Name: MARKING GUIDE

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P525/1
CHEMISTRY
Paper 1
Jul / Aug.2018
2 ¾ hours

UGANDA TEACHERS' EDUCATION CONSULT (UTEC)

Uganda Advanced Certificate of Education

CHEMISTRY

Paper 1

2 hours 45 minutes

INSTRUCTIONS TO CANDIDATES:

Answer **ALL** *questions in Section* **A** *and* **six** *questions in Section* **B.**

All *questions must be answered in the spaces provided.*

Mathematical tables (3- figure) and non-programmeable electronic calculators may be used.

Illustrate your answers with equations where applicable.

Molar gas constant, R = 8.31 $J K^{-1} mol^{-1}$

Molar volume of a gas at s.t.p. is 22.4 litres.

Standard temperature = 273 K

Standard pressure = 101325 Nm^{-2}

For Examiner's Use Only																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
16	15	15	16	16	15	15	15	15	19	19	19	19	19	19	19	19	

SECTION A: (46 MARKS)

Answer all questions in this section.

1. The elements tin and lead belong to group (IV) of the Periodic table.

(a) Write equation for the preparation of the tetra chlorides of the elements: *(01 mark)*

Tin

$Sn_{(s)} + 2Cl_{2(g)} \rightarrow SnCl_{4(l)}$ (01)

(01 mark)

Lead

$Pb_{(s)} + 2Cl_{2(g)} \rightarrow PbCl_{4(l)} \rightleftharpoons PbCl_{2(s)} + Cl_{2(g)}$ (01)

(b) Tin(IV) chloride fumes in most air. Explain this observation. *(03 marks)*

Tin(IV) chloride reacts with water vapour in the atmosphere (under goes hydrolysis) forming tin(IV) oxide and hydrogen chloride gas which fumes in air. (02)

$SnCl_{4(l)} + 2H_2O_{(l)} \rightarrow SnO_{2(s)} + 4HCl_{(g)}$ (01)

2. (a) Complete the following nuclear reactions;

(i) $^{9}_{4}Be + \gamma \longrightarrow {}^{8}_{4}Be + \ldots\ldots$ *(01 mark)*

$^{1}_{0}n$ (01)

(ii) $^{19}_{9}F + {}^{1}_{0}n \longrightarrow \ldots\ldots + {}^{4}_{2}He$ *(01 mark)*

$^{16}_{7}N$ (01)

(b) It takes 5 days for 0.025 mg of bismuth – 214 to disintegrate into 0.0125 mg of bismuth – 210. Calculate the time required for 0.016 mg bismuth – 214 to change into 0.001 mg bismuth -210. *(03 marks)*

$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

$\lambda = \frac{0.693}{5}$

$\lambda = 0.1386\ day^{-1}$

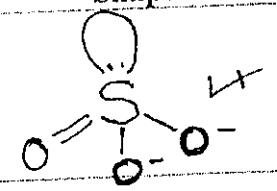
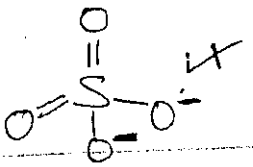
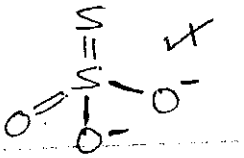
$\ln \frac{A_0}{A_t} = \lambda t$

$\ln\left(\frac{0.016}{0.001}\right) = 0.1386 \times t$

$t = \frac{\ln\left(\frac{0.016}{0.001}\right)}{0.1386} = 20\ days$

(03)

3. (a) Draw a structure and name the shape of the following anion. *(03 marks)*

Anion	Shape	Name of shape
SO_3^{2-}		Trigonal pyramidal shape ✓✓
SO_4^{2-}		Tetrahedral shape ✓
$S_2O_3^{2-}$		Tetrahedral shape ✓

(b) Name a reagent(s) which can be used to distinguish between the SO_3^{2-} and SO_4^{2-}. State what would be observed.

Reagent(s) Dilute nitric acid and barium nitrate solution or Dilute hydrochloric acid and Barium chloride solution. ✓ *(01 mark)* (01)

Accept: Dilute hydrochloric acid

Observation : A white precipitate with SO_4^{2-} ✓ no observable change with SO_3^{2-} ✓ *(01 mark)* (01)

Observation: Bubbles of a colourless gas with SO_3^{2-} ✓

no observable change with SO_4^{2-}

4. (a) At 25°C, a 0.1M solution of ethylamine is 7.3% ionized.

