Candidate's Name: MUNICEL

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(Do not write your School/Centre Name or Number anywhere on this booklet.)

P525/1
CHEMISTRY
Paper 1
(Theory)
Nov./Dec. 2023
2¾ hours

UGANDA NATIONAL EXAMINATIONS BOARD

Uganda Advanced Certificate of Education

CHEMISTRY

Paper 1
(Theory)

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.*

The Periodic Table, with relative atomic masses, is attached at the end of the paper.

Mathematical tables (3–figure tables) are adequate or non-programmable scientific electronic calculators may be used.

Illustrate your answers with equation(s) where applicable.

Where necessary, use the following:

Molar gas constant, $R = 8.31\ JK^{-1}\ mol^{-1}$.
Molar volume of gas at s.t.p is 22.4 litres.
Standard temperature = 273 K.
Standard pressure = 101325 Nm^{-2}.

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

SECTION A (46 MARKS)

Answer **all** *questions in this section.*

1. (a) Kinetic data for the decomposition of nitrogen(V) oxide is shown in table **1**.

Table 1

$[N_2O_5]$ (mol dm^{-3})	Initial Rate (mol dm^{-3} s^{-1})
0.0016	0.12
0.0024	0.18
0.0032	x

Calculate the;

Award consequentially; failure of orders, reject all computations.

(i) order of the reaction. *(1½ marks)*

Let rate = $K[N_2O_5]^y$ Let order be y.

$0.18 = K(0.0024)^y$ ---(i) ✓+ - Accept alternative

$0.12 = K(0.0016)^y$ ---(ii) } numerical reasoning eg Wsanthumi etc.

$\frac{0.18}{0.12} = \left(\frac{0.0024}{0.0016}\right)^y$ ✓+ (1½) - Accept logical reasoning ie * increasing concentration by 1.5 times, rate also increases by 1.5 time. Therefore first order.

$1.5 = 1.5^y \therefore y = 1$ ✓+

Order of reaction is one.

(ii) rate constant for the reaction. *(1½ marks)*

Rate = $K[N_2O_5]^1$ ✓+

$K = \frac{0.18}{0.0024}$ ✓+ = 75 s^{-1} ✓+ unit (1½) Accept $\left(\frac{0.0024}{0.0032}\right) = \left(\frac{0.18}{x}\right)^y$

deny mark without units. order is correct

(iii) value of x. *(01 mark)*

$x = (75 \times 0.0032)$ ✓+ (01)

$= 0.24$ mol dm^{-3} s^{-1} ✓+ deduct ½ mark for wrong units

(b) Name **two** methods that can be used to determine orders of reactions. *(01 mark)*

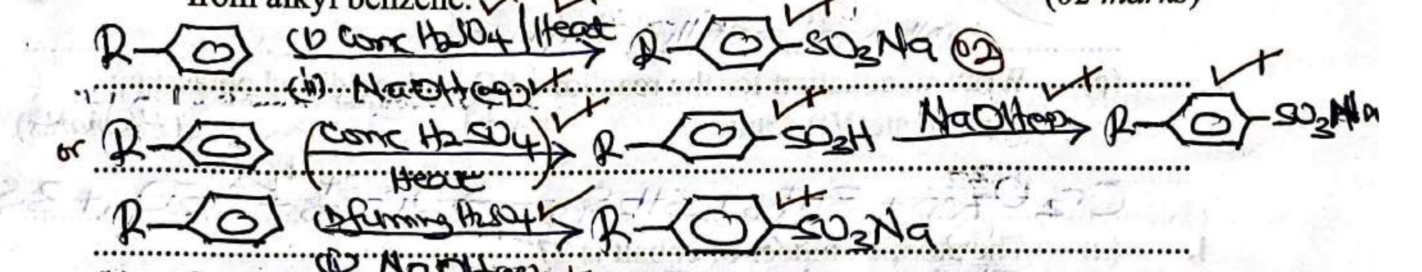
- Titrimetric method ✓+ accept - Volumetric titration ;
- Calorimetric method ✓+ eg: Volumetric analysis ; 05
- Optical method
- Pressure measurement
- Conductimetric method/analysis ; eg: conductimetric titration.

eg: - Initial rate method
- Graphical
- Half life
- Inspection

* deduct ½ mark for extra wrong one

Allow fuming H_2SO_4 / warm or 35–50°C; reject heat. Accept without temp condition. Accept R ≥ 12 carbon atoms. Ignore balancing.

