Candidate's Name: SAMPLE SCORE

Signature: Tr. Julius

STREAM:							

525/1
CHEMISTRY
Paper 1
August
2025
$2^1/_2$ hours

END OF TERM II ASSESSMENT

Uganda Advanced Certificate of Education

S.5 CHEMISTRY

Paper 1

(Set II)

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

This paper has **two** *sections* **A** *and* **B.**

Section **A** *has two compulsory items while* **B** *has* **four** *items answer only* **<u>three</u>** *in* **B**.

Answers to Section **A** ***must*** *be written in the spaces provided and Section* **B** ***must*** *be written in the answer booklet(s) provided*

Answer five in all.

Where necessary use,

Molar gas volume at s.t.p = 22.4dm^3

FOR EXAMINER'S USE ONLY							
ITEM	1	2	3	4	5	6	TOTAL
CODE	CA EP S M SCN [illegible]	L GO AU D	Th	Mc	Hc	PT	
SCORE	[illegible]	[illegible]	18	18	18	18	100%

26 20
SCTA = 46
SCTB = 54
100

@S.5 END OF TERM II EXAMINATIONS 2025

Julius W.M 0787093081

SECTION A

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

ITEM 1

At a Kampala specialty chemicals firm, researchers have isolated a chlorinated organic compound, **Q**, from oilseed residues. Suspected to be a chlorinated hydrocarbon, **Q** is targeted as a precursor for antifungal agents for maize, a building block for aromatic solvents for a paint maker in Wakiso, and a starting monomer for plastic packaging.

In pre-tests, a 3.0 g sample of **Q** burnt in excess oxygen produced 2.67 g of CO_2 and 1.09 g of H_2O. The label indicates a vapour density of 49.5. When refluxed with excess alcoholic KOH, **Q** yielded a volatile product F that burned with a very sooty flame, raising concerns about safety.

The firm plans two product lines: converting **Q** into aromatic compound **R**, later derivatized into solvent **R_1** for paints, and into compound **D**, an alkene monomer for plastics. Compound **D** also reacts with HBr under different conditions to yield antifungal agents for maize. You have been contacted to assist.

https://share.google/images/vjDHu6ulKyOzjhLnj

Task

As a learner of Chemistry, guide the company on how to;

(a) Determine Molecular formula of compound **Q**.

Turn Over

Mass of C = $\frac{12}{44} \times 2.67 = 0.728$ g
Mass of H = $\frac{2}{18} \times 1.09 = 0.121$ g ✓ CA
Mass of Cl = $3.0 - (0.728 + 0.121) = 2.151$

elements:		C	H	Cl
Mass	:	0.728	0.121	2.151
Moles	:	$\frac{0.728}{12}$	$\frac{0.121}{1}$	$\frac{2.151}{35.5}$
	=	0.0606	0.121	0.0606 ✓ CA
Ratio	:	$\frac{0.0606}{0.0606}$	$\frac{0.121}{0.0606}$	$\frac{0.0606}{0.0606}$
		1	2	1

Empirical Formula is CH_2Cl
Molecular Mass = 2 × VD = 2 × 49.5
= 99 g

$\because (CH_2Cl)_n = 99$
$(12 + 2 + 35.5)n = 99$
$49.5n = 99$
$n = 2$
$\therefore$ Molecular Formula is
$C_2H_4Cl_2$ ✓ CA

CA = (03)

(b) Show the analyst using an equation formation of compound **F**

$ClCH_2CH_2Cl \xrightarrow[\text{heat}]{\text{excess KOH, Alcohol}} HC\equiv CH$ ✓ Eq = (01)

(c) Predict the properties, possible environmental dangers and their mitigations that result from **F**

* Compound F is ethyne; it has the following properties
- Has a ~~triple~~ triple bond that makes it reactive hence ✓ Pi used in Organic Synthesis.
- Burns in Oxygen producing a high heat energy ✓ hence used as a fuel.
- Ethyne undergoes polymerisation hence used ✓ in Manufacture of plastics

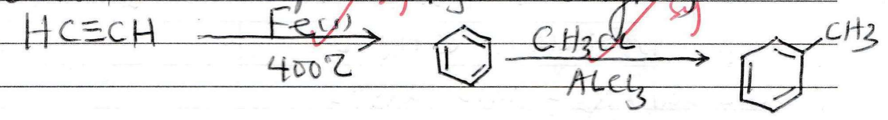
* It has got the following dangers;
- Burning of ethyne ✓ produces Carbondioxide which is a green house gas leading to global warming hence increased drought, death of animals and drying off of vegetation. This can be mitigated ✓ by Afforestation.

3D + 3Pi = (06)

- Ethyne is highly ✓ flammable and can lead to fire out breaks to workers handling it ✓ it can also produce toxic fumes like carbon monoxide hence death. This can be mitigated by following proper handling ✓ procedures.

(d) Synthesis the solvent and monomer.

The solvents are benzene (R) and Methylbenzene (R₁), can be synthesised ✓ from ethyne;



The Monomer is an alkene compound which is ethene synthesised from ethyne;

$HC\equiv CH \xrightarrow[\text{Ni, 150°C}]{H_2} H_2C=CH_2$ ✓ Sy

or Pd or Pt catalysts

3 Sy = (03)

Turn Over

(e) Explain mechanisms of reaction of monomer **D** with hydrogen bromide through two different ways yielding antifungal agents for post-harvest treatment of maize.

Monomer D is ethene, Formula $H_2C=CH_2$

- Ethene react with HBr at room temperature to give 1-Bromoethane, Following Markonikov's rule.

$H_2C=CH_2 \xrightarrow{HBr} CH_3CH_2Br$

Mechanism:

$H_2C=CH_2$ + $H^{\delta+}-Br^{\delta-}$ $\longrightarrow$ $CH_3\overset{+}{C}H_2$ + Br^- $\longrightarrow$ CH_3CH_2Br

$M_{c_1} = 02$

- Ethene can also react with HBr in presence of a ~~catalyst~~ perroxide to form 1-Bromoethane through free radical Mechanism; Following antimarkonikov's rule

$H_2C=CH_2 \xrightarrow[ROOR]{HBr} CH_3CH_2Br$

Mechanism

$ROOR \longrightarrow 2R\dot{O}$

$R\dot{O} + H-Br \longrightarrow ROH + B\dot{r}$

$B\dot{r} + H_2C=CH_2 \longrightarrow BrCH_2\dot{C}H_2$

$BrCH_2\dot{C}H_2 + H-Br \longrightarrow BrCH_2CH_3 + B\dot{r}$

$M_{c_2} = 02$

$M_{c_1} + M_{c_2} = M = 06$

(f) Evaluate the suitability of the aromatic compound **R** and its derivative **R**$_1$ produced to be used in the industry.

- They are less volatile solvents therefore they can easily be handled.

- They are good organic solvents for paints, Varnishes and adhesives (glue).

- Methylbenzene is less toxic therefore is minimal environmental effect and health risks.

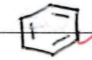
- They are insoluble in water but miscible with organic solvents.

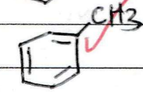
$3R_i = S = 02$

(g) Give the IUPAC names and structures of all the chemicals substances the company intends to use

Q is 1,2-dichloroethane — $ClCH_2CH_2Cl$

F is Ethyne — $HC\equiv CH$

R is Benzene — 

R is Methylbenzene — 

$4N_i = N = 04$

ITEM 2

At the Uganda Nuclear Research Center, scientists are researching two radioisotopes of importance for nuclear medicine, industry, and environmental science,

Iodine-131 and Cesium-137, isotopes used extensively in medical diagnostics and industrial gauging, are known for their different half-lives but good enough for practical applications. Both isotopes undergo beta decay to form stable nuclei releasing a lot of energy called "nuclear energy". The students are finding it had to study the atomic structures, radioactive decay behavior, and safety considerations to optimize their use and ensure environmental protection for the isotopes.

Both isotopes were measured for activity over a period of time recorded in hours and activities in counts per second (cps),

Time (hours)	4	6	8	10	12	14	16
Iodine-131 Activity (cps)	320	180	100	56	32	18	10
Cesium-137 Activity (cps)	600	425	300	210	150	105	75

The Principal at the research Center has organized a workshop session and you have been invited for guidance.

Task

As the learner of chemistry help the students to;

(a) Come up with the electronic configurations and predict the locations in the periodic table and the nature of the isotopes given.

- Iodine Has Atomic Number = 53
Electron Configuration is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^5$ ✓EC1
- Cesium Has Atomic Number = 55
Electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^1$ ✓EC2
- Iodine is Found in period 5, group (VII), it is a non-metal, ~~Format~~ because it cangains electrons to form an anion.
- Cesium is Found in period 6 and group (I), it is a metal, because it loses electrons to form cations. ✓L

EC1+EC2+L1+L2 = L = 04

(b)(i) Explain the concept of radioactivity and the nuclear transformations, identifying isotopes formed for both substances above.

Radioactivity is spontaneous disintegration of heavy unstable radioactive isotope to form a lighter and stable atomic nuclei by emission of radiations. ✓C0

Nuclear transformations are; both beta decay;

$^{131}_{53}I \longrightarrow ^{131}_{54}Xe + ^{0}_{-1}e + energy$ ✓T1

$^{137}_{55}Cs \longrightarrow ^{137}_{56}Ba + ^{0}_{-1}e + Energy$ ✓T2

C0+T1+T2 = C0 = 03

(ii) Analyze the data in the table in order to determine the decay constants and half-lives for both isotopes. Comment on your results for medical application.

Time (hrs)	4	6	8	10	12	14	16
Iodine-(Activity) Ci	320	180	100	56	32	18	10
Cesium-(Activity)	600	425	300	210	150	105	75
$\log A_I$	2.505	2.255	2.000	1.748	1.505	1.255	1.000
$\log A_{Cs}$	2.778	2.628	2.477	2.322	2.176	2.021	1.875

Iodine: slope $= \left(\frac{1.0 - 2.50}{16 - 4}\right) = \frac{-\lambda}{2.303}$ ∴ $\lambda = 2.303 \times 0.3775 = 0.8636\,hr^{-1}$ ✓CA

$\Rightarrow t_{1/2} = \frac{0.693}{0.8636\,25} = 0.8024\,hrs$ ✓CA

Cesium: Slope $= \left(\frac{1.96 - 2.34}{15 - 10}\right) = \frac{-\lambda}{2.303}$ ∴ $\lambda = 2.303 \times 0.076 = 0.175028\,hr^{-1}$ ✓CA

$\Rightarrow t_{1/2} = \frac{0.693}{0.175028} = 3.96\,hours$ ✓CA

CA+CA+CA+CA = CA = 04

(c) (i) Describe the practical applications of the process relevant to Uganda's sectors.

Iodine-131 is used in radiotherapy to treat cancers and other diseases. ✓U1

Radiations produced during the process can be used in sterilizing medical equipment to ensure they are free from harmful microorganisms. ✓U2

Radioactive sources are used for gauging thickness, density and level in industrial process ensuring product quality and consistency. ✓U3

U1+U2+U3 = U = 03

(d)(ii) Explain the possible side effects of the process and how they can be mitigated.

- Prolonged exposure to radioactive materials may lead to damage of body cells and tissues due to breakage of DNA and proteins hence cell death, mutations and cancer. This can be mitigated by using personal protective clothing such as lead coats when dealing with radioactive materials.

- Radioactive isotopes released into air, water or soil lead to contamination of ecosystems such as isotope cesium-137 affects plants, animals and humans. This can be mitigated by proper disposal of radioactive materials.

2di + 2de + 2dm = D = 06

SECTION B

Attempt **three** *items in this section*

Item 3

A school chemistry club is investigating heat production from the formation of ionic compounds for use in small portable heaters during science exhibitions. They are considering three compounds: **X**, **Y**, and **Z**.

The club has collected thermochemical data in kJ mol^{-1} for the compounds are as follows;
For **X** (lithium fluoride): enthalpy of atomization of fluorine (+150), electron affinity of fluorine (–351), enthalpy of atomization of lithium (+155), first ionization energy of lithium (+518), and lattice energy (–1030).
For **Y** (calcium oxide): enthalpy of atomization of calcium (+117), first and second ionization energies of calcium (+59, +1100), heat of atomization of oxygen (+249), first and second electron affinities of oxygen (–141, +790), and lattice energy (–2810).
For **Z** (aluminium chloride): enthalpy of atomization of aluminium (+326), first, second, and third ionization energies of aluminium (+578, +1817, +2745), bond dissociation energy of chlorine (+242), electron affinity of chlorine (–364), and lattice energy (–5290).
All values are in kilojoules per mole.

The club wants to select the reaction that produces the most heat while remaining safe for a demonstration. You have been invited to provide guidance.

Task

As a student of Chemistry, Outline the method you would use to help the club choose between the three substances, and justify your choice based on your calculations and safety considerations.

ITEM 4

At the National Agricultural Research Organisation in Arua district, soil within the area was found to contain a sodium salt, $NaHCO_3 \cdot XH_2O$, affecting crop growth.

In analysis, 6.0 g of $\mathbf{NaHCO_3 \cdot xH_2O}$ was dissolved to one liter, and 25cm^3 of this solution required 15cm^3 of 0.05M hydrochloric acid for complete neutralization.

The organization seeks to determine the actual formula of the salt, its nature, and soil pH, and to make recommendations for improving crop yields. You have been contacted to provide guidance.

Task

As a chemistry student, make a write up you use to help the organization.

ITEM 5

An environmental agency is investigating air pollution near an industrial zone suspected of hydrocarbon release and open combustion. A 20.0 cm^3 sample of hydrocarbon **Z** was reacted with 200.0 cm^3 of oxygen; after cooling, total gas volume was 160.0 cm^3, and passing residual gases through aqueous sodium hydroxide reduced the volume to 20.0 cm^3.

Hydrocarbon **Z** burns with a sooty flame. When treated with hot alkaline potassium manganate(VII) and then acidified with dilute hydrochloric acid, it produces compound **T**, which reacts with magnesium to liberate hydrogen.

The agency seeks to understand the chemical equation for combustion of **Z**, the molecular formula, IUPAC names and structures of **Z** and **T**, a method to synthesize **Z** from ethanol, and the environmental hazards of **Z** with mitigation measures. You have been contacted to provide guidance.

Task

As a student of Chemistry, prepare a presentation you will use upon invitation.

ITEM 6

A scientist is studying the Periodic properties of several elements and needs to determine the trend of atomic radius across the period and down the group in the Periodic Table. He is focusing on the elements in the third period from sodium to chlorine and elements in group (II) from beryllium to barium. He obtained the following data but lacks explanation for the two trends.

Element	**Be**	**Na**	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**	**Ca**	**Sr**	**Ba**
Atomic number	4	11	12	13	14	15	16	17	20	38	56
Atomic radius (nm)	0.089	0.156	0.136	0.125	0.117	0.110	0.104	0.099	0.174	1.191	0.198

The scientist seeks guidance to interpret the data for Period 3 and Group II elements and to analyze and explain the observed trends in atomic radius for use in a science exhibition presentation.. You have approached for guidance.

Task

As a learner of chemistry prepare a write up to help him.

THE PERIODIC TABLE

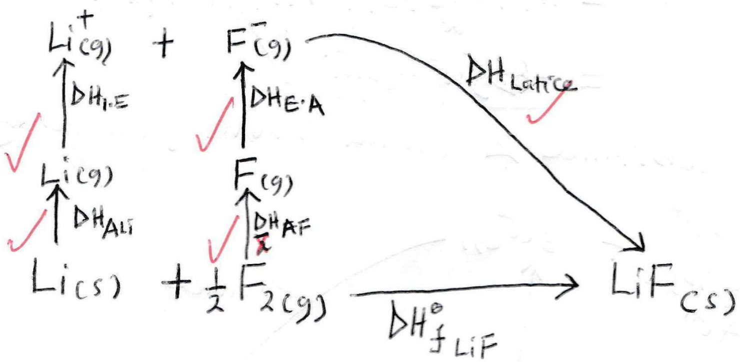
1	2											3	4	5	6	7	8
1.0 H 1																1.0 H 1	4.0 He 2
6.9 Li 3	9.0 Be 4											10.8 B 5	12.0 C 6	14.0 N 7	16.0 O 8	19.0 F 9	20.2 Ne 10
23.0 Na 11	24.3 Mg 12											27.0 Al 13	28.1 Si 14	31.0 P 15	32.1 S 16	35.4 Cl 17	40.0 Ar 18
39.1 K 19	40.1 Ca 20	45.0 Sc 21	47.9 Ti 22	50.9 V 23	52.0 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 Te 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 Ti 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 68	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

Item 3

Using the knowledge of Enthalpy cycles; such as Born Haber cycle;

For substance X involves formation of LiF



By Hess's law

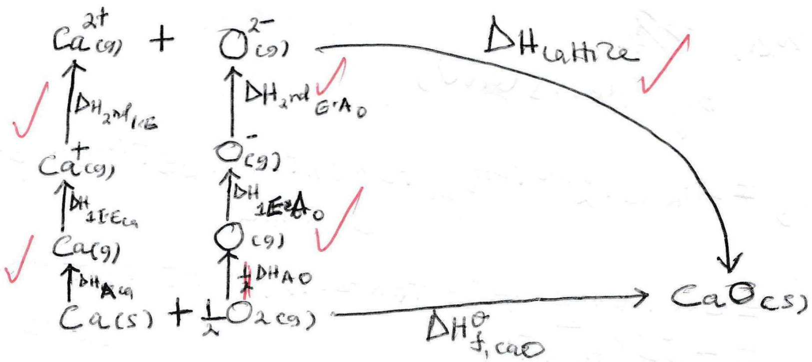
$\Delta H^{\theta}_{f\,LiF} = \Delta H_{A\,Li} + \frac{1}{2}\Delta H_{AF} + \Delta H_{I.E} + \Delta H_{E.A} + \Delta H_{lattice}$

$= 155 + \frac{150}{2} + 518 + -351 - 1030$

$= -633\ kJ\,mol^{-1}$ ✓

X = 06

For substance Y involves formation of CaO



By Hess's law

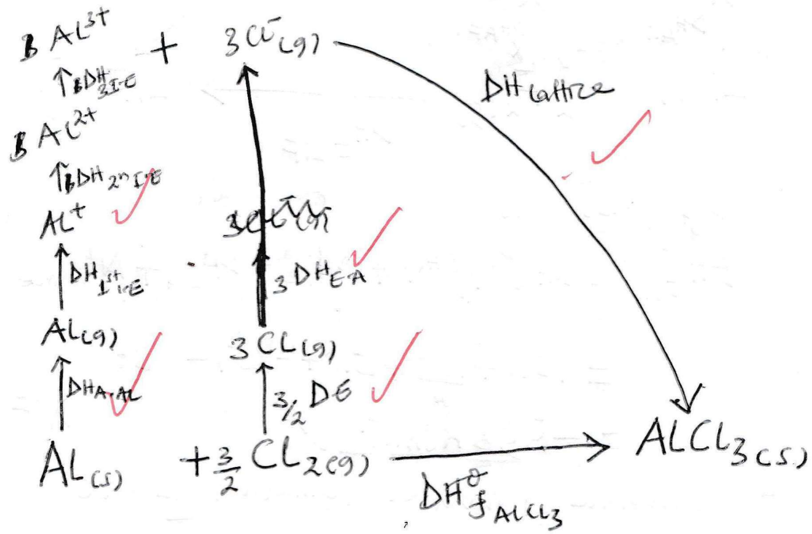
$\Delta H^{\theta}_{f,\,CaO} = \Delta H_{A\,Ca} + \frac{1}{2}\Delta H_{A.O} + \Delta H_{1st\,I.E\,Ca} + \Delta H_{1st\,E.A\,O} + \Delta H_{2nd\,I.E\,Ca} + \Delta H_{2nd\,E.A\,O} + \Delta H_{lattice}$

$= 117 + \frac{249}{2} + 59 + -141 + 1100 + 790 + -2810$

$= -635.5\ kJ\,mol^{-1}$ ✓

Y = 06

For substance Z, which involves formation of $AlCl_3$



By Hess's law;

$\Delta H^{\theta}_{f,\,AlCl_3} = \Delta H_{A\,Al} + \frac{3}{2}D.E + \Delta H_{1st\,IE} + 3\Delta H_{E.A} + \Delta H_{2nd\,I.E} + \Delta H_{3rd\,I.E} + \Delta H_{lattice}$

$= 326 + \frac{242 \times 3}{2} + 578 + (3 \times -364) + 1817 + 2745 + -5290$

$= -553\ kJ\,mol^{-1}$ ✓

Z = 06

Since substance X, Y and Z produce −93, − , and −553 $kJmol^{-1}$ respectively;

Substance Y can be choosen by the club because of it's high exothermic heat of formation. (02)

Th = X+Y+Z+C = 18

Item 4

$1000cm^3$ of solution contains 0.05 moles HCl

$15cm^3$ of solution contains $\left(\frac{0.05 \times 15}{1000}\right)$ moles HCl

= 0.00075 moles HCl

CA = 03

From Equation;

$NaHCO_{3(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

1 mole of HCl reacts with 1 mole of $NaHCO_3$.

0.00075 mole of HCl react with $\left(\frac{1 \times 0.00075}{1}\right)$ moles

= 0.00075 moles $NaHCO_3$

CA = 03

$25.0cm^3$ of solution contains 0.00075 moles $NaHCO_3$

$1000cm^3$ of solution contains $\left(\frac{0.00075 \times 10^3}{25}\right)$

= 0.03 M $NaHCO_3$

CA = 03

0.03 moles in one litre weigh 6.0g.

1 mole in one litre weigh $\left(\frac{6.0 \times 1}{0.03}\right)$

= 200g of salt.

CA = 03

$NaHCO_3 \cdot xH_2O$ = 200

$(23 \times 1) + (1 \times 1) + (12 \times 1) + (16 \times 3) + 18x = 200$

$84 + 18x = 200$

$18x = 116$

$x = 6$

CA = 03

∴ Actual Formula of salt is $NaHCO_3 \cdot 6H_2O$

Nature; The salt is hydrated and basic.

PH of soil; The soil has a pH greater than 7

Recommendation: Use an acidic fertilizer to the soil to neutralise and lower the pH of soil to required levels.

3ei = 04 C = 02

Mc = 20 18

Item 5

(a)

Let the hydrocarbon compound be C_xH_y.

$C_xH_{y(g)} + \left(x + \frac{y}{4}\right)O_{2(g)} \rightarrow xCO_{2(g)} + \frac{y}{2}H_2O_{(l)}$

Volume of Hydrocarbon Z = $20cm^3$

Original Volume of O_2 = $200cm^3$

Total Volume of residual gases = $160cm^3$

Volume of CO_2 produced = $(160 - 20) = 140cm^3$ CA

Volume of O_2 used = $(200 - 20) = 180cm^3$ CA

From Equation;

$20x = 140$

$x = \frac{140}{20} = 7$ ∴ $x = 7$ CA

$20\left(x + \frac{y}{4}\right) = 180$

$7 + \frac{y}{4} = 9$

$\frac{y}{4} = 9 - 7$

$y = 4(2)$ CA

$\therefore y = 8$

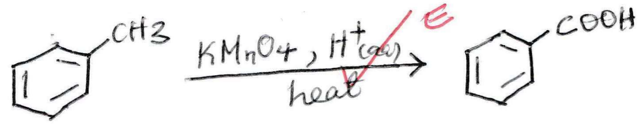
CA = 04

$\therefore$ The formula of hydrocarbon Z is C_7H_8 F

Structure is  S

Name; Methylbenzene. N

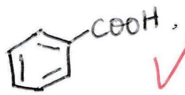
$\therefore$ The compound T is formed as follows;



CA = 04

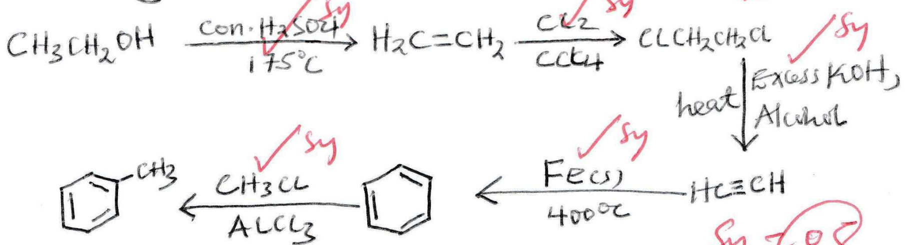
compound T is;

Name: Benzoic acid N

structure;  S

N = 04
Sy = 05
D = 06

- Synthesis of Z from Ethanol.



Sy = 05

Dangers:

- Leads to water pollution when poorly disposed into the surrounding water bodies hence harming aquatic organisms such as fish. This can be mitigated by proper disposal of waste organic compounds.

- Leads to fire out break because it is highly flammable hence leading death and destruction of property. This can be mitigated by proper storage of Methyl benzene away from heat sources.

2di + 2de + 2dm = D = 06

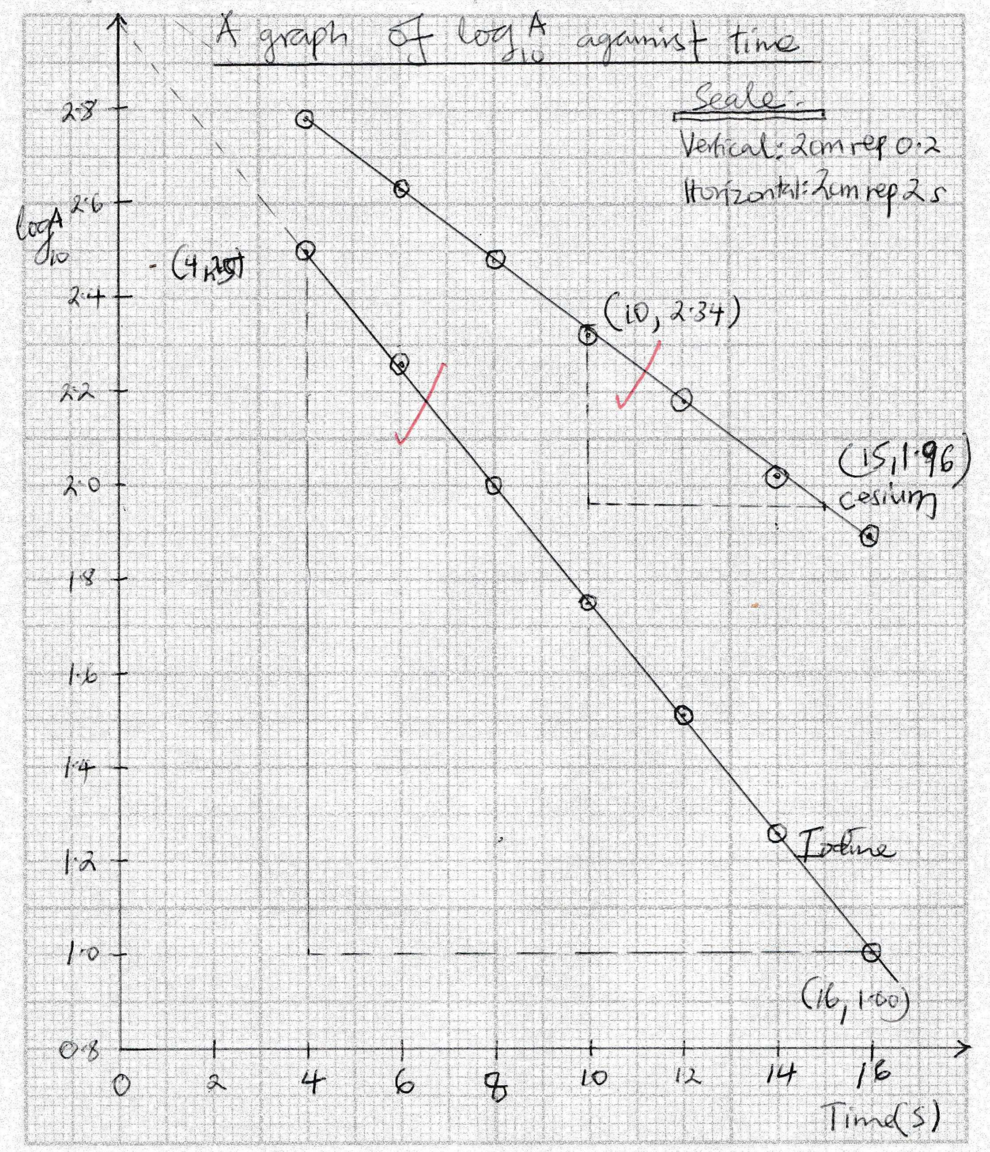
(to be fastened together with other answers to paper)

UACE

Candidate's Name ....
Signature ....
Subject .... Paper code ..../....

Random No.
Personal Number

2b(ii)



Item 6

(a) Intepretation of the data:

– Across period 3 from Na to Cl, the atomic radius decreaseses from left to right i.e Na has 0.156nm and Cl has 0.099nm.

– Down group(II) from Be to Ba, the atomic radius increases as you move down of the group i.e Be has 0.089nm and Ba has 0.198

(b) From the graph;

Across period 3;

Trend; Atomic radius decreases from left to right.

Reason; As you move a cross a period, the nuclear charge increases because a proton is added to the nucleus from element to element. Screening effect almost remains constant, because electrons are added to the same energy level. Effective Nuclear charge increases, and outer most electrons get closer and more strongly attracted than repelled by the nucleus.

