in the following polymers;

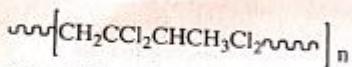
- (i) Semi aromatic polyamide



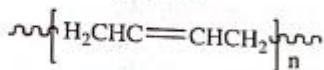
- (ii) Neoprene (oil resistant elastomer)



- (iii) Saran (packaging film)

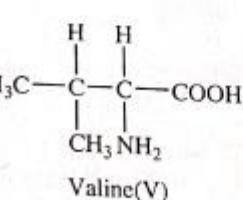
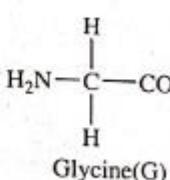
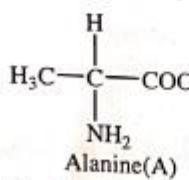


- (iv) Oil soluble polymer



(6 marks)

- (c) Alanine(A), Glycine(G) and Valine(V) with the following structures are among the natural amino acids for protein synthesis.



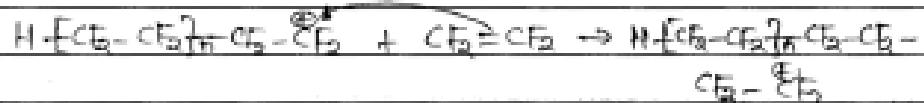
- Identify the functional groups in those amino acids.
- Show how polymerization of those monomers can be done.
- Provide the common name of the resulting polymer in (ii).
- Write the minor product common to all in (ii).
- What name is given to the bond combining the three amino acids?

(6.5 marks)

10 (a)	The monomer for the polymer; Polytetrafluoroethane (PTFE) is $\text{CF}_2=\text{CF}_2$ (1,1,2,2-tetrafluoroethene).
(i)	In free radical polymerization, these steps are carried as follows: The initiation step: This involves homolytic bond cleavage of the organic peroxide when heated at higher temperatures to give free radicals. That is, $\text{R-O}-\text{O-R} \xrightarrow{\Delta} \text{R-O}^\bullet + \text{R-O}^\bullet$
(ii)	The propagation step: The free radicals formed in the step above attack the monomers ( $\text{CF}_2=\text{CF}_2$ ) to form another free radicals, which attack another molecules of monomers until the chain lengthen. That is,
	$\text{R-O}^\bullet + \text{CF}_2=\text{CF}_2 \rightarrow \text{R-O-CF}_2-\dot{\text{C}}\text{F}_2$ ,
	$\text{R-O-CF}_2-\dot{\text{C}}\text{F}_2 + \text{CF}_2=\text{CF}_2 \rightarrow \text{R-O-CF}_2-\text{CF}_2-\dot{\text{C}}\text{F}_2$
	$\text{R-O-CF}_2-\text{CF}_2-\dot{\text{C}}\text{F}_2 + \text{CF}_2=\text{CF}_2 \rightarrow \text{R-O-CF}_2-\text{CF}_2-\text{CF}_2-\dot{\text{C}}\text{F}_2$
(iii)	In cationic polymerization, these steps occur as follows: The initiation step: This involves the formation of a Lewis acid initiator and its attack on the monomer molecule ( $\text{CF}_2=\text{CF}_2$ in our case). That is, $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$
	$\text{H}^+ + \text{CF}_2=\text{CF}_2 \rightarrow \text{H}-\text{CF}_2-\overset{\oplus}{\text{C}}\text{F}_2$

20 (ii) Propagation step: The carbocation formed on the initial step attacks further monomer molecule ( $\text{CF}_2=\text{CF}_2$ ) to form a cation of increased size and the process carries on the same manner.

That is,



And so on.

(iii) In Anionic polymerization, these steps occur as follows:

The initiation step: This involves the formation of an anion from the base which attacks the monomer molecule ( $\text{CF}_2=\text{CF}_2$ ) to form a cation anion (carbanion).

That is,

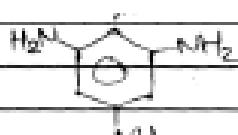


The propagation step: The carbanion so formed in the initiation step attacks other monomer molecule ( $\text{CF}_2=\text{CF}_2$ ), leading to increase in size of the chain.