2. (a) Write an equation to show how soapless detergent can be prepared from alkyl benzene. *(02 marks)*



(b) State;

rej: Produce lather

(i) **one** advantage of soapless detergent over soapy detergent. *(01 mark)*

award a full mark { - don't form scum with hard water (1)
- Form soluble salts with calcium ions or magnesium ions in hard water.

award ½ mark { * More effective in hard water; Produce lather easily; can be used in acidic medium

(ii) **one** disadvantage of soapless detergent over soapy detergent. *(01 mark)*

{ - Not biodegradable / Non biodegradable / Not degraded by bacteria
- cause water pollution. rej: degrade slowly

* They are expensive

[04]

3. (a) A compound **Q** consists of 94.11% sulphur, the rest being hydrogen. Calculate the empirical formula of **Q**. *(02 marks)*

% H = (100 − 94.11) = 5.89% (subtraction)

Element	S	H
Moles	$\frac{94.11}{32}$ = 2.94	$\frac{5.89}{1}$ = 5.89 (No. of moles)
Mole ratio	$\frac{2.94}{2.94}$ = 1	$\frac{5.89}{2.94}$ = 2 (ratios)

Empirical formula SH_2 — accept SH_2 or H_2S

(b) When 0.15 g of **Q** was vapourised at 293 K, the vapour produced occupied 106 cm^3 at 101325 Nm^{-2}. Determine the molecular formula of **Q**. *(02 marks)*

$Mr = \frac{mRT}{PV}$

$Mr = \frac{0.15 \times 8.314 \times 293}{101325 \times 106 \times 10^{-6}}$

= 34

$(H_2S)n = 34$

$34n = 34$

n = 1

Molecular formula H_2S — rej: SH_2

Accept alternative approaches

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ or

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ since P is constant

Turn Over

reg: $Cr_2O_{7(aq)}^{2-} + 3S^{2-}_{(aq)} + 14H^+_{(aq)} \rightarrow 2Cr^{3+}_{(aq)} + 3S_{(s)} + 7H_2O_{(l)}$

written for metallic sulphides

(c) Write an equation for the reaction of **Q** with acidified potassium dichromate(VI) solution. *(1½ marks)*

$Cr_2O_{7(aq)}^{2-} + 8H^+_{(aq)} + 3H_2S_{(g)} \rightarrow 2Cr^{3+}_{(aq)} + 7H_2O_{(l)} + 3S_{(s)}$ (1½)

4. (a) The atomic number of cobalt is 27.

reg. $[Ar]4s^23d^7$, or $[Ar]3d^74s^2$

(i) Write the electronic configuration of cobalt. *(01 mark)*

$1s^22s^22p^63s^23p^63d^74s^2$ ✓ or $1s^22s^22p^63s^23p^64s^23d^7$

(ii) State how cobalt is able to form ions with oxidation state of +2 and +3. *(02 marks)*

Accept: Subshell or Sublevel

reg: Sub orbital

- should specify the orbital having the $\bar{e}$

It is able to form +2 by loosing / using two electrons in the 4s orbital. ✓ (1)

reg: $4s^2$ orbital

Able to form +3 by loosing two electrons in the 4s orbital and one electron in the 3d orbital. ✓ (1)

(b) When concentrated ammonia solution was added to cobalt(II) chloride solution, a blue precipitate was formed which dissolved giving a red-brown solution. Write equation(s) for the reaction(s) that took place. *(03 marks)*

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

$Co(OH)_{2(s)} + 6NH_{3(aq)} \rightarrow Co(NH_3)_6^{2+}{}_{(aq)} + 2\bar{O}H$ ✓ } (3)

Symbol of cobalt Co

reg: Co

or $Co^{2+}_{(aq)} + 6NH_{3(aq)} \rightarrow Co(NH_3)_6^{3+}{}_{(aq)}$ ✓ (3)

Accept: $Co(H_2O)_6^{2+}{}_{(aq)} + 2\bar{O}H_{(aq)} \rightarrow 6H_2O_{(l)} + Co(OH)_{2(s)}$

Ignore: $Co(NH_3)_6^{2+}{}_{(aq)} \rightarrow Co(NH_3)_6^{3+}{}_{(aq)} + \bar{e}$ [06

5. State what would be observed and write equation(s) for the reaction(s) that would take place when the following pairs of substances are mixed:

(a) $CH_3C(CH_3)=CH_2$ and bromine in tetrachloromethane.

reg. decolourised

reg: when trying to colour.

Accept: Red solution / liquid

Brown solution / Liquid

Observation Award (Colour + solution / liquid) *(01 mark)*

Reddish brown solution turns colourless ✓ (1)

Equation *(01 mark)*

$CH_3C(CH_3)=CH_2 + Br_2 \xrightarrow{CCl_4} CH_3C(CH_3)(Br)-CH_2Br$ ✓ (1)

Ignore

- balance equation

- Ignore state when they are wrong

- Ignore CCl_4

Accept $CH_3C(CH_3)=CH_2$ $\xrightarrow{Br_2/CCl_4}$ $CH_3C(CH_3)(Br)-CH_2Br$

4

Accept $CH_3COCH_3 \xrightarrow{\bar{O}H_{(aq)}/I_{2(aq)}} CH_3COO^-_{(aq)} + CHI_{3(s)}$

(b) $CH_3\overset{\overset{O}{\|}}{C}CH_3$ and sodium hydroxide in iodine solution.

Observation – Ignore balancing but correct physical states, deduct ½ mark for wrong physical states. *(½ mark)*

Pale yellow / yellow precipitate ✓ Accept solid ✓ (½)

Equation *(01 mark)*

$CH_3COCH_{3(l)} + NaOH_{(aq)} + I_{2(aq)} \longrightarrow CH_3COONa_{(aq)} + CHI_{3(s)}$ ✓ (1)

reg. CH_3COOH

Accept $CH_3COCH_{3(l)} \xrightarrow{NaOH_{(aq)}/I_{2(aq)}} CH_3COONa_{(aq)} + CHI_{3(s)}$

(c) $CH_3CH(OH)CH_3$ and acidified potassium dichromate(VI) solution.