R = 05

8

Down group(II);

Trend; Atomic radius increase from Be to Ba

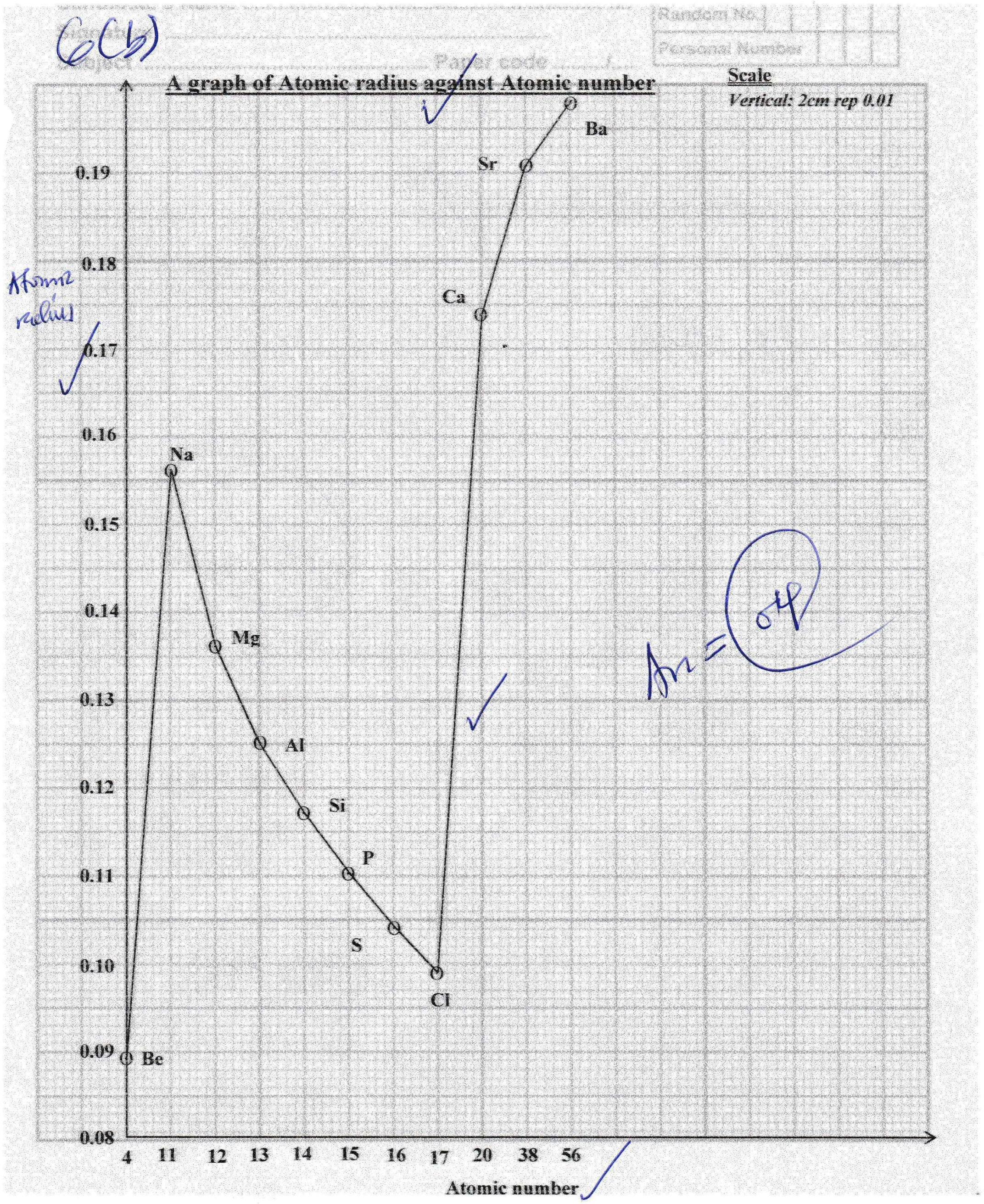
Reason; ~~This is because an extra energy level completely filled with electrons is added.~~

Reason; This is because from Be to Ba, nuclear charge increases; screening effect also increases, because an extra energy level completely filled with electrons is added. Increase in screening effect outweighs increase in nuclear charge. Effective nuclear charge decreases, and outer most electrons are far and weakly attracted by the nucleus.

R = 05

END.

6(b)



Candidate's Name: ……SAMPLE SCORE………………………………………………

Signature: ……………………………… | **STREAM:** | | | | | | | |

525/1
CHEMISTRY
Paper 1
October/November
2025
$2^1/_2$ hours

MID OF TERM III ASSESSMENT

Uganda Advanced Certificate of Education

S.5 CHEMISTRY

Paper 1

(*Set I*)

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

This paper has **two** *sections* **A** *and* **B.**

Section **A** *has two compulsory items while* **B** *has two parts* **Part I** *and* **Part II**

Each of part I and part II has two items, Answer only ***one*** *from each.*

Answers to Section **A** ***must*** *be written in the spaces provided and Section* **B** ***must*** *be written in the answer booklet(s) provided*

Answer four in all.

Where necessary use,

Molar gas volume at s.t.p = 22.4dm^3

FOR EXAMINER'S USE ONLY																				
ITEM	1						2						3/4				5/6				T.
CODE	F_1	C_1	C_2	D_1	C_3	D_2	E_c	C_4	C_5	E_1	P	D_3	G_r	T_r	E_2	P_r	F_2	S_e	M_c	D_4	X/80
SCORE	04	03	03	03	04	03	06	02	03	03	03	03	05	08	05	02	04	08	05	03	80

KEY TO SAMPLE SCORE

F_1, F_2 – Formula; D_1, D_2, D_3, D_4 - Danger; C_1, C_2, C_3, C_5, C_6 - Calculation
E_c – Energy cycle; E_1, E_2 – Evaluation; P - Properties; G_r – Graphing
T_r – Trend; P_r – Prediction; S_e - Synthetic equations; M_c - Mechanisms

SECTION A

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

ITEM 1

AgroTech Minerals Ltd. has developed a new inorganic fertilizer labeled **X** in Hydrated Form. Laboratory analysis shows that the solid contains 9.37% magnesium, 10.93% nitrogen, and 42.18% water of crystallization and rest being oxygen. Molar mass of **X** is 256g. 5.0 kg of the fertilizer was available for sale, the manager sought to know the amount in mass of nitrate nutrient in **X** that would be delivered to maize. Keen to know about environmental hazards, **X** was burnt in absence of air and decomposed with brown gas of nitrogen dioxide according to equation:

Equation 1: $2\,Mg(NO_3)_2(s) \rightarrow 2\,MgO(s) + 4\,NO_2(g) + O_2(g)$

The company sought to know the volume at s.t.p of the brown gas produced from burning 1.0 kg of the fertilizer and assess the environmental impacts of the emissions and mitigations.

Due to available rocks containing magnesium in the area, the company manager further seeks to evaluate the industrial synthesis of the fertilizer **X** from magnesium oxide:

Equation 2: $MgO(s) + 2\,HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$.

The supplier reported that he would potentially supply 10.0 kg of magnesium oxide per day, and the manager intends to know how much fertilizer would be available in one month and also possible environmental impacts of using the fertilizer and mitigations.

Task

As a learner of Chemistry, help the company to know;

(a) The Molecular formula of compound **X**.

% Mg = 9.37%, % N = 10.93%, % H_2O = 42.18%, % O = 100 − (9.37+10.93+42.18)
= 37.52%

Elements	Mg	N	O	H_2O
% composition	9.37	10.93	37.52	42.18
Moles	9.37/24.3	10.93/14	37.52/16	42.18/18
	= 0.386	0.781	2.345	2.343
Simplest Ratio	0.386/0.386	0.781/0.386	2.345/0.386	2.342/0.386
	= 1	2	6	6

CA CA

∴ Empirical Formula is $MgN_2O_6 \cdot 6H_2O$ or $Mg(NO_3)_2 \cdot 6H_2O$

$(MgN_2O_6 \cdot 6H_2O)n = 256$

$(24.3 \times n) + (14 \times 2 \times n) + (16 \times 6 \times n) + (6 \times 18 \times n) = 256$

$256.3n = 256$, $n = 1$

∴ Molecular formula of X is $MgN_2O_6 \cdot 6H_2O$ or $Mg(NO_3)_2 \cdot 6H_2O$

F

CA + CA + F = F_1 = 03

(b) Mass of nitrate nutrient in **X** that would be delivered to maize.

X is a Fertilizer of Formula $MgN_2O_6 \cdot 6H_2O$ or $Mg(NO_3)_2 \cdot 6H_2O$
In the compound;
Mass of Nitrate $= (14.0 \times 2) + (16 \times 6)$
$= 28.0 + 96.0$
$= 124g$ of Nitrate nutriente ~~would be delivered to plants.~~
Total Mass, RMM = 256.
∴ Mass of Nitrate Supplied $= \frac{124}{256} \times 5.0\,kg = 2.5\,kg$
$= 2.421875\,kg.$

CA + CA + CA = 4 = (03)

(c) (i)The volume at s.t.p of the brown gas produced from burning the fertilizer.

From Equation 1; $2Mg(NO_3)_{2(s)} \rightarrow 2MgO_{(s)} + 4NO_{2(g)} + O_{2(g)}$
Molar mass of $Mg(NO_3)_2 = 24.3 + (14 \times 2) + (16 \times 6) = 148.3g$
2 moles of $Mg(NO_3)_2$ produce 4 moles of NO_2 gas (brown)
$(2 \times 148.3)g$ of $Mg(NO_3)_2$ produce $(4 \times 22.4)dm^3$ of NO_2 gas.
296.6g of $Mg(NO_3)_2$ produce $89.6dm^3$ of NO_2 gas.
1000g of $Mg(NO_3)_2$ produce $\left(\frac{89.6 \times 1000}{296.6}\right)dm^3$ of NO_2 gas
$= 302.090\,dm^3$ of NO_2 gas (brown)

CA + CA + CA = C2 = (02)

(ii) The environmental impacts of the brown gas emissions and mitigations.

Nitrogen dioxide leads to global warming because it is a green house gas when it accumulates in the atmosphere creates, a green house effect that increased drought. This can be mitigated by using alternative organic fertilizers. Dm
Nitrogen dioxide also leads to acid rains because
Di + De + Dm = D1 = (03)

3 Turn Over

it is an acidic gas, when it reacts with water forms a weak acid that may affect soil pH leading drying off of vegetation. Can be mitigated by strict laws on industries that generate it.

(d) (i)Mass of the fertilizer produced in one month.

Using Equation 2: $MgO_{(s)} + 2HNO_{3(aq)} \rightarrow Mg(NO_3)_{2(aq)} + H_2O_{(l)}$
Molar mass of $MgO = (24.3 \times 1) + (16 \times 1) = 40.3g$
Molar mass of $Mg(NO_3)_2 = 148.3g$
1 mole of MgO raw material produce 1 mole of $Mg(NO_3)_2$
40.3g of MgO raw material produce 148.3g of $Mg(NO_3)_2$
$(10 \times 10^3)g$ of MgO raw material produce $\left(\frac{148.3 \times 10 \times 10^3}{40.3}\right)g$ of $Mg(NO_3)_2$
$= 36799.007g$ per day.
In One Month $= (30 \times 36799.007) = 1{,}103{,}970.219$
or $= 1{,}103.970\,kg$ $Mg(NO_3)_2$

CA + CA + CA + CA = C3 = (04)

(ii) Possible environmental impacts of using the fertilizer and their mitigations

Poor disposal of this fertilizer leads to water pollution in the water bodies hence making water unsafe for both human consumption and aquatic life. This can be mitigated by proper disposal of fertilizer.
Prolonged dependency on magnesium nitrate which is an artificial fertilizer may lead to acidification of the soil due to repeated nitrate content added time to time hence reduced soil fertility in turn. This can be mitigated by using organic manure.

Di + De + Dm = D

4 Turn Over

Item 2

An aluminium smelting company in Jinja uses a substance called aluminium fluoride as a flux to lower the melting point of cryolite during aluminium extraction. However, the production unit is facing high energy costs, and the environmental team reports challenges in dissolving waste AlF_3 residues before disposal. The research chemist is tasked to analyse the thermochemical feasibility of both forming and dissolving AlF_3 using available thermodynamic data to determine whether these processes are spontaneous or energy-intensive.

Across a certain article the following data was discovered by the researcher:

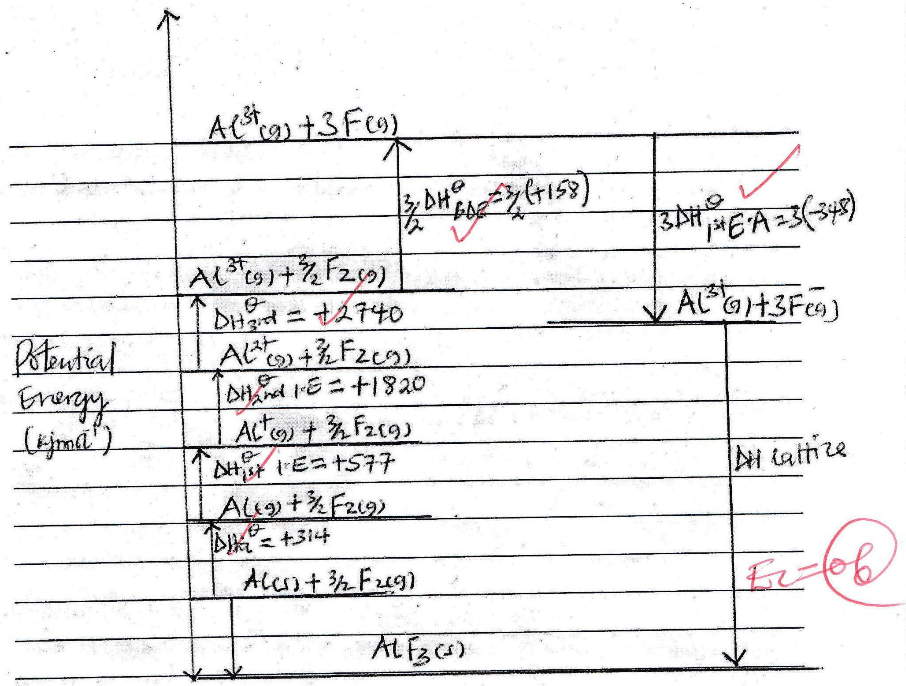
Type of enthalpy change	Magnitude (kJ mol⁻¹)
Standard enthalpy of formation of AlF_3(s)	−1301
Enthalpy of atomization of aluminium	+314
Bond dissociation energy of flourine	+158
First, second, and third ionization energies of Al	+577, +1820, and +2740 respectively
First electron affinity of flourine	−348
Hydration enthalpies aluminium and fluoride ions	−4690 , −364 respectively

The researcher struggles to use this information to construct and interpret an energy cycle diagram, perform calculations, evaluate the feasibility of the key processes and properties that suit aluminium fluoride for use in the process. You have been contacted for help.

Tasks

As a student of chemistry, help the researcher;

(a) Analyse the data to construct an energy cycle diagram for the formation of solid substance.



(b) Know the lattice energy of substance.

By Hess' law;

$\Delta H^{\theta}_{f,AlF_3} = \Delta H^{\theta}_{at} + \Delta H^{\theta}_{1st} I.E + \Delta H^{\theta}_{2nd} I.E + \Delta H^{\theta}_{3rd} I.E + \frac{3}{2}\Delta H^{\theta}_{BDE} + 3\Delta H^{\theta}_{1st}EA + \Delta H_{latt}$

$\therefore \Delta H_{lattice} = -1301 - (314 + 577 + 1820 + 2740 + \frac{3}{2}(+158) + 3(-348))$

$= -5945 \text{ kJmol}^{-1}$

(c) Know the enthalpy of solution substance

For $AlF_{3(aq)} \longrightarrow Al^{3+}_{(aq)} + 3F^{-}_{(aq)}$

$\Delta H_{hydration\ AlF_3} = \Delta H_{hydration\ Al^{3+}} + 3\Delta H_{hydration\ F^-}$

$= -4690 + 3(-364) = -5782\ kJmol^{-1}$ CA

But; $\Delta H_{solution\ AlF_3} = \Delta H_{lattice\ AlF_3} + \Delta H_{hydration\ AlF_3}$

$= +5945 + (-5782) = +163\ kJmol^{-1}$ CA

CA + CA + CA = C5 = 03

(d) Evaluate whether the dissolution of the substance in water is thermodynamically feasible and spontaneous under standard conditions.

Dissolution of AlF_3 in water is not feasible, not spontaneous; because it has a larger positive lattice energy than the negative hydration energy. Hence enthalpy of solution is positive (endothermic) and requires that energy must be absorbed for dissolution to occur.

E1 + E2 + E3 = E1 = 03

(i) State the properties that make the substance suitable to serve the above purpose

Aluminium Flouride has a high melting points hence suitable for maintaining its role in the electrolyte at high temperature. Aluminium flouride is soluble in cryolite hence suitable to be mixed with electrolyte.

3Pi = P = 03

(ii) Suggest the possible impacts and mitigations of the substance to the environment.

Soil pollution due to increased fluoride accumulation in soil affecting plant growth and ecosystems. This can be mitigated by proper disposal of Aluminium Flouride.

Water pollution due to poor disposal contaminating water sources, harming aquatic life and human health. mitigated by proper disposal of aluminium flouride.

Di + Dt + Dm = D3 = 03

SECTION B

Part I

Attempt **One** *item in this section*

Item 3

A manufacturing company in Mukono produces parts for high-temperature furnaces and electrical systems. The durability of each component depends on the melting point of the material, higher melting points ensure better heat resistance and mechanical strength. To guide selection, the research team compared melting points of selected Group II and Period 3 elements.. Following data was available

Group/period	**Group II**					**Period 3**							
Element	Be	Mg	Ca	Sr	Ba	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	4	12	20	38	56	11	12	13	14	15	16	17	18
Melting point (°C)	1280	650	850	770	720	97.8	650	660.3	1414	44.2	115.2	−101.5	−189.4

The engineering department seeks a scientific analysis to select materials for different temperature ranges. The company is also considering an unknown element X, positioned between aluminium and silicon in the periodic table. *Plotting graphs* of melting point against atomic number for Group II and Period 3 (separately), *describing and explaining* trends and irregularities in melting points across Period 3 and down Group II, *evaluating, with reasons*, which elements are most suitable for furnace linings and electrical connectors and *predicting* the likely melting point range and industrial suitability of the unknown element X.

Task

As a chemistry student, make a write up you will use to help the company.

Item 4

A chemical company in Tororo manufactures halide compounds used in disinfectants. The first electron affinity (EA) of an element indicates how readily it gains an electron to form stable anions. Elements with more negative EA values are more reactive and suitable for halide formation, while those with low or positive EA are less effective.

The company is analysing Group VII and Period 3 elements to identify the most suitable for halide production and is also considering an unknown element X between aluminium and silicon.

Group/period	**Group VII**				**Period 3**							
Element	F	Cl	Br	I	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	9	17	35	53	11	12	13	14	15	16	17	18
First EA (kJ/mol)	−354	−370	−348	−320	−21	+67	−44	−135	−72	−200	−364	0

The manager seeks to analysis the data to make informed decisions by *plotting* first electron affinity vs. atomic number for Group VII and Period 3 elements separately. Describe and explain *trends* and all *irregularities* in electron affinity across Period 3 and down Group VII. Evaluate which elements are(is) most suitable for industrial halide production, giving reasons. Predict the likely electron affinity of element X and comment on its potential suitability for forming halides.

Task

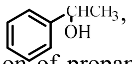
As a chemistry student, make a write up you will use to help the company.

Part II

Attempt **One** *item in this section*

ITEM 5

A chemical manufacturing firm in Uganda produces a variety of organic-based materials used in plastics, solvents, fuels, and disinfectants. The firm has identified an inorganic compound containing 62.5% calcium and 37.5% carbon as a starting material. When this compound was reacted with water, it released a colourless flammable gas that burned with a sooty flame, which has numerous industrial applications in Uganda, including the production of alkenes, alkyl halides, and aromatic compounds.

The firm sought to convert it into valuable organic materials such as propanol, chloroethane, benzene, which can be further converted to 1-phenylethan-1-ol 

, ethylbenzene, and nitrobenzene. Key mechanisms involved include dehydration of propanol to propene, electrophilic substitution reactions on benzene ring.

The company seeks a comprehensive evaluation: *determine* the empirical formula of inorganic compound, confirm the identity of the gas evolved, *predict* the functional groups of resulting organic compounds, and illustrate stated *mechanisms*. Additionally, assess *synthetic* pathways in the formation of stated compounds, and evaluate *health* and *environmental* impacts of producing both aliphatic and aromatic compounds in an industry. You have contacted for assistance on this.

Task

As a student of Chemistry, prepare a presentation you will use upon invitation.

ITEM 6

A chemical research laboratory in Uganda is investigating a gaseous hydrocarbon X obtained from a petrochemical facility. Elemental analysis shows that X contains 11.11% hydrogen by mass, its vapour density is 27 and on treatment with Tollens' reagent gave positive test. Hydrogenation of X with 1 mole of hydrogen and 1 mole of X over a lindlar's catalyst produced a carbon–carbon double bond. When the resulting compound of *hydrogenation* is treated with concentrated sulphuric acid and water, it forms Y, which is further oxidized using hot acidified potassium dichromate to yield a compound Z. Z gives a negative test with Tollens' reagent. Multi-step synthesis from but-1-ene, propene, and ethene are explored to generate X and its derivatives, which are important for producing alcohols, carbonyl compounds, and polymer intermediates in Uganda's chemical industry, while safety considerations such as flammability and waste management are observed.

An analyst, wishes to know *molecular formula* X, all structural *isomers* of X with IUPAC names, *identity* of X, Y, and Z, *write equations* to be involved, *mechanisms* for formation of Y, propose multi-step *synthesis* of X from but-1-ene, propene, and ethene, and discuss the industrial applications, *environmental impact*, and mitigations of X, Y, and Z. You have been contacted for your help.

Task:

As a student of Chemistry, prepare a presentation you will use to help the firm.

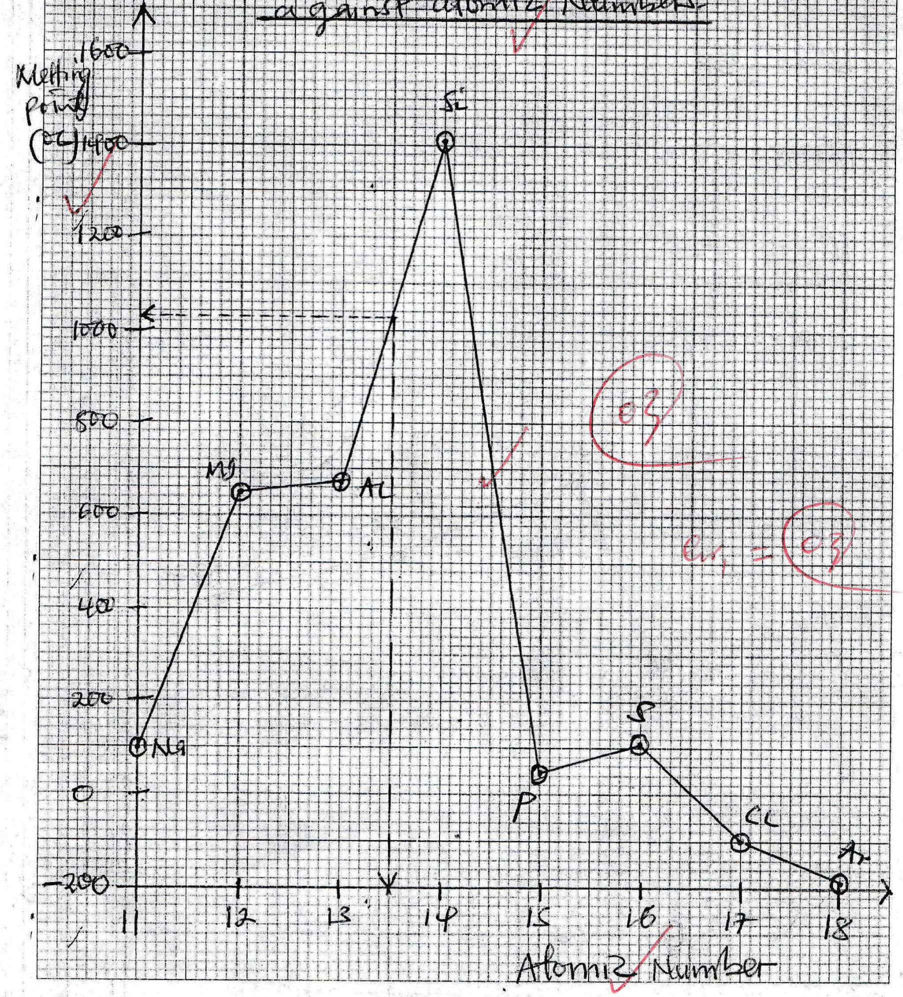
THE PERIODIC TABLE

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	35.4 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 Te 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 Ti 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 68	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

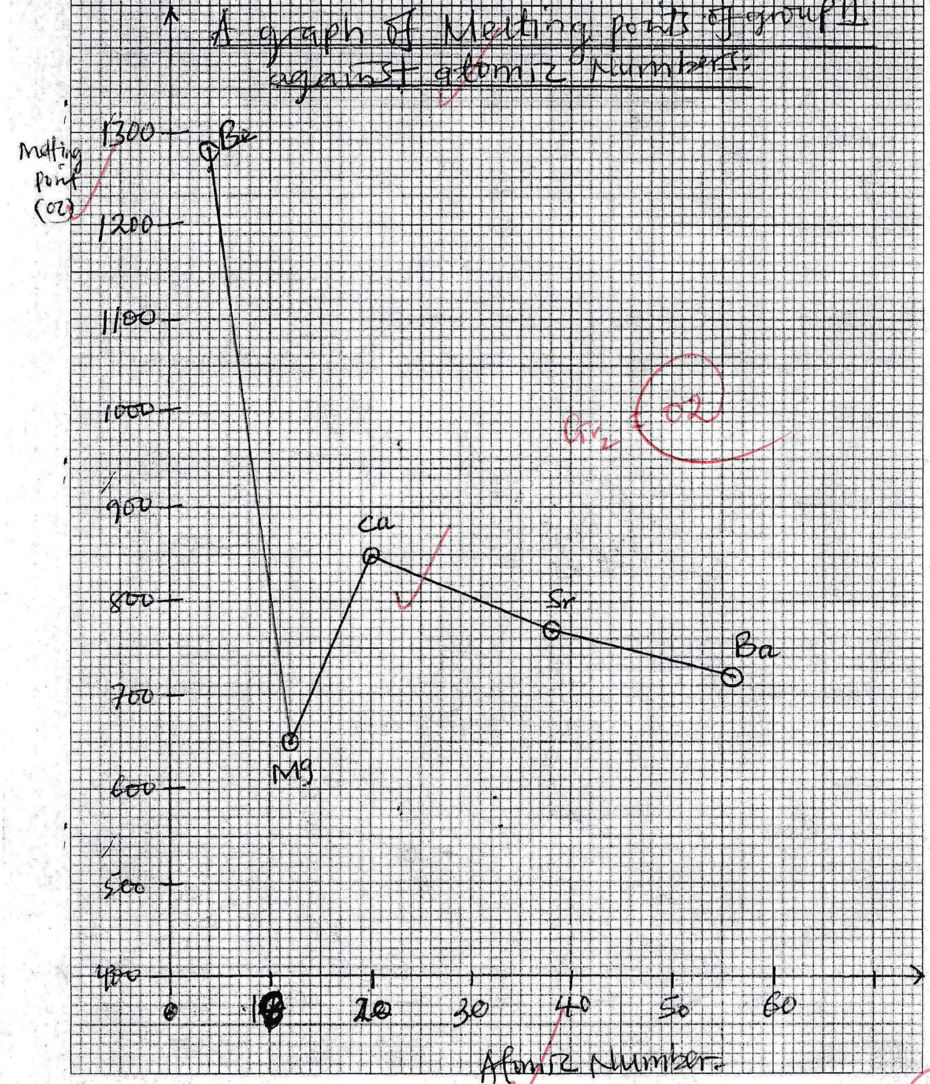
Item 3 (graph 1)

A graph of Melting point of period 3 against atomic Numbers:



Item 3 (graph 2)

A graph of Melting points of group II against atomic Numbers:



Gr1 + Gr2 = Gr = 05

Item 3

Trend in Melting Points; Down group II;

For group II, Melting point generally decreases from Beryllium to Barium with magnesium having an abnormally lower Melting point than calcium. Tr   Tr = 01

Explanation;

From Beryllium to Barium, atomic radius increases, bond length increases and bond strength decreases reducing the amount of energy required to break the metallic bonds. R1 R2   4R₂ = 03

Irregularities;

Magnesium has an abnormally lower melting point than calcium because magnesium has a hexagonal close packed structure compared to calcium with a packed structure. R1

Trend in Melting points; Across Period 3;

For Period 3, Melting point generally increases from silicon, to argon, with sulphur having a higher melting point than phosphorus. Tr   Tr = 01

Explanation;

Sodium, magnesium and aluminium have giant metallic structures held by metallic bonds whose strength increases with increase in number of electrons contributed per atom to metallic bond. Sodium contributes one electron per atom, Magnesium contributes two electrons and aluminium contributes three electrons. Magnesium form stronger metallic bonds than sodium. However, due to smaller atomic radius of aluminium, it forms stronger and shorter

metallic bonds than magnesium resulting into a slightly higher melting point than magnesium. R2

Silicon has a giant molecular structure, in which each silicon atom is bonded to four other silicon atoms, forming very many strong covalent bonds that require a high amount of energy to break, thus a high melting point. R2

Phosphorus, sulphur, chlorine and argon have simple molecular structures with weak Van der waal's forces of attraction whose magnitude increase in strength with increase in Molecular weight. Sulphur is octatomic (S_8) with a higher molecular weight hence stronger Van-der-waal's forces of attraction than phosphorus which is tetraatomic (P_4). Chlorine is diatomic (Cl_2), with a higher molecular weight and stronger Van-der-waals forces than argon which is monoatomic. R2 R2   4R₂ = 03

The energy required to break the Van-der waals forces therefore decreases from phosphorus to argon.

~~Tr + 4R = 04 scores~~
2Tr + 4R₁ + 4R₂ = Tr = 08 scores

Most suitable elements for furnace and electrical linings;

All metals have high melting points and can withstand high temperatures making them suitable. Es Er

However, Be is a toxic metal in dust form, Mg, Ca Sr, Ba, Na are reactive metals with water therefore corrosive. Silicon even though has a very high melting point is a semi conductor and not suitable. Ed

Al has a high melting point, non-reactive therefore not corrosive due to formation of a protective layer and not toxic. It also conducts electricity making it most suitable element. C

Es + Er + Ed + C = E₂ = 05

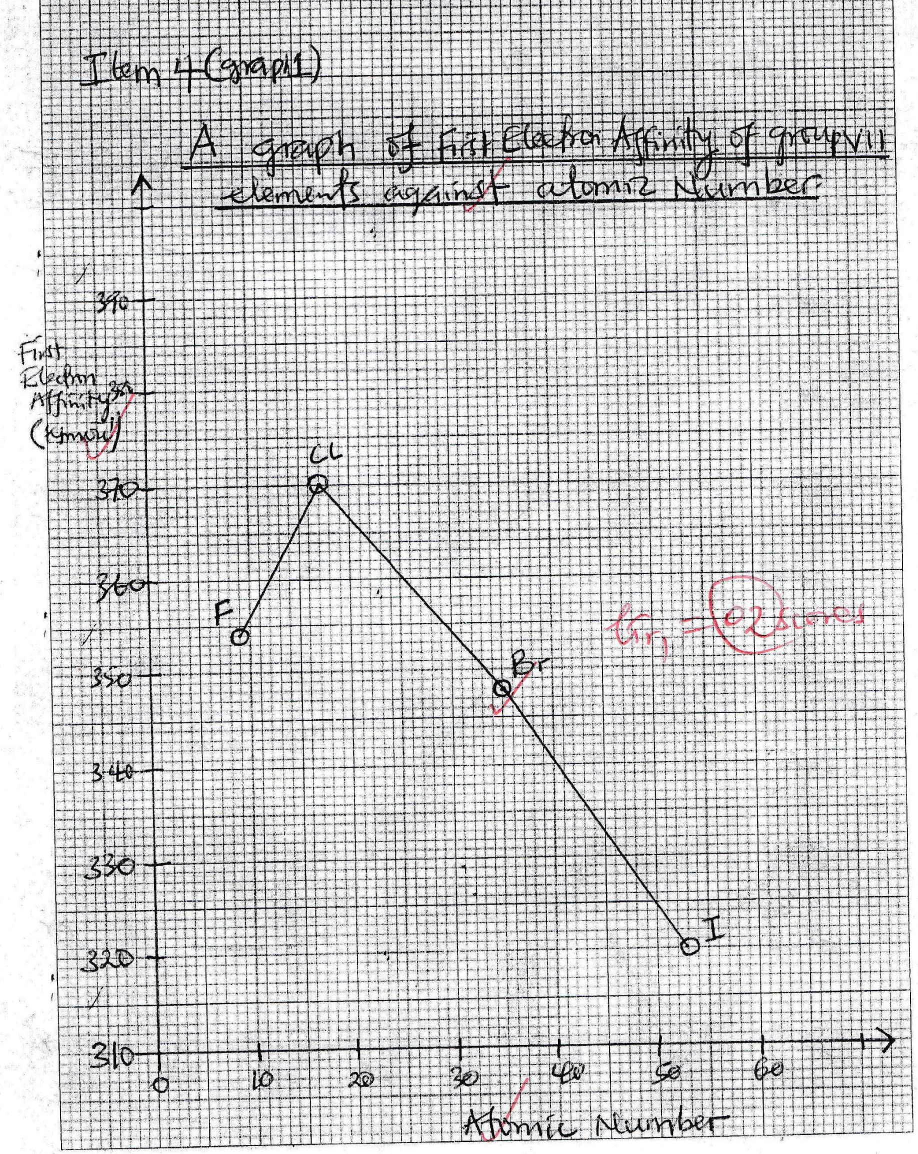
Melting point of Element X:

The melting point of X is most likely to be between 660.3 and 1414 and it is estimated from the graph to be close to 1030°C.