That is,



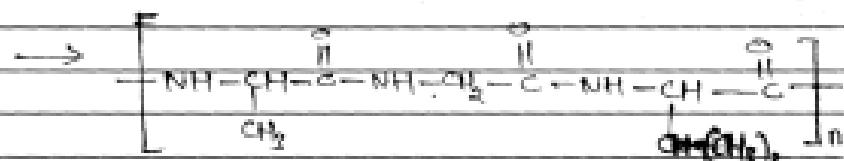
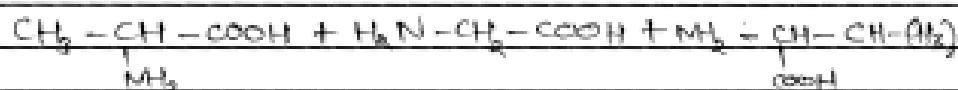
The process is carried until the chain is very long.

Ques	Ans	MONOMERS	IUPAC NAMES
(i)			1,2,5-triaminobenzene
(ii)		$\text{HO}-\text{C}(\text{O})-\text{CH}_2-\text{CH}_2-\text{C}(\text{O})-\text{OH}$	Butane-3,4-dioic acid (Butane-3,4-dicarboxylic acid)
(iii)		$\begin{array}{c} \text{CH}_3 = \text{C} - \text{CH} = \text{CH}_2 \\   \\ \text{Cl} \end{array}$	2-chlorobuta-1,3-diene
(iv)		$\text{CH}_2=\text{CHCH=CH}_2$	Butene-1,3-diene (1,3-butadiene)

(c) (i) The functional groups are:

- The carboxyl group ( $-\text{COOH}$ )
- The amino group ( $-\text{NH}_2$ )

(ii) Polymerization of Alanine (A) <sup>and</sup> is done as follows:



Ques	(iii) The name is Protein.
	(iv) The minor product is $\text{H}_2\text{O}$ (water molecule).
	(v) The name is the peptide bond.

Extract 24.1: A sample of correct responses in question 10.

## 2015 PAST PAPERS - 2

9.	(a) Define the following terms: (i) Polymer (ii) Additional polymerization (iii) Condensation polymerization.	(3 marks)
	(b) (i) Name at least four common natural polymers. (ii) Giving example, differentiate a thermosetting polymer from a thermoplastic polymer.	(4 marks)
	(c) Using example of polymerization of vinyl chloride ( $C_2H_3Cl$ ) to form PVC, show the following steps: (i) Initiation step (ii) Propagation step (iii) Termination step.	(6 marks)
	(d) Draw the complete structures of monomers which were used to prepare the following condensation polymers.	
	(i) $\text{--NH-CH-C(=O)-NH-CH-C(=O)-NH-CH-C(=O)--}$ (protein)	
	(ii) $\left[ \text{O} \text{---} \text{C}_6\text{H}_4 \text{---} \text{C(=O)} \text{---} \text{O} \text{---} \text{CH}_2\text{CH}_2\text{---} \text{O} \right]_n$ dacron	
	(iii) $\left[ \text{C(=O)} \text{---} (\text{CH}_2)_4 \text{---} \text{C(=O)} \text{---} \text{NH} \text{---} (\text{CH}_2)_6 \text{---} \text{NH} \right]_n$ nylon.	(7 marks)

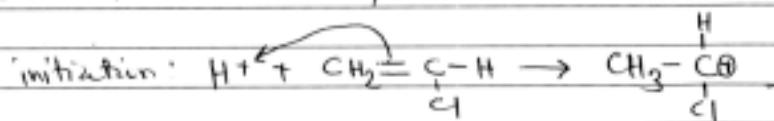
Q.	<p>(a)(i) Polymer is the long chain like molecule made up of many small repeating molecules of the same or different functional group called monomers. Polymer is the molecule of very large molecular weight.</p> <p>(ii) Additional polymerization - is the process whereby small molecules of lower molecular weight combine themselves by addition reaction to form a polymer. Addition polymerization involves the combination of reactants unsaturated monomers which is accompanied by the addition reaction.</p> <p>(iii) Condensation polymerization - is the process by which polymers are synthesized or prepared from the combination of monomers of the same or different nature but they have more than one functional group. Condensation polymerization involves monomers of more than one functional group and they combine one another by condensation reaction, (with loss of water).</p> <p>b(i) Common natural polymers include:</p> <ul style="list-style-type: none"> <li>- proteins such as keratin.</li> <li>- Cellulose</li> <li>- natural rubber</li> <li>- polynucleotide which are DNA and RNA</li> </ul>
----	--

## Difference between thermosetting and thermo plastics.

Thermosetting Polymer	Thermoplastic polymer.
a - example of thermosetting include bakelite	example of thermoplastic polymer is nylon 6,6
b - Cross-linking between its chains which makes it strong and tough so that it is insoluble	- no cross linking between its chains which make it soft and soluble in organic solvent to form colloidal solution
→ Once moulded, can't be remoulded again	Thermoplastic polymer can be moulded into different shapes on heating + cooling

### (c) (i) Initiation Step

The first step during polymerization involves the initiation of the monomers by the use of the initiator molecules or ions; for the case of PVC, the initiator involved is  $H^+$  from  $HCl$  but other initiators may be used also.