Observation *(01 mark)*

Orange solution turns green on heating ✓ ✓

Equation *(01 mark)*

$CH_3CH(OH)CH_3 \xrightarrow[\text{Heat}]{Cr_2O_7^{2-}/H^+} CH_3COCH_3$ ✓ (1)

Ignore Heat

– Ignore physical states and balancing. [05½

6. (a) Define the term **standard enthalpy of formation.** *(01 mark)*

reg: directional definition ie Heat evolved / absorbed.

Heat change that occurs when one mole of compound is formed from its elements under standard conditions ✓ (1)

Accept in their standard states or normal physical state.

(b) The bond energies of some bonds are shown in table 2.

Accept: at 298K, 1Atm

reg: Standard temperature and pressure

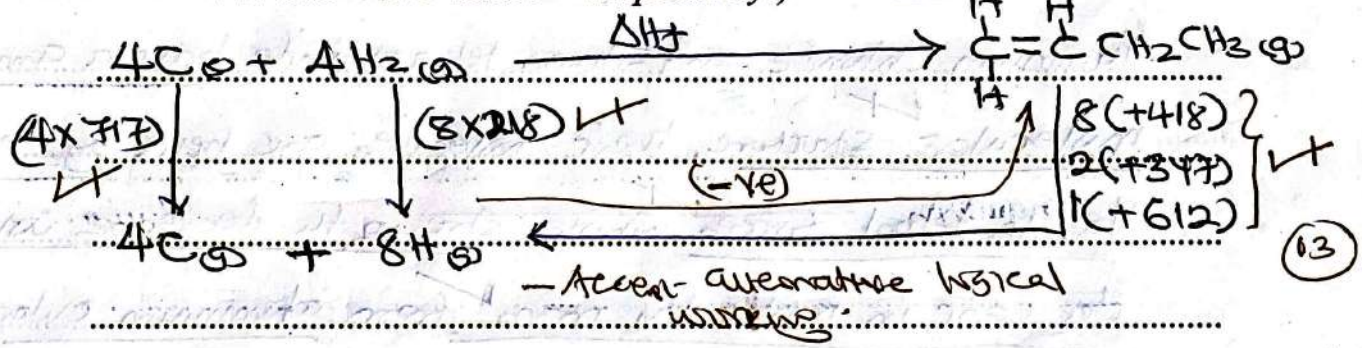
reg: normal conditions

Table 2

Bond	Bond enthalpy (kJ mol^{-1})
$C-H$	+413
$C-C$	+347
$C=C$	+612

Calculate the enthalpy of formation of but-1-ene. *(03 marks)*

(The Standard enthalpies of atomisation of carbon and hydrogen are +717 and +218 kJmol^{-1} respectively.)



(03)

– Accept alternative logical workings.

$\Delta H_f = (4X717) + (8X218) - [(8X418) + (2X347) + (1X612)]$ ✓

$= +2 kJmol^{-1}$ ✓ ✓

– deduct ½ mark for wrong unit

– deduct ½ mark if +ve sign is missing (2½) [04

7. The boiling points of some chlorides of period 3 elements of the Periodic Table are shown in table 3.

Table 3

Formula of chlorides	$NaCl$	$MgCl_2$	Al_2Cl_6	$SiCl_4$
Boiling points (°C)	1465	1418	423	57

Accept $SiCl_4 < AlCl_3 < MgCl_2 < NaCl$

(a) State the trend in the boiling points of the chlorides. *(01 mark)*

Boiling point decreases from sodium chloride to silicon tetrachloride ✓(1) Statement trend should not have symbol

Accept: boiling point decreases in the order ~~$NaCl > MgCl_2$~~ $NaCl > MgCl_2 > Al_2Cl_6 > SiCl_4$

- Wrong trend - No marks for explanation.