X also suitable for furnace linings and electrical connects is compared to that of Aluminium due to it slightly higher melting point.

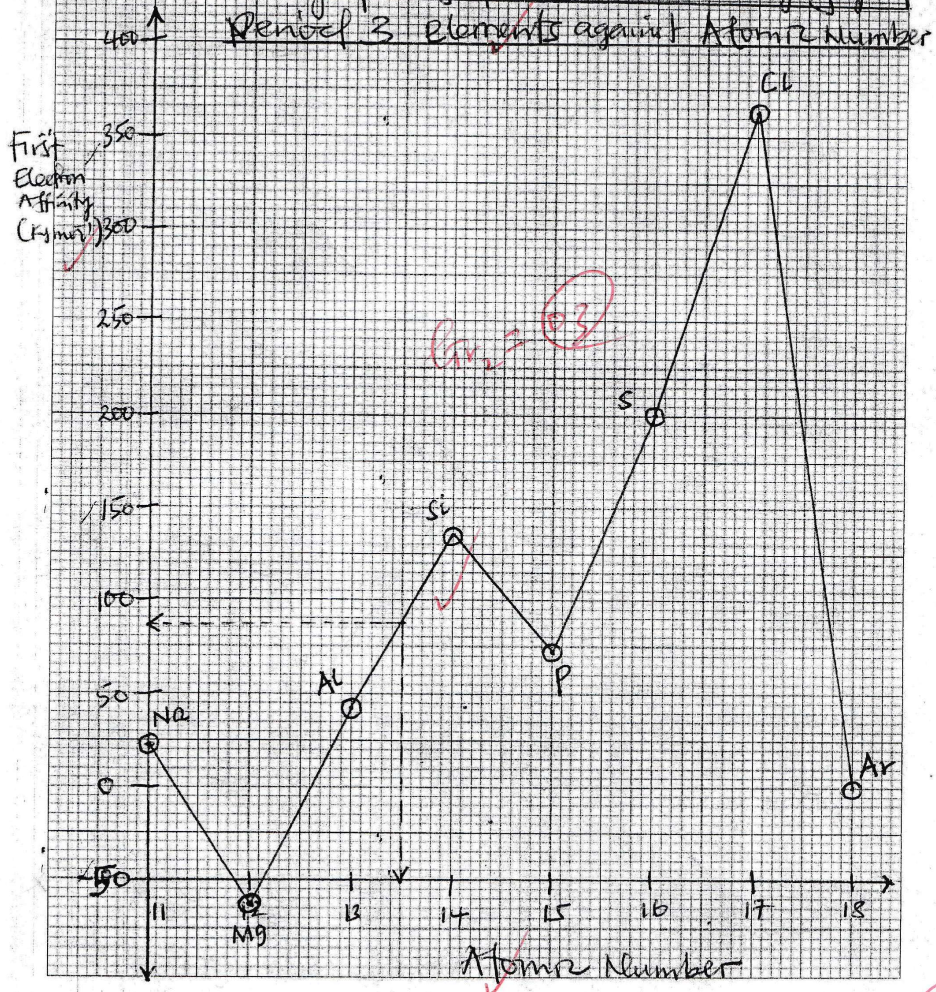
2pi = Pr = 02 scores

NAME ....



Item 4 (graph 2)

A graph of First Electron Affinity of ~~group~~ ~~Wenol~~ Period 3 elements against Atomic Number



Gr₂ = 02

Gr₁ + Gr₂ = Gr = 05

Item 4

Trend in First Electron Affinity down group VII;

First Electron Affinity generally decreases from flourine to iodine. Tr = 01

This is because from flourine to iodine nuclear charge increases, screening effect also increases, because an extra energy level completely filled with electrons is added from element to element. Increase in screening effect outweighs increase in nuclear charge. Effective nuclear charge decreases, atomic radius increases and incoming electron is far and weakly attracted by the nucleus giving off a low amount of energy.

Abnormality / irregularity:

Flourine has a lower first Electron Affinity than chlorine. This is because flourine has the smallest atomic radius, highest electron density, strongly repels the incoming electron and energy is absorbed to add the electron to its atom. 4R₁ = 02

Trend in First Electron Affinity Across Period 3;

NB: A graph of EA against atomic Number can be plotted by leaving out negative first as shown on graph paper. EA is exothermic

First Electron Affinity generally idecreases from sodium to argon. Tr = 01

Explanation:

Moving from sodium to argon, nuclear charge increases because a proton is added to the nucleus from element to element. Screening effect almost remains constant, because electrons are added to the same energy level. Effective nuclear charge increases, atomic radius reduces. The attraction for the incoming electron increases thus increasing the Electron affinity ✓R2

Irregularities/Abnormalities;

First Electron Affinity of Magnesium is much lower than the rest of elements and it's endothermic, ✓R2 due to thermal stable nature of Magnesium with configurations; $1s^2 2s^2 2p^6 3s^2$, An electron is added to a completely filled 3s-sub energy level which's thermodynamically stable ✓R2. The incoming electron experiences greater repulsion by existing ones than nuclear attraction. Energy must be supplied to add an incoming electron. ✓R2

First Electron Affinity of phosphorus is lower than that of sulphur. Phosphorus has electron configuration; $1s^2 2s^2 2p^6 3s^2 3p^3$ and sulphur; ✓R2 $1s^2 2s^2 2p^6 3s^2 3p^4$. 4R2 = 03

Phosphorus has a half filled 3p-sub energy level which is thermodynamically stable in which an electron is being added. Incoming electron experiences more repulsion than attraction by the nucleus. Sulphur has a partially ✓R2 filled 3p-sub energy level which is thermodynamically unstable, in which an electron is being added. Incoming electron experiences greater nuclear attraction than repulsion by ✓R2 the existing electrons.

2Ir + 4R1 + 4R2 = Tr = 08 scores.

Evaluation;

All non-metals in group VII ✓Es and period 3 except argon have high negative electron affinities showing strong tendencies to gain electrons. ✓ER

However, ✓Ed Chlorine with the most favourable and stable ✓Ed Electron Affinity (−370) is the most

suitable for halide formation ✓Ed as it combines high reactivity with safer, ✓ER more controlled use ✓E than Fluorine.

Es + 2Er + 3Ed + C = E2 = 05

Electron affinity of element X;

The first electron affinity of element X is most likely to be between −44 and −135 $kJmol^{-1}$ ✓R and it is estimated from the graph to be close to −87.5 $kJmol^{-1}$.

Element X is unsuitable for halide ✓formation due to its low negative value of first electron affinity. ✓

2Ri = R = 02

SECTION B

Item 5

Formula of the inorganic compound;

% calcium = 62.5% , % carbon = 37.5%

Element	Ca	C
% composition	62.5	37.5
moles	62.5/40	37.5/12
	= 1.563	3.125
Simplest ratio	1.563/1.563	3.125/1.563
	= 1	2

∴ Empirical Formula of inorganic compound is CaC_2

2CA + F + I = F2 = 04 scores

Name: Calcium carbide

Reaction of calcium carbide with water;

$CaC_{2(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + HC \equiv CH_{(g)}$ si_1 = 01

The gas liberated is Ethyne gas.

Conversion of ethyne gas to valuable organic materials.

Propanol

$HC \equiv CH \xrightarrow{Na/Liq\ NH_3(aq)} HC \equiv C^-Na^+ \xrightarrow{CH_3Cl} CH_3C \equiv CH$

$CH_3C \equiv CH \xrightarrow[CaCO_3;\ quinoline]{H_2/Pd} CH_3CH=CH_2 \xrightarrow[H^+,\ warm]{H_2O} CH_3CH_2CH_2OH$ si_2 = 02

or

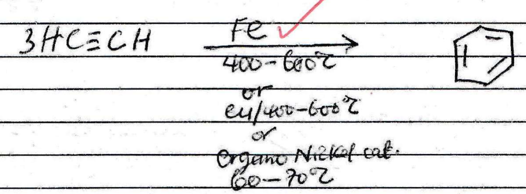
H_2/Lindlar's catalyst

Reject – $H_2/Ni/150°C$
– H_2/Pd

Chloroethane;

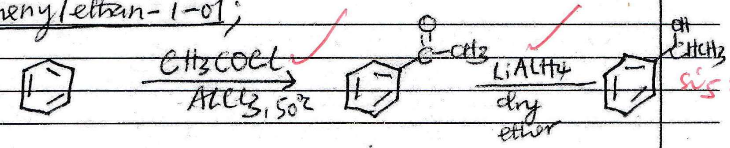
$HC \equiv CH \xrightarrow[\text{Lindlar's cat or } H_2/Pd/CaCO_3 \text{ Quinoline}]{H_2} H_2C=CH_2 \xrightarrow{HCl,\ CH_3OCH_3} CH_3CH_2Cl$ si_3 = 01

Benzene;



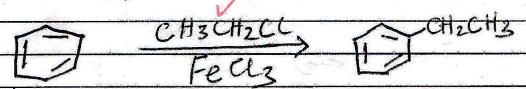
si_4 = 01

1-Phenylethan-1-ol;



si_5 = 01

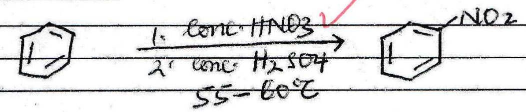
Ethylbenzene;



Accept any other correct

si_6 = 01

Nitrobenzene;



si_7 = 01

$si_1 + si_2 + si_3 + si_4 + si_5 + si_6 + si_7$ = 08 scores

Key mechanisms;

Dehydration of propanol to propene;

$$CH_3CH_2CH_2OH \xrightarrow[170°C]{conc\ H_2SO_4} CH_3CH=CH_2$$

Mechanism:

$$H_2SO_4 \rightleftharpoons H^+ + \bar{O}SO_3H$$

$$CH_3CH_2CH_2OH \xrightarrow{H^+} CH_3CH_2CH_2-\overset{+}{O}H_2$$

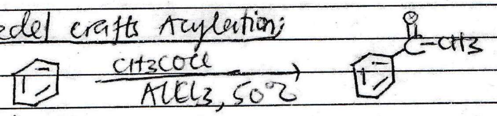
$$\downarrow -H_2O$$

$$CH_3CH=CH_2 \leftarrow CH_3CH-\overset{+}{C}H_2 \quad (H \leftarrow \bar{O}SO_3H)$$

M₁ = 01 score

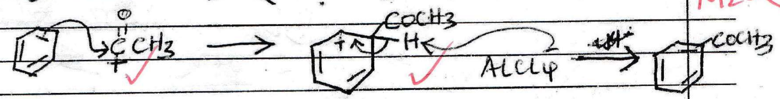
Electrophilic substitution reactions on the benzene ring;

Friedel crafts Acylation;



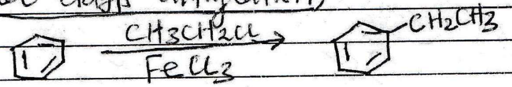
Mechanism

$$CH_3\overset{O}{\overset{\|}{C}}-Cl + AlCl_3 \rightleftharpoons CH_3\overset{O}{\overset{\|}{C}}^+ + AlCl_4^-$$



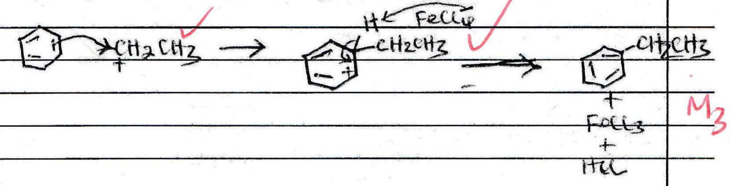
M₂ = 01 score

Friedel crafts alkylation;



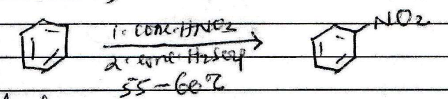
Mechanism;

$$CH_3CH_2-Cl + FeCl_3 \rightleftharpoons CH_3\overset{+}{C}H_2 + FeCl_4^-$$



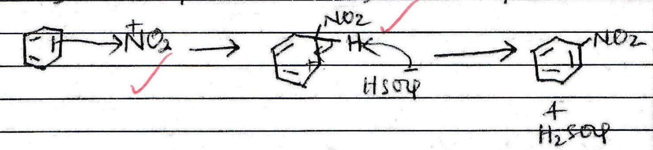
M₃ = 01 score

Nitration;



Mechanism;

$$HNO_3 + 2H_2SO_4 \rightleftharpoons \overset{+}{N}O_2 + H_3\overset{+}{O} + 2HSO_4^-$$



M₄ = 02 score

M₁+M₂+M₃+M₄ = 05 Mc

Dangers and mitigations;

Inhalation of volatile aliphatic hydrocarbons such as propane can lead to dizziness, headaches and long term nervous damage on workers. mitigated by use of personal protective equipment like gas masks.

Release of unburnt hydrocarbons into the atmosphere contribute to photochemical smog formation and green house effects. mitigated by installing catalytic converters to capture and oxide hydrocarbons.

Exposure to benzene vapour lead to carcinogenic reactions leading to leukemia and anemia. mitigated by use of closed system reactors to prevent escape of benzen vapour.

D₁+D₂+Dm = D₄ = 03
Any one correct.

Discharge of aromatic effluents into water bodies lead to water pollution affecting aquatic organisms because they are toxic, thus reducing on aquatic biodiversity. mitigated by treating waste water before disposal. ✓ Di ✓ DE ✓ DM

Item 6

hydrogen = 11.11%, C = (100 − 11.11) = 88.89%

elements	C	H
% composition	88.89	11.11
moles	$\frac{88.89}{12}$	$\frac{11.11}{1}$
	= 7.408	11.11 ✓ CA
Simplest ratio	$\frac{7.408}{7.408}$	$\frac{11.11}{7.408}$ ✓ CA
	= 1	1.5
	= 2	3

Multiply through by 2

∴ Empirical Formula is C_2H_3 ✓ F

Molar Mass = 2 Vapour density = (2×27) = 54g.

$(C_2H_3)n = 54$

$(12\times2n)+(1\times3n) = 54$

$24n + 3n = 54$

$27n = 54$, $n = 2$. ✓ F

∴ Molecular Formula of X is C_4H_6

~~Name;~~

Isomers;

$CH_3CH_2C\equiv CH$	1-Butyne or But-1-yne ✓ I
$CH_3C\equiv CCH_3$	2-Butyne or But-2-yne ✓ I
Ignore { $H_2C=CHCH=CH_2$	1,2-Butadiene or Buta-1,2-diene
$H_2C=C=CHCH_3$	1,3-Butadiene or Buta-1,3-diene

Identity;

X is $CH_3CH_2C\equiv CH$, but-1-yne or 1-butyne ✓ I

Y is $CH_3CH_2CH(OH)CH_3$, butan-2-ol or 2-butanol ✓ I

Z is $CH_3CH_2C(=O)CH_3$, butanone ✓ I

2CA + 2F + 5I = $\frac{8}{2}$ = 04 scores

Equations Involved;

Reaction with tollen's reagent with X;

$CH_3CH_2C\equiv CH_{(g)} + AgNO_{3(aq)} + NH_{3(aq)} \rightarrow 2CH_3CH_2C\equiv CAg_{(s)} + NH_4NO_{3(aq)}$ ✓

Hydrogenation of X;

$CH_3CH_2C\equiv CH \xrightarrow[\text{Lindlar's catalyst}]{H_2} CH_3CH_2CH=CH_2$ ✓

Hydration of compound of hydrogenation;

$CH_3CH_2CH=CH_2 \xrightarrow[H_2O,\ warm]{conc.H_2SO_4} CH_3CH_2CH(OH)CH_3$ ✓

Oxidation of compound Y;

$CH_3CH_2CH(OH)CH_3 \xrightarrow[heat]{K_2Cr_2O_{7(aq)}/H^+_{(aq)}} CH_3CH_2C(=O)CH_3$ ✓

$\frac{S_4}{}$ = 04

Mechanisms;

formation of Y from $CH_3CH_2CH=CH_2$;

$CH_3CH_2CH=CH_2 \xrightarrow[H_2O,\ warm]{conc.H_2SO_4} CH_3CH_2CH(OH)CH_3$

$CH_3CH_2CH=CH_2$ + $H^{\delta+}-O^{\delta-}SO_3H$ ✓ $\xrightarrow{-\bar{O}SO_3H}$ $CH_3CH_2\overset{+}{C}HCH_3$ + $:OH_2$ ✓

↓

$CH_3CH_2CH(OH)CH_3 \xleftarrow{-H_2SO_4} CH_3CH_2CH(\overset{+}{O}H)CH_3$ + $^-OSO_3H$ ✓

Mc = 05 score

Synthesis of X;

From but-1-ene;

$CH_3CH_2CH=CH_2 \xrightarrow{Cl_2/CCl_4} CH_3CH_2CHClCH_2Cl$

$\xrightarrow{\text{Excess KOH, Ethanol, Heat}} CH_3CH_2C\equiv CH_3$

$Si_2 = 01$

From Propene;

$CH_3CH=CH_2 \xrightarrow{Br_2/CCl_4} CH_3CHBrCH_2Br$

$\xrightarrow{\text{Excess KOH, Ethanol}} CH_3C\equiv CH$

$\xrightarrow{\text{1. Na/Liq. }NH_3\text{; 2. }CH_3Cl\text{, dry ether}} CH_3C\equiv CCH_3$

$\xrightarrow{H_2\text{, Lindlar's catalyst}} CH_3CH=CHCH_3$

$\xrightarrow{\text{conc. }H_2SO_4\text{, }H_2O\text{, warm}} CH_3CH_2CH(OH)CH_3$

$\xrightarrow{\text{conc. }H_2SO_4\text{, }180^\circ C} CH_3CH_2CH=CH_2$

$\xrightarrow{Br_2/CCl_4} CH_3CH_2CHBrCH_2Br$

$\xrightarrow{\text{Excess KOH, Ethanol, heat}} CH_3CH_2C\equiv CH$

$Si_3 = 02$

From Ethene;

$H_2C=CH_2 \xrightarrow{Cl_2/CCl_4} ClCH_2CH_2Cl$

$\xrightarrow{\text{Excess KOH, Ethanol, heat}} HC\equiv CH$

$\xrightarrow{\text{1. Na/Liq. }NH_3\text{; 2. }CH_3CH_2Cl\text{, dry ether}} CH_3CH_2C\equiv CH$

$Si_4 = 01$

$Si_1 + Si_2 + Si_3 + Si_4 = Se = 08$

Industrial Application;

(Ignore. Already described in scenario)

X, 1-butyne is used in the manufacture of polymers such as polyvinyl chloride (PVC).

Y, 2-butanol is used in industries as an organic solvent for extracting organic compounds from plants.

Z, butanone is used in manufacture of chloroform, ~~perspex~~ and as a solvent for plastics, vanishes and greases.

Dangers and Mitigations;

Compounds X, Y and Z are highly flammable thus lead to fire out breaks destroying property and even death to humans. (Di) (De) mitigated by proper handling and storage. (Dm)

Compound X, Y and Z when burnt, produce carbon dioxide, a green house gas, when accumulates in the atmosphere, leads to global warming, hence drought. mitigated by afforestation near industries as trees absorb carbondioxide naturally.

$Di + De + Dm = 02$ scores. Anyone correct.

— END —

— 2025 —

Candidate's Name: …SAMPLE SCORE…………………………………………………………

Signature: ……………………………… STREAM: | | | | | | | |

525/1
CHEMISTRY
Paper 1
October/November
2025
$2^1/_2$ hours

AOIs OF TERM III ASSESSMENT

Uganda Advanced Certificate of Education

S.5 CHEMISTRY

Paper 1

(***Set II***)

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

This paper has **two** *sections* **A** *and* **B.**

Section **A** *has two compulsory items while* **B** *has two parts* **Part I** *and* **Part II**

Each of part I and part II has two items, Answer only **one** *from each.*

Answers to Section **A** ***must*** *be written in the spaces provided and Section* **B** ***must*** *be written in the answer booklet(s) provided*

Answer four in all.

Where necessary use,

Molar gas volume at s.t.p = 22.4dm³

FOR EXAMINER'S USE ONLY

ITEM	CODE	SCORE
1	C_1	03
	E_f	08
	C_2	03
	C_3	03
	D_1	03
2	E_c	06
	C_4	02
	C_5	04
	E_1	05
	D_2	03
3/4	G_r / V_p	05 / 08
	T_r / R	08 / 09
	E_v / D_3	04 / 03
	P_r	03
5/6	F	06
	Mc	02
	S	11
	D_3	03
TOTAL	$\frac{x}{80}$	80

Key

C_1, C_2, C_3, C_4, C_5: Calculations
E_f: Effect
D_1, D_2, D_3: Danger
E_c: Energy Cycle
E_V: Evaluation
G_r: Graphing
T_r: Trend
P_r: Prediction
F: Formula
Mc: Mechanism
S: Synthesis
V_p: VSEPR theory
R: Reason

SECTION A

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

ITEM 1

A report from Kabong Chemical Works (U) Ltd revealed that the company is improving its sulphuric acid production process, an essential raw material used in fertilizers and lead acid batteries.

In one of the experiments, the company's chemists reacted *0.425 moles* of sulphur dioxide with *0.294 moles* of oxygen gas in a *1.60 dm³* sealed vessel. The gases were heated in the presence of a catalyst, and equilibrium was established according to the reversible reaction:

Equation 1: $2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3$ $\quad \Delta H = -196\ kJ/mol$

After analysis, it was discovered that *52%* of the oxygen gas had reacted this made the management curious how operating conditions influence both the position of equilibrium and rate of attainment of equilibrium in the process, and environmental effects of emissions.

Sulphur trioxide, is always converted to sulphuric acid, the plant's key product. For quality control, *25 cm³* of *0.05 M* sulphuric acid was diluted with *750 cm³* of pure water, and the resulting solution was tested for acidity. To confirm whether the product meets safety and concentration standards, the manager must know the *pH* of diluted acid sample.

The acid is used to produce lead(II) sulphate used in battery plates. The company's environmental unit reported that only *0.035g/dm³* of it dissolves water at 17 °C, and the manager sought to know its solubility product, so as to predict the effects of waste discharge on nearby water sources. Concerned about these findings, the Plant Manager has invited you.

Task

As a learner of Chemistry, help the company to know;

(a) The equilibrium constant for the gaseous reaction **(Kc)**.

	$2\,SO_2(g)$ +	$O_2(g)$ $\rightleftharpoons$	$2\,SO_3$
Initial moles	0.425	0.294	0
Moles reacted/formed	$2x$	x	$2x$ ✓CA
Moles at equilibrium	$(0.425-2x)$	$(0.294-x)$	$2x$

Total moles at equilibrium $= 0.425 - 2x + 0.294 - x + 2x = (0.719 - x)$ ✓CA

Moles of O_2 *that reacted* $= x$

$x = \frac{52}{100} \times 0.294 = 0.15288$

Moles of O2 at equilibrium $= 0.294 - 0.15288 = 0.14112$

Moles of SO2 at equilibrium $= 0.425 - 2(0.15288) = 0.11924$ ✓CA

Moles of SO3 SO3at equilibrium $= 2(0.15288) = 0.30576$

Since volume is 1.6 litres,

$[O_2] = \frac{0.14112}{1.6} = 0.0882M$, $[SO_2] = \frac{0.11924}{1.6} = 0.0745M$, $[SO_3] = \frac{0.30576}{1.6} = 0.1911M$

$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$, $= \frac{(0.1911)^2}{(0.0745)^2(0.0882)}$ $\quad K_c = 74.6 mol^{-1}dm^3$ ✓CA

$4CA = C_1 = 03$ scores

Turn Over

(b) Explain effect on the position of equilibrium, the value of Kc, and the rate of attainment of equilibrium by:

i. adding more Sulphur dioxide gas.

According to Lechatelier's principle, the concentration of sulphur dioxide increases and the excess sulphur dioxide reacts with oxygen to produce sulphur trioxide, so as to ***keep the equilibrium constant value the same.*** ✓K *Equilibrium therefore* ***shifts from left to right*** ✓P *and equilibrium constant value remains unchanged. The* ***rate of attainment of equilibrium increases*** ✓R *since there is an increase in the number of particles in the reaction vessel.*

ii. introducing a catalyst.

According to Lechatelier's principle, introducing a catalyst(Vanadium(V) oxide), has ***no effect on position*** ✓P *of equilibrium and* ***no effect on the value*** ✓K *of equilibrium constant but only alters the rate of backward and forward reaction equally. A catalyst therefore* ***increases the rate of attainment of equilibrium*** ✓R *by decreasing the activation energy.*

iii. increasing temperature.

According to Lechatelier's principle, Since the reaction is ***exothermic*** *(ΔH = −196 kJ/mol), increasing temperature adds heat. The equilibrium shifts from* ***right to the left*** ✓P *to absorb the added heat. The* ***value of Kc decreases,*** ✓K *because for exothermic reactions, increasing temperature reduces the equilibrium constant. The* ***rate increases initially,*** ✓R *because higher temperature gives molecules more kinetic energy, increasing collision frequency and energy, though less SO_3 is produced at equilibrium*

iv. increasing pressure.

According to Lechatelier's principle, the reaction involves a ***decrease in gas molecules*** *(3 → 2). Increasing pressure shifts the equilibrium from* ***left to the right,*** ✓P *favouring the formation of SO_3, to reduce total pressure. The* ***value of Kc remains constant,*** ✓K *because pressure changes do not affect Kc (only temperature does). The* ***rate of attainment of equilibrium rate increases,*** ✓R *because higher pressure increases the frequency of molecular collisions, speeding up both forward and reverse reactions.*

$4K + 4P + 4R = E_f = 08$ *scores*

(c) Calculate the pH of the solution obtained.

$Moles\ of\ H_2SO_4 in\ 25cm^3\ of\ solution = \frac{25\times0.5}{1000} = 0.0125$ ✓CA

$Total\ volume\ of\ solution = (25 + 750) = 775cm^3$

$775cm^3 of\ solution\ contain\ 0.0125\ moles\ of\ H_2SO_4$

$1000cm^3\ of\ solution\ contain \frac{1000\times0.0125}{775} moles\ of\ H_2SO_4 = 0.0161M$ ✓CA

$H_2SO_4\ (aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$ ✓CA

$Mole\ ratio\ of\ H_2SO_4 : H^+ = 1:2$

$[H^+] = 2[H_2SO_4] = 2 \times 0.0161 = 0.0322M$

$pH = -\log_{10}[H^+] = -\log_{10}(0.03220 = \mathbf{1.5}$ ✓CA

$4CA = C_2 = 03\ Scores$

(d) Determine the solubility product of lead(II) sulphate.

$PbSO_4(s) + (aq) \leftrightharpoons Pb^{2+}(aq) + SO_4^{2-}(aq)$ ✓CA

$K_{sp} = [Pb^{2+}][SO_4^{2-}]$

$Molar\ mass\ of\ PbSO_4 = 207 + 32 + 64 = 303g$

$\therefore Moles\ of\ PbSO_4 in\ 1\ litre = \frac{0.035}{303} = 1.16 \times 10^{-4} moles$ ✓CA

$[PbSO_4] = 1.16 \times 10^{-4}M$

$Since\ mole\ ratio\ of\ PbSO_4 : Pb^{2+} : SO_4^{2-} = 1:1:1$ ✓CA

$Then, [H^+] = [PbSO_4] = [SO_4^{2-}] = 1.16 \times 10^{-4}M$

$\therefore K_{sp} = (1.16 \times 10^{-4})^2 = \mathbf{1.33 \times 10^{-8} mol^2 dm^{-6}}$ ✓CA

$4CA = C_3 = 03\ Scores$

(e) Environmental impacts of the gaseous or aqueous equilibria and their mitigations.

Both SO_2 and SO_3 are ***acidic oxides*** *which dissolve in atmospheric moisture to form* ***sulphurous acid*** *and* ***sulphuric acid*** *, which fall as acid rain,* ✓di *reacting with metals and limestone structures, causing corrosion and damage on buildings.* ✓de *Mitigated by proper installation of* ***scrubbers*** *in chimneys to absorb SO_2 before release.* ✓dm

Lead (II) sulphate when improperly disposed of, it releases ***Pb^{2+} ions*** *into the environment, which are non-biodegradable and* ***bioaccumulate*** *through food chains thus food poisoning to both humans and anaimals. Mitigated by proper recycling of lead-acid batteries in controlled facilities.*

$di + de + dm = D_1 = 03 scores$

Item 2

A recent report from Tororo Industrial Chemicals Ltd, one of Uganda's emerging producers of industrial reagents and laboratory kits, revealed that the company is developing a dual-purpose field chemical pack for technicians working in rural agricultural and health sectors. The pack is intended to include one safe *warming* substance for sterilising small instruments and generating heat in remote operations, and one *cooling* substance for preserving biological samples and stabilising temperature sensitive reactions.

The company's research department is currently *comparing* ethanol, a locally available biofuel derived from sugarcane waste, with *sodium chloride*, obtained from the salt works around Lake Katwe.

The thermochemical data obtained from a certain article about ethanol indicate that the standard heats of formation of ethanol, carbon dioxide and water are (−227.0) , (−393.5), (−285.5) kJ mol⁻¹ respectively.

For sodium chloride, the enthalpy of sublimation of sodium, bond dissociation energy of chlorine, first ionisation energy of sodium, first electron affinity of chlorine, enthalpy of formation of sodium chloride, hydration enthalpy of $Na^+(aq)$ and hydration enthalpy of $Cl^-(aq)$,(+109), (+242), (+494), (−364), (−411), (−406), and (−363) kJ mol⁻¹ respectively.