(i) Write an equation for the ionization of ethylamine in water. *(01mark)*

$CH_3CH_2NH_{2(aq)} + H_2O_{(l)} \rightleftharpoons CH_3CH_2\overset{+}{N}H_{3(aq)} + \bar{O}H_{(aq)}$ ✓ (01)

(b) Calculate the concentration of hydroxide ions at equilibrium. *(01 mark)*

At equilibrium, $[\bar{O}H] = c\alpha$

$= 0.1 \times \frac{7.3}{100}$ ✓ (01)

$= 7.3 \times 10^{-3}$ ✓ mol dm^{-3}

rej. without units

(c) 1×10^{-2} mol of ethylamine hydrochloride was added to 1 dm^3 of ethylamine solution in (a). Calculate the hydroxide ion concentration of the resultant solution. State any assumptions made. *(04 marks)*

$K_b = \frac{[CH_3CH_2\overset{+}{N}H_3][\bar{O}H]}{[CH_3CH_2NH_2]}$ ✓ $\therefore [\bar{O}H] = 5.75\times10^{-4} \times \frac{0.1}{0.01}$ ✓

$= 0.00575$ ✓ $mol\,dm^{-3}$

$[\bar{O}H] = K_b \times \frac{[CH_3CH_2NH_2]}{[CH_3CH_2\overset{+}{N}H_3]}$

But $K_b = \frac{c\alpha^2}{1-\alpha}$

$= \frac{0.1\times(0.073)^2}{(1-0.073)}$ ✓

$= 5.75\times10^{-4}$ ✓ $mol\,dm^{-3}$

Assumptions:

- The concentration of $CH_3CH_2\overset{+}{N}H_3$ is regarded as entirely derived from ethylamine hydrochloride (salt). ✓
- The volume of solution remained constant when 1×10^{-2} mol of salt were added

(04)

5. (a) (i) State the condition(s) under which chlorine reacts with sulphur dioxide. *(01 mark)*

Accept: In aqueous solution. ✓

When the two gases are dry ✓ (01)

(ii) Write equation for the reaction. *(01 mark)*

$SO_{2(g)} + 2H_2O_{(l)} + Cl_{2(g)} \rightarrow SO_4^{2-}{}_{(aq)} + 4H^+_{(aq)} + 2Cl^-_{(aq)}$ ✓

$SO_{2(g)} + Cl_{2(g)} \rightarrow SO_2Cl_{2(l)}$ ✓ (01)

(b) Chlorine was bubbled through sodium thiosulphate and lead(II) nitrate solution added to the resultant solution.

(i) State what was observed. *(01 mark)*

White precipitate ✓ (01)

(ii) Write equation(s) for the reaction(s) that took place. (01) *(02 marks)*

$4Cl_{2(g)} + S_2O_3^{2-}{}_{(aq)} + 5H_2O_{(l)} \rightarrow 2SO_4^{2-}{}_{(aq)} + 10H^+_{(aq)} + 8Cl^-_{(aq)}$ ✓

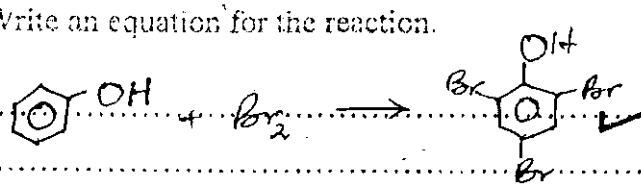
$Pb^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4(s)}$ ✓ (01)

6. (a) Phenol was added to bromine water.

(i) State what was observed. *(01 mark)*

White precipitate ✓

(ii) Write an equation for the reaction. *(01 mark)*



(b) Name a reagent which can be used to distinguish between phenol and cyclohexanol. State what would be observed if the reagent is treated with each compound. Bromine water; white precipitate with phenol, no observable change with cyclohexanol. *(01 mark)*

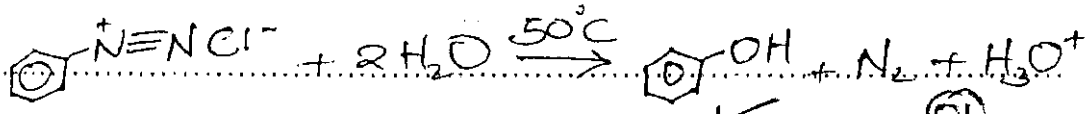
Reagent Neutral iron(III) chloride solution. (01)

OR: Concentrated Sulphuric acid.

Observation: A colourless *(01 mark)*

A violet solution is formed with phenol, no observable change with cyclohexanol.