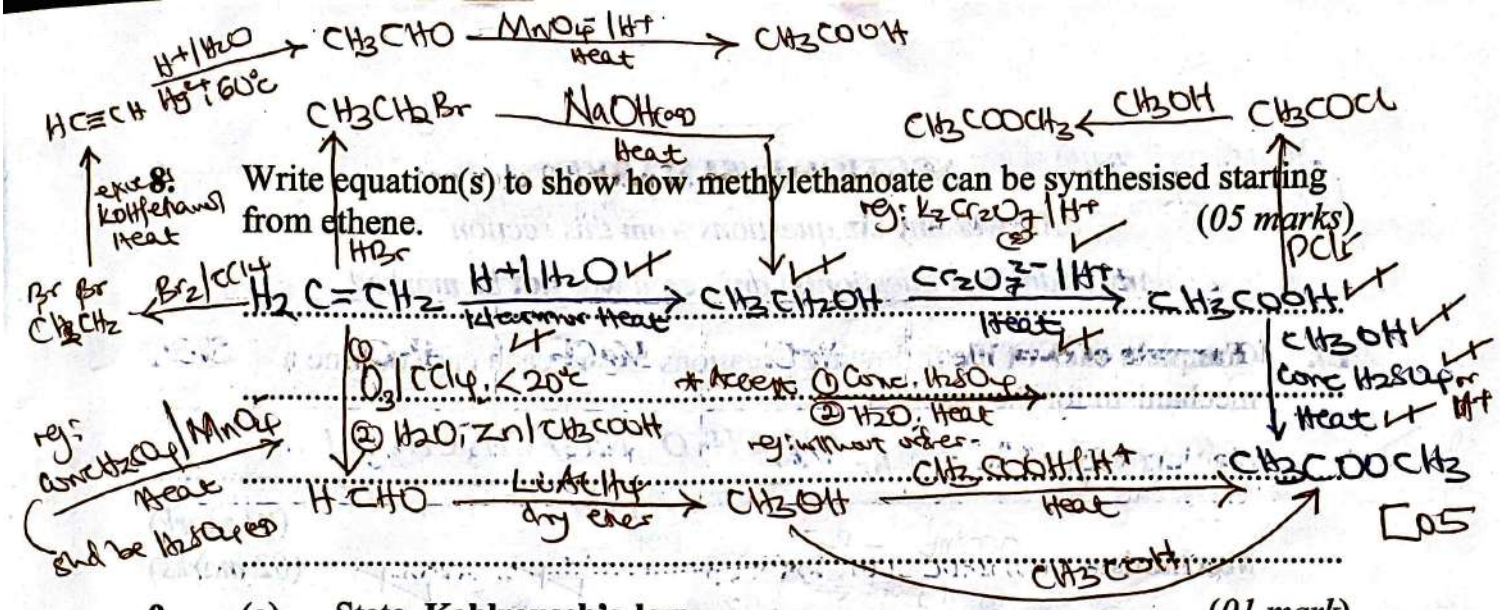
(b) Explain your answer in (a). *(05 marks)*

Sodium chloride and magnesium chloride have ~~ionic~~ giant ionic ✓ structure composed of oppositely charged ions held together by strong ionic ✓ bonds. Magnesium ion has a smaller ionic radius and higher charge density than sodium ion ✓, magnesium ion polarises ✓ the chloride ion more than the sodium ion does making magnesium chloride less ionic ✓ some covalent character and has weaker ionic bond than sodium chloride thus a less boiling point. (05)

Aluminium chloride and silicon tetrachloride have a simple molecular ✓ structure, their molecule are held by weak Vander Waal forces ✓ whose strength decrease with decrease in molecular mass ✓ from aluminium chloride to silicon tetrachloride. ✓ [06]

- No symbols and formulae allowed
- Award logical argument
- Award logical argument, reject regular argument

6



8. Write equation(s) to show how methylethanoate can be synthesised starting from ethene. *(05 marks)*

9. (a) State **Kohlrausch's law.** *(01 mark)*

The molar conductivity of an electrolyte at infinite dilution is equal to the sum of the molar conductivities of the constituent ions at infinite dilution. (1)

emphasize infinite dilution

(b) The molar conductivities at infinite dilution for some electrolytes at 18 °C are shown below.

$BaCl_2$, $\Lambda\infty = 240.6\ \Omega^{-1}\ cm^2\ mol^{-1}$.

NH_4Cl, $\Lambda\infty = 129.6\ \Omega^{-1}\ cm^2\ mol^{-1}$.

$Ba(OH)_2$, $\Lambda\infty = 457.6\ \Omega^{-1}\ cm^2\ mol^{-1}$.

Determine the molar conductivity of NH_4OH at 18 °C. *(03 marks)*

$2\Lambda_m^\infty NH_4OH = \Lambda_m^\infty Ba(OH)_2 + 2\Lambda_m^\infty NH_4Cl - \Lambda_m^\infty BaCl_2$

$= 457.2 + 2(129.6) - 240.6$

$\Lambda_m^\infty NH_4OH = \frac{476.2}{2}$ (03)

$= 238.1\ \Omega^{-1} cm^2 mol^{-1}$

reg without ∞ or ○ symbol

deduct ½ mark for wrong units

Accept $\Lambda_m^\infty NH_4OH = \frac{1}{2}\Lambda_m^\infty Ba(OH)_2 + \Lambda_m^\infty NH_4Cl - \frac{1}{2}\Lambda_m^\infty BaCl_2$

(c) State **one** application of conductivity measurements. *(01 mark)*

- determine solubility product of sparingly soluble salt (1)
- Determine degree of ionisation of weak electrolytes
- Determine dissociation constants for weak electrolytes
- conductimetric titration
- determine formular of complex reg: structure of complexes
- Determine ionic product of water
- Determine molar conductivity of strong electrolyte at infinite dilution.