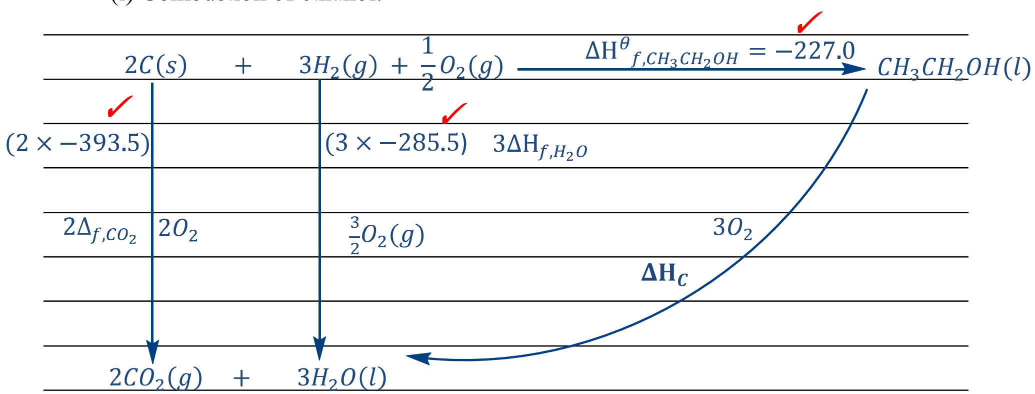
Preliminary tests by the plant's laboratory team indicated that combustion of ethanol and, dissolution of sodium chloride in water produces minimal temperature change. To ensure the most energy-efficient and environmentally safe field pack, the company manager has invited you.

Task

As a student of chemistry, help the researcher;

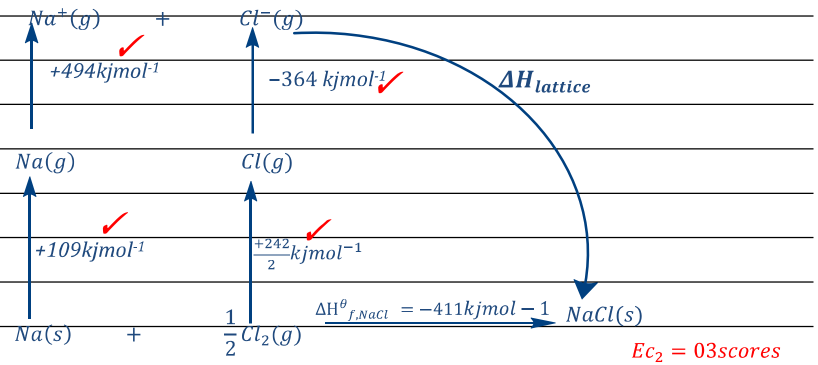
(a) Analyse the data to construct an energy cycle for the changes in the:

(i) Combustion of ethanol.



$Ec_1 = 03 scores$

(ii) Formation of sodium chloride.



$Ec_2 = 03 scores$

$Ec_1 + Ec_2 = E_c = 06\ scores$

(b) Use the energy cycles constructed to calculate;

(i). Enthalpy of combustion of ethanol.

By Hess' law;

$2\Delta_{f,CO_2} + 3\Delta H_{f,H_2O} = \Delta H^\theta_{f,CH_3CH_2OH} + \boldsymbol{\Delta H_C}$

$\boldsymbol{\Delta H_C} = 2\Delta_{f,CO_2} + 33\Delta H_{f,H_2O} - \Delta H^\theta_{f,CH_3CH_2OH}$

$= (2 \times -393.5) + (3 \times -285.5) - (-227.0)$ CA

$\boldsymbol{\Delta H_C = -1416.5kjmol^{-1}}$ CA

$2CA = C_4 = 02\ Scores$

(ii). Lattice of sodium chloride and its enthalpy of solution.

By Hess' law;

$\Delta H^\theta_{f,NaCl} = \Delta H^\theta_{sublimatio} + \Delta H^\theta_{1st\ IE} + \frac{1}{2}\Delta H^\theta_{BDE} + \Delta H^\theta_{HA} + \boldsymbol{\Delta H_{lattice}}$

$\boldsymbol{-411 = 109 + 494 + \frac{1}{2} \times 242 + -364 + \Delta H_{lattice}}$ CA

$\boldsymbol{\Delta H_{lattice} = -771kjmol^{-1}}$ CA

$$\Delta H_{\underset{Nacl}{solution}} = +\Delta H_{\underset{Nacl}{lattice}} + +\Delta H_{\underset{Nacl}{hydration}}$$

$$\Delta H_{\underset{Nacl}{solution}} = +771 + \left(\Delta H_{\underset{Na^+}{hydration}} + \Delta H_{\underset{Cl^-}{hydration}}\right) = +771 + (-406 + -363)$$ ✓CA

$$\Delta H_{\underset{NaCl}{solution}} = +2kjmol^{-1}$$ ✓CA

$4CA = C_5 = 04\ Scores$

(c) (i) Evaluate industrial usefulness of the two systems to advise the manager choose the best substance for warming, and cooling with reason.

*Ethanol ✓Ev is more suitable for warming functions; due its **high** ✓Er **exothermic** enthalpy of combustion of* $-1416.5kjmol^{-1}$*, this energy is supplied for heating up other substances.*

Whereas;

*Sodium ✓Ev chloride is more suitable for cooling functions; due to its ✓Er **endothermic** enthalpy of solution* $+2kjmol^{-1}$*, during solution of sodium chloride, heat is absorbed from other substances leaving them cooler.*

(ii). State any other ideal industrial use of ethanol.

*Used as a ✓U **solvent** for extracting perfumes, drugs, plant essences, and paints since it acts as both polar and non-polar solvent.*

*70% ethanol is used in **hand sanitizers** ✓U and medical wipes since it kills bacteria and viruses on skin and surfaces.*

$2Ev + 2Er + 1U = E_{v1} = 05\ Scores$

(d) Suggest the possible impacts and mitigations of the substances to the environment.

*When ethanol burns, it produces **carbon dioxide** (CO_2), a greenhouse gas that contributes to ✓di **global warming** if released in large quantities resulting to increased drought. ✓de mitigated by **adopting clean energy technologies** ✓dm such as solar energy systems to reduce emissions.*

*Excessive discharge of NaCl brine from industries increases **salinity** in soil and water thus soil and water pollution. Mitigated by properly disposing brine wastes.*

$1di + 1de + 1dm = D_2 = 03\ Scores$

SECTION B
Part I
Attempt **One** *item in this section*

Item 3

A chemical manufacturing company in Uganda, Kyoga Chemicals Ltd, produces industrial chemicals and water treatment agents. The company has been advised that substances suitable for use in water treatment plants and in construction industries, for stabilizing concrete and producing heat resistant materials must have the strongest ionic characters. The engineering department is analyzing the melting points of chlorides of Group II and Period 3 elements to select materials suitable for operations. The data is shown below:

Group/period	Group II chlorides					Period 3 chlorides							
Element	$BeCl_2$	$MgCl_2$	$CaCl_2$	$SrCl_2$	$BaCl_2$	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	PCl_5	S_2Cl_2	Cl_2
Atomic No	4	12	20	38	56	11	12	13	14	15	15	16	17
Melting pt/°C	405	714	782	875	962	808	714	192	-68	-92	160	-76	-80

The engineering department seeks a scientific analysis to select materials for different intended purpose. The company is also considering an unknown element X, positioned between aluminium chloride and silicon chloride in the periodic table. *Plotting graphs* of melting point against atomic number for Group II and Period 3 chlorides (separately), *describing and explaining* trends and irregularities in melting points across Period 3 and down Group II chlorides, *evaluating, with reasons*, which chlorides are most suitable for water treatment and stabilizing concrete, casting molds, and producing heat resistant materials and *predicting* the likely melting point range and industrial suitability of the element X chloride.

Task

As a chemistry student, make a write up you will use to help the company.

Item 4

Kilembe Chemical Works Ltd, in Kasese, is investigating how bonding and molecular structure affect the properties and industrial uses of several compounds used in fertilizer formulation, water purification, and manufacturing of plastics and ceramics.

The *compounds* under study include *water*, *phosphorus trichloride*, *carbon tetrachloride*, *tin(II) chloride*, *ammonia*, *tin(IV) chloride*, *nitrate ion*, and *phosphorus pentachloride*.

It was reported that some compounds such as carbon tetrachloride and phosphorus trichloride are liquids at room temperature and insoluble in water, ammonia and water are highly soluble and have strong intermolecular attractions. tin(II) chloride conducts *electricity* in molten form, while tin(IV) chloride does not.

The manager seeks to know *molecular shape*, *bond type*, and *bond angle* for each substance, use bond type and molecular structure in the compounds *account for their differences* in melting point, solubility, and electrical conductivity. why water and ammonia form hydrogen bonds, and how this affects their boiling points and solubility compared to phosphorus trichloride and phosphorus pentachloride. Compare the bonding and structure of tin(II) chloride and tin(IV) chloride explain their difference in electrical conductivity and melting points.to guide the design of safe storage systems and efficient cooling and purification processes. Evaluate the environmental impacts of using nitrate ions in fertilizers

Task

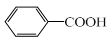
As a chemistry student, make a write up you will use to help the company.

Part II

Attempt **One** *item in this section*

ITEM 5

Nile Chemical Industries Ltd, a chemical manufacturing firm located in Jinja, produces a range of organic-based materials used in plastics, fuels, solvents, and disinfectants. In one of its experiments, 20.0 cm^3 of a gaseous hydrocarbon W was exploded with 150 cm^3 of excess oxygen. After complete combustion, the residual gas measured 110 cm^3, and when concentrated potassium hydroxide solution was added, the volume further decreased to 30 cm^3

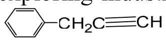
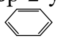
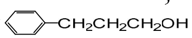
The company noted that ozonolysis of W produced only one compound and that W readily decolourised bromine water. These findings prompted the research team to seek a deeper understanding of W and its possible industrial applications in the synthesis of propan-1-ol, benzoic acid, {  }, 1,2-dibromopentane and 1-chlorobutane.

The company seeks a comprehensive evaluation: to determine the *formulae* of W, draw and name all possible *isomers*, *identify* W with reason(s), and illustrate the mechanism for the reaction between W and bromine water. Additionally, confirm the identity of the gas absorbed by potassium hydroxide solution, *predict* the functional groups of resulting organic compounds, describe *synthetic* pathways to related products, and assess the *environmental* impacts of producing above compounds in industry. You have been contacted for assistance.

Task

As a student of Chemistry, prepare a presentation you will use upon invitation.

ITEM 6

Albertine Oil Fractionation Ltd, an industrial chemical company in the Albertine region, produces fuels, solvents, and organic feedstocks for plastics and chemical synthesis. During a research study, an organic compound P was isolated from a distillation fraction. Complete combustion of a sample of P yielded 8.8 g carbondioxide and 1.8 g water, while 0.100 g of P, vapourised at 273°C and 734 mmHg, occupied 4.46×10^{-2} dm^3. Ozonolysis of P followed by hydrolysis produced a mixed Q of two different compounds, and P was observed to react readily with bromine and concentrated sulphuric acid. The company is exploring industrial applications of these compounds for synthesis of prop-2-yn-1-ylbenzene{  } a component in manufacture of new drugs, benzene{  }solvent, and {  }chemical feedstocks.

The manager seeks to know the formulae of P, all possible structural *isomers*, *identity* of P with reasons, deduce the structure and functional groups of mixture Q, illustrate *mechanisms* for reactions of P with *bromine* and *concentrated sulphuric acid*, , outline *synthetic* pathways from Albertine oil fractions P to synthesis industrial compounds stated, and evaluate the environmental impacts of producing compounds in industry and their mitigations. You have been invited to help the manager.

Task

As a student of Chemistry, prepare a presentation you will use to help the firm.

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	35.4 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 Te 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 Ti 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 68	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

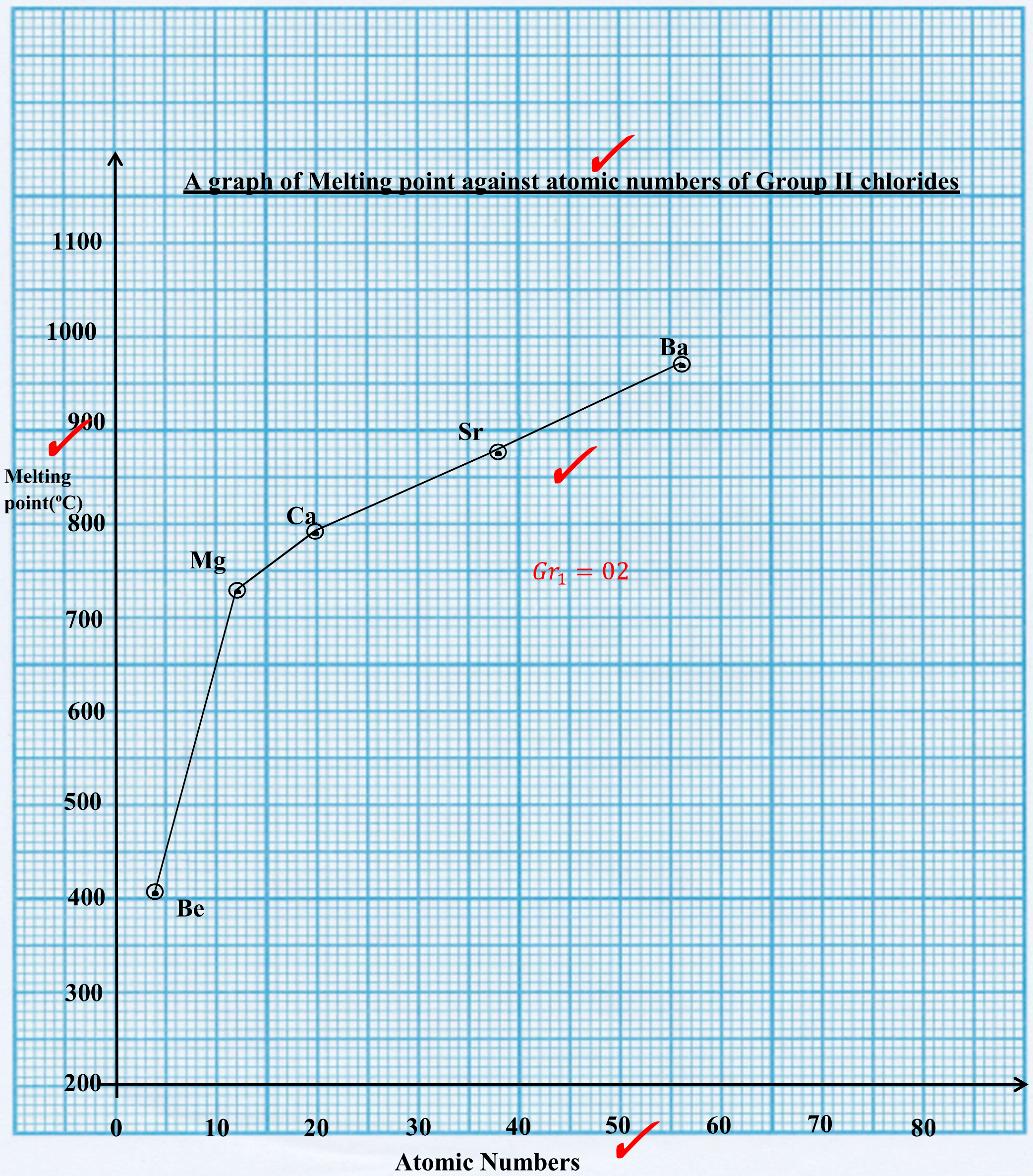
END

UGANDA NATIONAL EXAMINATIONS BOARD
(to be fastened together with other answers to paper)

UACE

Candidate's Name ....
Signature ....
Subject .... Paper code ..../....

Random No.					
Personal Number					



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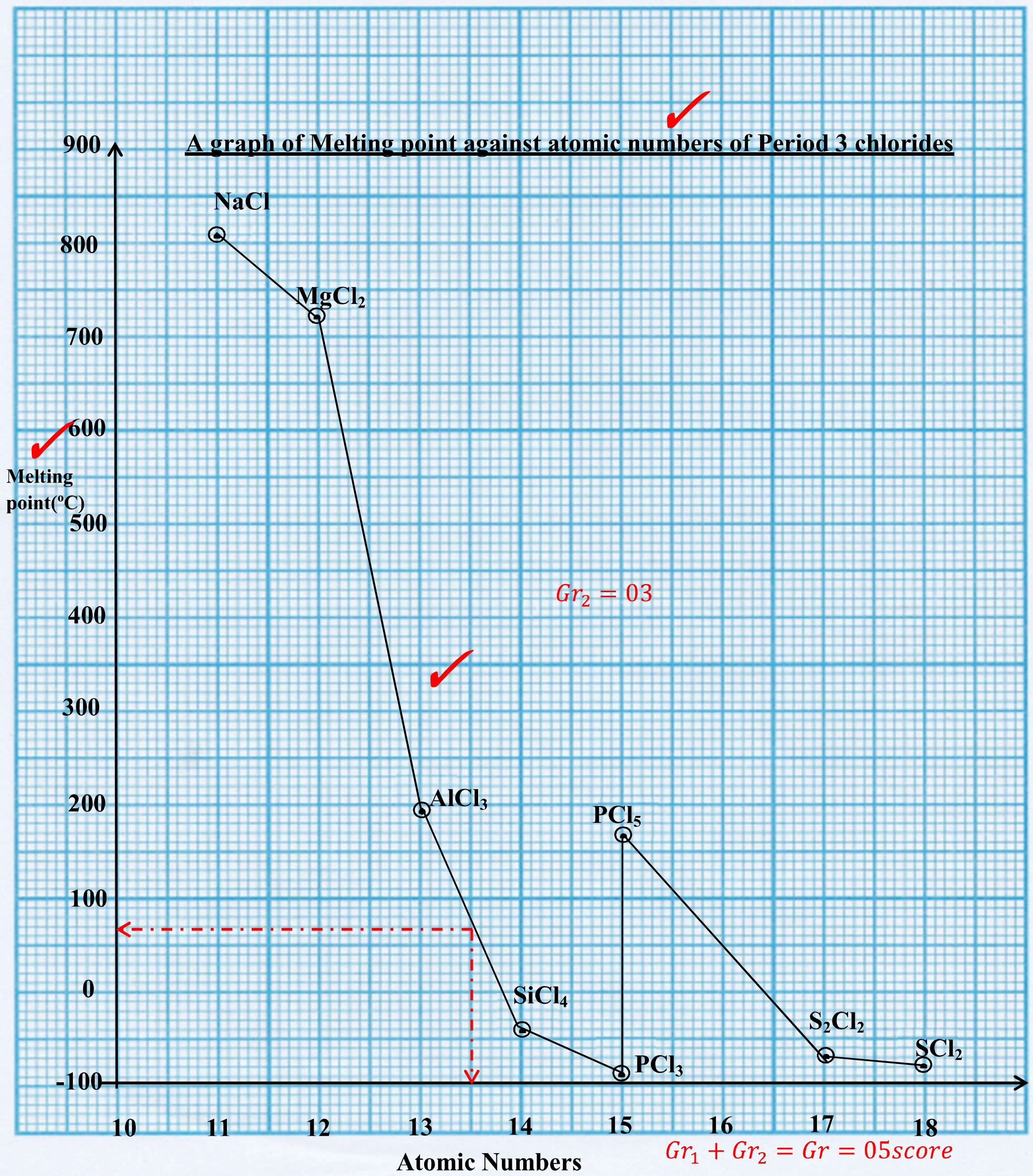
Personal Number					



3. **Trend down group (II) chlorides;**

Melting point ***increases*** *from beryllium chloride to barium chloride* ✓Tr_1

Reason;

The ***cationic radius increases****,* ***charge density*** *and* ***polarising power*** ✓R_1 *of the cations* ***decrease****, and* ***ionic character increases****, requiring an increasing amount of energy to* ***break the increasingly strong ionic bonds.*** ✓R_1

Irregularities;

The melting point of ***beryllium chloride*** *is* ***very low*** ✓R_1 *compared to other chlorides because the beryllium ion has a* ***very small ionic radius****,* ***high polarising power*** *and* ***high charge density*** *making beryllium chloride predominantly* ***covalent****. A low amount of energy is required to* ***break the covalent bond****.* ✓R_1

Trend across period 3 chlorides;

Melting points of the chlorides generally ***decrease*** ✓Tr_2 *from sodium chloride to sulphur dichloride.*

Reason;

Sodium chloride and magnesium ✓R_2 *chloride have* ***giant ionic*** ✓R_2 ***structures*** *held by* ***strong ionic bonds*** *which require a* ***high amount of energy to break****. The decrease in melting point from sodium chloride to magnesium chloride is because magnesium ion has a* ***smaller ionic radius****,* ***higher charge density*** *and* ***higher polarising power*** ✓R_2 *than sodium ion making magnesium chloride* ***less ionic*** *than sodium chloride. Aluminium chloride has a* ***lower*** ✓R_2 ***melting point*** *than magnesium chloride because among the cations, the aluminium ion has the* ***smallest ionic radius****, a* ***very high charge density*** *and* ***high polarising power****. Aluminium chloride is therefore predominantly* ***covalent****. Silicon tetrachloride is* ***covalent*** ✓R_2 *and its molecules are held by* ***weak Van der Waals' forces of attraction that require a low amount of energy to break*** *hence a low melting point. Phosphorus trichloride has a* ***simple molecular structure*** *thus a low melting point.* ✓R_2 *Disulphur dichloride and sulphur dichloride form simple molecular structures held by weak Van der Waals' forces of attraction.*

Irregularities;

Phosphorus pentachloride has an ***abnormally high*** ✓R_2 *melting point because at ordinary temperatures it consists of* PCl_4^+ *+ and* PCl_6^+ *ions hence exhibiting ionic character.*

$Tr_1 + Tr_2 + 4Tr_1 + 4Tr_2 = T_r = 08scores$

Evaluation and choice;

The chlorides $BaCl_2$*,* $SrCl_2$*,* $CaCl_2$*,* $MgCl_2$*, and NaCl are all* ***ionic*** ✓E_S *compounds, due to their* ***very high melting points****, which indicate strong electrostatic forces between metal cations and chloride anions.*

However,

$CaCl_2$ *and* $MgCl_2$ *are ideal for* ***water treatment*** *because they are* ***highly soluble*** *and* ***less toxic****, where they effectively release metal ions that remove impurities through precipitation.* ✓E_d

$CaCl_2$ *is the most suitable chloride in* ***construction purposes*** *for stabilizing concrete because it is* ***hygroscopic****, absorbs moisture from the environment, and accelerates cement setting, thereby increasing the strength and durability of the concrete structure.* ✓E_d

$BaCl_2$ *and* $SrCl_2$*, are the most stable for* ***heat-resistant materials and casting molds*** *used in metal extraction processes. due to* ***highest melting points*** *and* ***strongest ionic bonds*** ✓E_d *among all chlorides listed, they can withstand extremely high temperatures without decomposing, making them reliable choices for high-heat industrial applications.*

$1E_S + 3E_d = E_v = 04scores$

Prediction of melting point, nature and industrial suitability of chloride X;

Chloride of element X exists between $AlCl_3$ *and its melting point is likely to be between* ***192*** *and* ***−68 °C,*** *approximately* ***70°C.*** ✓Pr

Likely properties of XCl_n*;* ***partial covalent molecular*** ✓Pr ***character*** *rather than a full ionic lattice. Possibly a* ***low-molecular*** *covalent chloride.*

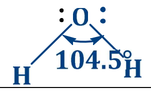
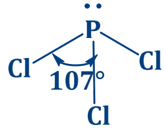
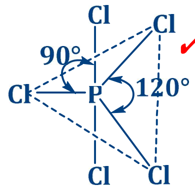
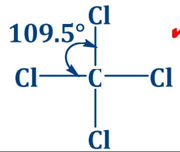
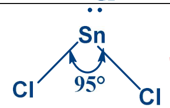
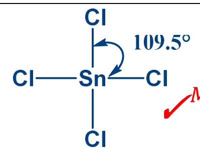
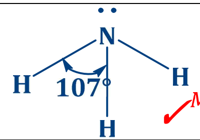
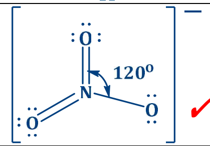
Industrial suitability of XCl_n;

X is ***unsuitable*** *for water treatment, concrete stabilization and heat-resistant structural materials since it is* ***covalent.*** ✓Pr

X can be used as a Lewis acid (like $AlCl_3$*) in* ***organic synthesis*** *or as an* ***intermediate*** ✓Pr *in chemical manufacture, but not as a refractory or concrete stabilizer.*

$3Pr = P_r = 03scores$

4. Molecular shape, bond type, and bond angle;

Name of substance	Molecular structure	Name of molecular shape	Bond type	Bond angle
Water	 Mi	*bent shape/ V-shape* Ni	*Polar covalent* Bi	104.5° Ai
Phosphorus trichloride	 Mi	*trigonal pyramidal* Ni	*Polar covalent* Bi	107° Ai
Phosphorus pentachloride	 Mi	*trigonal bipyramidal* Ni	*Covalent* Bi	90° and 120°. Ai
Carbon tetrachloride	 Mi	*tetrahedral* Ni	*Non-polar covalent* Bi	109.5°. Ai
Tin(II) chloride	 Mi	Bent shape/ V-shape Ni	*Ionic with covalent character* Bi	95° Ai
Tin(IV) chloride	 Mi	*tetrahedral* Ni	*Pure covalent* Bi	109.5°. Ai
Ammonia	 Mi	*trigonal pyramidal* Ni	*Polar covalent* Bi	107° Ai
Nitrate ion	 Mi	*trigonal planar* Ni	*Covalent with resonance delocalization* Bi	120° Ai

$9Mi + 9Ni + 9Bi + 9Ai = V_p = 08scorers$

Account for differences in melting point, solubility, and electrical conductivity:

*The **differences in solubility, melting point, and conductivity** among these compounds are due to the type of bonding and molecular structure.*
Ionic compounds *($SnCl_2$, nitrate salts) have **high melting points** and **conduct electricity when molten or in solution**, while **covalent molecular compounds** (CCl_4, PCl_3, $SnCl_4$) have **low melting points**, are **non-conductors**, and are **insoluble** in water.*
Hydrogen bonding *in water and ammonia leads to **strong intermolecular attractions**, giving them higher boiling points than similar covalent molecules like PCl_3 and PCl_5.*

$3R_3 = R_3 = 03scores$

Comparison of boiling points and solubility of water and ammonia to those of phosphorus trichloride, phosphorus pentachloride and carbon tetrachloride;

*Water is a **bent polar molecule** with an angle of **104.5°**, and ammonia is **trigonal pyramidal** with an angle of **107°**; both have **polar covalent bonds** and form **hydrogen bonds** between molecules. Hydrogen bonding gives them **high boiling points** and makes them **highly soluble in water**.*
*In contrast, **PCl_3** (trigonal pyramidal, 107°) and **PCl_5** (trigonal bipyramidal, 90° & 120°) are **covalent** and **cannot form hydrogen bonds**. They have **low melting points** are **liquid or volatile solids**, and **do not dissolve** in water because they hydrolyse, producing **HCl** and **phosphoric acids**.*

$3R_4 = R_4 = 03scores$

Comparison of electrical conductivity and melting points of tin(II) and tin(IV) chloride;

*Tin(II) chloride ($SnCl_2$) is **ionic with some covalent character** forming a **bent structure** (≈95°) and a **solid** at room temperature. It **conducts electricity when molten** because it contains **mobile ions (Sn^{2+} and Cl^-)**.*
*Tin(IV) chloride ($SnCl_4$), on the other hand, is **tetrahedral (109.5°)** and **purely covalent**, existing as a **molecular liquid** that **does not conduct electricity**. Its weak molecular forces give it a **lower melting point** than $SnCl_2$.*

$3R_5 = R_5 = 03scores$

$R_3 + R_4 + R_5 = R = 09scores$

Evaluation of the environmental impacts of using nitrate ions in fertilizers;

*In fertilizer use, **nitrate ions (NO_3^-)** improve plant growth.*
*However when overused, cause **environmental pollution** since Nitrates are **highly soluble** and can **leach into groundwater**, causing **eutrophication** and **oxygen depletion** in water bodies, leading to fish deaths and **blue-baby syndrome** in humans. Mitigated by controlled, fertilizer application, and use of organic manure.*

$1di + 1de + 1dm = D_3 = 03\ Scores$

5. **Formulae of W ;**

$C_xH_y(g) + \left(x + \frac{y}{4}\right)O_2(g) \longrightarrow xCO_2(g) + \frac{y}{2}H_2O(g)$

Volume of hydrocarbon $= 20cm^3$

Volume of carbon diode produced $= 110 - 30 = \mathbf{80cm^3}$

Volume of oxygen used up in reaction = original volume − volume unreacted $= 150 - 30 = \mathbf{120cm^3}$ ✓CA

Volume of hydrocarbon $\times x$ = *volume of carbondioxide*

$\Longrightarrow 20x = 80$

$\therefore x = {}^{80}/_{20} = \mathbf{4}$

Also volume of hydrocarbon $\times \left(x + \frac{y}{4}\right)$ = *volume of oxygen used up* ✓CA

$\Longrightarrow 20\left(4 + \frac{y}{4}\right) = 120$

$\therefore y = (6 - 4) \times 4 = 8$

$\therefore$ ***The formula of W is C_4H_8*** ✓CA

Possible isomers, identity of W with reason(s)

$\mathbf{CH_3CH_2CH = CH_2}$

$\mathbf{CH_3CH = CHCH_3}$

Since ozonolysis of W produced only one compound, it indicates that it has a symmetrical carbon-carbon double bond. ✓CA

$CH_3CH = CHCH_3 \xrightarrow[2.\ H_2O,\ Zn,\ CH_3COOH]{1.\ O_3,\ CCl_4,\ <20^0C} 2CH_3CHO$ ***, One compound produced is ethanal***

Therefore, W is CH3CH = CHCH3 but-2-ene ✓CA

Comfirmatory Test for Carbon dioxide; ✓I

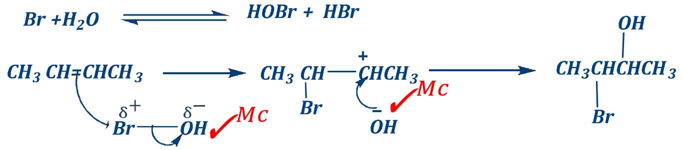
*If the gas is CO_2, KOH will absorb it so the **limewater remains clear** (no milky cloud), because CO_2 was removed by the KOH beforehand. But the gas is not absorbed by KOH, the limewater will still **go milky**.* ✓I

5CA + 2I = F = 06 Scores

Mechanism for reaction between W and bromine water;

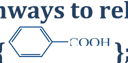
$CH_3CH = CHCH_3 \xrightarrow{Br_2/H_2O} CH_3CHBrCH(OH)CH_3 + HBr$