Hydrogen ions  $H^+$ , approach to the monomer where

it results the bond (pi bond) to break and it react with one molecule of the vinyl chloride molecule to acquire positive charge.

### (ii) Propagation Step

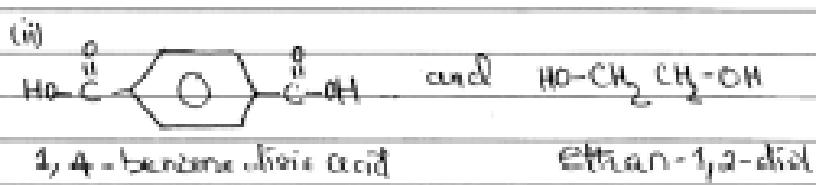
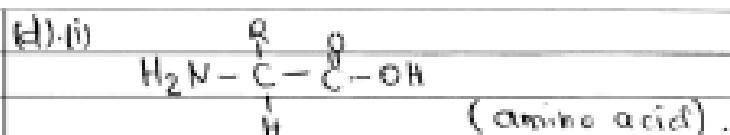
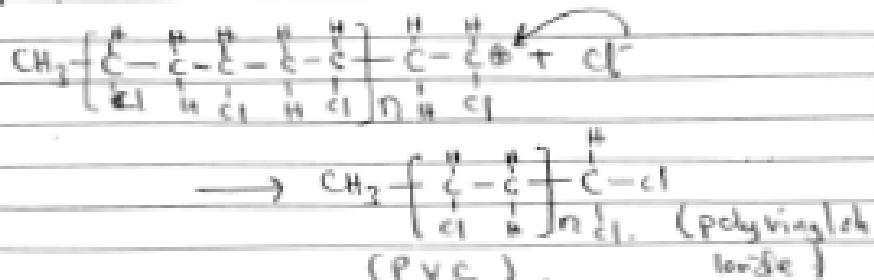
The positively charged molecule formed from the initiation step results in combination of the monomers by the addition reaction which involves the breaking of pi bonds as follows:



The chain continues to be propagated by the addition reaction.

### (iii) Termination Step

-This is the last step during polymerisation of the monomers where by, the growing chain - which is positively charged react with - the negative ion (anion) which mark the end of the polymerisation, as in case of polyvinyl chloride seen below (terminator c<sup>-</sup>)



In Extract 9.1, the candidates presented accurate answers clearly according to the requirement of the question. She/he differentiated a thermosetting polymer from a thermoplastic polymer correctly.

## 10.0 ENVIRONMENTAL CHEMISTRY

### 2018 PAST PAPERS - 2

8. (a) Outline any six control measures which are useful in minimizing the chemical pollution of water bodies. (6 marks)
- (b) Outline any four possible causes of environmental degradation. (6 marks)
- (c) Briefly explain eight effects of air pollution to living organisms. (8 marks)

Q(a)	The control measures which are useful in minimizing the chemical pollution of water are
	(i) The farmers should not cultivate near water body This will minimize fertilizer that pollute the water
	(ii) Avoiding fishing using chemicals Some people use chemicals to kill the fish while fishing
	(iii) The discharge from industries should not become directed into water bodies - This will minimize the pollution of water by chemicals
	(iv) The sewage should be treated to minimize the chemicals from water that is directed towards water bodies
	(v) The government should enhance a law towards the entire industries that direct their effluent to water bodies
	(vi) The education should be provided on the importance of