(c) Write equation to show how phenol may be prepared from benzene diazonium chloride. *(01 mark)*



(01)

7. (a) State Graham's law of gaseous diffusion. *(01 mark)*

The rate of diffusion of a gas at constant temperature and pressure is inversely proportional to the square root of its density. (01)

(b) A mixture of carbon monoxide and carbon dioxide diffuses through a porous partition in half the time taken for the same volume of bromine vapour. Calculate the percentage of carbon dioxide in the mixture. *(04 marks)*

Rmm of $CO = 12+16 = 28$

Rmm of $CO_2 = 12+(16\times2) = 44$

Rmm of $Br_2 = (80\times2) = 160$

Let the time taken by bromine be t units

$\therefore$ Time taken by the mixture $= \frac{1}{2}t$

Rate of diffusion of Br_2 vapour $= \frac{V}{t}$

Rate of diffusion of mixture $= \frac{2V}{t}$; V = volume of gas.

From Graham's law; $\frac{\text{Rate of diffusion of } Br_2}{\text{Rate of diffusion of mixture}} = \sqrt{\frac{\text{Rmm of mixture}}{160}}$

$\frac{V}{t} \times \frac{t}{2V} = \sqrt{\frac{(\frac{x}{100} \times 44) + (\frac{100-x}{100} \times 28)}{160}}$ ✓

$\frac{1}{2} = \sqrt{\frac{\frac{44x}{100} + \frac{2800-28x}{100}}{160}}$ ✓

$\frac{1}{4} = \frac{44x + 2800 - 28x}{16000}$ (04)

$x = \frac{4000-2800}{16} = 75$

$\therefore$ % $CO_2 = 75\%$ ✓ % $CO = 100 - 75 = 25\%$ ✓

8. (a) Write equation for the reaction between sodium hydroxide solution and;

(i) Aluminium oxide. *(01 mark)*

$Al_2O_{3(s)} + 2\bar{O}H_{(aq)} + 3H_2O_{(l)} \rightarrow 2Al(OH)_4^-{}_{(aq)}$ ✓ (01)

(ii) Chlorine gas *(02 marks)*

$Cl_{2(g)} + 2\bar{O}H_{(aq)} \rightarrow OCl^-_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$ (01)

$3Cl_{2(g)} + 6\bar{O}H_{(aq)} \rightarrow ClO_3^-{}_{(aq)} + 5Cl^-_{(aq)} + 3H_2O_{(l)}$ (01)

(b) Sodium hydroxide solution was added to nickel(II) sulphate solution.

(i) State what was observed. *(01 mark)*

Green precipitate ✓ (01)

(ii) Write equation for the reaction. *(01 mark)*

$Ni^{2+}_{(aq)} + 2\bar{O}H_{(aq)} \rightarrow Ni(OH)_{2(s)}$ ✓ (01)

9. The atomic number of element **X** is 32.

(a) Write down the electronic configuration of **X**. *(01 mark)*

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2$ ✓ (01)

(b) Write the formula of the;

(i) Hydride of **X**. *(½mark)*

XH_4 ✓ (½)

(ii) Chloride of **X**. *(½ mark)*

XCl_4 ✓ (½)

(c) Water was added to the chloride of **X**. State whether the resultant solution was neutral, acidic or alkaline. Explain your answer giving an equation for the reaction. *(03 marks)*

The resultant solution was acidic ✓. The chloride undergoes hydrolysis ✓ forming hydrochloric acid ✓ which makes the solution acidic.

$XCl_4(l) + 2H_2O(l) \rightarrow XO_2(s) + 4HCl(aq)$ ✓ (03)

Total = 46 Mks.

SECTION B (54 MARKS)

Answer **SIX** *questions from this section*

10. (a) When heated, carbon dioxide decomposes according to the equation

$2\,CO_2(g) \rightleftharpoons 2\,CO(g) + O_2(g)$

If at a certain temperature and one atmosphere pressure, 60% of the original carbon dioxide remained undissociated, calculate the equilibrium constant K_p for the reaction. *(05 marks)*

$2\,CO_2(g) \rightleftharpoons 2\,CO(g) + O_2(g)$

$CO_2(g) \rightleftharpoons CO + \frac{1}{2}O_2$

	CO_2	CO	$\frac{1}{2}O_2$
At equilibrium	0·6	0·4	$\frac{1}{2}\times 0{\cdot}4 = 0{\cdot}2$

Total number of moles $= 0{\cdot}6 + 0{\cdot}4 + 0{\cdot}2 = 1{\cdot}2$ moles ✓

$\therefore p_{CO_2} = \left(\frac{0{\cdot}6}{1{\cdot}2} \times 1\right) = \frac{0{\cdot}6}{1{\cdot}2}$ atm ✓, $p_{CO} = \frac{0{\cdot}4}{1{\cdot}2} \times 1 = \frac{0{\cdot}4}{1{\cdot}2}$ atm ✓