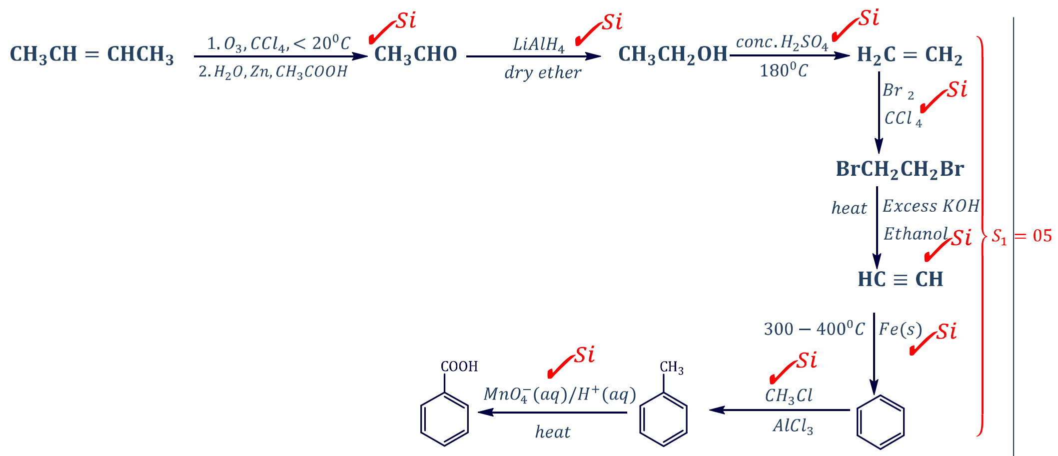
Mechanism



2Mc = Mc = 02 Scores

Synthetic **pathways to related products;**

Benzoic acid,{  **};**



1,2-dibromopentane;

$\mathbf{CH_3CH = CHCH_3} \xrightarrow[2.\ H_2O,\ Zn,\ CH_3COOH]{1.\ O_3,\ CCl_4,\ <20^0C} \mathbf{CH_3CHO} \xrightarrow[dry\ ether]{LiAlH_4} \mathbf{CH_3CH_2OH} \xrightarrow[180^0C]{conc.\ H_2SO_4} \mathbf{H_2C = CH_2} \xrightarrow[CCl_4]{Br_2} \mathbf{CH_2BrCH_2Br}$

$\xrightarrow[heat]{Excess\ KOH/ethanol} \mathbf{HC \equiv CH} \xrightarrow[CH_3CH_2CH_2Cl]{Na(s)/LiqNH_3} \mathbf{CH_3CH_2CH_2C \equiv CH} \xrightarrow[lindlar's\ catalyst]{H_2} \mathbf{CH_3CH_2CH_2CH = CH_2} \xrightarrow[CCl_4]{Br_2} \mathbf{CH_3CH_2CH_2CHBrCH_2Br}$

$S_2 = 05$

1-chlorobutane;

$\mathbf{CH_3CH = CHCH_3} \xrightarrow[warm]{H_2O/H^+} \mathbf{CH_3CH_2CH(OH)CH_3} \xrightarrow[180^0C]{conc.\ H_2SO_4} \mathbf{CH_3CH_2CH = CH_2} \xrightarrow[ROOR]{HCl} \mathbf{CH_3CH_2CH_2CH_2Cl}$

$S_3 = 01$

$S_1 + S_2 + S_3 = S = 11$ *Scores*

Environmental impacts of producing above compounds in industry;

*When burnt, they give off poisonous gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to **air pollution**, **acid rain**, **respiratory problems**, and **global warming**. The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid **open-air burning** and instead use **safe chemical disposal methods**.* ✓di ✓de ✓dm

$1di + 1de + 1dm = D_3 = 03$ *Scores*

6. **Formulae of P ;**

Mass of carbondiode formed $= \mathbf{8.8g}$ ***and mass of water formed*** $= \mathbf{1.8}$

mass of carbon $= \frac{12}{44} \times 8.8 = \mathbf{2.4g}$

mass hydrogen $= \frac{2}{18} \times 1.8 = \mathbf{0.2g}$

Element	C	H
%composition	2.4	0.2
Moles	$\frac{2.4}{12}$ $= \mathbf{0.2}$	$\frac{0.2}{1}$ $= \mathbf{0.2}$
Simplest ratio	$\frac{0.2}{0.2}$ $= 1$	$\frac{0.2}{0.2}$ $= \mathbf{1}$

CA

$\therefore$ *Empirical formula is* **CH**

Mass of p vaporised $= 0.100g$

At a Temperature $T = 273 + 273 = 546K$

At a Pressure $P = \left(\frac{734}{760} \times 1\right)\ atm$

At a Volume $V = 4.46 \times 10^{-2} dm^3$

Note: 1. *we use*; $\boldsymbol{R = 0.0821}\ \text{L}\cdot\text{atm/(mol}\cdot\text{K)}$, *when, P is in atm and V is in litre/dm*^{3}

2. *we use*; $\boldsymbol{R = 8.314\ J/(molK)}$, *when, P is in Pa and Volume is in m*^{3}

From ideal gas law $PV = nRT$

$$PV = \frac{m}{M_r}RT$$

$$\Longrightarrow M_r = \frac{mRT}{PV} = \frac{0.100 \times 0.0821 \times 546}{\left(\frac{734}{760} \times 1\right) \times 4.46 \times 10^{-2}} = \frac{4.48266}{0.04307} \approx \mathbf{104g}$$

CA

$\therefore \mathbf{(CH)_n = 104}$

$(12 \times 1 \times n) + (1 \times 1 \times n) = 104$

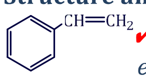
$13n = 104$

$n = \frac{104}{13} = 8$

$\therefore$ *Molecular formula is* $\mathbf{C_8H_8}$

CA

Structure and IUPAC Name;



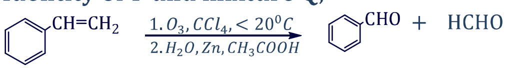
CA

ethenylbenzene CA

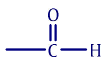
Structural isomers;

P *has no other strural isomers.* I

Identity of P and mixture Q;



Q *is a mixture of benzylaldehyde and methanal with functional group*

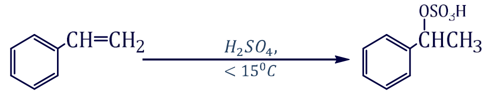


I

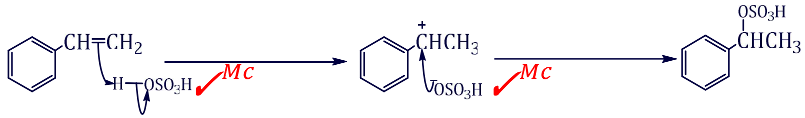
$5CA + 2I = F = 06\ Scores$

Mechanisms for reactions of P with bromine and concentrated sulphuric acid;

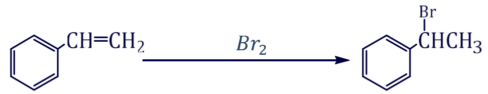
With concentrated sulphuric acid;

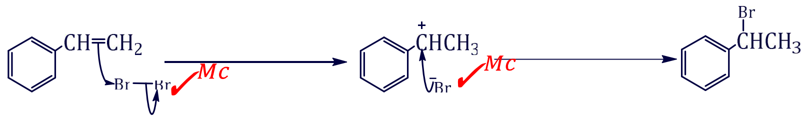


Mechanisim



With bromine;



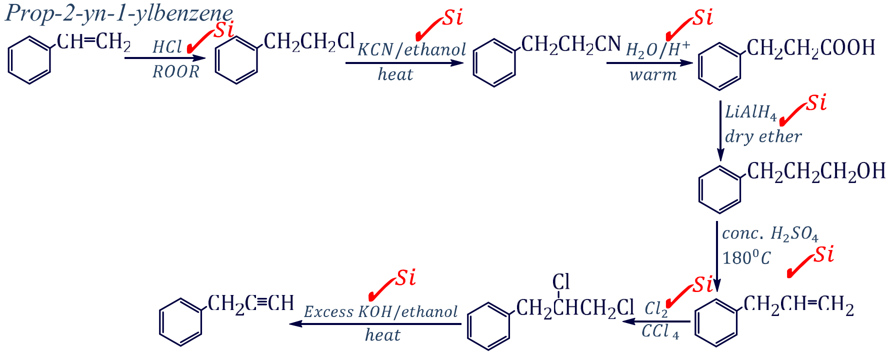


$M_c = 02$

$4Mc = Mc = 02\ Scores$

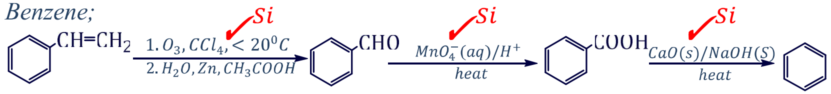
Synthetic pathways from Albertine oil fractions P to synthesis industrial compounds ;

Prop-2-yn-1-ylbenzene



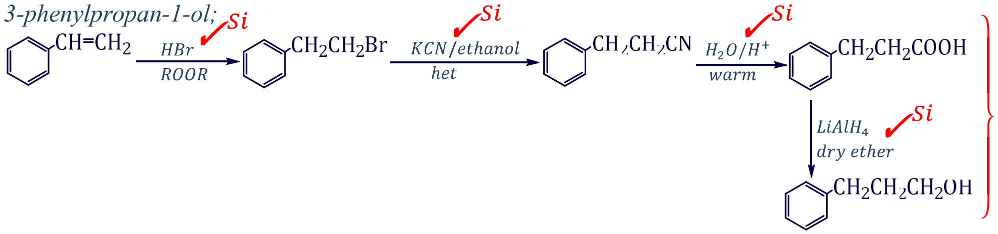
$S_1 = 05$

Benzene;



$S_3 = 01$

3-phenylpropan-1-ol; Si



$S_1 = 05$

$S_1 + S_2 + S_3 = S = 03$ Scores

Environmental impacts of producing above compounds in industry;

*When burnt, they give off poisonous (di) gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to **air pollution**, **acid rain**, **respiratory problems**, and **global warming**. (de) The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid **open-air burning** and instead use **safe chemical disposal methods**.* (dm)

1di+1de+1dm=D₃=03 Scores

END
2025
It is All about mindset change

Turn Over

Tr. Julius.W.M 0787093081

Candidate's Name: SAMPLE SCORE ……………………………………………………

Signature: ………………………………… **STREAM:** | | | | | | | |

525/1
CHEMISTRY
Paper 1
Nov./Dec.
2025
$2^1/_2$ hours

END OF YEAR ASSESSMENT 2025

Uganda Advanced Certificate of Education

S.5 CHEMISTRY

Paper 1

(***Set I***)

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

This paper has **two** *sections* **A** *and* **B.**

Section **A** *has two compulsory items while* **B** *has two parts* **Part I** *and* **Part II**

Each of part I and part II has two items, Answer only **one** *from each.*

Answers to Section **A** ***must*** *be written in the spaces provided and Section* **B** ***must*** *be written in the answer booklet(s) provided*

Answer four in all.

Where necessary use,

Molar gas volume at s.t.p = 22.4dm^3

FOR EXAMINER'S USE ONLY				
ITEM	CODE		SCORE	
1	F_1		04	
	C_1		04	
	C_2		06	
	C_3		03	
	D_1		03	
2	E_c		06	
	C_4		02	
	C_5		04	
	E_1		05	
	D_2		03	
3/4	G_r	V_p	05	08
	T_r	R	08	09
	E_v	D_3	04	03
	P_r		03	
5/6	F_2		06	
	Mc		02	
	S		11	
	D_3		03	
TOTAL			80	

Key

C_1, C_2, C_3, C_4, C_5: *Calculations*
D_1, D_2, D_3: *Danger*
E_c: *Energy Cycle*
E_V: *Evaluation*
G_r: *Graphing*
T_r: *Trend*
P_r: *Pridiction*
F: *Formula*
Mc: *Mechanism*
S: *Synthesis*
V_p: *VSEPR theory*
R: *Reason*

SECTION A

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

ITEM 1

During a rapid response investigation near Kitezi landfill, the Water Quality Surveillance Unit discovered heavy metal contamination in a borehole supplying a large number of households.

A fragment of metallic lead from a nearby illegal battery recycling site was analysed using a mass spectrometer. The detector registered four isotopic signals with currents of *0.16 mA (mass 204), 2.72 mA (mass 206), 2.50 mA (mass 207)* and *5.92 mA (mass 208)*. The investigation team was briefed that these readings can help determine an accurate relative atomic mass (RAM) of lead.

Further laboratory tests on the contaminated water revealed that the dissolved poisonous salt responsible for the lead toxicity contained *62.6%* lead, *8.45%* nitrogen, and the rest oxygen molar mass of the salt was reported as *331.22* g/mol.

The concentration of the dissolved salt in the borehole water was measured as 0.90 mol dm^{-3}, and the borehole supplies approximately 1200 litres of water per day. Chemists concluded that this salt can be removed by treating the water with sodium sulphate solution, which reacts to produce insoluble lead(II) sulphate.

In extreme contamination cases, *0.45 moles* of nitrogen dioxide gas was released during side reactions at 28°C and 98 kPa. To protect public health, the Ministry has assigned your team to analyse the data and provide a complete stoichiometric and methodological evaluation of the situation.

Task:

As a learner of Chemistry, help the company to know;

(a) The relative atomic mass of lead. **(RAM)**.

$Total\ current = 0.16 + 2.72 + 2.50 + 5.92 = 11.3mA$ ✓CA

$Percentage\ abundance\ of\ lead - 204 = \left(\frac{0.16}{11.3} \times 100\right) = 1.42$

$Percentage\ abundance\ of\ lead - 206 = \left(\frac{2.72}{11.3} \times 100\right) = 24.07$

$Percentage\ abundance\ of\ lead - 207 = \left(\frac{5.92}{11.3} \times 100\right) = 22.12$ ✓CA

$Percentage\ abundance\ of\ lead - 208 = \left(\frac{2.72}{11.3} \times 100\right) = 52.40$

$R.A.M = \sum Relative\ isotopic\ mass \times proportion\ of\ isotope$

$R.A.M = \left(204 \times \frac{1.42}{100}\right) + \left(206 \times \frac{24.07}{100}\right) + \left(207 \times \frac{22.12}{100}\right) + \left(208 \times \frac{52.4}{100}\right)$ ✓CA

$R.A.M = 207.26$ ✓CA

$4CA = C_1 = 04\ scores$

(b) To determine the molecular formula of the poisonous salt in water.

$Lead = 62.6\%, Nitrogen = 8.45\%, Oxygen = 100 - (62.6 + 8.45) = 28.95\%$ ✓CA

Element	Pb	N	O
%composition	62.6	8.45	28.95
Moles	$\frac{62.6}{207.26}$ $= 0.302$	$\frac{8.45}{14}$ $= 0.604$	$\frac{28.95}{16}$ $= 1.809$ ✓CA
Simplest ratio	$\frac{0.302}{0.302}$ $= 1$	$\frac{0.604}{0.302}$ $= 2$	$\frac{1.809}{0.302}$ $= 6$

$Empirical\ formula\ of\ salt\ is\ PbN_2O_6$ ✓F

$(PbN_2O_6)n = 303.3$

$(207.26 \times 1n) + (14 \times 2n) + (16 \times 6n) = 331.22 \quad \therefore n = 1$

$Molecular\ formula\ of\ the\ salt\ is\ Pb(NO_3)_2$ ✓F Name: $Lead(ii)nitrate$ ✓NA

$2CA + 2F + NA = F_1 = 04\ Scores$

(c) To calculate the mass of lead(II)sulphate formed if all the dissolved salt was removed

$0.9moll^{-1} means; 1litre\ of\ borehole\ water\ contain\ 0.9moles\ of\ Pb(NO_3)_2$ ✓CA

$1200litres\ of\ borehole\ water\ contain\ \left(\frac{0.9 \times 1200}{1}\right)$ ✓CA

$= 1080moles\ of\ Pb(NO_3)_2$

$From\ equation: Pb(NO_3)_2(aq) + Na_2SO_4(aq) \longrightarrow PbSO_4(s) + 2NaNO_3(aq)$ ✓CA

$1mole\ of\ Pb(NO_3)_2\ produces\ 1mole\ of\ PbSO_4$

$1080moles\ of\ Pb(NO_3)_2\ produce\ \left(\frac{1}{1} \times 1080\right) moles\ of\ PbSO_4. = 1080moles$ ✓CA

$Molar\ mas\ of\ PbSO_4\ is\ (207 \times 1) + (32 \times 1) + (16 \times 4) = 303g$ ✓CA

$1mole\ of\ PbSO_4\ weigh\ 303g$

$\therefore 1080moles\ of\ PbSO_4\ weigh\ \left(\frac{303 \times 1080}{1}\right) = 327240g\ or\ 3.27 \times 10^5 kg\ of\ PbSO_4$ ✓CA ✓CA

$7CA = C_2 = 06\ scores$

(d) Know the volume of gas produced using the gas law.

$From\ gas\ law: PV = nRT; P = 98 \times 10^3 pa, T = (28 + 273) = 301k\ and\ R = 8.314$ ✓CA

Note: *We use*;

1. $R = 0.0821\ L \cdot atm/(mol \cdot K), when, P\ is\ in\ atm\ and\ V\ is\ in\ litre/dm^3$
2. $R = 8.314\ J/(molK), when, P\ is\ in\ Pa\ and\ Volume\ is\ in\ m^3$

$\therefore V = \frac{nRT}{P} = \left(\frac{0.45 \times 8.314 \times 301}{98 \times 10^3}\right)$ ✓CA

$= 0.0115m^3$ ✓CA

$3CA = C_3 = 06\ scores$

(e) Environmental impacts of the gaseous or aqueous system and their mitigations.

*Nitrogen dioxide contributes to **global warming** when it accumulates in the atmosphere, since it traps heat and creating the greenhouse effect, leading to rising temperatures hence **drought**. This can be mitigated by using catalytic converters to reduce it into less harmful substances such as nitric acid.*

*Nitrogen dioxide causes **respiratory problems** and **poor air quality.** When inhaled, it irritates the lungs and reduces oxygen uptake, increasing cases of **asthma** and **bronchitis.** Using personal protective gears like gas masks during scientific investigations.*

$di + de + dm = D_1 = 03scores$

Item 2

A recent report from Tororo Industrial Chemicals Ltd, one of Uganda's emerging producers of industrial reagents and laboratory kits, revealed that the company is developing a dual-purpose field chemical pack for technicians working in rural agricultural and health sectors. The pack is intended to include one safe *warming* substance for sterilising small instruments and generating heat in remote operations, and one *cooling* substance for preserving biological samples and stabilising temperature sensitive reactions.
The company's research department is currently *comparing* ethanol, a locally available biofuel derived from sugarcane waste, with *sodium chloride*, obtained from the salt works around Lake Katwe.

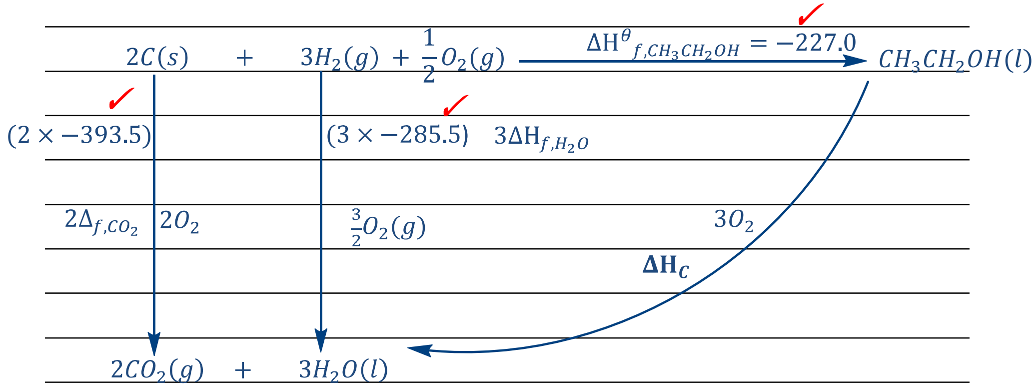
The thermochemical data obtained from a certain article about ethanol indicate that the standard heats of formation of ethanol, carbon dioxide and water are (−227.0) , (−393.5), (−285.5) kJ mol^{-1} respectively.
For sodium chloride, the enthalpy of sublimation of sodium, bond dissociation energy of chlorine, first ionisation energy of sodium, first electron affinity of chlorine, enthalpy of formation of sodium chloride, hydration enthalpy of Na^+(aq) and hydration enthalpy of Cl^-(aq) ,(+109), (+242), (+494), (−364), (−411), (−406), and (−363) kJ mol^{-1} respectively.
Preliminary tests by the plant's laboratory team indicated that combustion of ethanol and, dissolution of sodium chloride in water produces minimal temperature change. To ensure the most energy-efficient and environmentally safe field pack, the company manager has invited you.

Task

As a student of chemistry, help the researcher;

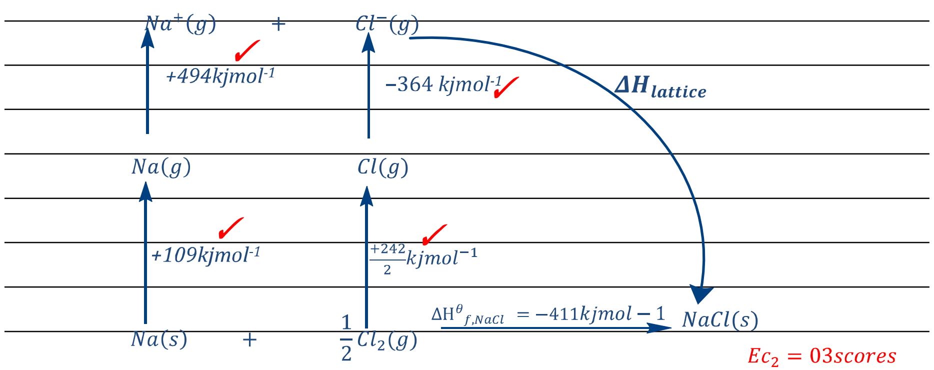
(a) Analyse the data to construct an energy cycle for the changes in the:

(i) Combustion of ethanol.



$Ec_1 = 03scores$

(ii) Formation of sodium chloride.



$Ec_2 = 03scores$

$Ec_1 + Ec_2 = E_c = 06\ scores$

(b) Use the energy cycles constructed to calculate;

(i). Enthalpy of combustion of ethanol.

By Hess' law;

$2\Delta_{f,CO_2} + 3\Delta H_{f,H_2O} = \Delta H^{\theta}{}_{f,CH_3CH_2OH} + \boldsymbol{\Delta H_C}$

$\boldsymbol{\Delta H_C} = 2\Delta_{f,CO_2} + 33\Delta H_{f,H_2O} - \Delta H^{\theta}{}_{f,CH_3CH_2OH}$

$= (2 \times -393.5) + (3 \times -285.5) - (-227.0)$ CA

$\boldsymbol{\Delta H_C = -1416.5kjmol^{-1}}$ CA

$2CA = C_4 = 02\ Scores$

(ii). Lattice of sodium chloride and its enthalpy of solution.

By Hess' law;

$\Delta H^{\theta}{}_{f,NaCl} = \Delta H^{\theta}{}_{sublimatio} + \Delta H^{\theta}{}_{1st\ IE} + \frac{1}{2}\Delta H^{\theta}{}_{BDE} + \Delta H^{\theta}{}_{HA} + \boldsymbol{\Delta H_{lattice}}$

$\boldsymbol{-411 = 109 + 494 + \frac{1}{2} \times 242 + -364 + \Delta H_{lattice}}$ CA

$\boldsymbol{\Delta H_{lattice} = -771kjmol^{-1}}$ CA

$\boldsymbol{\Delta H_{solution\ Nacl} = +\Delta H_{lattice\ Nacl} + +\Delta H_{hydration\ Nacl}}$

$\boldsymbol{\Delta H_{solution\ Nacl} = +771 + \left(\Delta H_{hydration\ Na^+} + \Delta H_{hydration\ Cl^-}\right) = +771 + (-406 + -363)}$ CA

$\boldsymbol{\Delta H_{solution\ NaCl} = +2kjmol^{-1}}$ CA

$4CA = C_5 = 04\ Scores$

(c) (i) Evaluate industrial usefulness of the two systems to advise the manager choose the best substance for warming, and cooling with reason.

Ethanol is more suitable for warming functions; due its ***high exothermic*** *enthalpy of combustion of* $\boldsymbol{-1416.5kjmol^{-1}}$*, this energy is supplied for heating up other substances.*

Whereas;

Sodium chloride is more suitable for cooling functions; due to its ***endothermic*** *enthalpy of solution* $\boldsymbol{+2kjmol^{-1}}$*, during solution of sodium chloride, heat is absorbed from other substances leaving them cooler.*

(ii). State any other ideal industrial use of ethanol.

Used as a ***solvent*** *for extracting perfumes, drugs, plant essences, and paints since it acts as both polar and non-polar solvent.*

70% ethanol is used in ***hand sanitizers*** *and medical wipes since it kills bacteria and viruses on skin and surfaces.*

$2Ev + 2Er + 1U = E_{v1} = 05\ Scores$

(d) Suggest the possible impacts and mitigations of the substances to the environment.

When ethanol burns, it produces ***carbon dioxide (CO₂)****, a greenhouse gas that contributes to* ***global warming*** *if released in large quantities resulting to increased drought. mitigated by* ***adopting clean energy technologies*** *such as solar energy systems to reduce emissions.*

Excessive discharge of NaCl brine from industries increases ***salinity*** *in soil and water thus soil and water pollution. Mitigated by properly disposing brine wastes.*

$1di + 1de + 1dm = D_2 = 03\ Scores$

SECTION B
Part I
Attempt **One** *item in this section*

Item 3

A chemical manufacturing company in Uganda, Kyoga Chemicals Ltd, produces industrial chemicals and water treatment agents. The company has been advised that substances suitable for use in water treatment plants and in construction industries, for stabilizing concrete and producing heat resistant materials must have the strongest ionic characters. The engineering department is analyzing the melting points of chlorides of Group II and Period 3 elements to select materials suitable for operations. The data is shown below:

Group/period	Group II chlorides					Period 3 chlorides							
Element	$BeCl_2$	$MgCl_2$	$CaCl_2$	$SrCl_2$	$BaCl_2$	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	PCl_5	S_2Cl_2	Cl_2
Atomic No	4	12	20	38	56	11	12	13	14	15	15	16	17
Melting pt/°C	405	714	782	875	962	808	714	192	-68	-92	160	-76	-80

The engineering department seeks a scientific analysis to select materials for different intended purpose. The company is also considering an unknown element X, positioned between aluminium chloride and silicon chloride in the periodic table. *Plotting graphs* of melting point against atomic number for Group II and Period 3 chlorides (separately), *describing and explaining* trends and irregularities in melting points across Period 3 and down Group II chlorides, *evaluating, with reasons*, which chlorides are most suitable for water treatment and stabilizing concrete, casting molds, and producing heat resistant materials and *predicting* the likely melting point range and industrial suitability of the element X chloride.

Task

As a chemistry student, make a write up you will use to help the company.

Item 4

Kilembe Chemical Works Ltd, in Kasese, is investigating how bonding and molecular structure affect the properties and industrial uses of several compounds used in fertilizer formulation, water purification, and manufacturing of plastics and ceramics.

The *compounds* under study include *water*, *phosphorus trichloride*, *carbon tetrachloride*, *tin(II) chloride*, *ammonia*, *tin(IV) chloride*, *nitrate ion*, and *phosphorus pentachloride*.

It was reported that some compounds such as carbon tetrachloride and phosphorus trichloride are liquids at room temperature and insoluble in water, ammonia and water are highly soluble and have strong intermolecular attractions. tin(II) chloride conducts *electricity* in molten form, while tin(IV) chloride does not.

The manager seeks to know *molecular shape*, *bond type*, and *bond angle* for each substance, use bond type and molecular structure in the compounds *account for their differences* in melting point, solubility, and electrical conductivity. why water and ammonia form hydrogen bonds, and how this affects their boiling points and solubility compared to phosphorus trichloride and phosphorus pentachloride. Compare the bonding and structure of tin(II) chloride and tin(IV) chloride explain their difference in electrical conductivity and melting points.to guide the design of safe storage systems and efficient cooling and purification processes. Evaluate the environmental impacts of using nitrate ions in fertilizers

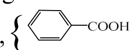
Task

As a chemistry student, make a write up you will use to help the company.

Part II
Attempt **One** *item in this section*

ITEM 5

Nile Chemical Industries Ltd, a chemical manufacturing firm located in Jinja, produces a range of organic-based materials used in plastics, fuels, solvents, and disinfectants. In one of its experiments, 20.0 cm^3 of a gaseous hydrocarbon W was exploded with 150 cm^3 of excess oxygen. After complete combustion, the residual gas measured 110 cm^3, and when concentrated potassium hydroxide solution was added, the volume further decreased to 30 cm^3

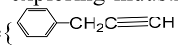
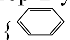
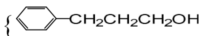
The company noted that ozonolysis of W produced only one compound and that W readily decolourised bromine water. These findings prompted the research team to seek a deeper understanding of W and its possible industrial applications in the synthesis of propan-1-ol, benzoic acid, {  }, 1,2-dibromopentane and 1-chlorobutane.

The company seeks a comprehensive evaluation: to determine the *formulae* of W, draw and name all possible *isomers*, *identify* W with reason(s), and illustrate the mechanism for the reaction between W and bromine water. Additionally, confirm the identity of the gas absorbed by potassium hydroxide solution, *predict* the functional groups of resulting organic compounds, describe *synthetic* pathways to related products, and assess the *environmental* impacts of producing above compounds in industry. You have been contacted for assistance.

Task

As a student of Chemistry, prepare a presentation you will use upon invitation.

ITEM 6

Albertine Oil Fractionation Ltd, an industrial chemical company in the Albertine region, produces fuels, solvents, and organic feedstocks for plastics and chemical synthesis. During a research study, an organic compound P was isolated from a distillation fraction. Complete combustion of a sample of P yielded 8.8 g carbondioxide and 1.8 g water, while 0.100 g of P, vapourised at 273°C and 734 mmHg, occupied 4.46×10^{-2} dm^3. Ozonolysis of P followed by hydrolysis produced a mixed Q of two different compounds, and P was observed to react readily with bromine and concentrated sulphuric acid. The company is exploring industrial applications of these compounds for synthesis of prop-2-yn-1-ylbenzene{  } a component in manufacture of new drugs, benzene{  }solvent, and {  }chemical feedstocks.

The manager seeks to know the formulae of P, all possible structural *isomers*, *identity* of P with reasons, deduce the structure and functional groups of mixture Q, illustrate *mechanisms* for reactions of P with *bromine* and *concentrated sulphuric acid*, , outline *synthetic* pathways from Albertine oil fractions P to synthesis industrial compounds stated, and evaluate the environmental impacts of producing compounds in industry and their mitigations. You have been invited to help the manager.