Q(1)	<p>the availability of water body. This will minimise the chemical pollution of water.</p>
Q(2)	<p>The four possible causes of environmental degradation are as follows:</p>
	<p>(i) The chemicals released from industries - They can be in gaseous or liquid state</p>
	<p>(ii) Domestic Domestic waste materials also cause environmental degradation</p>
	<p>it paves of cloth, food remains</p>
	<p>(iii) Mining activities They tend to leave the land bare hence surface erosion and soil become impermeable</p>
	<p>(iv) Deforestation this also causes environmental degradation that cause erosion to the land</p>
Q(3)	<p>The eight effects of air pollution to living organisms includes below</p>
	<p>(i) Air pollution cause the loss of vision to the people especially when there is a formation of smog this in turn can lead to accident</p>
	<p>(ii) Air pollution cause the spread of diseases like the respiratory tract infections that can lead to decrease in number of organisms</p>

(iii)	Air pollution hinders photosynthesis to the plants This is because the sufficient gaseous exchange in plants does not occur.
(iv)	Air pollution can alter the soil pH through acidic rain which reduces soil productivity. This can cause the occurrence of famine or饥荒.
(v)	Air pollution leads to death of living organisms. This normally is due to the insufficient air for gaseous exchange.
(vi)	Air pollution results to increased temperature of the earth through global warming. Thus air pollution leads to depletion of ozone layer.
(vii)	Air pollution leads to accumulation of harmful gases in atmosphere hence difficult to breathing occurs in the living organisms.
(viii)	Air pollution can cause the destruction of pollution of water bodies when because not safe for use by the living organisms, this can lead to death of organism.

Extract 22.1 represents a set of correct responses whereby the candidate demonstrated appropriate competencies; outlined six measures useful in minimizing the chemical pollution of water, outlined correctly the four causes of environmental pollution and explained the eight effects of air pollution to living organisms.

## 2017 PAST PAPERS - 2

8. (a) Briefly describe the following:  
 (i) Ozone layer.  
 (ii) Greenhouse effect.  
 (iii) Acid rain. (9 marks)
- (b) With the aid of chemical equations, describe how the ozone layer is formed and depleted or destroyed. (8 marks)
- (c) Outline six effects of ozone layer depletion. (3 marks)

b) Ozone layer depletion & the process by which (in which) ozone layer is destroyed.

It's caused by different reactions taking place in the Earth's atmosphere leading to the destruction of ozone layer.

Consider the following ways in which ozone layer is depleted.

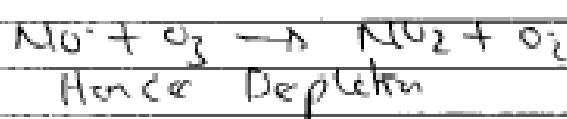
Thus, let's consider the cases of  
Nitrogen dioxide ( $\text{NO}_2$ ) as well  
(ii) Chlorofluorocarbons (FCF)

84 A: Through Nitrogen dioxide ( $\text{NO}_2$ )

High ultraviolet radiation splits the Nitrogen dioxide molecule ( $\text{NO}_2$ ) into two directly. Also lighting can cause the splitting of Nitrogen dioxide ( $\text{NO}_2$ ) molecule as per equation.



Then Nitrogen monoxide radical formed is very reactive and react with oxygen from the ozone layer ( $\text{O}_3$ ) and creating the hole in it according to the following equation.



B: Through chlorofluorocarbons (FC)

AFC: Chlorofluorocarbon (CFC) is the main agent in depletion of ozone layer;  $\text{O}_3$

Under high ultraviolet radiation the molecules split according to the equation



Then chlorine radical formed also is very reactive and react rapidly with oxygen from ozone layer ( $\text{O}_3$ ) as per equation:



Hence leading to the ozone depletion because the process is continuous.

In Extract 22.2 the candidate correctly illustrated how the ozone layer is destroyed by the reaction of chlorofluorocarbons (CFCs), and by the reaction with the oxides of nitrogen ( $\text{NO}$ ).

## 2016 PAST PAPERS - 2

8. (a) (i) Name three human activities which increase amount of carbon dioxide in the atmosphere  
(ii) Describe greenhouse effect.  
(iii) List three climatic effects caused by rise in temperature due to greenhouse effect. **(6 marks)**
- (b) (i) Define cation exchange capacity of a soil sample.  
(ii) Briefly explain how cation exchange capacity of a soil sample is measured. **(3 marks)**
- (c) A certain soil contains the following cations in meq/100 g of oven-dry soil:  
 $\text{Na}^+ = 2.00$ ;  $\text{K}^+ = 3.00$ ;  $\text{Mg}^{2+} = 10.00$ ;  $\text{Ca}^{2+} = 15.00$ ;  $\text{Al}^{3+} = 4.00$  and  $\text{H}^+ = 5.50$ . Calculate the  
(i) percentage base saturation  
(ii) quantity in grams of sodium present in 100 g of oven-dry soil. **(8 marks)**
- (d) A certain soil has been identified to have a pH < 5. Identify two major ions which prevail in this soil and two compounds which can be used to raise the pH of this soil. **(3 marks)**