04

SECTION B (54 MARKS)

Answer any **six** *questions from this section.*

Any additional question(s) answered will **not** *be marked.*

10. Complete each of the following equations and in each case outline a mechanism for the reaction.

(a) $(CH_3CH_2)_3C{-}Br \xrightarrow[\text{Heat}]{CH_3CH_2O^-Na^+ / CH_3CH_2OH}$ ..... *(01 mark)*

Mechanism *(02 marks)*

accept $-Br^-$ ignore $\rightleftharpoons$

$(CH_3CH_2)_3C{-}Br \rightleftharpoons (CH_2CH_2)_3\overset{+}{C} + Br^-$

$CH_3\overset{H}{C}{-}C(CH_2CH_3)_2 \longrightarrow (CH_2CH_2)_2C{=}CHCH_3$

$CH_3CH_2\ddot{O}$ (03) $CH_3CH_2\ddot{O}$: reg without charge

(b) $CH_3CH_2OH \xrightarrow[140\ ^oC]{\text{Accept } Conc.\ H_2SO_4}$ ..... *(01 mark)*

Mechanism *(02 marks)*

$CH_3CH_2\overset{+}{O}H \longrightarrow CH_3CH_2\overset{+}{O}H \xrightarrow{-H_2O} CH_3\overset{+}{C}H_2$ (2½)

$CH_3CH_2OCH_2CH_3 \xleftarrow{-H^+} CH_3CH_2\overset{+}{O}(H)CH_2CH_3 \xleftarrow{} CH_3CH_2\ddot{O}H$

reg.

(c)  $\xrightarrow{HBr}$ emphasise H—Br proximity ..... *(01 mark)*

Mechanism: *(02 marks)*

(both arrows)

09

11. Beryllium and magnesium are elements in group (II) of the Periodic Table.

(a) Explain the following:

(i) The first ionisation energy of beryllium is higher than that of magnesium. *(02 marks)*

All reasons should end up in effective nuclear attraction.

Beryllium has a smaller atomic radius and a higher effective nuclear charge than magnesium, so its outermost electron in beryllium experience stronger nuclear attraction (02) leading to a higher first ionisation energy than magnesium. emphasize comparative language.

(ii) The polarising power of magnesium ions is lower than that of beryllium ions. *(01 mark)*

Beryllium ion has a smaller ionic radius and higher charge density than magnesium or magnesium ion has a larger ionic radius and a smaller charge density

- comparative language

(01)

(b) Beryllium reacts with aqueous sodium hydroxide solution. Write an equation for the reaction. *(1½ marks)*

$Be_{(s)} + 2\bar{O}H_{(aq)} \longrightarrow BeO_2^{2-}{}_{(aq)} + H_{2(g)}$

Balanced Ionic/state symbols

$Be_{(s)} + 2\bar{O}H_{(aq)} + 2H_2O_{(l)} \longrightarrow Be(OH)_4^{2-}{}_{(aq)} + H_{2(g)}$

(c) State the conditions under which beryllium oxide and magnesium oxide react with the following substances and where applicable, write equation(s) for the reaction(s):

(i) Water. *(02 marks)*

Beryllium oxide does not react with water

Magnesium oxide reacts with water on heating to form magnesium hydroxide

Accept hot water; reject steam

(02)

$MgO_{(s)} + H_2O_{(l)} \longrightarrow Mg(OH)_{2(s)}$

(ii) Sodium hydroxide. *(2½ marks)*

Beryllium oxide reacts with concentrated sodium hydroxide to form beryllate ion. Magnesium oxide does not react with sodium hydroxide

hot concentrated

(01½)

$BeO_{(s)} + 2\bar{O}H_{(aq)} \longrightarrow BeO_2^{2-}{}_{(aq)} + H_2O_{(l)}$

09

12. (a) Calcium phosphate(V), $Ca_3(PO_4)_2$, is sparingly soluble in water. Write the;

(i) equation for the solubility of calcium phosphate(V) in water. *(01 mark)*

deduct ½ mark

$Ca_3(PO_4)_{2(s)} \rightleftharpoons 3Ca^{2+}{}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$ (1)

or $Ca_3(PO_4)_{2(s)} \rightleftharpoons 3Ca^{2+}{}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$

(ii) expression for the solubility product, ***Ksp***, of calcium phosphate(V). *(01 mark)*

$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$ (½)

(b) The solubility product of calcium phosphate(V) is $2.0 \times 10^{-29} mol^5\ dm^{-15}$ at 25 °C. Calculate the solubility of calcium phosphate(V) in gdm^{-3} at 25 °C. *(03 marks)*

Let solubility of $Ca_3(PO_4)_2$ be x ; $[Ca^{2+}] = 3x$; $[PO_4^{3-}] = 2x$

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

$2.0 \times 10^{-29} = (3x)^3 (2x)^2$

$108x^5 = 2.0 \times 10^{-29}$

$x = \left(\frac{2.0 \times 10^{-29}}{108}\right)^{\frac{1}{5}}$

$x = 7.14 \times 10^{-7}$ mol dm3 Accept RAm Ca 40.3

Rfm $Ca_3(PO_4)_2 = (3 \times 40) + (2 \times 31) + (2 \times 4 \times 16) = 310$

solubility in $gdm^{-3} = (7.14 \times 10^{-7} \times 310)$

$= 2.21 \times 10^{-4}\ gdm^{-3}$

(c) Explain how the solubility of calcium phosphate(V), would be affected if to its saturated solution a few drops of ;