Task

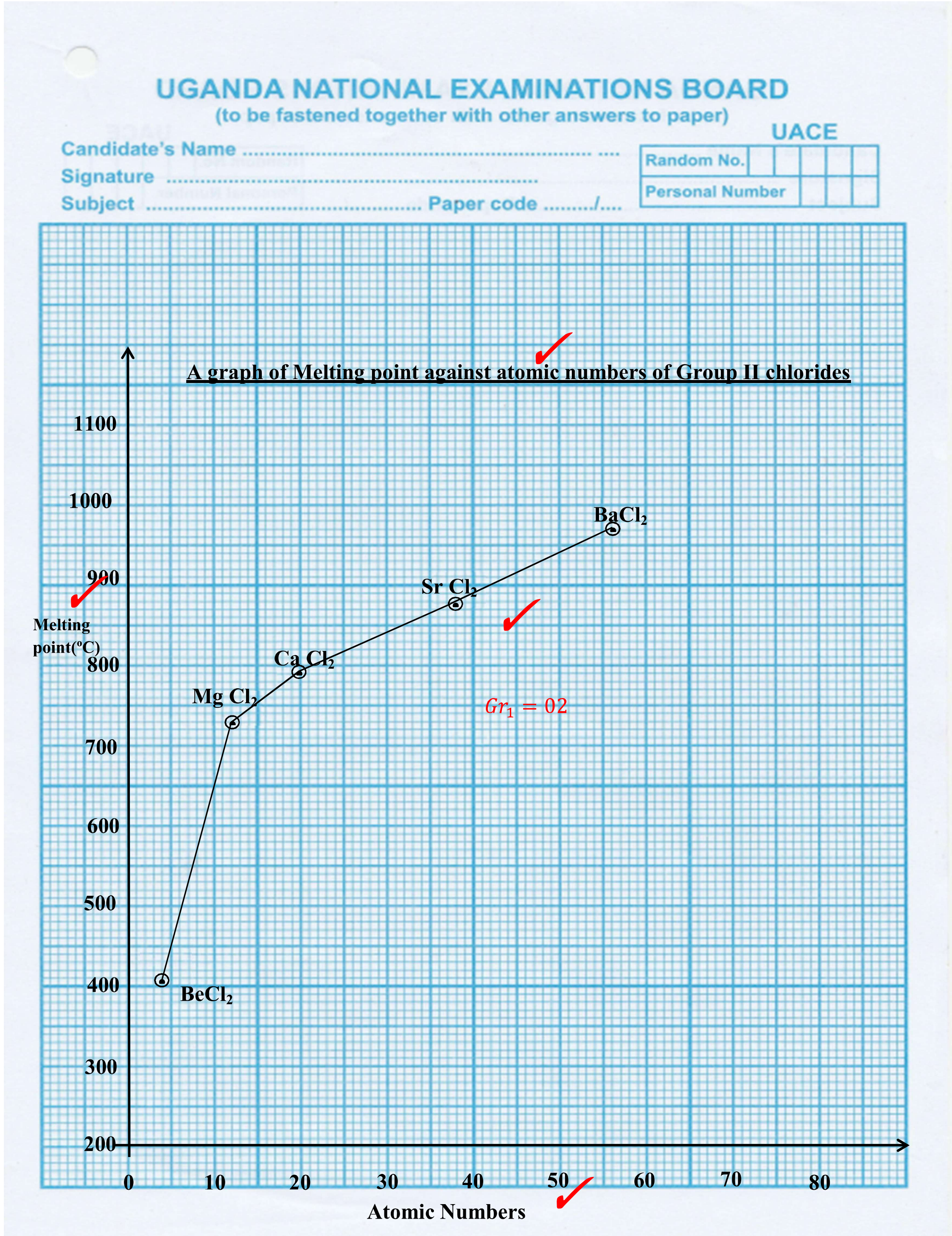
As a student of Chemistry, prepare a presentation you will use to help the firm.

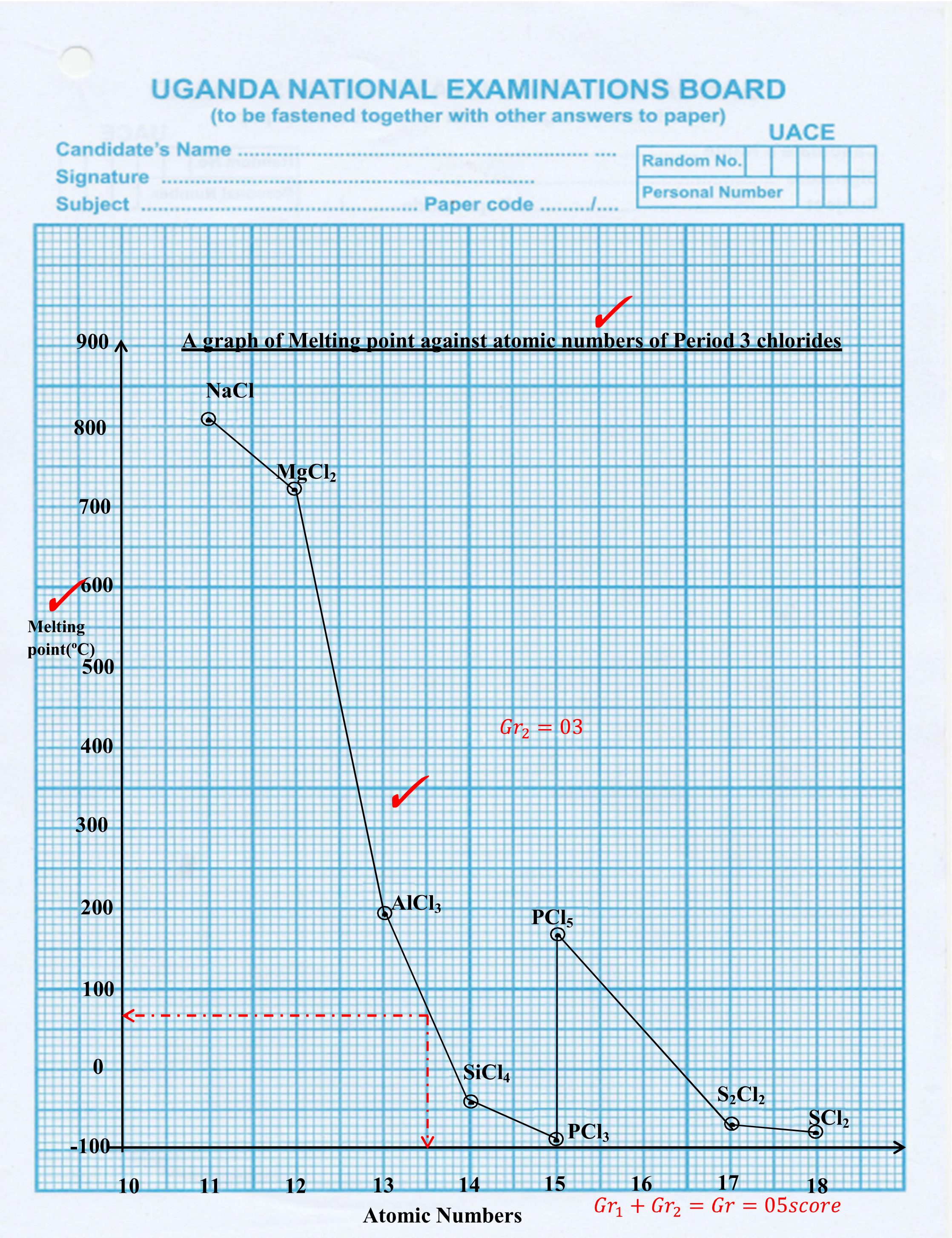
THE PERIODIC TABLE

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	35.4 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 Te 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 Ti 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 68	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

Turn Over





3. **Trend down group (II) chlorides;**

*Melting point **increases** from beryllium chloride to barium chloride* ✓Tr_1

Reason;

*The **cationic radius increases**, **charge density** and **polarising power** ✓R_1 of the cations **decrease**, and **ionic character increases**, requiring an increasing amount of energy to **break the increasingly strong ionic bonds.*** ✓R_1

Irregularities;

*The melting point of **beryllium chloride** is **very low** ✓R_1 compared to other chlorides because the beryllium ion has a **very small ionic radius**, **high polarising power** and **high charge density** making beryllium chloride predominantly **covalent**. A low amount of energy is required to **break the covalent bond**.* ✓R_1

Trend across period 3 chlorides; ✓Tr_2

*Melting points of the chlorides generally **decrease** from sodium chloride to sulphur dichloride.*

Reason;

*Sodium chloride and magnesium chloride have **giant ionic** ✓R_2 **structures** held by **strong ionic bonds** which require a **high** ✓R_2 **amount of energy to break**. The decrease in melting point from sodium chloride to magnesium chloride is because magnesium ion has a **smaller ionic radius**, **higher charge density** and **higher polarising power** ✓R_2 than sodium ion making magnesium chloride **less ionic** than sodium chloride. Aluminium chloride has a **lower** ✓R_2 **melting point** than magnesium chloride because among the cations, the aluminium ion has the **smallest ionic radius**, a **very high charge density** and **high polarising power**. Aluminium chloride is therefore predominantly **covalent**. Silicon tetrachloride is **covalent** and its molecules are held by **weak Van der Waals' forces of attraction that require a low** ✓R_2 **amount of energy to break** hence a low melting point. Phosphorus trichloride has a **simple molecular structure** thus a low melting point.* ✓R_2 *Disulphur dichloride and sulphur dichloride form simple molecular structures held by weak Van der Waals' forces of attraction.*

Irregularities;

*Phosphorus pentachloride has an **abnormally high** ✓R_2 melting point because at ordinary temperatures it consists of PCl_4^+ + and PCl_6^- ions hence exhibiting ionic character.*

$Tr_1 + Tr_2 + 4Tr_1 + 4Tr_2 = T_r = 08scores$

Evaluation and choice;

*The chlorides $BaCl_2$, $SrCl_2$, $CaCl_2$, $MgCl_2$, and NaCl are all **ionic** ✓E_S compounds, due to their **very high melting points**, which indicate strong electrostatic forces between metal cations and chloride anions.*

However,

*$CaCl_2$ and $MgCl_2$ are ideal for **water treatment** because they are **highly soluble** and **less toxic**, where they effectively release metal ions that remove impurities through precipitation.* ✓Ed

*$CaCl_2$ is the most suitable chloride in **construction purposes** for stabilizing concrete because it is **hygroscopic**, absorbs moisture from the environment, and accelerates cement setting, thereby increasing the strength and durability of the concrete structure.* ✓Ed

*$BaCl_2$ and $SrCl_2$, are the most stable for **heat-resistant materials and casting molds** used in metal extraction processes. due to **highest melting points** and **strongest ionic bonds** ✓Ed among all chlorides listed, they can withstand extremely high temperatures without decomposing,*

making them reliable choices for high-heat industrial applications.

$1E_S + 3E_d = E_v = 04scores$

Prediction of melting point, nature and industrial suitability of chloride X;

Chloride of element X exists between AlCl₃ and its melting point is likely to be between ***192*** *and* ***−68 °C,*** *approximately* ***70°C.*** Pr

Likely properties of XCl_n; ***partial covalent molecular*** Pr ***character*** *rather than a full ionic lattice. Possibly a* ***low-molecular*** *covalent chloride.*

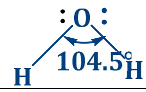
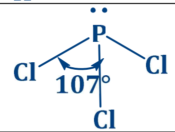
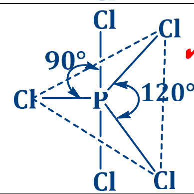
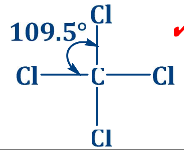
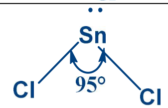
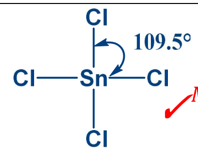
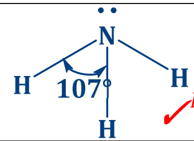
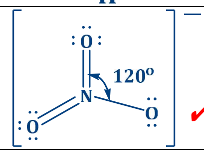
Industrial suitability of XCl_n;

X is ***unsuitable*** *for water treatment, concrete stabilization and heat-resistant structural materials since it is* ***covalent.*** Pr

X can be used as a Lewis acid (like AlCl₃) in ***organic synthesis*** *or as an* ***intermediate*** Pr *in chemical manufacture, but not as a refractory or concrete stabilizer.*

$3Pr = P_r = 03scores$

4. Molecular shape, bond type, and bond angle;

Name of substance	Molecular structure	Name of molecular shape	Bond type	Bond angle
Water	 Mi	*bent shape/ V-shape* Ni	*Polar covalent* Bi	104.5° Ai
Phosphorus trichloride	 Mi	*trigonal pyramidal* Ni	*Polar covalent* Bi	107° Ai
Phosphorus pentachloride	 Mi	*trigonal bipyramidal* Ni	*Covalent* Bi	90° and 120°. Ai
Carbon tetrachloride	 Mi	*tetrahedral* Ni	*Non-polar covalent* Bi	109.5°. Ai
Tin(II) chloride	 Mi	Bent shape/ V-shape Ni	*Ionic with covalent character* Bi	95° Ai
Tin(IV) chloride	 Mi	*tetrahedral* Ni	*Pure covalent* Bi	109.5°. Ai
Ammonia	 Mi	*trigonal pyramidal* Ni	*Polar covalent* Bi	107° Ai
Nitrate ion	 Mi	*trigonal planar* Ni	*Covalent with resonance delocalization* Bi	120° Ai

$9Mi + 9Ni + 9Bi + 9Ai = V_p = 08scorers$

Account for differences in melting point, solubility, and electrical conductivity:

The ***differences in solubility, melting point, and conductivity*** *among these compounds are due to the type of bonding and molecular structure.*

Ionic compounds *($SnCl_2$, nitrate salts) have* ***high melting points*** *and* ***conduct electricity when molten or in solution****, while* ***covalent molecular compounds*** *(CCl_4, PCl_3, $SnCl_4$) have* ***low melting points****, are* ***non-conductors****, and are* ***insoluble*** *in water.*

Hydrogen bonding *in water and ammonia leads to* ***strong intermolecular attractions****, giving them higher boiling points than similar covalent molecules like PCl_3 and PCl_5.*

$3R_3 = R_3 = 03scores$

Comparison of boiling points and solubility of water and ammonia to those of phosphorus trichloride, phosphorus pentachloride and carbon tetrachloride;

Water is a ***bent polar molecule*** *with an angle of* ***104.5°****, and ammonia is* ***trigonal pyramidal*** *with an angle of* ***107°****; both have* ***polar covalent bonds*** *and form* ***hydrogen bonds*** *between molecules. Hydrogen bonding gives them* ***high boiling points*** *and makes them* ***highly soluble in water****.*

In contrast, ***PCl_3*** *(trigonal pyramidal, 107°) and* ***PCl_5*** *(trigonal bipyramidal, 90° & 120°) are* ***covalent*** *and* ***cannot form hydrogen bonds****. They have* ***low melting points****, are* ***liquid or volatile solids****, and* ***do not dissolve*** *in water because they hydrolyse, producing* ***HCl*** *and* ***phosphoric acids****.*

$3R_4 = R_4 = 03scores$

Comparison of electrical conductivity and melting points of tin(II) and tin(IV) chloride;

Tin(II) chloride ($SnCl_2$) is ***ionic with some covalent character****, forming a* ***bent structure*** *(≈95°) and a* ***solid*** *at room temperature. It* ***conducts electricity when molten*** *because it contains* ***mobile ions (Sn^{2+} and Cl^-)****.*

Tin(IV) chloride ($SnCl_4$), on the other hand, is ***tetrahedral (109.5°)*** *and* ***purely covalent****, existing as a* ***molecular liquid*** *that* ***does not conduct electricity****. Its weak molecular forces give it a* ***lower melting point*** *than $SnCl_2$.*

$3R_5 = R_5 = 03scores$

$R_3 + R_4 + R_5 = R = 09scores$

Evaluation of the environmental impacts of using nitrate ions in fertilizers;

In fertilizer use, ***nitrate ions (NO_3^-)*** *improve plant growth.*

However when overused, cause ***environmental pollution*** *since Nitrates are* ***highly soluble*** *and can* ***leach into groundwater****, causing* ***eutrophication*** *and* ***oxygen depletion*** *in water bodies, leading to fish deaths and* ***blue-baby syndrome*** *in humans. Mitigated by controlled, fertilizer application, and use of organic manure.*

$1di + 1de + 1dm = D_3 = 03\ Scores$

5. **Formulae of W ;**

$$C_xH_y(g) + \left(x+\frac{y}{4}\right)O_2(g) \longrightarrow xCO_2(g) + \frac{y}{2}H_2O(g)$$

Volume of hydrocarbon $= 20cm^3$

Volume of carbon diode produced $= 110 - 30 = \mathbf{80cm^3}$

Volume of oxygen used up in reaction = original volume − volume unreacted $= 150 - 30 = \mathbf{120cm^3}$

Volume of hydrocarbon × x = volume of carbondioxide

$$\Rightarrow 20x = 80$$
$$\therefore x = {}^{80}/_{20} = \mathbf{4}$$

Also volume of hydrocarbon $\times \left(x+\frac{y}{4}\right)$ *= volume of oxygen used up*

$$\Rightarrow 20\left(4+\frac{y}{4}\right) = 120$$
$$\therefore\ y = (6-4)\times 4 = 8$$

$\therefore$ ***The formula of W is C_4H_8***

Possible isomers, identity of W with reason(s)

$CH_3CH_2CH = CH_2$

$CH_3CH = CHCH_3$

Since ozonolysis of W produced only one compound, it indicates that it has a symmetrical carbon-carbon double bond.

$$CH_3CH = CHCH_3 \xrightarrow[2.\ H_2O,\ Zn,\ CH_3COOH]{1.\ O_3,\ CCl_4,\ <20^0C} 2CH_3CHO$$ ***, One compound produced is ethanal***

Therefore, W is $CH3CH = CHCH3$ but-2-ene

Comfirmatory Test for Carbon dioxide;

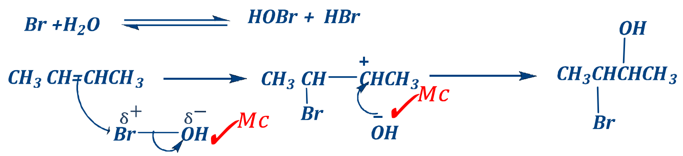
If the gas is CO_2, KOH will absorb it so the ***limewater remains clear*** *(no milky cloud), because CO_2 was removed by the KOH beforehand. But the gas is not absorbed by KOH, the limewater will still* ***go milky****.*

$5CA + 2I = F = 06\ Scores$

Mechanism for reaction between W and bromine water;

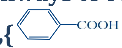
$$CH_3CH = CHCH_3 \xrightarrow{Br_2/H_2O} CH_3CHBrCH(OH)CH_3 + HBr$$

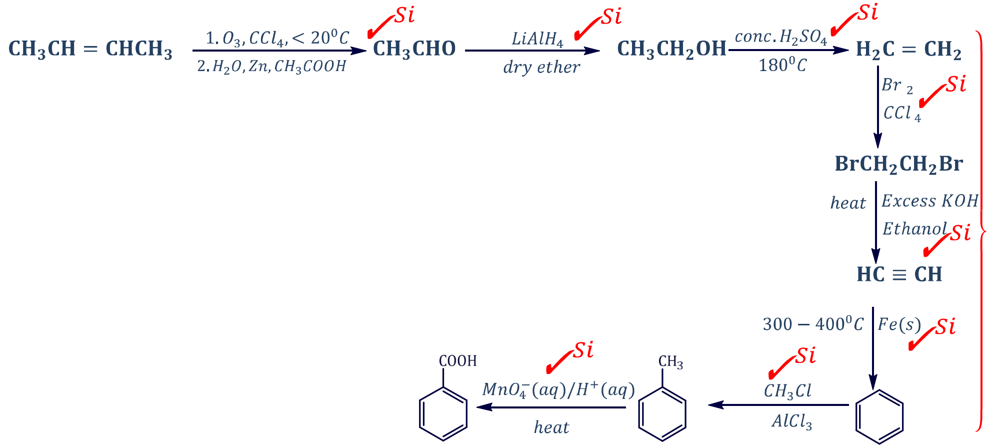
Mechanism



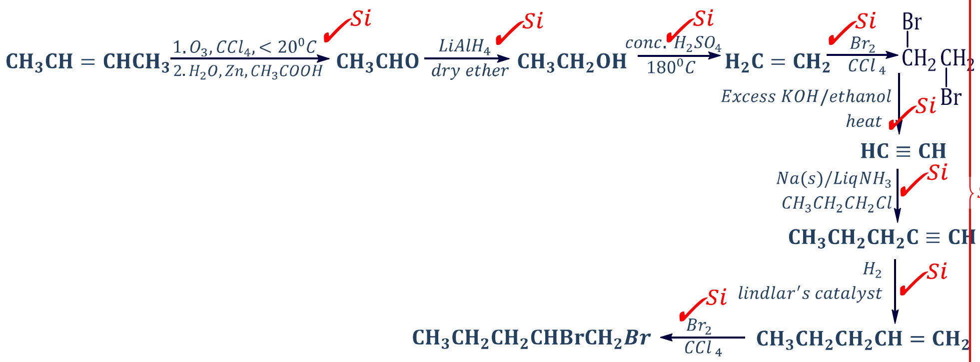
$2Mc = Mc = 02\ Scores$

Synthetic **pathways to related products;**

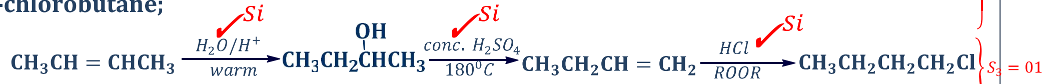
Benzoic acid,{  **};**



1,2-dibromopentane;



1-chlorobutane;



$S_1 + S_2 + S_3 = S = 11\ Scores$

Environmental impacts of producing above compounds in industry;

When burnt, they give off poisonous gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to ***air pollution****,* ***acid rain****,* ***respiratory problems****, and* ***global warming****. The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid* ***open-air burning*** *and instead use* ***safe chemical disposal methods****.*

$1di + 1de + 1dm = D_3 = 03\ Scores$

6. Formulae of P ;

$\boldsymbol{Mass\ of\ carbondiode\ formed = 8.8g \quad and\ mass\ of\ water\ formed = 1.8}$

$\boldsymbol{mass\ of\ carbon = \frac{12}{44} \times 8.8 = 2.4g}$

$\boldsymbol{mass\ hydrogen = \frac{2}{18} \times 1.8 = 0.2g}$

Element	C	H
%composition	2.4	0.2
Moles	$\frac{2.4}{12} = \mathbf{0.2}$	$\frac{0.2}{1} = \mathbf{0.2}$
Simplest ratio	$\frac{0.2}{0.2} = 1$	$\frac{0.2}{0.2} = \mathbf{1}$

$\therefore$ *Empirical formula is* **CH**

Mass of p vaporised $= 0.100g$

At a Temperature $T = 273 + 273 = 546K$

At a Pressure $P = \left(\frac{734}{760} \times 1\right)\ atm$

At a Volume $V = 4.46 \times 10^{-2} dm^3$

Note: 1. *we use;* $\boldsymbol{R = 0.0821}$ $L \cdot atm/(mol \cdot K)$, *when, P is in atm and V is in litre/*dm^3

2. *we use;* $\boldsymbol{R = 8.314\ J/(molK)}$, *when, P is in Pa and Volume is in* m^3

From ideal gas law $PV = nRT$

$$PV = \frac{m}{M_r}RT$$

$$\Rightarrow M_r = \frac{mRT}{PV} = \frac{0.100 \times 0.0821 \times 546}{\left(\frac{734}{760} \times 1\right) \times 4.46 \times 10^{-2}} = \frac{4.48266}{0.04307} \approx \mathbf{104g}$$

$\therefore \mathbf{(CH)_n = 104}$

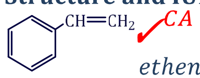
$(12 \times 1 \times n) + (1 \times 1 \times n) = 104$

$13n = 104$

$n = \frac{104}{13} = 8$

$\therefore$ *Molecular formula is* $\mathbf{C_8H_8}$

Structure and IUPAC Name;

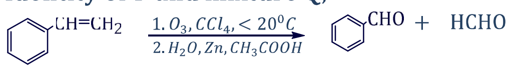


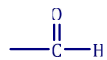
ethenylbenzene

Structural isomers;

P *has no other strural isomers.*

Identity of P and mixture Q;

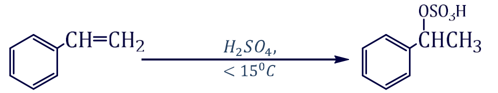


Q *is a mixture of benzylaldehyde and methanal with functional group* 

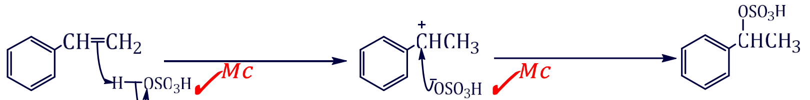
$5CA + 2I = F = 06$ *Scores*

Mechanisms for reactions of P with bromine and concentrated sulphuric acid;

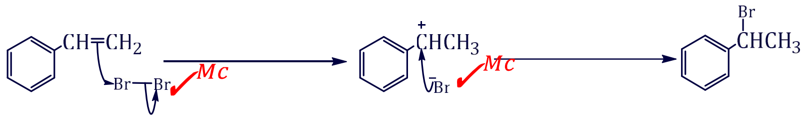
With concentrated sulphuric acid;



Mechanisim



With bromine;

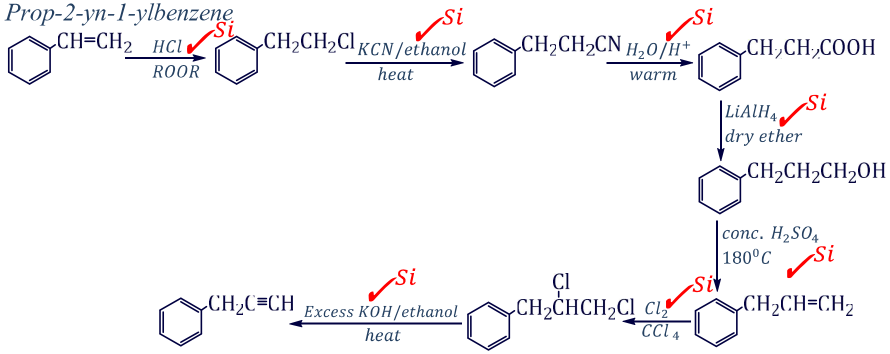


$M_c = 02$

$4Mc = Mc = 02$ *Scores*

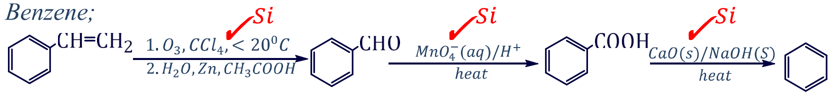
Synthetic pathways from Albertine oil fractions P to synthesis industrial compounds ;

Prop-2-yn-1-ylbenzene



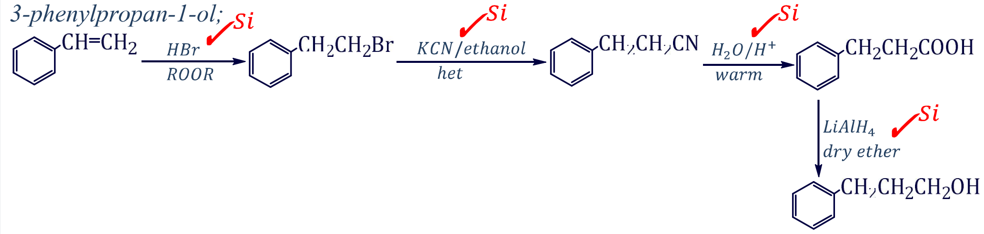
$S_1 = 05$

Benzene;



$S_3 = 01$

3-phenylpropan-1-ol;



$S_1 = 05$

$S_1 + S_2 + S_3 = S = 03$ *Scores*

Environmental impacts of producing above compounds in industry;

When burnt, they give off poisonous gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to ***air pollution****,* ***acid rain****,* ***respiratory problems****, and* ***global warming****. The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid* ***open-air burning*** *and instead use* ***safe chemical disposal methods****.*

di de dm

1di+1de+1dm=D₃=03 Scores

END

2025

It is All about mindset change

Tr. Julius W. M 0787093081

Candidate's Name: ....SAMPLE SCORE..

Signature: .... | STREAM: | | | | | | | |

525/1
CHEMISTRY
Paper 1
Nov./Dec.
2025
$2^1/_2$ hours

END OF YEAR ASSESSMENT 2025

Uganda Advanced Certificate of Education

S.5 CHEMISTRY

Paper 1

(Set II)

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

This paper has **two** *sections* **A** *and* **B.**

Section **A** *has two compulsory items while* **B** *has two parts* **Part I** *and* **Part II**

Each of part I and part II has two items, Answer only **one** *from each.*

Answers to Section **A** ***must*** *be written in the spaces provided and Section* **B** ***must*** *be written in the answer booklet(s) provided*

Answer four in all.

Where necessary use,

Molar gas volume at s.t.p = 22.4dm³

FOR EXAMINER'S USE ONLY				
ITEM	CODE		SCORE	
1	F_1		04	
	C_1		04	
	C_2		06	
	C_3		03	
	D_1		03	
2	E_c		06	
	C_4		02	
	C_5		04	
	E_1		05	
	D_2		03	
3/4	G_r	V_p	05	08
	T_r	R	08	09
	E_v	D_3	04	03
	P_r		03	
5/6	F_2		06	
	Mc		02	
	S		11	
	D_3		03	
TOTAL			80	

Key

C_1, C_2, C_3, C_4, C_5: Calculations
D_1, D_2, D_3: Danger
E_c: Energy Cycle
E_V: Evaluation
G_r: Graphing
T_r: Trend
P_r: Pridiction
F: Formula
Mc: Mechanism
S: Synthesis
V_p: VSEPR theory
R: Reason

SECTION A

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

ITEM 1

During a rapid response investigation near Kitezi landfill, the Water Quality Surveillance Unit discovered heavy metal contamination in a borehole supplying a large number of households.

A fragment of metallic lead from a nearby illegal battery recycling site was analysed using a mass spectrometer. The detector registered four isotopic signals with currents of *0.16 mA (mass 204), 2.72 mA (mass 206), 2.50 mA (mass 207)* and *5.92 mA (mass 208)*. The investigation team was briefed that these readings can help determine an accurate relative atomic mass (RAM) of lead.

Further laboratory tests on the contaminated water revealed that the dissolved poisonous salt responsible for the lead toxicity contained *62.6%* lead, *8.45%* nitrogen, and the rest oxygen molar mass of the salt was reported as *331.22* g/mol.

The concentration of the dissolved salt in the borehole water was measured as 0.90 mol dm⁻³, and the borehole supplies approximately 1200 litres of water per day. Chemists concluded that this salt can be removed by treating the water with sodium sulphate solution, which reacts to produce insoluble lead(II) sulphate.

In extreme contamination cases, *0.45 moles* of nitrogen dioxide gas was released during side reactions at 28°C and 98 kPa. To protect public health, the Ministry has assigned your team to analyse the data and provide a complete stoichiometric and methodological evaluation of the situation.