Q	(c) i) Major cations under exchange capacity Major cations are $\text{Na}^+$ , $\text{K}^+$ , $\text{Ca}^{2+}$ , $\text{Mg}^{2+}$
	ii) Total Cation Exchange Capacity $= (3 + 3 + 10 + 16) \text{ mequiv}$ $= 32 \text{ mequiv}$
	iii) $\text{pH} = \frac{2.0 \text{ mequiv}}{32 \text{ mequiv}} \times 14 = 2.5$
	Precipitation saturation = $75.95\% \text{ ARI}$
	ii) quantity in grams of calcium = $300 \text{ g} \times 0.95 \text{ or } 285 \text{ g}$
	From: $300 \text{ g} \rightarrow 2.00 \text{ mequiv of Calcium (A)}$
	But $1 \text{ mol of Calcium} = \left( \frac{300}{2.00} \right) \text{ g}$
	$\text{Molar mass of Calcium} = 24.3 \text{ g/mol}$ $24.3 \text{ g/mol} \rightarrow ? \text{ g}$ $24.3 \text{ g/mol} \times 2.00 = 48.6 \text{ grams}$
	i) Then, the quantity of calcium at 300 g ARI dry part is $0.96 \text{ grams ARI}$

Q	(d) When soil pH < 5 This means the soil is acidic
	The major ions that prevail in acidic soils are a) $\text{Al}^{3+}$ ( Aluminium ion) b) $\text{H}^+$ ( Hydrogen ion)
	Ca <sub>3</sub> O compound that can raise pH (can neutralize acidity act.) a) $\text{CaO}$ ( Calcium oxide ) b) $\text{Ca(OH)}_2$ ( Calcium hydroxide )

Extract 22.1 is a sample answer from one of the candidates who managed to answer all the parts of the question. For instance, in part (d), he/she recognized that the soil with pH < 5 is acidic, hence the prevailing ions are likely  $\text{Al}^{3+}$  and  $\text{H}^+$  and therefore the soil needs CaO and  $\text{Ca(OH)}_2$  as liming materials.

## **2015 PAST PAPERS - 2**

10. Conservation of water against pollution is of paramount importance for human health and development. Discuss this statement using the following sub headings:
- (i) Categories of water pollution.
  - (ii) Causes of water pollution (4 causes).
  - (iii) Effects of water pollution (4 effects).
  - (iv) Control measures to be taken (4 measures). (20 marks)

Q10 Water pollution is the addition of substance or pollutant in water sources which lower the quality of water for domestic uses and Industrial uses and damage aquatic life.

Categories of water pollution.

Water pollution is categorized into two  
Sources of Pollution.

- (1) Direct point of water pollution.
- (2) Indirect water pollution.

Direct water pollution is the category of water pollution in which the pollutants are directed towards the water sources or water bodies. Example Industrial wastes can be directed towards the Stream of flowing water.

(1) Indirect Water pollution. Here the pollutants are not directed to the water sources or water bodies instead other agents can take the pollutants to water bodies. example, the use of artificial fertilisers on farms can be leached and when the rainfall comes down, it washes away the fertilisers and go toward the flow of water to the water bodies like lakes, river or sea.

Causes of Water pollution:

(i) Industrial Wastes: These are wastes from Industrial activities such as Zinc, mercury and Sulphur compounds like Metal sulphides. This can be directed to water sources such

as rivers and lakes which then cause water pollution to an extent also may cause marine organisms like fishes to die.

(ii) Artificial Fertilisers; application of artificial fertilisers and herbicides or pesticides on agricultural activities may cause water pollution when fertilizer such as Urea is used on farms. It dissolves in the soil but when the current of flowing water passes, it can be washed away along with water which causes the water pollution.

(iii) Fishing and Marine transportation activities may cause water pollution. Example during fishing some poor methods can be used example uses of toxic grenades to kill fishes. This is not only killing fishes but also kills pollutes water. Since toxic is used for marine transportation, the huge ships may leak oil substances which may cause oil spills in water and hence water pollution.