$p_{O_2} = \left(\frac{0{\cdot}2}{1{\cdot}2} \times 1\right) = \frac{0{\cdot}2}{1{\cdot}2}$ atm ✓

$K_p = \frac{(p_{CO})^2 \times p_{O_2}}{(p_{CO_2})^2}$ ✓ $= \frac{\left(\frac{0{\cdot}4}{1{\cdot}2}\right)^2 \times \frac{0{\cdot}2}{1{\cdot}2}}{\left(\frac{0{\cdot}6}{1{\cdot}2}\right)^2}$ ✓ $= 0{\cdot}074$ atm. (05)

(b) State and explain the effect of:

(i) Increasing the pressure to 2 atmospheres on the equilibrium concentration of oxygen. *(02 marks)*

The equilibrium concentration of oxygen will decrease. The forward reaction proceeds with an increase in volume. Increasing pressure favours the backward reaction, oxygen and carbon monoxide will combine to produce carbon dioxide which decreases the equilibrium concentration of oxygen.

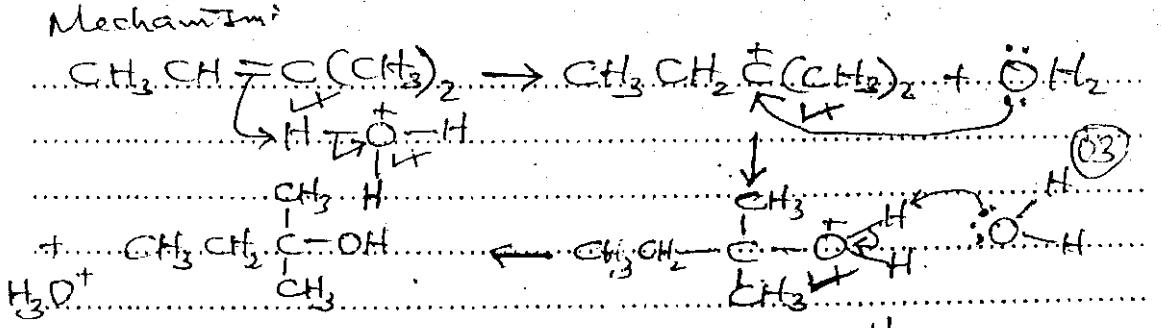
(ii) Carrying out the decomposition at a lower temperature on the value of the equilibrium constant Kp. *(02 marks)*

The value of the Kp will decrease. The decomposition of CO_2 is endothermic, therefore, favoured by high temperatures. When the reaction is carried out at low temperatures, the backward reaction (exothermic) will be favoured, CO and O_2 will combine, Kp decrease. 09

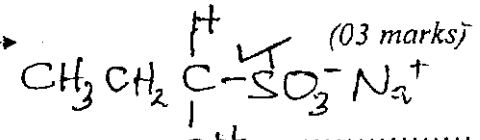
11. Complete the following equations and outline a mechanism for the reaction:

(a) $CH_3CH = C(CH_3)_2 \xrightarrow[\text{Warm}]{H_3O^+} CH_3CH_2C(CH_3)_2OH$ *(03 marks)*

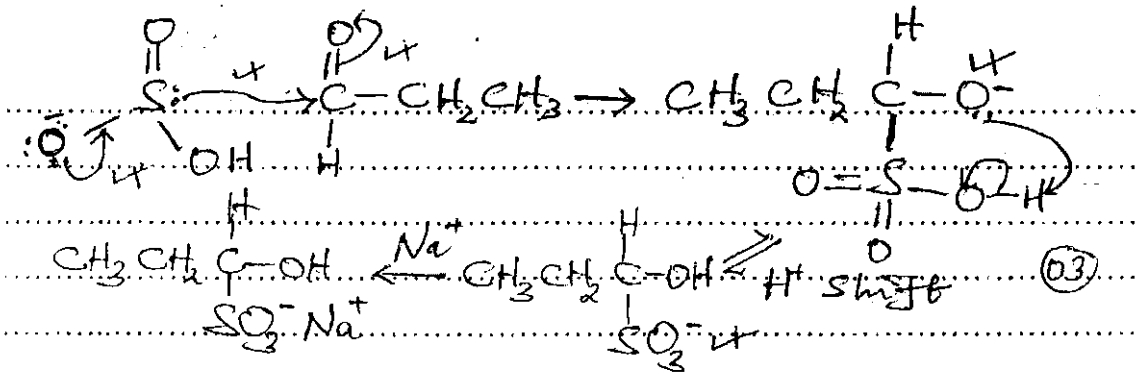
Mechanism:



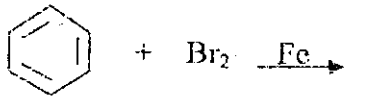
(b) $CH_3CH_2CHO + NaHSO_3 \longrightarrow$ *(03 marks)*

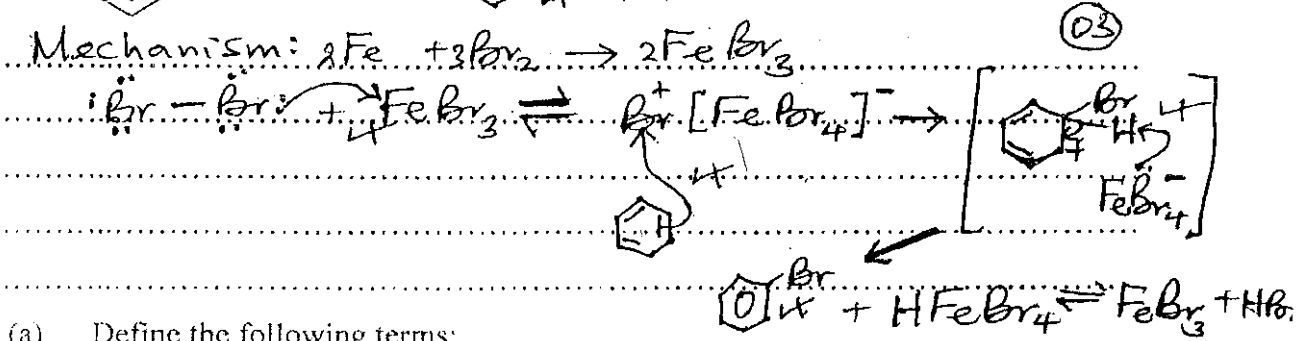


Mechanism: $NaHSO_3 \rightarrow Na^+ + HSO_3^-$



(03)

(c)  *(03 marks)*



(03)

12. (a) Define the following terms;

(i) Standard heat of formation of a substance. *(01 mark)* 09

The heat absorbed or evolved (enthalpy change) when one mole of a substance is formed from (01) its elements in their standard states at 298K and 1 atmosphere pressure.

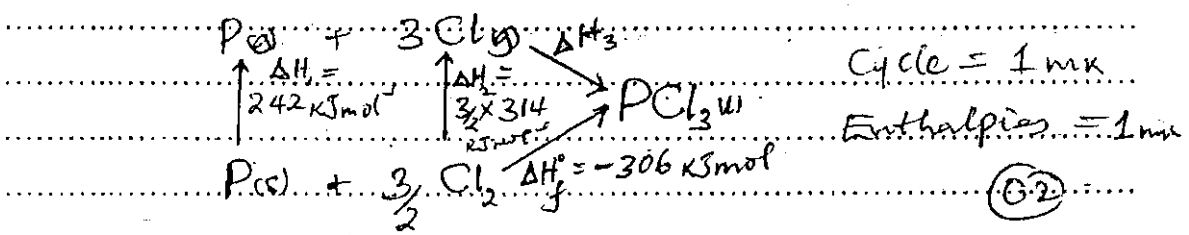
(ii) Lattice energy. *(01 mark)*

The heat evolved when one mole of a crystal lattice is formed from its constituent gaseous ions. (01)

OR. The heat absorbed when one mole of a crystal lattice is dissociated into its constituent gaseous ions.

(b) The standard heat of formation of phosphorus trichloride is $-306\ kJmol^{-1}$ The bond dissociation energy and enthalpy of atomization of chlorine and phosphorus are 314 and 242 $kJmol^{-1}$ respectively.

(i) Draw a Born – Haber cycle for the formation of phosphorus trichloride. *(02 marks)*



Cycle = 1 mk

Enthalpies = 1 mk

(02)

(ii) Use your cycle to calculate the P – Cl bond energy. *(02 marks)*

From the cycle $\Delta H_f^\circ = \Delta H_1 + \Delta H_2 + \Delta H_3$ $\therefore 3(P-Cl) = -1019$

$-306 = 242 + \frac{3}{2} \times 314 + \Delta H_3$ $\Rightarrow P-Cl = \frac{-1019}{3}$ (02)

$\Delta H_3 = -306 - 242 - 471 = -1019\ kJmol^{-1}$ $= -339.67\ kJmol^{-1}$

(c) Calculate the standard heat of formation of ethane if the standard heats of combustion of graphite, hydrogen and ethane are 403, 285 and 1395 $kJmol^{-1}$ respectively. *(03 marks)*