(i) aqueous sodium phosphate(V) were added. *(02 marks)*

Precipitation should come after a reaction

Solubility of calcium phosphate decreases; addition of sodium phosphate increases the concentration of phosphate ion in solution which reacts with calcium ion to precipitate calcium phosphate. (02)

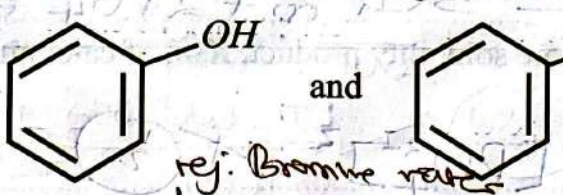
*Emphasize concentration

(ii) dilute nitric acid were added. *(02 marks)*

reject: calcium ion react with nitrate ion to form calcium nitrate.

Solubility calcium phosphate increases because hydrogen ion from nitric acid react with phosphate ion to form phosphoric acid; reduces the concentration of phosphate ion in solution; more calcium phosphate dissolve to restore the concentration of phosphate ion in solution. (02)

13. Name a reagent which can be used to distinguish between the following pairs of compounds and in each case state what would be observed if each member is separately treated with the reagent: *(03 marks)*

(a) 

and

reject: Bromine water

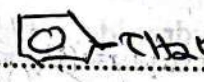
Reagent Neutral Iron(III) chloride solution (1)

reject: iii

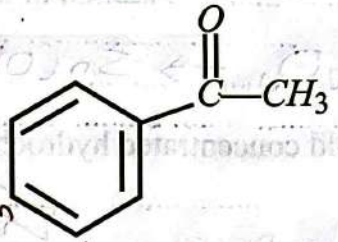
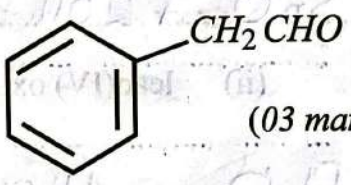
reject III

accept (III)

Observations  Violet/purple solution (1)

 No observation. (1)

Accept: Fehling and Benedicts solution; aldehyde → Reddish brown solid

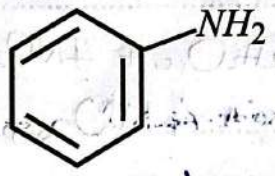
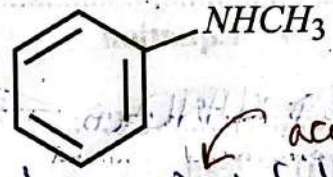
(b)  and  *(03 marks)*

Reagent Ammoniacal silver nitrate solution ✓

Observations  No observable change ✓ (03)

 – silver mirror ✓

rg: Sodium hydroxide solution and Iodine solution.

(c)  and  *(03 marks)*

rg: Bromine water

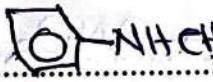
accept dilute

Reagent Sodium nitrite and concentrated hydrochloric acid ✓

0–5°C or ice cold rg >10°C, rg: nitrous acid solution

Observations

 colourless solution / No observable change ✓

 – Yellow oily liquid. ✓ (03) [09

14. (a) Some elements in group (IV) of the Periodic Table are given in table 4. Complete the table by;

(i) writing the formula of the oxide in which each element is in the +4 oxidation state. *(1½ marks)*

(ii) stating the class of each oxide. *(1½ marks)*

Table 4

Element	Formula of oxide	Class of oxide.
Tin	SnO_2 ✓	Amphoteric ✓
Silicon	SiO_2 ✓	Acidic ✓
Lead	PbO_2 ✓	Amphoteric ✓

(03)

(b) Write an equation for the reaction between;

(i) tin(IV) oxide and concentrated sodium hydroxide. *(1½ marks)*

$SnO_{2(s)} + 2OH^-_{(aq)} \longrightarrow SnO_3^{2-}{}_{(aq)} + H_2O_{(l)}$ ✓✓ (1½)

$SnO_{2(s)} + 2OH^-_{(aq)} + 2H_2O_{(l)} \longrightarrow Sn(OH)_6^{2-}{}_{(aq)}$

(ii) lead(IV) oxide and cold concentrated hydrochloric acid. *(1½ marks)*

$PbO_{2(s)} + 4HCl_{(aq)} \longrightarrow PbCl_{4(l)} + 2H_2O_{(l)}$ ✓✓ (1½)

(c) State the condition and write an equation for the reaction between concentrated nitric acid and;

(i) tin.

Condition *(½ mark)*

Heat ✓

Equation *(01 mark)*

$Sn_{(s)} + 4HNO_{3(l)} \rightleftharpoons SnO_2 \cdot 2H_2O_{(s)} + 4NO_{2(g)}$ ✓ $SnO_{2(s)} + 4NO_{2(g)} + 2H_2O_{(l)}$ ✓ (1½)

(ii) lead.