(iv) Improper Water Waste disposal. Some people especially in populated cities, tend to dispose the home waste products in water bodies. This wastes consists of rotten fruits and meat, kitchen wastes, plastics and other toxic substances. This cause water pollution.

#### 10(i) Effects of Water pollution

(1) Health Hazards - due to the eruption of epidemic diseases such as cholera, typhoid. This is due to contaminated water.

(2) Destruction of Marine life and ecosystem. Some toxic substance such as mercury cause death on aquatic organism this destroy the aquatic ecosystem.

(3) Lack of water for Industrial and Domestic uses. If water is very polluted, it can't be used in domestic and industrial uses, if it proceeds, it results in shortage of water which has quality for the uses.

(4) Marine Eutrophication: If lasting water pollution will occur due to artificial fertilizers, marine plants such as weeds will grow rapidly, a process known as Eutrophication, these plants has the other disadvantage because they inhibit the penetration of Sun light to the water and also lower the amount of oxygen that dissolves in water.

(iv)	Control Measures to be taken:
	(i) Establishment of proper waste disposal; this is by establishing the permanent place for wastes to be distributed instead of directing them to water bodies.

(iv)	(ii) Enacting laws for those who tend to cause water pollution, this will minimize the water pollution cases.
	(iii) Sewage treatments: If water is polluted once, it can be treated properly for the domestic and Industrial uses. Hence may minimize health hazards and chances of water body pollution.
	(iv) Minimizing the use of fertilisers on the Agricultural Activities.
	(v) Minimizing the rate of Industrial production of wastes, this will lower the amount of pollutants to the water bodies.

In Extract 10.1, the candidate presented accurate answers according to the requirement of the question. The candidate gave correct explanations for the conservation of water against pollution. Precisely categorized water pollution and identified the causes of water pollution, its effects to human health and finally, suggested the control measures.

## 11.0 SOIL CHEMISTRY

### 2021 PAST PAPERS

5. (a) Justify on the following facts:
- Ion exchange in the soil system is a reversible process.
  - All calcium or magnesium compounds can be used as liming materials.
  - Aluminium contributes to soil acidity.
- (b) Rungwe high school farm soil requires 100 kg of nitrogen to fulfill the plant requirement of nitrogen per hectare. If the farm has 60 hectares, calculate the number of bags of ammonium sulphate,  $(\text{NH}_4)_2\text{SO}_4$  fertilizer required to meet this demand. (One bag of fertilizer weighs 25 kg). (4 marks)

5. (a) i) This is because, ions can be exchanged between soil colloid and soil solution in either direction. This means that ions can move either from Soil colloid to Soil solution or from Soil solution to Soil colloid.  
For example



ii) No, Not all compounds of calcium and magnesium can be used in liming. Only oxides, hydroxides, carbonates and silicates of calcium and magnesium are used in liming.

- This is because, these compounds are naturally basic and they therefore will rise the soil pH.

iii) - This is because aluminium while in soil, tends to form complex with aqua regia. The formed complex tends to release hydrogen ions,

5. (a) iii) which contributes to soil acidity



b) Data given

Requirements of nitrogen per hectare = 100kg

Number of hectares = 60

Fertilizer required =  $(\text{NH}_4)_2\text{SO}_4$

Weight of one bag = 25 kg

Required = number of bags

from

solution

one hectare = 100kg

60 hectares = x

then

$$x = \frac{6000 \text{ kg}}{1 \text{ hectare}}$$

$$x = 6000 \text{ kg} = 6,000,000 \text{ g}$$

where x is number of kilograms (mass) of nitrogen required for 60 hectares

from

$$\text{Total molecular mass g } (\text{NH}_4)_2\text{SO}_4 \text{ is} \\ = ((14 + 4 \times 2) \times 2) + 32 + (6 \times 16) \text{ g/mol} \\ = 132 \text{ g/mol}$$

then

in  $(\text{NH}_4)_2\text{SO}_4$ , there are  $(14 \times 2)$  g/mole of nitrogen