$2C(s) + 3H_2(g) \xrightarrow{\Delta H_f^\circ} C_2H_6(g)$ $\Delta H_1 = (2 \times -403) + (3 \times -285)$

$= -1661\ kJmol^{-1}$ (1)

$\frac{7}{2}O_2$ ΔH_1 ΔH_2 $\frac{3}{2}O_2$ (1) $\Delta H_2 = -1395$

$2CO_2(g) + 3H_2O$ $\Rightarrow -1661 = \Delta H_f^\circ - 1395$

From the cycle ΔH_f° ethane $= 1395 - 1661$

$\Delta H_1 = \Delta H_f^\circ + \Delta H_2$ $= -266\ kJmol^{-1}$ (1)

0.9

13. (a) Silver chromate is sparingly soluble in water. Write;

(i) An equation for the solubility of silver chromate in water. *(01 mark)*

$Ag_2CrO_4(s) + H_2O(l) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$ (01)

(ii) An expression of the solubility product constant Ksp for silver chromate. *(01 mark)*

$Ksp = [Ag^+]^2[CrO_4^{2-}]$ (01)

(b) The solubility of silver chromate is 6.64×10^{-4} g per 100 g water at a certain temperature. Calculate the solubility product of silver chromate. *(04 marks)*

Assuming the density of water at that temperature is $1 g/cm^3$, $100 cm^3$ of solution contain 6.64×10^{-4} g Ag_2CrO_4

$\therefore$ $1000 cm^3$ of the solution contain $6.64 \times 10^{-4} \times \frac{1000}{100}$

$= 6.64 \times 10^{-3}$ g

RFm of Ag_2CrO_4 = (2×108) + 52 + (16×4) = 332 ✓

(04)

No. of moles of Ag_2CrO_4 = $\frac{6.64\times10^{-3}}{332}$ = 2×10^{-5} moles ✓

$K_{sp} = [Ag^+]^2[CrO_4^{2-}]$ ✓

$\therefore [Ag^+] = (2\times2\times10^{-5}) = 4\times10^{-5}M$, $[CrO_4^{2-}] = 2\times10^{-5}M$, $= (4\times10^{-5})^2 \times 2\times10^{-5}$

$= 3.2\times10^{-14}$ mol^3dm^{-9} ✓

(c) Calculate the solubility of silver chromate in 1.0 dm^3 of 0.1 M silver nitrate. *(03 marks)*

Let x moldm^{-3} be the solubility of Ag_2CrO_4 in 0.1M silver nitrate solution.

$[Ag^+] = (0.1 + x) \approx 0.1$ ✓ $[CrO_4^{2-}] = x$ ✓ $x = \frac{3.2\times10^{-14}}{(0.1)^2}$

$K_{sp} = [Ag^+]^2[CrO_4^{2-}]$ ✓

$= 3.2\times10^{-12}$ moldm^{-3} ✓

$3.2\times10^{-14} = (0.1)^2 \times x$ ✓

03

04

14. (a) Explain what is meant by the term order of a reaction. *(03 marks)*

Order of reaction is the sum of the powers to which the concentration of reactants are raised in the rate equation. The order of a reaction can be 0, 1, 2 and rarely 3, positive or negative or fractional. The order of a reaction is experimentally determined and not deduced from the stoichiometric equation. ✓

(03)

(b) The following kinetics data was obtained for the reaction between an alkyl halide S and aqueous sodium hydroxide.

[S] (moldm^{-3})	[$\bar{O}H$] (moldm^{-3})	Initial rate (moldm^{-3} s^{-1})
0.100	0.50	2×10^{-3}
0.050	0.25	1×10^{-3}
0.100	0.25	2×10^{-3}
0.075	0.25	1.5×10^{-3}

(i) Determine the order of the reaction with respect to S and sodium hydroxide. *(03 marks)*
Give a reason for your answer.

Order with respect to S. First order ✓ (½)

Reason:

Keeping the concentration of $\bar{O}H$ and doubling the concentration of S, the rate of the reaction doubles. ✓ (1)

Order with respect to $\bar{O}H$ Zero order. ✓ (½)

Reason

Keeping the concentration of S and

(ii) Write an equation for the rate of reaction. *(01 mark)*

Rate = K [S] ✓ (01)

(iii) Calculate the rate constant and give its units. *(01 mark)*

Using experiment 1 results:

$2.0 \times 10^{-3} = K \times (0.1)$

$K = \frac{2.0 \times 10^{-3}}{0.1} = 2.0 \times 10^{-2}\ s^{-1}$ ✓ (01)

(iv) Write the general structure of S. *(01 mark)*

(O) $-\underset{X}{CH}-R$ or $R-\underset{k}{\overset{R}{C}}-X$ ✓ R = Alkyl group

X = Halogen.