Task:

As a learner of Chemistry, help the company to know;

(a) The relative atomic mass of lead. **(RAM).**

$Total\ current = 0.16 + 2.72 + 2.50 + 5.92 = 11.3mA$ ✓CA

$Percentage\ abundance\ of\ lead - 204 = \left(\frac{0.16}{11.3} \times 100\right) = 1.42$

$Percentage\ abundance\ of\ lead - 206 = \left(\frac{2.72}{11.3} \times 100\right) = 24.07$ ✓CA

$Percentage\ abundance\ of\ lead - 207 = \left(\frac{5.92}{11.3} \times 100\right) = 22.12$

$Percentage\ abundance\ of\ lead - 208 = \left(\frac{2.72}{11.3} \times 100\right) = 52.40$

$R.A.M = \sum Relative\ isotopic\ mass \times proportion\ of\ isotope$

$R.A.M = \left(204 \times \frac{1.42}{100}\right) + \left(206 \times \frac{24.07}{100}\right) + \left(207 \times \frac{22.12}{100}\right) + \left(208 \times \frac{52.4}{100}\right)$ ✓CA

$R.A.M = 207.26$ ✓CA

$4CA = C_1 = 04\ scores$

Turn Over

(b) To determine the molecular formula of the poisonous salt in water.

$Lead = 62.6\%, Nitrogen = 8.45\%, Oxygen = 100 - (62.6 + 8.45) = 28.95\%$ CA

Element	Pb	N	O
%composition	62.6	8.45	28.95
Moles	$\frac{62.6}{207.26} = 0.302$	$\frac{8.45}{14} = 0.604$	$\frac{28.95}{16} = 1.809$
Simplest ratio	$\frac{0.302}{0.302} = 1$	$\frac{0.604}{0.302} = 2$	$\frac{1.809}{0.302} = 6$

CA

Empirical formula of salt is PbN_2O_6 F

$(PbN_2O_6)n = 303.3$

$(207.26 \times 1n) + (14 \times 2n) + (16 \times 6n) = 331.22 \quad \therefore n = 1$

Molecular formula of the salt is $Pb(NO_3)_2$ F Name: *Lead(ii)nitrate* NA

$2CA + 2F + NA = F_1 = 04\ Scores$

(c) To calculate the mass of lead(II)sulphate formed if all the dissolved salt was removed

$0.9moll^{-1}$ *means; 1litre of borehole water contain 0.9moles of* $Pb(NO_3)_2$ CA

1200litres of borehole water contain $\left(\frac{0.9 \times 1200}{1}\right)$ CA

$= 1080 moles\ of\ Pb(NO_3)_2$

From equation: $Pb(NO_3)_2(aq) + Na_2SO_4(aq) \longrightarrow PbSO_4(s) + 2NaNO_3(aq)$ CA

1mole of $Pb(NO_3)_2$ *produces 1mole of* $PbSO_4$

1080moles of $Pb(NO_3)_2$ *produce* $\left(\frac{1}{1} \times 1080\right)$ *moles of* $PbSO_4$. $= 1080 moles$ CA

Molar mas of $PbSO_4$ *is* $(207 \times 1) + (32 \times 1) + (16 \times 4) = 303g$ CA

1mole of $PbSO_4$ *weigh 303g*

$\therefore$ *1080moles of* $PbSO_4$ *weigh* $\left(\frac{303 \times 1080}{1}\right) = 327240g$ *or* $3.27 \times 10^5 kg$ *of* $PbSO_4$ CA CA

$7CA = C_2 = 06\ scores$

(d) Know the volume of gas produced using the gas law.

From gas law: $PV = nRT; P = 98 \times 10^3 pa, T = (28 + 273) = 301k\ and\ R = 8.314$ CA

Note: *We use*;

1. $R = 0.0821\ \mathrm{L \cdot atm/(mol \cdot K)}$, *when, P is in atm and V is in litre/*dm^3
2. $R = 8.314\ J/(molK)$, *when, P is in Pa and Volume is in* m^3

$\therefore V = \frac{nRT}{P} = \left(\frac{0.45 \times 8.314 \times 301}{98 \times 10^3}\right)$ CA

$= 0.0115m^3$ CA

$3CA = C_3 = 03\ scores$

(e) Environmental impacts of the gaseous or aqueous system and their mitigations.

Nitrogen dioxide contributes to ***global warming*** *when it accumulates in the atmosphere, since it traps heat and creating the greenhouse effect, leading to rising temperatures hence* ***drought****. This can be mitigated by using catalytic converters to reduce it into less harmful substances such as nitric acid.* di de dm

Nitrogen dioxide causes ***respiratory problems*** *and* ***poor air quality.*** *When inhaled, it irritates the lungs and reduces oxygen uptake, increasing cases of* ***asthma*** *and* ***bronchitis.*** *Using personal protective gears like gas masks during scientific investigations.*

$di + de + dm = D_1 = 03 scores$

Item 2

A recent technical brief from Namanve Metals & Ceramics Corporation (NMCC), a rapidly expanding Ugandan manufacturer of refractory linings and water-treatment chemicals, revealed that the company is designing a *high-temperature resistant* coating for industrial furnaces used in steel rolling mills in Jinja and Tororo.

The project requires evaluating aluminium oxide and sodium fluoride, in order to make best choice of the most stable substance during formation to apply in *ceramics, abrasives,* and *furnace linings*.

At the same time, to select a substance in which temperature control depends on dissolution in water to use as a *cooling and stabilising agent* in chemical preparation units. The research division has sourced pure aluminium from scrap recycling operations in Namanve and oxygen gas from Uganda Oxygen Ltd. Sodium and fluorine also have been sourced from Lake Katwe in Kasese.

Thermochemical data obtained from an industrial materials report show the following values

$Al(s) \rightarrow Al(g)$: +330 kJ mol⁻¹	$Na(s) \rightarrow Na(g)$: $+109\ kJ\ mol^{-1}$
$Al(g) \rightarrow Al^{+}(g) + e^{-}$: +578 kJ mol⁻¹	$Na(g) \rightarrow Na^{+}(g) + e^{-}$: $+494\ kJ\ mol^{-1}$
$Al(s) \rightarrow Al^{2+}(g) + 2e^{-}$: +1820 kJ mol⁻¹	$F_2(g) \rightarrow 2F(g)$: $+158\ kJ\ mol^{-1}$
$Al(s) \rightarrow Al^{3+}(g) + 3e^{-}$: +2750 kJ mol⁻¹	$F(g) + e^{-} \rightarrow F^{-}(g)$: $-328\ kJ\ mol^{-1}$
$2Al^{3+}(g) + 3O^{2-}(g) \rightarrow Al_2O_3(s)$: −15346.5kJ mol⁻¹	$Na(s) + \frac{1}{2}F_2(g) \rightarrow NaF(s)$: $-569\ kJ\ mol^{-1}$
$\frac{1}{2}O_2(g) \rightarrow O(g)$: +249 kJ mol⁻¹	$Na^{+}(g) + (aq) \rightarrow Na^{+}(aq)$: $-406\ kJmol^{-1}$
$O(g) \rightarrow O^{-}(g)$: −142 kJ mol⁻¹	$F^{-}(g) + (aq) \rightarrow F^{-}(aq)$: $-505\ kJmol^{-1}$
$O(g) \rightarrow O^{2-}(g)$: +798 kJ mol⁻¹	

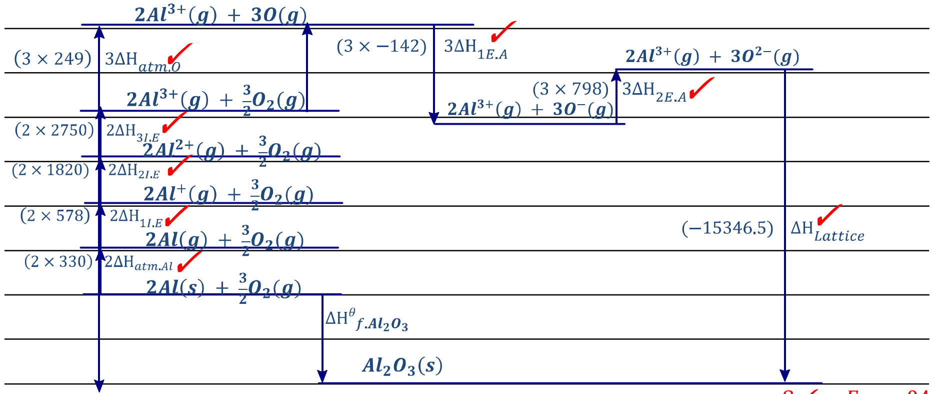
Preliminary tests by NMCC's laboratory team indicated that dissolution of NaF produces a measurable temperature change. To ensure that the chosen materials are safe, energy-efficient, and suitable for industrial use, the technical manager has invited you.

Task

As a student of chemistry, help the manager;

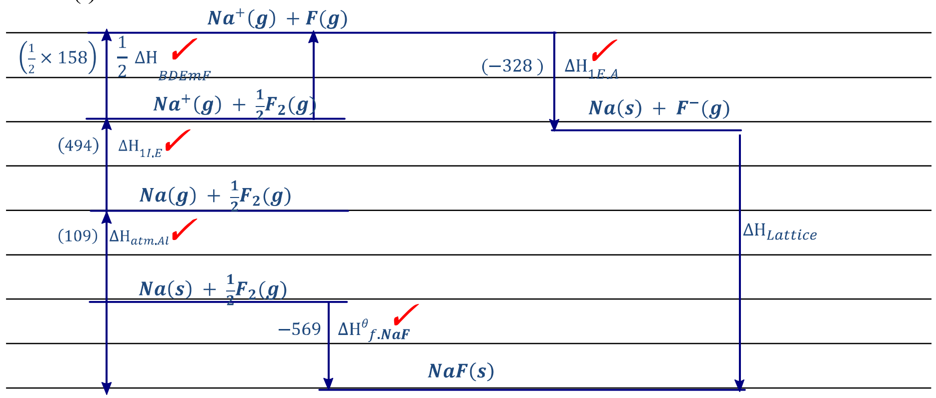
(a) Analyse the data to construct an energy level diagram for the changes in the:

(ii) Formation of aluminium oxide.



8✓ = Ec_1 = 04scores

(i) Formation of sodium fluoride.



5✓ = Ec_2 = 02scores

$Ec_1 + Ec_2 = Ec$ = 06 scores

(b) Use the energy cycles constructed to calculate;

(i). Enthalpy of formation of aluminium oxide.

From Hess' law;

$\Delta H^{\theta}{}_{f.Al_2O_3} = 2\Delta H_{atm.Al} + 2\Delta H_{1I.E} + 2\Delta H_{2I.E} + 2\Delta H_{3I.E} + 3\Delta H_{atm,O} + 3\Delta H_{1.E.A} + 3\Delta H_{2E.A} + \Delta H_{Lattice}$

$\Delta H^{\theta}{}_{f.Al_2O_3} = (2\times330) + (2\times578) + (2\times1820) + (2\times2750) + (3\times249) + (3\times-142) + (3\times798) + (-15346.5)$ ✓CA

$\therefore \Delta H^{\theta}{}_{f.Al_2O_3} = -1675.5kjmol^{-1}$ ✓CA

2CA = C_4 = 02 Scores

(ii). Lattice energy of sodium fluoride and its enthalpy of solution.

From Hess' law;

$\Delta H^{\theta}{}_{f.NaF} = \Delta H_{atm.Al} + \Delta H_{1I.E} + \frac{1}{2}\Delta H_{BDE.F} + \Delta H_{1.E.A} + \Delta H_{Lattice}$ ✓CA

$\Delta H_{Lattice} = -569 - \left(109 + 494 + \frac{1}{2}\times158 - 348\right) = -923kjmol^{-1}$ ✓CA

$\Delta H_{Solution.NaF} = \Delta H_{Lattice} + \Delta H_{hydration.NaF}$

$\Delta H_{Solution.NaF} = \Delta H_{Lattice.NaF} + (\Delta H_{hydration.Na^+} + \Delta H_{hydration.F^-})$

$\Delta H_{Solution.NaF} = +923 + (-406 + -505)$ ✓CA

$\therefore \Delta H_{Solution.NaF} = +12kjmol^{-1}$ ✓CA

4CA = C_5 = 04 Scores

(c) (i) Evaluate the industrial usefulness of the two systems to advise the manager which substance is most suitable for furnace lining and cooling applications, giving reasons. Ev

Aluminium oxide *is the best choice for ceramics, abrasives and furnace linings due to* ***a very large exothermic enthalpy of formation*** *of* $-1675.5kjmol^{-1}$*, thus extremely* ***thermal dynamically stable, heat-resistant*** *and* ***chemically inert****.* Er

Whereas:

Sodium fluoride *can be choosen for cooling applications due to it* ***endothermic enthalpy solution*** *of* $+12kjmol^{-1}$ *, meaning it* ***absorbs a heat from surrounding equipment when dissolving in water****. However, its cooling effect is small because of low heat absorption.* Ev Er

(ii). State any other important industrial use of aluminium oxide.

- *Used as an* ***electrical Insulator*** *in electrical and electronic devices; due to good electrical resistance and heat stability.* U
- *Production of* ***Aluminium*** *Metal during the electrolytic processes due to its high purity .* U
- *Used as a* ***catalyst in petroleum refining*** *and chemical manufacture due to its high surface area and chemical stability.* U

$2Ev + 2Er + 1U = E_{v1} = 05\ Scores$

(d) Suggest the possible impacts and mitigations of the substances to the environment.

- *Aluminium Oxide can* ***contaminate soil*** *if waste powder poorly disposed. Since fine particles are insoluble they settle in soil,* ***altering pH*** *reduce plant yields. Mitigated by recycling waste powders and using dust filter systems.* di de dm
- *Sodium Fluoride leads to* ***water pollution*** *when in high amounts. Since fluoride ions are* ***mobile and toxic to plants, aquatic organisms, and wildlife, and can corrode infrastructure****. Mitigated by proper wastewater treatment before releasing it to surrounding water streams.*

$1di + 1de + 1dm = D_2 = 03\ Scores$

SECTION B

Part I

Attempt **One** *item in this section*

Item 3

A manufacturing company in Uganda, Victoria Industrial Chemicals Ltd, produces industrial grade materials for construction, ceramics, and high-temperature processes. The company has been advised that substances suitable for furnace linings, kiln refractory materials, and heat-resistant construction components must have high thermal stability and bonding character.

The engineering department is evaluating two types of available compounds from Period 3 elements: oxides and chlorides, to select the most suitable materials for industrial applications. The baseline requirement is that a suitable substance must remain solid above 1400 °C, must have strong ionic bonding, and be mechanically stable under operational conditions. The data provided for Period 3 oxides and chlorides are shown below:

period	Period 3 chlorides and oxides							
Chlorides Oxides	$NaCl$ Na_2O	$MgCl_2$ MgO	$AlCl_3$ Al_2O_3	$SiCl_4$ SiO_2	PCl_3 P_4O_6	PCl_5 P_4O_{10}	S SO_3	Cl_2 Cl_2O_7
Melting pt of chlorides/°C	808	714	192	-68	-92	160	-76	-80
Melting pt of Oxides/°C	1275	2827	2007	1607	24	560	30	−91

The engineering team requires a comparative analysis of oxides and chlorides to determine which compounds are most suitable to serve the purpose.

They seek guidance on which properties make a substance "good", and how to evaluate *graphs* in melting points of the available compounds to explain *trends* in order to guide *selection* of suitable compounds for the intended industrial purpose, and to *predict* the likely melting point and industrial suitability of an oxide of element X between Al_2O_3 and SiO_2.

Task

As a chemistry student, make a write up you will use to help the company.

Item 4

Kilembe Kilembe Chemical Works Ltd, Kasese, is studying how bonding and molecular structure affect the properties and industrial uses of compounds in fertilizers, water purification, and plastics and ceramics manufacture. The compounds include water, ammonia, phosphorus trichloride, phosphorus pentachloride, carbon tetrachloride, tin(II) chloride, tin(IV) chloride, and nitrate ions. It was reported that some, like carbon tetrachloride and phosphorus trichloride, are liquids and insoluble in water, while water and ammonia are highly soluble with strong intermolecular attractions. Tin(II) chloride conducts electricity when molten, whereas tin(IV) chloride does not.

The manager seeks information on *molecular shape*, *bond type*, and *bond angle*, and how these explain bonding type *account for differences* in melting point, solubility, and electrical conductivity. *Compare* boiling points and solubility of water and ammonia to those of phosphorus trichloride, phosphorus pentachloride and carbon tetrachloride. *Compare* electrical conductivity and melting points of tin(II) and tin(IV) chloride. And evaluate environmental impacts of nitrate ions in fertilizers. You have been contacted for assistance.

Task;

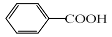
As a chemistry student, make a write up you will use to help the company.

Part II

Attempt **One** *item in this section*

ITEM 5

Nile Chemical Industries Ltd, a chemical manufacturing firm located in Jinja, produces a range of organic-based materials used in plastics, fuels, solvents, and disinfectants. In one of its experiments, 20.0 cm^3 of a gaseous hydrocarbon W was exploded with 150 cm^3 of excess oxygen. After complete combustion, the residual gas measured 110 cm^3, and when concentrated potassium hydroxide solution was added, the volume further decreased to 30 cm^3

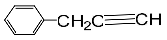
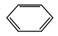
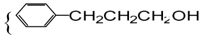
The company noted that ozonolysis of W produced only one compound and that W readily decolourised bromine water. These findings prompted the research team to seek a deeper understanding of W and its possible industrial applications in the synthesis of propan-1-ol, benzoic acid, {}, 1,2-dibromopentane and 1-chlorobutane.

The company seeks a comprehensive evaluation: to determine the *formulae* of W, draw and name all possible *isomers*, *identify* W with reason(s), and illustrate the mechanism for the reaction between W and bromine water. Additionally, confirm the identity of the gas absorbed by potassium hydroxide solution, *predict* the functional groups of resulting organic compounds, describe *synthetic* pathways to related products, and assess the *environmental* impacts of producing above compounds in industry. You have been contacted for assistance.

Task:

As a student of Chemistry, prepare a presentation you will use upon invitation.

ITEM 6

Albertine Oil Fractionation Ltd, an industrial chemical company in the Albertine region, produces fuels, solvents, and organic feedstocks for plastics and chemical synthesis. During a research study, an organic compound P was isolated from a distillation fraction. Complete combustion of a sample of P yielded 8.8 g carbondioxide and 1.8 g water, while 0.100 g of P, vapourised at 273°C and 734 mmHg, occupied 4.46×10^{-2} dm^3. Ozonolysis of P followed by hydrolysis produced a mixed Q of two different compounds, and P was observed to react readily with bromine and concentrated sulphuric acid. The company is exploring industrial applications of these compounds for synthesis of prop-2-yn-1-ylbenzene {} a component in manufacture of new drugs, benzene {}solvent, and {}chemical feedstocks.

The manager seeks to know the formulae of P, all possible structural *isomers*, *identity* of P with reasons, deduce the structure and functional groups of mixture Q, illustrate *mechanisms* for reactions of P with *bromine* and *concentrated sulphuric acid*, , outline *synthetic* pathways from Albertine oil fractions P to synthesis industrial compounds stated, and evaluate the environmental impacts of producing compounds in industry and their mitigations. You have been invited to help the manager.

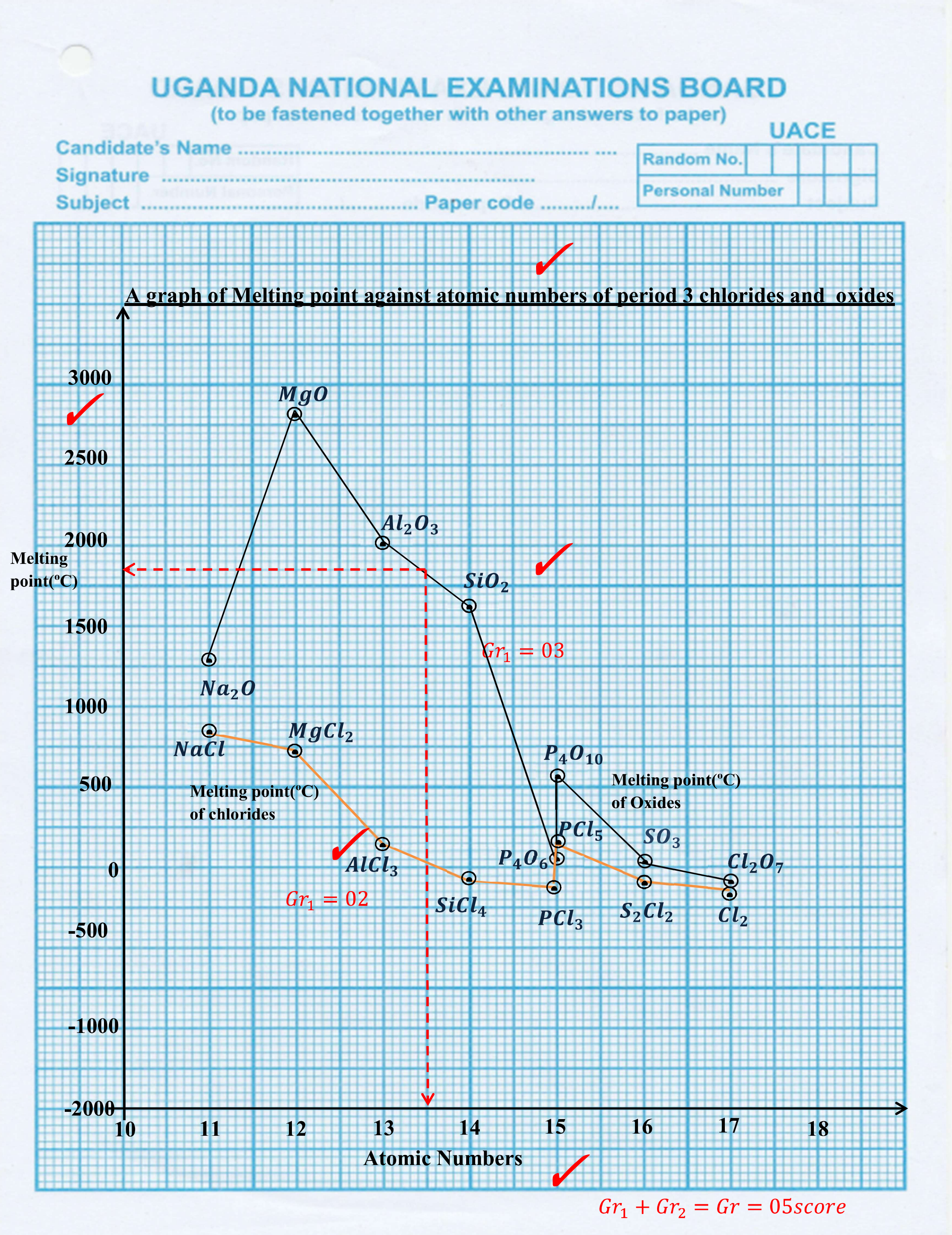
Task:

As a student of Chemistry, prepare a presentation you will use to help the company.

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	35.4 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 Te 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 Ti 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 68	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



3. **Trend in Melting points across period 3 oxides**

Generally, melting point ***increases*** *from sodium oxide to magnesium oxide and then* ***reduces*** *to Chlorine (VII) oxide.*

Reason;

Sodium oxide, magnesium oxide and aluminium oxide have ***giant ionic structures*** *whose ions are held by* ***strong ionic bonds****. Melting point increases from sodium oxide to magnesium oxide because magnesium oxide has a* ***higher product of charges*** *than sodium oxide. Melting point* ***decreases*** *from magnesium oxide to aluminium oxide because the* ***aluminium ion has a small ionic radius, very high charge density*** *and* ***high polarising power****, making aluminium oxide* ***less ionic****. Silicon(IV) oxide has a* ***giant covalent structure*** *in which each silicon atom is bonded to four oxygen atoms making* ***very many strong covalent bonds*** *that require a* ***high amount of energy to break****. Phosphorus pentoxide, sulphur trioxide and Chlorine(VII) oxide have* ***simple molecular structures*** *whose molecules are held by* ***weak van der waal's forces of attraction whose strength decreases with decrease in polarity of the molecules*** *as a result of increase in electronegativities of the atoms bonded to oxygen.*

Irregularities;

MgO has ***higher melting point*** *than Na_2O becau it has* ***stronger ionic bonding*** *due to* ***smaller, doubly charged ions****, giving it a much* ***higher lattice energy*** *than Na_2O, whose ions carry only* ***single positive charges*** *and have larger interionic distances.*

P_4O_{10} *has higher melting point than* **P_4O_6**, *beucause it has a* ***larger molecular size*** *and* ***stronger van der Waals forces*** *that* ***require more energy to be overcome*** *than those in the smaller* **P_4O_6** *molecule.*

Trend in Melting points across period 3 chlorides;

Melting point of the chlorides generally ***decrease*** *from sodium chloride to dichloride.*

Reason;

Sodium chloride and magnesium chloride have ***giant ionic structures*** *held by* ***strong ionic bonds*** *which require a* ***high amount of energy to break****. The decrease in melting point from sodium chloride to magnesium chloride is because magnesium ion has a* ***smaller ionic radius, higher charge density*** *and* ***higher polarising power*** *than sodium ion making magnesium chloride* ***less ionic*** *than sodium chloride. Aluminium chloride has a* ***lower melting point*** *than magnesium chloride because among the cations, the aluminium ion has the* ***smallest ionic radius****, a* ***very high charge density*** *and* ***high polarising power****. Aluminium chloride is therefore predominantly* ***covalent****. Silicon tetrachloride is* ***covalent*** *and its molecules are held by* ***weak Van der Waals' forces of attraction that require a low amount of energy to break*** *hence a low melting point. Phosphorus trichloride has a* ***simple molecular structure*** *thus a low melting point. Disulphur dichloride and dichloride form simple molecular structures held by weak Van der Waals' forces of attraction.*

Irregularities;

Phosphorus pentachloride has an ***abnormally high*** melting point because at ordinary temperatures it consists of PCl_4^+ + and PCl_6^+ ions hence exhibiting ionic character.

$Tr_1 + Tr_2 + 4Tr_1 + 4Tr_2 = T_r = 08scores$

Evaluation and choice;

Both period 3 ***metal*** *oxides and chlorides exhibit* ***ionic*** *characters, due to their* ***very high melting points****, which indicate* ***strong electrostatic forces*** *between metal cations and chloride anions.*

However,

The Period-3 ***oxides*** *are far better substances for furnace linings, kiln refractories and heat-resistant construction than the chlorides because oxides such as* ***MgO (m.p. 2827 °C), Al_2O_3 (2007 °C)*** *and* ***SiO_2 (1607 °C) remain solid*** *well above the 1400 °C baseline and are* ***thermal dynamically stable****.*

They have high melting points due to ***very large lattice energies*** *and* ***strong network covalent bonding.***

Whereas;

The metal ***chlorides*** *(NaCl 808 °C),($MgCl_2$ 714 °C),($AlCl_3$ 192 °C), and the molecular chlorides of non-metals have* ***low melting points*** *and are* ***volatile*** *because they are* ***simple covalent molecules****; therefore they* ***fail the >1400 °C requirement*** *and unsuitable for high-temperature structural use.*

$1E_S + 3E_d = E_v = 04scores$

Prediction of melting point, nature and industrial suitability of chloride X;

The oxide of element ***X****, lying between Al_2O_3 and SiO_2 will likely have a melting point between 1607 °C and 2007°C, approximately 1850°C.*

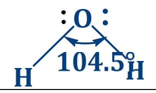
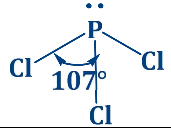
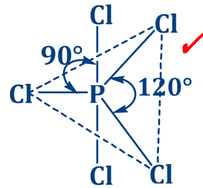
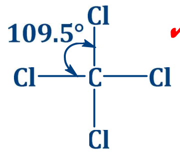
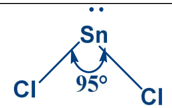
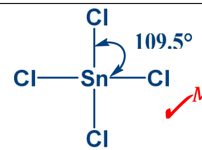
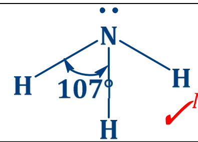
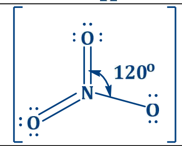
Its bonding is expected to bean oxide with mixed ***covalent and ionic*** *bonding rather than a purely ionic or simple molecular structure.*

Industrial suitability:

such an oxide would be ***suitable for high-temperature applications*** *(furnace linings, kiln refractories, and heat-resistant ceramics) because it meets the >1400 °C requirement and offers good thermal stability.*

$3Pr = P_r = 03scores$

4. Molecular shape, bond type, and bond angle;

Name of substance	Molecular structure	Name of molecular shape	Bond type	Bond angle
Water		*bent shape/ V-shape*	*Polar covalent*	104.5°
Phosphorus trichloride		*trigonal pyramidal*	*Polar covalent*	107°
Phosphorus pentachloride		*trigonal bipyramidal*	*Covalent*	90° and 120°.
Carbon tetrachloride		*tetrahedral*	*Non-polar covalent*	109.5°.
Tin(II) chloride		Bent shape/ V-shape	*Ionic with covalent character*	95°
Tin(IV) chloride		*tetrahedral*	*Pure covalent*	109.5°.
Ammonia		*trigonal pyramidal*	*Polar covalent*	107°
Nitrate ion		*trigonal planar*	*Covalent with resonance delocalization*	120°

$9Mi + 9Ni + 9Bi + 9Ai = V_p = 08scorers$

Account for differences in melting point, solubility, and electrical conductivity:

The ***differences in solubility, melting point, and conductivity*** among these compounds are due to the type of bonding and molecular structure.
Ionic compounds ($SnCl_2$, nitrate salts) have ***high melting points*** and ***conduct electricity when molten or in solution***, while ***covalent molecular compounds*** (CCl_4, PCl_3, $SnCl_4$) have ***low melting points***, are ***non-conductors***, and are ***insoluble*** in water.
Hydrogen bonding in water and ammonia leads to ***strong intermolecular attractions***, giving them higher boiling points than similar covalent molecules like PCl_3 and PCl_5.

$3R_3 = R_3 = 03scores$

Comparison of boiling points and solubility of water and ammonia to those of phosphorus trichloride, phosphorus pentachloride and carbon tetrachloride;

Water is a ***bent polar molecule*** with an angle of ***104.5°***, and ammonia is ***trigonal pyramidal*** with an angle of ***107°***; both have ***polar covalent bonds*** and form ***hydrogen bonds*** between molecules. Hydrogen bonding gives them ***high boiling points*** and makes them ***highly soluble in water***.
In contrast, ***PCl_3*** (trigonal pyramidal, 107°) and ***PCl_5*** (trigonal bipyramidal, 90° & 120°) are ***covalent*** and ***cannot form hydrogen bonds***. They have ***low melting points*** are ***liquid or volatile solids***, and ***do not dissolve*** in water because they hydrolyse, producing ***HCl*** and ***phosphoric acids***.