then

$$132 \text{ g } \xrightarrow{(\text{NH}_4)_2\text{SO}_4} 28 \text{ g N}$$

$$x = \frac{6,000,000 \text{ g}}{28 \text{ g}}$$

5.	<p>b) <math>X = \frac{600,000 \text{ g} \times 122 \text{ g}}{28 \text{ g}}</math>  <math>= 28,285,714.29 \text{ g.} = 28,285.71429 \text{ kg}</math></p> <p>where <math>X</math> is mass of <math>\text{CaHg}_2\text{Soy}</math> that contain 6000kg of nitrogen from</p> <p>Then</p> <p>Since 1 bag = 25kg.  <math>X = 28,285.71429 \text{ kg}</math>  <math>X = \frac{1 \text{ bag} \times 28,285.71429 \text{ kg}}{25 \text{ kg}}</math>  <math>= 1131.43 \text{ bags}</math>  <math>X \approx 1132 \text{ bags.}</math></p> <p>Where <math>X</math> is number of bags containing 28,285.71429kg of <math>\text{CaHg}_2\text{Soy}</math></p> <p><math>\therefore 1132</math> bags of <math>\text{CaHg}_2\text{Soy}</math> are required to sat the requirements of 60 hectares at Pungo Secondary School.</p>
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#### Extract 5.1: A sample of correct responses in question 5

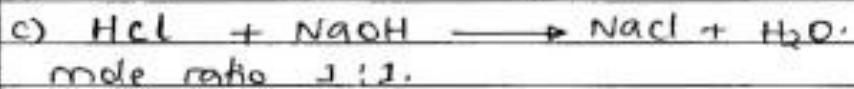
### 2020 PAST PAPERS

2. (a) Explain two detrimental effects of excessive salts in the soil. (2 marks)
- (b) Give four advantages of adding organic manures in the soil. (4 marks)
- (c) 20 g of a soil sample was shaken with 40 cm<sup>3</sup> of 0.1 M HCl solution. After filtering and washing the soil, the filtrate required 27 cm<sup>3</sup> of 0.1 M NaOH solution for complete neutralization. The total Cation Exchange Capacity (CEC) of the soil is 29 milli. eq. per 100 g of the soil sample. Calculation the Percent Base Saturation (PBS) of the soil sample. (4 marks)

Q. a) - Make the salt to be acidic if acidic salts such as  $\text{AlCl}_3$  are in excess or more basic if basic salts are excess such as  $\text{CaCO}_3$ , hence become not conducive for some plants to grow on them.

- Affects microbial activities by changing the pH of the soil whether by decreasing due to excess acidic salts and/or increasing due to the presence of basic salts.

2. b) - Improves soil structure.
- Increasing water holding capacity of the soil.
  - Increase soil nutrients such as humus.
  - Increase microbial activities such as decomposing of organic matters.



$$\text{Excess volume of HCl} = 40\text{cm}^3 - 27\text{cm}^3 \\ = 13\text{cm}^3$$

$$\text{Number of moles of H}^+ = 13\text{dm}^3 \times 0.1\text{M} \\ = \frac{1000}{1.3 \times 10^{-3}} \text{ moles.}$$

number of moles of  $\text{H}^+$  = number of moles of  $\text{OH}^-$   
 since the reaction involved ratio of 1 to 1.  
 $1.3 \times 10^{-3}$  moles =  $1.3 \times 10^{-3}$  eq.

$$1\text{eq} \rightarrow 1000\text{meq.} \\ 1.3 \times 10^{-3}\text{eq} \rightarrow ? \\ = 1.3\text{meq.}$$

Then,

$$1.3\text{meq} \rightarrow 200\text{g of a soil sample.} \\ ? \rightarrow 100\text{g of a soil sample.} \\ = \frac{1.3\text{meq} \times 100\text{g}}{200} \\ = 6.5\text{meq per 100g of soil.}$$

$$\text{P.B.S} = \frac{\Sigma \text{Base exchange capacity} \times 100}{\text{C.E.C.}}$$

2. c)

$$\text{P.B.S} = \frac{6.5\text{meq} \times 100}{29\text{meq}} \\ = 22.41\%.$$

∴ Percentage Base saturation of soil sample was 22.41%.

Extract 2.1: A sample of correct responses in question 2

## 2019 PAST PAPERS – 2

7. (a) (i) State four significance of soil colloids.  
 (ii) Briefly explain two effects of soil pH on plant growth. (6 marks)
- (b) Why is it important to manage the soil pH? (4 marks)
- (c) A certain soil sample was analyzed in the laboratory and found to contain the following ions in meq/100 g of oven dry soil:  $K^+ = 0.28$ ,  $Mg^{2+} = 0.12$ ,  $Ca^{2+} = 1.00$ ,  $Na^+ = 0.03$  and  $H^+ = 10.00$ . If the cation exchange capacity (C.E.C) of the soil is 3.83 meq/100 g of oven dry soil, calculate the percentage base saturation (PBS). (4 marks)
- (d) A 21 g of soil sample was dried in oven and lost its weight by 1 g. The soil was analyzed and found to contain 0.0015 g of  $Ca^{2+}$ . Calculate the concentration (in meq/100 g oven dry soil) of calcium in the soil sample ( $Ca = 40 \text{ gmol}^{-1}$ ). (6 marks)