(01)

15. (a) Write the name and formula of one ore from which aluminium can be extracted.

Name : Bauxite ✓

Formula of the ore: $Al_2O_3 \cdot 2H_2O$ ✓ *(01 mark)*

(01)

(b) (i) Describe how the ore is purified. *(04 marks)*

- The ore is crushed into fine powder then roasted at low temperature.
- The finely powdered product is digested with hot concentrated sodium hydroxide under pressure.
- Aluminium oxide dissolves forming sodium aluminate leaving the impurities (iron(III) oxide and titanium(IV) oxide) undissolved which are then filtered off.
- The filtrate is cooled diluted with water and seeded with freshly precipitated aluminium hydroxide and

filtered off, washed, dried and heated to produce pure aluminium oxide. (04)

(ii) Describe the reaction of aluminium metal with acids. *(04 marks)*

- The metal reacts with concentrated, hot sulphuric acid evolving sulphur dioxide gas.

$2Al(s) + 6H_2SO_4(l) \rightarrow Al_2(SO_4)_3(aq) + 6H_2O(l) + 3SO_2(g)$ (04) max

- Aluminium reacts with warm dilute hydrochloric acid evolving hydrogen. $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$

- Aluminium does not react with dilute, cold hydrochloric acid due to a protective layer formed when the metal is exposed to moist air.

- Aluminium is rendered passive by both conc. and dil. nitric acid

16. Compound **Q** contains 62.1% carbon, 10.3% hydrogen, the rest being oxygen. 09

(a) Calculate the empirical formula of **Q**. *(03 marks)*

% O = 100 − 62.1 − 10.3 = 27.6% ∴ The empirical formula of Q is C_3H_6O

Elements:	C	H	O
% by mass	62.1	10.3	27.6
No. of moles	$\frac{62.1}{12}$	$\frac{10.3}{1}$	$\frac{27.6}{16}$
	= 5.175	10.3	1.725
Mole ratio	$\frac{5.175}{1.725}$	$\frac{10.3}{1.725}$	$\frac{1.725}{1.725}$
	3	5.971 ≈ 6	1

(03)

(b) **Q** distills in steam at 98°C and 1.01×10^5 Nm^{-2}. If the vapour pressure of water at 98°C is 9.5×10^4 Nm^{-2}.

(i) Calculate the molecular mass of **Q** if the distillate contained 16.67% by mass of **Q**. *(02 marks)*

$V.P_Q = 1.01 \times 10^5 - 9.5 \times 10^4 = 6000$ Nm^{-2}

$\frac{V.P_Q}{V.P_{water}} = \frac{n_Q}{n_{water}}$

$\frac{6000}{9.5 \times 10^4} = \frac{\frac{16.67}{RFm\ of\ Q}}{\frac{83.33}{18}}$

$RFm\ of\ Q = \frac{9.5 \times 10^4 \times 16.67 \times 18}{6000 \times 83.33} = 57$ (02)

(ii) Determine the molecular formula of **Q**. *(01 mark)*

$(C_3H_6O)_n = 57$

$[(12 \times 3) + (1 \times 6) + 16]n = 57$

$58n = 57$

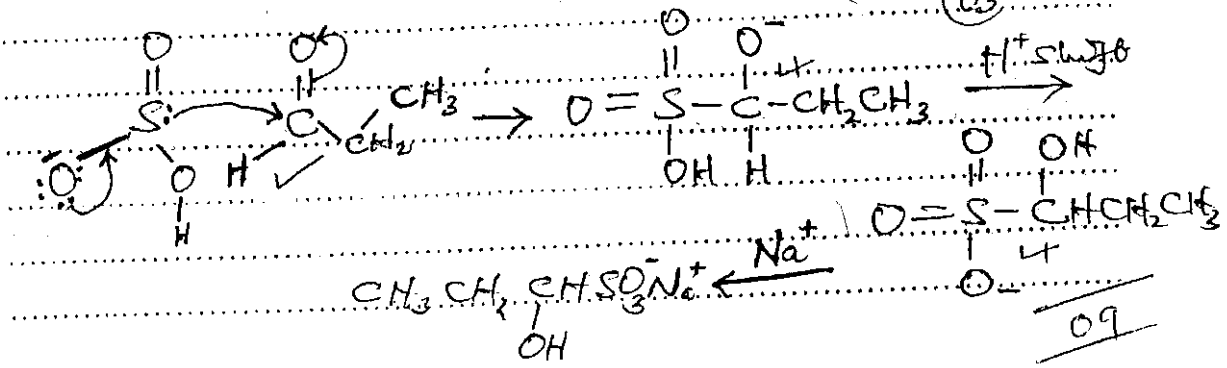
$n = 1$

∴ Molecular formula of Q is C_3H_6O (01)