Condition *(½ mark)*

Cold ✓ accept Room temperature

Equation *(01 mark)*

$Pb_{(s)} + 4HNO_{3(l)} \longrightarrow Pb(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$ ✓ (1)

[09

15. (a) Write an equation for the ionisation of benzoic acid in water. *(01 mark)*

$C_6H_5COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons C_6H_5COO^-_{(aq)} + H_3O^+_{(aq)}$ ✓ (1)

$C_6H_5COOH_{(aq)} \rightleftharpoons C_6H_5COO^-_{(aq)} + H^+_{(aq)}$

(b) Calculate the ***pH*** of a solution containing 2.06 g of benzoic acid per dm^3. *(04 marks)*

*(The acid dissociation constant, **Ka**, for benzoic acid = 6.3×10^{-5} mol dm^{-3}.)*

reg: $C_6H_5COOH_{(s)} + (aq) \rightleftharpoons C_6H_5COO^-_{(aq)} + H^+_{(aq)}$

Pfm C_6H_5COOH: $(7\times12) + (6\times1) + (2\times16) = 122$ ✓

$[C_6H_5COOH] = \frac{2.06}{122} = 0.0169$ M ✓

$K_a = \frac{[C_6H_5COO^-][H^+]}{[C_6H_5COOH]}$ ✓ (03)

At equilibrium: $[C_6H_5COO^-] = [H^+]$

$K_a = \frac{[H^+]^2}{[C_6H_5COOH]}$ ✓

$6.3\times10^{-5} = \frac{[H^+]^2}{0.0169}$

$[H^+] = \sqrt{(6.3\times10^{-5} \times 0.0169)}$

$[H^+] = 1.032\times10^{-3}$ M ✓

$pH = -\lg[H^+]$ ✓

$= -\lg(1.032\times10^{-3})$

$= 2.99$ ✓

12

(c) 4.32 g of sodium benzoate was dissolved in one dm^3 of benzoic acid in (b). Calculate the ***pH*** of the resultant solution. *(04 marks)*

Gfm of $C_6H_5COONa = (12\times7)+(5\times1)+(2\times16)+(1\times23) = 144$ ✓

$[C_6H_5COONa] = \frac{4.32}{144} = 0.03M$ ✓✓

Assumption: $[C_6H_5COOH] = 0.0169M$ Acid dissociation suppressed (04)

Salt being electrolyte $[C_6H_5COO^-] = [salt]$ ✓

$K_a = \frac{[salt][H^+]}{[Acid]}$ ✓ ; $6.3\times10^{-5} = \frac{0.03\times[H^+]}{0.0169}$ ✓✓ ; $[H^+] = 3.549\times10^{-5}M$

$pH = -\log[H^+]$; $pH = -\log(3.549\times10^{-5})$; $= 4.45$ ✓

Accept alternative logically referenced approaches.

MH II

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

$= -\log(6.3\times10^{-5}) + \log\left(\frac{0.03}{0.0169}\right)$ ✓

$= 4.45$ ✓ Accept $pH = pK_a - \log\left(\frac{acid}{salt}\right)$

16. (a) During the extraction of aluminium from bauxite, $Al_2O_3 \cdot 2H_2O$, the ore is first purified.

(i) Name **two** major impurities in the ore. *(01 mark)*

Silicon(IV) oxide ✓ | silicon dioxide accep silica

Iron (III) oxide ✓ accept ferric oxide

rej (IV; III), rej: (13(iv), (iii))

rej: ~~Tata~~ Titanium oxide - minor impurity

(ii) Write equations to show how the ore is purified. *(06 marks)*

$SiO_{2(s)} + 2OH^-_{(aq)} \longrightarrow SiO_3^{2-}{}_{(aq)} + H_2O_{(l)}$ ✓✓

$Al_2O_{3(s)} + 2OH^-_{(aq)} + 3H_2O_{(l)} \longrightarrow 2Al(OH)_4^-{}_{(aq)}$ ✓✓ (06)

$2Al(OH)_4^-{}_{(aq)} + CO_{2(g)} \longrightarrow 2Al(OH)_{3(s)} + CO_3^{2-}{}_{(aq)} + H_2O_{(l)}$ ✓✓

$2Al(OH)_{3(s)} \xrightarrow{Heat} Al_2O_{3(s)} + 3H_2O_{(g)}$ ✓✓

Seeding $Al(OH)_4^-{}_{(aq)} + Al(OH)_{3(s)} \longrightarrow 2Al(OH)_{2(s)} + OH^-_{(aq)}$

(b) Describe how aluminium is obtained from the pure ore.
(*Equations are* **not** *required.*) *(02 marks)*

Cryolite ✓ is added to the pure ore and the mixture heated ✓ to melt. The molten mixture is electrolysed ✓ using graphite electrodes / carbon electrodes ✓ to obtain aluminium. eg. cryolite = sodium hexafluoroaluminate

17. (a) State what is meant by the term **partition coefficient**. *(01 mark)*

The ratio of concentration of a solute dissolved in two immiscible solvents in contact when equilibrium is established at constant temperature. ✓ (1)

eg: Molar concentration.