7.	<p>(a) (i) Significance of soil colloids:</p> <ul style="list-style-type: none"> <li>- They provide soil fertility.</li> <li>- They are sites where the cations between soil colloids and soil solution.</li> <li>- They aid in balancing of nutrients.</li> <li>- They give the soil its structure.</li> </ul> <p>(ii) Effects of soil pH on plant growth.</p> <p>→ It may lead to loss of other nutrients required by plants.</p> <p>→ It may lead to the wilting of the plants.</p> <p>(b)</p> <ul style="list-style-type: none"> <li>- To balance nutrients in the soil.</li> <li>- To select which kind of crop to be cultivated or planted.</li> <li>- To make favourable conditions for microorganisms in decomposition of organic matter.</li> <li>- It is important in measuring the Cation exchange capacity of the soil.</li> </ul>
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7. (c) Data given:

$$K^+ = 0.28 \text{ Meq}/100g$$

$$Mg^{2+} = 0.12 \text{ Meq}/100g$$

$$Ca^{2+} = 1.00 \text{ Meq}/100g$$

$$Na^+ = 0.03 \text{ Meq}/100g$$

$$H^+ = 10.00 \text{ Meq}/100g$$

$$\text{For Cation exchange Capacity (CEC)} = 3.83 \text{ Meq}/100g$$

Percentage base saturation (P.B.S) = ?

from :

$$P.B.S = \frac{\sum \text{Exchangeable basic cations}}{\text{Cation exchange capacity}} \times 100\%$$

$$\text{where } P.B.S = \frac{\sum \text{Exchangeable basic (EB)}}{CEC} \times 100\%$$

where

$$\sum \text{Exchangeable basic cations} = K^+ + Mg^{2+} + Ca^{2+} + Na^+$$

$$\sum EB = 0.28 + 0.12 + 1.00 + 0.03$$

$$\sum EB = 1.43 \text{ Meq}/100g$$

Then :

$$P.B.S = \frac{\sum EB}{CEC} \times 100\%$$

$$P.B.S = \frac{1.43}{3.83} \times 100\%$$

$$P.B.S = 37.34\%$$

∴ The Percentage base saturation (P.B.S) is 37.34%

(d) Data given:

$$\text{Mass of soil sample} = 21g$$

$$\text{Mass of soil lost} = 1g$$

$$\text{Mass of Calcium} = 0.0015g$$

7 (d) .

Concentration of Calcium ( $\text{Ca}^{2+}$ ) in meq/100g  
of oven dry soil = ?

Molar mass of Calcium =  $40 \text{ g mol}^{-1}$

- First, because we have given mass of  
soil sample = 21g and mass lost the soil  
lost its mass by 1g, so in order to get  
the mass in calculation of the concen-  
tration of calcium( $\text{Ca}^{2+}$ ) must be as  
follows:

$$21\text{g} - 1\text{g} = 20\text{g}$$

∴ The mass of soil sample will be 20g.

Then :

(i) To find the equivalent weight (eq)

$$\text{eq} = \frac{\text{mass}}{\text{Molar mass of Cation}}$$

Valency

$$= \frac{40}{2} = 20 \text{ g}$$

(ii) To find the milliequivalent weight

(meq)

from

$$1\text{eq} = 1000 \text{ meq}$$

$$\text{Meq} = \frac{\text{eq}}{1000}, \text{ where eq} = 20\text{g}$$

$$\text{Meq} = \frac{20}{1000} = 0.02\text{g}$$

Therefore

$$1\text{meq of } \text{Ca}^{2+} \rightarrow 0.02\text{g}$$

$$? = 0.00159$$

7.	(d)
	= 0.075 Meq
	This means that,
	0.075 Meq $\rightarrow$ 20g
	? = 100g
	= 0.375 Meq / 100g
	$\therefore$ The concentration of (in Meq / 100g oven dry soil) of Calcium in the Soil Sample is
	0.375 Meq / 100g .

Extract 21.1: A sample of correct responses in question 7.

## 12.0 CHEMICAL ANALYSIS