(c) Q formed a grey precipitate when treated with ammonical silver nitrate. Write equation and out a mechanism for the reaction between Q and sodium hydrogen sulphite solution. *(03 marks)*

$CH_3CH_2CHO + NaHSO_3 \rightarrow CH_3CH_2CH(OH)SO_3^-Na^+$ ✓

Mech: $NaHSO_3 \rightarrow Na^+ + HSO_3^-$



03 09

17. (a) To 25 cm^3 of 0.1 M zinc sulphate solution was added 25 cm^3 of 1.7 M aminomethane. The resultant solution was shaken with trichloromethane and left to settle. 10 cm^3 of the aqueous layer required 16.5 cm^3 of 0.5 M nitric acid. If the partition coefficient for the distribution of aminomethane between water and trichloromethane is 25 at 25°C. Calculate:

(i) The concentration of aminomethane in the organic layer. *(04 marks)*

1000 cm^3 of 1·7 M aminomethane contain 1·7 mol CH_3NH_2

∴ 25 cm^3 of the solution contain $\frac{1·7 \times 25}{1000}$ = 0·0425 moles

⇒ 50 cm^3 of the aq. layer contain 0·0425 mol CH_3NH_2 before shaking

1000 cm^3 of the aq. layer contain $0·0425 \times \frac{1000}{50}$ = 0·85 mol ✓

⇒ $[CH_3NH_2]_{cplx} + [CH_3NH_2]_{free} + [CH_3NH_2]_{org} = 0·85$ M

After shaking:

1000 cm^3 of 0·5 M HNO_3(aq) contain 0·5 mol HNO_3

16·5 cm^3 of the solution contain $\frac{0·5 \times 16·5}{1000} = 8·25 \times 10^{-3}$ ✓

$CH_3NH_2(aq) + HNO_3(aq) \rightarrow CH_3\overset{+}{N}H_3NO_3^-(aq)$ ✓ 04

Mole ratio of $CH_3NH_2 : HNO_3 = 1:1$

∴ No. of moles of CH_3NH_2 that reacted = $8·25 \times 10^{-3}$ moles

⇒ [illegible] ... the aq. layer after shaking = $8·25 \times 10^{-3} \times \frac{1000}{10}$

$\therefore [CH_3NH_2]_{cplx'd} + [CH_3NH_2]_{free} = 0.825\ M$

$\therefore [CH_3NH_2]_{org} = 0.85 - 0.825$ ✓

$= 0.025\ M$ ✓

(ii) The concentration of aminomethane that formed a complex with zinc ions. *(03 marks)*

$K_b = \dfrac{[CH_3NH_2]_{free}}{[CH_3NH_2]_{org}}$ ✓ $\therefore [CH_3NH_2]_{free} = 25 \times 0.025$

$= 0.625\ M$ ✓

$\therefore [CH_3NH_2]_{complexed} = 0.825 - 0.625$ (03)

$= 0.2\ M$ ✓

(b) Use your answer in (a) (ii) to write an equation for the reaction between aminomethane and zinc ions. *(02 marks)*

$1000\ cm^3$ of $0.1M\ ZnSO_4$ aq. Contain 0.1 mol Zn^{2+}

$\therefore 25\ cm^3$ of the solution contain $\dfrac{25 \times 0.1}{1000} = 2.5 \times 10^{-3}$ moles.

$\Rightarrow 50\ cm^3$ of the aq. Layer contain 2.5×10^{-3} mol Zn^{2+} ✓

$\therefore 1000\ cm^3$ of the aq-layer contain $2.5 \times 10^{-3} \times \dfrac{1000}{50} = 0.05$ mole

$\Rightarrow 0.05$ mol of Zn^{2+} complex with 0.2 mol CH_3NH_2

$\therefore 1$ mol of Zn^{2+} complexes with $\dfrac{0.2}{0.05} = 4$ ✓ (02)

$\Rightarrow Zn^{2+}_{(aq)} + 4\,CH_3NH_{2(aq)} \xrightarrow[\text{END}]{} [Zn(CH_3NH_2)_4]^{2+}_{(aq)}$ ✓

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