(b) 4.5 g of an impure sample of zinc sulphide was dissolved in excess concentrated solution of ammonia and the solution diluted to 500 cm^3. The resultant solution was shaken with 25 cm^3 of carbon tetrachloride and allowed to settle.
12.5 cm^3 of aqueous layer required 20.0 cm^3 of a 0.25 M hydrochloric acid for complete reaction, while 25.0 cm^3 of the carbon tetrachloride layer required 12.5 cm^3 of a 0.025 M hydrochloric acid for complete reaction.

Calculate the number of moles of;

(i) free ammonia in aqueous layer. *(2½ marks)*
(*The partition coefficient,* K_D*, for ammonia between carbon tetrachloride and water is 0.04*)

No. of moles NH_3 in 25cm^3 CCl_4 = Moles HCl = $\left(\frac{12.5 \times 0.025}{1000}\right)$ ✓✓
= 3.125×10^{-4} moles ✓

No of moles NH_3 in 1000cm³ CCl_4 = $\frac{(3.125\times10^{-4}\times1000)}{25}$ = 0.0125M.

$K_D = \frac{[NH_3]_{CCl_4}}{[NH_3]_{free}} = 0.04$ (2k)

$[NH_3]_{free} = \frac{0.0125}{0.04} = 0.3125M$

Moles NH_3 in 500cm³ 2k = $\frac{(3.125\times10^{-4}\times500)}{25}$ = 6.25×10^{-3} moles

$K_D = \frac{[NH_3]_{CCl_4}}{[NH_3]_{free}}$

$0.04 = \frac{6.25\times10^{-3}}{[NH_3]_{free}}$

$[NH_3]_{free} = \frac{(6.25\times10^{-3})}{0.04}$ = 0.15625 moles

Student calculate in 500cm³

(ii) complexed ammonia. (2½ marks)

Total moles NH_3 in 12.5cm³ = $\frac{(0.25\times20)}{1000}$ = 5.0×10^{-3} moles

Moles NH_3 in 1000cm³ of water = $\frac{(5.0\times10^{-3}\times1000)}{12.5}$ = 0.4M

Moles NH_3 complexed = (0.4 − 0.3125) = 0.0875M. (02)

Moles HCl = $\frac{(20\times0.25)}{1000}$ = 5×10^{-3} moles

Moles NH_3 = 5.0×10^{-3} moles

Moles NH_3 in 500 cm³ = $\frac{(5.0\times10^{-3}\times500)}{125}$ = 0.2 moles

Moles NH_3 complexed = (0.2 − 0.15625)

= 0.04375 moles.

(c) Determine the percentage by mass of zinc in the impure zinc sulphide.

$Zn^{2+}_{(aq)} + 4NH_{3(aq)} \longrightarrow Zn(NH_3)^{2+}_{4(aq)}$ (1) (03 marks)

Moles Zn^{2+} = $(\frac{1}{4}\times0.0875) = 0.021875M$

Mass of Zinc = $(0.021875\times65) = 1.421875$ g (03)

Mass of impure Zinc in 1litre = $(4.5\times2) = 9.0$ g

% Zinc = $\frac{(1.421875\times100)}{9.0} = 15.8\%$

Moles Zn^{2+} = $\frac{1}{4}$ × moles NH_3

= $\frac{1}{4}\times0.04375$

= 0.010937 moles

Mass of zinc = (0.010937×65)

= 0.710937 g

% zinc = $\frac{(0.710937\times100)}{4.5}$

= 15.7986%

Turn Over

THE PERIODIC TABLE

1	2										3	4	5	6	7	8
1.0 H 1															1.0 H 1	4.0 He 2
6.9 Li 3	9.0 Be 4										10.8 B 5	12.0 C 6	14.0 N 7	16.0 O 8	19.0 F 9	20.2 Ne 10
23.0 Na 11	24.3 Mg 12										27.0 Al 13	28.1 Si 14	31.0 P 15	32.1 S 16	35.5 Cl 17	40.0 Ar 18
39.1 K 19	40.1 Ca 20	45.0 Sc 21	47.9 Ti 22	50.9 V 23	52.0 Cr 24	54.9 Mn 25	55.8 Fe 26	58.9 Co 27	58.7 Ni 28	63.5 Cu 29	65.7 Zn 30	69.7 Ga 31	72.6 Ge 32	74.9 As 33	79.0 Se 34	79.9 Br 35	83.8 Kr 36
85.5 Rb 37	87.6 Sr 38	88.9 Y 39	91.2 Zr 40	92.9 Nb 41	95.9 Mo 42	98.9 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 49	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
133 Cs 55	137 Ba 56	139 La 57	178 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86
223 Fr 87	226 Ra 88	227 Ac 89															

139 La 57	140 Ce 58	141 Pr 59	144 Nd 60	147 Pm 61	150 Sm 62	152 Eu 63	157 Gd 64	159 Tb 65	162 Dy 66	165 Ho 67	167 Er 68	169 Tm 69	173 Yb 70	175 Lu 71
227 Ac 89	232 Th 90	231 Pa 91	238 U 92	237 Np 93	244 Pu 94	243 Am 95	247 Cm 96	247 Bk 97	251 Cf 98	254 Es 99	257 Fm 100	256 Md 101	254 No 102	260 Lw 103

END