$3R_4 = R_4 = 03scores$

Comparison of electrical conductivity and melting points of tin(II) and tin(IV) chloride;

Tin(II) chloride ($SnCl_2$) is ***ionic with some covalent character***, forming a ***bent structure*** (≈95°) and a ***solid*** at room temperature. It ***conducts electricity when molten*** because it contains ***mobile ions (Sn^{2+} and Cl^-)***.
Tin(IV) chloride ($SnCl_4$), on the other hand, is ***tetrahedral (109.5°)*** and ***purely covalent***, existing as a ***molecular liquid*** that ***does not conduct electricity***. Its weak molecular forces give it a ***lower melting point*** than $SnCl_2$.

$3R_5 = R_5 = 03scores$

$R_3 + R_4 + R_5 = R = 09scores$

Evaluation of the environmental impacts of using nitrate ions in fertilizers;

In fertilizer use, ***nitrate ions (NO_3^-)*** improve plant growth.
However when overused, cause ***environmental pollution*** since Nitrates are ***highly soluble*** and can ***leach into groundwater***, causing ***eutrophication*** and ***oxygen depletion*** in water bodies, leading to fish deaths and ***blue-baby syndrome*** in humans. Mitigated by controlled, fertilizer application, and use of organic manure.

$1di + 1de + 1dm = D_3 = 03\ Scores$

5. **Formulae of W ;**

$C_xH_y(g) + \left(x+\frac{y}{4}\right)O_2(g) \longrightarrow xCO_2(g) + \frac{y}{2}H_2O(g)$
Volume of hydrocarbon $= 20cm^3$
Volume of carbon diode produced $= 110 - 30 = \mathbf{80cm^3}$
Volume of oxygen used up in reaction = original volume − volume unreacted
$= 150 - 30 = \mathbf{120cm^3}$

Volume of hydrocarbon × x = volume of carbondioxide
$\Longrightarrow 20x = 80$
$\therefore x = {}^{80}/_{20} = \mathbf{4}$

Also volume of hydrocarbon $\times \left(x+\frac{y}{4}\right)$ = *volume of oxygen used up*
$\Longrightarrow 20\left(4+\frac{y}{4}\right) = 120$
$\therefore\ y = (6-4) \times 4 = 8$

$\therefore$ ***The formula of W is C_4H_8***

Possible isomers, identity of W with reason(s)
$CH_3CH_2CH = CH_2$
$CH_3CH = CHCH_3$
Since ozonolysis of W produced only one compound, it indicates that it has a symmetrical carbon-carbon double bond.

$CH_3CH = CHCH_3 \xrightarrow[2.\,H_2O,\,Zn,\,CH_3COOH]{1.\,O_3,\,CCl_4,\,<20^0C} 2CH_3CHO$, ***One compound produced is ethanal***

Therefore, W is $CH3CH = CHCH3$ but-2-ene

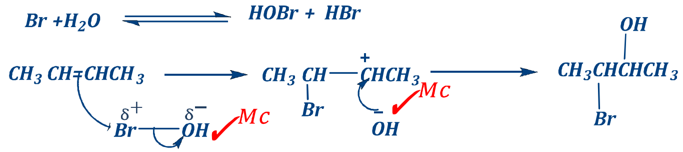
Comfirmatory Test for Carbon dioxide;
If the gas is CO_2, KOH will absorb it so the ***limewater remains clear*** *(no milky cloud), because CO_2 was removed by the KOH beforehand. But the gas is not absorbed by KOH, the limewater will still* ***go milky***.

$5CA + 2I = F = 06\ Scores$

Mechanism for reaction between W and bromine water;

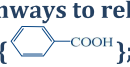
$CH_3CH = CHCH_3 \xrightarrow{Br_2/H_2O} CH_3CHBrCH(OH)CH_3 + HBr$

Mechanism



$2Mc = Mc = 02\ Scores$

Synthetic **pathways to related products;**

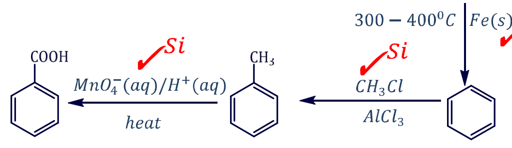
Benzoic acid,{  **};**

$CH_3CH = CHCH_3 \xrightarrow[2.H_2O, Zn, CH_3COOH]{1.O_3, CCl_4, <20^0C} CH_3CHO$ ✓Si $\xrightarrow[dry\ ether]{LiAlH_4} CH_3CH_2OH$ ✓Si $\xrightarrow[180^0C]{conc.H_2SO_4} H_2C = CH_2$ ✓Si

$\xrightarrow{Br_2 / CCl_4}$ ✓Si $BrCH_2CH_2Br$

$\xrightarrow{heat,\ Excess\ KOH / Ethanol}$ ✓Si $HC \equiv CH$

$\xrightarrow{300-400^0C,\ Fe(s)}$ ✓Si



$S_1 = 05$

1,2-dibromopentane;

$CH_3CH = CHCH_3 \xrightarrow[2.H_2O, Zn, CH_3COOH]{1.O_3, CCl_4, <20^0C} CH_3CHO$ ✓Si $\xrightarrow[dry\ ether]{LiAlH_4} CH_3CH_2OH$ ✓Si $\xrightarrow[180^0C]{conc.H_2SO_4} H_2C = CH_2$ ✓Si $\xrightarrow[CCl_4]{Br_2}$ ✓Si $CH_2(Br)CH_2(Br)$

$\xrightarrow{Excess\ KOH/ethanol,\ heat}$ ✓Si $HC \equiv CH$

$\xrightarrow{Na(s)/LiqNH_3,\ CH_3CH_2CH_2Cl}$ ✓Si $CH_3CH_2CH_2C \equiv CH$

$\xrightarrow{H_2,\ lindlar's\ catalyst}$ ✓Si $CH_3CH_2CH_2CH = CH_2 \xrightarrow[CCl_4]{Br_2}$ ✓Si $CH_3CH_2CH_2CHBrCH_2Br$

$S_2 = 05$

1-chlorobutane;

$CH_3CH = CHCH_3 \xrightarrow[warm]{H_2O/H^+} CH_3CH_2CH(OH)CH_3$ ✓Si $\xrightarrow[180^0C]{conc.\ H_2SO_4} CH_3CH_2CH = CH_2$ ✓Si $\xrightarrow[ROOR]{HCl} CH_3CH_2CH_2CH_2Cl$ ✓Si

$S_3 = 01$

$S_1 + S_2 + S_3 = S = 11\ Scores$

Environmental impacts of producing above compounds in industry;

When burnt, they give off poisonous gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to ***air pollution***, ***acid rain***, ***respiratory problems***, *and* ***global warming***. *The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid* ***open-air burning*** *and instead use* ***safe chemical disposal methods***. ✓dm

$1di + 1de + 1dm = D_3 = 03\ Scores$

6. **Formulae of P ;**

Mass of carbondiode formed $= 8.8g$ ***and mass of water formed*** $= 1.8$

mass of carbon $= \frac{12}{44} \times 8.8 = 2.4g$

mass hydrogen $= \frac{2}{18} \times 1.8 = 0.2g$

Element	C	H
%composition	2.4	0.2
Moles	$\frac{2.4}{12} = 0.2$	$\frac{0.2}{1} = 0.2$
Simplest ratio	$\frac{0.2}{0.2} = 1$	$\frac{0.2}{0.2} = 1$

✓CA

$\therefore$ *Empirical formula is* **CH**

Mass of p vaporised $= 0.100g$

At a Temperature $T = 273 + 273 = 546K$

At a Pressure $P = \left(\frac{734}{760} \times 1\right)\ atm$

At a Volume $V = 4.46 \times 10^{-2} dm^3$

Note: 1. *we use*; $R = 0.0821\ L \cdot atm/(mol \cdot K)$, *when, P is in atm and V is in litre/*dm^3

2. *we use*; $R = 8.314\ J/(molK)$, *when, P is in Pa and Volume is in* m^3

From ideal gas law $PV = nRT$

$$PV = \frac{m}{M_r}RT$$

$$\Rightarrow M_r = \frac{mRT}{PV} = \frac{0.100 \times 0.0821 \times 546}{\left(\frac{734}{760} \times 1\right) \times 4.46 \times 10^{-2}} = \frac{4.48266}{0.04307} \approx 104g$$ ✓CA

$\therefore (CH)_n = 104$

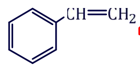
$(12 \times 1 \times n) + (1 \times 1 \times n) = 104$

$13n = 104$

$n = \frac{104}{13} = 8$

$\therefore$ *Molecular formula is* C_8H_8 ✓CA

Structure and IUPAC Name;



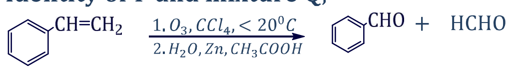
✓CA

ethenylbenzene ✓CA

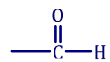
Structural isomers;

P *has no other strural isomers.* ✓I

Identity of P and mixture Q;



Q *is a mixture of benzylaldehyde and methanal with functional group*

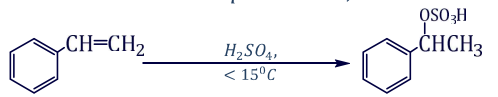


✓I

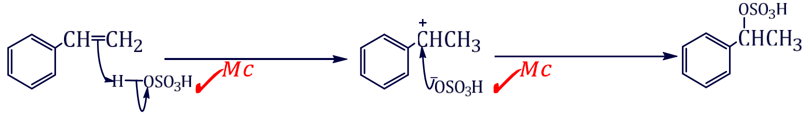
$5CA + 2I = F = 06$ *Scores*

Mechanisms for reactions of P with bromine and concentrated sulphuric acid;

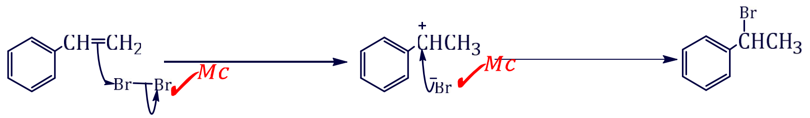
With concentrated sulphuric acid;



Mechanisim



With bromine;

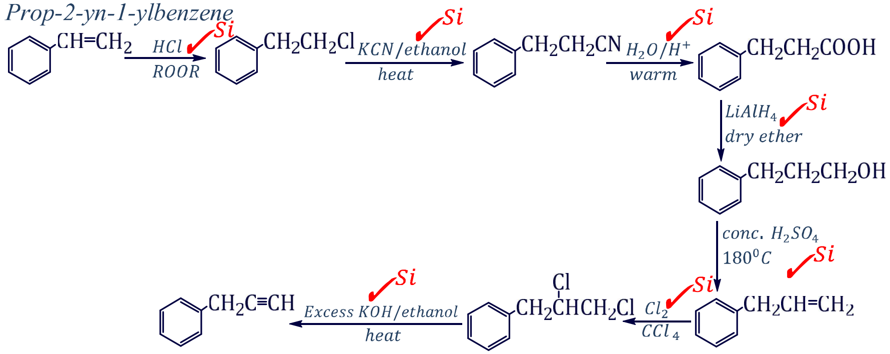


$M_C = 02$

$4Mc = Mc = 02$ *Scores*

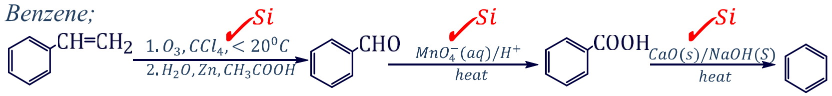
Synthetic pathways from Albertine oil fractions P to synthesis industrial compounds ;

Prop-2-yn-1-ylbenzene



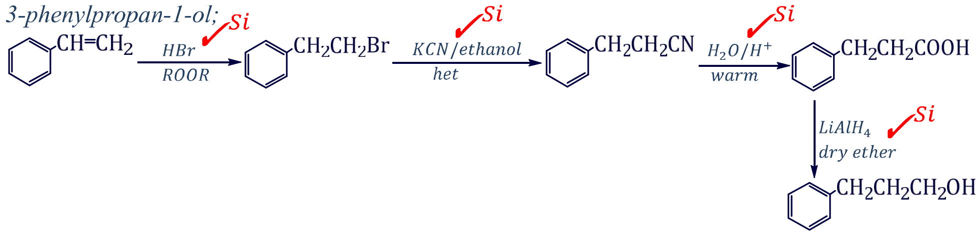
$S_1 = 05$

Benzene;



$S_3 = 01$

3-phenylpropan-1-ol;



$S_1 = 05$

$S_1 + S_2 + S_3 = S = 03$ *Scores*

Environmental impacts of producing above compounds in industry;

When burnt, they give off poisonous gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to ***air pollution, acid rain, respiratory problems,*** *and* ***global warming***. *The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid* ***open-air burning*** *and instead use* ***safe chemical disposal methods.***

1di+1de+1dm=D₃=03 Scores

END

2025

It is All about mindset change

Tr. Julius.W **0787093081**

Candidate's Name: ……………………………………………………………………………..

Signature: …………………………….. | **STREAM:** | | | | | | | |

525/1
CHEMISTRY
Paper 1
Nov./Dec.
2025
$2^1/_2$ hours

END OF YEAR ASSESSMENT 2025

Uganda Advanced Certificate of Education

S.5 CHEMISTRY

Paper 1

(***Set III***)

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

This paper has **two** *sections* **A** *and* **B.**

Section **A** *has two compulsory items while* **B** *has two parts* **Part I** *and* **Part II**

Each of part I and part II has two items, Answer only **one** *from each.*

Answers to Section **A** ***must*** *be written in the spaces provided and Section* **B** ***must*** *be written in the answer booklet(s) provided*

Answer four in all.

Where necessary use,

Molar gas volume at s.t.p = 22.4dm³

FOR EXAMINER'S USE ONLY				
ITEM	**CODE**	**SCORE**		
1	C_1	03		
	E_f	08		
	C_2	02		
	F_i	04		
	D_1	03		
2	E_c	06		
	C_4	02		
	C_5	04		
	E_1	05		
	D_2	03		
3/4	G_r	05	V_p	08
	T_r	08	R	09
	E_v	04	D_3	03
	P_r	03		
5/6	F	06		
	Mc	02		
	S	11		
	D_3	03		
TOTAL		80		

Key

C_1, C_2, C_3, C_4, C_5: *Calculations*
D_1, D_2, D_3: *Danger*
E_c: *Energy Cycle*
E_V: *Evaluation*
G_r: *Graphing*
T_r: *Trend*
E_f: *Effect*
P_r: *Pridiction*
F: *Formula*
Mc: *Mechanism*
S: *Synthesis*
V_p: *VSEPR theory*
R: *Reason*
F_i: *function*

SECTION A

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

ITEM 1

A technical report from Moroto Agro Chem Industries (U) Ltd indicates that the company is optimizing its large scale ammonia production system, a key raw material used in fertilizers, cleaning agents and pH-control formulations.

During pilot testing, the industrial chemists introduced *1.00 mole* of nitrogen gas and *3.00 moles* of hydrogen gas into a *2.00 dm³* high-pressure reactor. The mixture was compressed to *100 atm* and heated to 400°C, allowing equilibrium to be established according to the reversible reaction:

Equation 1: $N_2(g) + 3H_2(g) \rightleftharpoons 2\,NH_3 \quad \Delta H = -92\ kJ/mol$

Gas analysis later revealed that the equilibrium mixture contained *25%* ammonia by volume, prompting management to evaluate how changes in operating variables such as pressure, temperature and catalysts might influence the position of equilibrium, the value of the equilibrium constant, and the rate of attainment of equilibrium in the reactor.

The company also manufactures buffered cleaning solutions by passing a equilbrium mixture through hydrochloric acid.

To test the stability of one formulation, the Quality Assurance Unit prepared a *0.001 M* ammonia solution and needed to determine its pH, as well as verify how the mixture behaves when ammonium chloride is added to create an ammonia to ammonium chloride buffer system. Because the buffer is used to maintain constant pH in enzyme based cleaning agents, the Plant Manager must be confident that the solution must suit its purpose. You have been invited to assist in analysing the equilibrium data, pH, and functioning of the buffer system.

Task:

As a learner of Chemistry, help the company to know;

(a) The equilibrium constant for the gaseous reaction (Kp).

	$N_2(g)$ +	$3H_2(g)$	⇌	$2\,NH_3(g)$
Initial moles	1	3		0
Moles reacted/formed	x	$3x$		$2x$ ✓CA
Moles at equilibrium	$(1-x)$	$(3-3x)$		$2x$

Total moles at equilibrium $= (01-x)+(3-3x)+2x = (4-2x)$ ✓CA

BUT $\left(\frac{2x}{4-2x}\right)\times 100 = 25 \quad \therefore x = 0.4$

Moles of H_2 at equilibrium $= (3-3(0.4)) = 1.8$ moles

Moles of N_2 at equilibrium $= (1-0.4) = 0.6$ *moles* ✓CA

Moles of NH_3 at equilibrium $= 2(0.4) = 0.8$ *moles*

Total moles at equilibrium $= 4 - 2(0.4) = 3.2$

$P_{H_2} = \frac{1.8}{3.2}\times 100 = \mathbf{56.25}atm$; $P_{N_2} = \frac{0.6}{3.2}\times 100 = \mathbf{18.75}atm$; $P_{NH_2} = \frac{0.8}{3.2}\times 100 = \mathbf{25.00}atm$; ,

$K_p = \frac{(P_{NH_2})^2}{P_{N_2}\times(P_{H_2})^3} = \frac{25^2}{18.75\times 56.25^3} = \mathbf{1.87\times 10^{-4}atm^{-2}}$ ✓CA

4CA = C_1 = 03 scores

Turn Over

(b) How the equilibrium system is affected by:

i. Passing equilibrium mixture through hydrochloric acid.

According to Lechatelier's principle, the concentration of ammonia decreases as it reacts with the hydrochloric acid to form ammonium chloride. Therefore, more nitrogen react with hydrogen in order to ***replace the ammonia*** *being removed, so as to* ***keep the equilibrium constant value the same****. (K) Equilibrium therefore* ***shifts from left to right*** *(P) and equilibrium constant value remains unchanged. The* ***rate of attainment of equilibrium decreases*** *(R) since there is a decrease in the number of particles in the reaction vessel.*

ii. Introducing a catalyst.

According to Lechatelier's principle, introducing a catalyst(finely divide iron), has ***no effect on position*** *(P) of equilibrium and* ***no effect on the value*** *(K) of equilibrium constant but only alters the rate of backward and forward reaction equally. A catalyst therefore* ***increases*** *(R)* ***the rate of attainment of equilibrium*** *by decreasing the activation energy needed for hydrogen and nitrogen to combine producing more and more ammonia gas..*

iii. Increasing temperature.

According to Lechatelier's principle, Since the reaction is ***exothermic*** *($\Delta H = -92$ kJ/mol), increasing temperature adds heat. The equilibrium shifts from* ***right to the left*** *(P) to absorb the added heat. The* ***value of Kp decreases*** *(K), because for exothermic reactions, increasing temperature reduces the equilibrium constant. The* ***rate increases initially*** *(R), because higher temperature gives molecules more kinetic energy, increasing collision frequency and energy, though less NH_3 is produced at equilibrium.*

iv. Increasing pressure.

According to Lechatelier's principle, the reaction involves a ***decrease in gas molecules*** *($4 \rightarrow 2$). Increasing pressure shifts the equilibrium from* ***left to the right*** *(P), favouring the formation of SO_3, to reduce total pressure. The* ***value of Kp remains constant*** *(K), because pressure changes do not affect Kp (only temperature does). The* ***rate of attainment of equilibrium rate increases*** *(R), because higher pressure increases the frequency of molecular collisions, speeding up both forward and reverse reactions.*

(c) Calculate the pH of the solution obtained. ($K_b = 1.8 \times 10^{-5} moldm^{-3}$).

$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(g)$

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$ But $[NH_4^+] = [OH^-]$ and $[NH_3] = 0.01M$

$K_b = \frac{[OH^-]^2}{[NH_3]}$;

$\therefore [OH^-] = \sqrt{1.8 \times 10^{-5} \times 0.001} = 1.34 \times 10^{-4}$M (CA)

$p^{OH} = \log_{10}[OH^-] = \log_{10}\{1.34 \times 10^{-4}\} = \mathbf{3.87}$ (CA)

$p^H = 14 - p^{OH}$;

$K_p = 14 - 3.87 = \mathbf{10.13}$ (CA)

$3CA = C_2 = 02$ *Scores*

(d) How the buffer system works.

Ammonium chloride is a ***strong electrolyte hence fully*** *(fi)* ***ionises*** *to form ammonium ions and chloride ions. Ammonia is a* ***weak base hence only slightly*** *(fi)* ***ionises*** *and its ionisation is suppressed by the high concentration of ammonium ions from the salt.*

$NH_4Cl(aq) \longrightarrow NH_4^+(aq) + Cl^-(aq)$

$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

The solution therefore contains a ***high concentration*** *(fi)* ***of ammonium ions*** *and a* ***high concentration of unionised ammonia molecules****. When a* ***small amount*** *(fi)* ***of acid is added****, the hydrogen ions react with ammonia molecules to form ammonium ions,* ***resisting*** *(fi)* ***a decrease in pH.*** $\mathbf{NH_3(aq) + H^+(aq) \rightleftharpoons NH_4^+(aq)}$

When a ***small amount of base is added****, the hydroxide ions react with ammonium ions to form ammonia molecules and water,* ***resisting an increase in pH.*** *(fi)*

$NH_4^+(aq) + OH^-(aq) \longrightarrow NH_3(g) + H_2O(l)$

$4f_i = F_i = 04$ *Scores*

(e) Environmental impacts of the gaseous or aqueous equilibria and their mitigations.

- *Ammonia gas is highly soluble in water and lead* ***water*** *(di)* ***pollution*** *causing eutrophication and* ***damaging aquatic life****. (de) Mitigated by using scrubbers or filters in industrial emissions to filter gaseous waste before disposal. (dm)*
- *Ammonia gas also lead to severe* ***respiratory damage at high levels*** *when exposed to it for a long time. Mitigated by using it in well-ventilated areas, stored securely, monitored for leaks, and handled with protective gear.*

$di + de + dm = D_1 = 03$*scores*

Item 2

A recent technical brief from Namanve Metals & Ceramics Corporation (NMCC), a rapidly expanding Ugandan manufacturer of refractory linings and water-treatment chemicals, revealed that the company is designing a *high-temperature resistant* coating for industrial furnaces used in steel rolling mills in Jinja and Tororo.

The project requires evaluating aluminium oxide and sodium fluoride, in order to make best choice of the most stable substance during formation to apply in *ceramics, abrasives,* and *furnace linings*.

At the same time, to select a substance in which temperature control depends on dissolution in water to use as a *cooling and stabilising agent* in chemical preparation units. The research division has sourced pure aluminium from scrap recycling operations in Namanve and oxygen gas from Uganda Oxygen Ltd. Sodium and fluorine also have been sourced from Lake Katwe in Kasese.

Thermochemical data obtained from an industrial materials report show the following values

$Al(s) \rightarrow Al(g)$: +330 kJ mol⁻¹	$Na(s) \rightarrow Na(g)$: $+109\ kJ\ mol^{-1}$
$Al(g) \rightarrow Al^{+}(g) + e^{-}$: +578 kJ mol⁻¹	$Na(g) \rightarrow Na^{+}(g) + e^{-}$: $+494\ kJ\ mol^{-1}$
$Al(s) \rightarrow Al^{2+}(g) + 2e^{-}$: +1820 kJ mol⁻¹	$F_2(g) \rightarrow 2F(g)$: $+158\ kJ\ mol^{-1}$
$Al(s) \rightarrow Al^{3+}(g) + 3e^{-}$: +2750 kJ mol⁻¹	$F(g) + e^{-} \rightarrow F^{-}(g)$: $-328\ kJ\ mol^{-1}$
$2Al^{3+}(g) + 3O^{2-}(g) \rightarrow Al_2O_3(s)$: −15346.5kJ mol⁻¹	$Na(s) + \frac{1}{2}F_2(g) \rightarrow NaF(s)$: $-569\ kJ\ mol^{-1}$
$\frac{1}{2}O_2(g) \rightarrow O(g)$: +249 kJ mol⁻¹	$Na^{+}(g) + (aq) \rightarrow Na^{+}(aq)$: $-406\ kJmol^{-1}$
$O(g) \rightarrow O^{-}(g)$: −142 kJ mol⁻¹	$F^{-}(g) + (aq) \rightarrow F^{-}(aq)$: $-505\ kJmol^{-1}$
$O(g) \rightarrow O^{2-}(g)$: +798 kJ mol⁻¹	

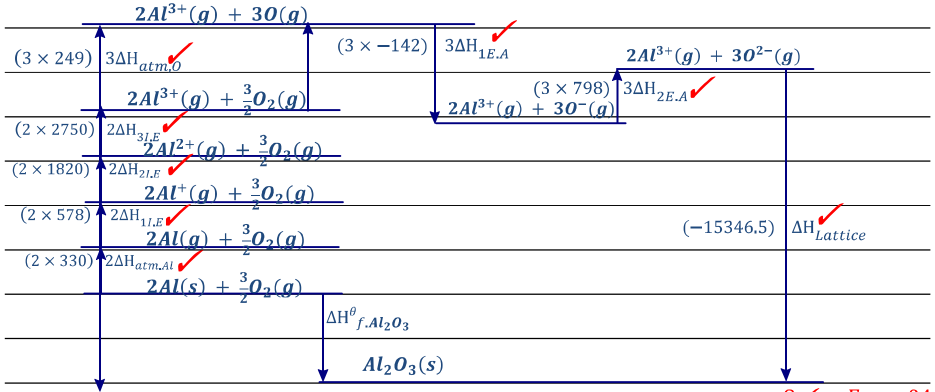
Preliminary tests by NMCC's laboratory team indicated that dissolution of NaF produces a measurable temperature change. To ensure that the chosen materials are safe, energy-efficient, and suitable for industrial use, the technical manager has invited you.

Task

As a student of chemistry, help the manager;

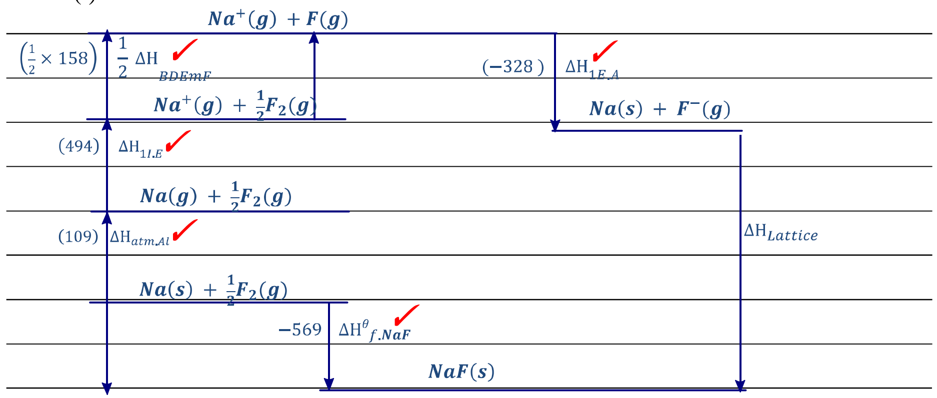
(a) Analyse the data to construct an energy level diagram for the changes in the:

(ii) Formation of aluminium oxide.



8✓ = Ec_1 = 04scores

(i) Formation of sodium fluoride.



5✓ = Ec_2 = 02scores

$Ec_1 + Ec_2 = Ec$ = 06 scores

(b) Use the energy cycles constructed to calculate;

(i). Enthalpy of formation of aluminium oxide.

From Hess' law;

$$\Delta H^{\theta}_{f.Al_2O_3} = 2\Delta H_{atm.Al} + 2\Delta H_{1I.E} + 2\Delta H_{2I.E} + 2\Delta H_{3I.E} + 3\Delta H_{atm,O} + 3\Delta H_{1.E.A} + 3\Delta H_{2E.A} + \Delta H_{Lattice}$$

$$\Delta H^{\theta}_{f.Al_2O_3} = (2 \times 330) + (2 \times 578) + (2 \times 1820) + (2 \times 2750) + (3 \times 249) + (3 \times -142) + (3 \times 798) + (-15346.5)$$ ✓CA

$$\therefore \Delta H^{\theta}_{f.Al_2O_3} = -1675.5kjmol^{-1}$$ ✓CA

2CA = C_4 = 02 Scores

(ii). Lattice energy of sodium fluoride and its enthalpy of solution.

From Hess' law;

$$\Delta H^{\theta}_{f.NaF} = \Delta H_{atm.Al} + \Delta H_{1I.E} + \frac{1}{2}\Delta H_{BDE.F} + \Delta H_{1.E.A} + \Delta H_{Lattice}$$ ✓CA

$$\Delta H_{Lattice} = -569 - \left(109 + 494 + \frac{1}{2} \times 158 - 348\right) = -923kjmol^{-1}$$ ✓CA

$$\Delta H_{Solution.NaF} = \Delta H_{Lattice} + \Delta H_{hydration.NaF}$$

$$\Delta H_{Solution.NaF} = \Delta H_{Lattice.NaF} + \left(\Delta H_{hydration.Na^{+}} + \Delta H_{hydration.F^{-}}\right)$$

$$\Delta H_{Solution.NaF} = +923 + (-406 + -505)$$ ✓CA

$$\therefore \Delta H_{Solution.NaF} = +12kjmol^{-1}$$ ✓CA

4CA = C_5 = 04 Scores

(c) (i) Evaluate the industrial usefulness of the two systems to advise the manager which substance is most suitable for furnace lining and cooling applications, giving reasons. Ev

Aluminium oxide *is the best choice for ceramics, abrasives and furnace linings due to* ***a very large exothermic enthalpy of formation*** *of* $-1675.5kjmol^{-1}$*, thus extremely* ***thermal dynamically stable, heat-resistant*** *and* ***chemically inert****.* Er

Whereas:

Sodium fluoride *can be choosen for cooling applications due to it* ***endothermic enthalpy solution*** *of* $+12kjmol^{-1}$ *, meaning it* ***absorbs a heat from surrounding equipment when dissolving in water****. However, its cooling effect is small because of low heat absorption.* Ev Er

(ii). State any other important industrial use of aluminium oxide.

- *Used as an* ***electrical Insulator*** *in electrical and electronic devices; due to good electrical resistance and heat stability.* U
- *Production of* ***Aluminium*** *Metal during the electrolytic processes due to its high purity .* U
- *Used as a* ***catalyst in petroleum refining*** *and chemical manufacture due to its high surface area and chemical stability.* U

$2Ev + 2Er + 1U = E_{v1} = 05\ Scores$

(d) Suggest the possible impacts and mitigations of the substances to the environment. di

- *Aluminium Oxide can* ***contaminate soil*** *if waste powder poorly disposed. Since fine particles are insoluble they settle in soil,* ***altering pH*** *reduce plant yields. Mitigated by recycling waste powders and using dust filter systems.* de dm
- *Sodium Fluoride leads to* ***water pollution*** *when in high amounts. Since fluoride ions are* ***mobile and toxic to plants, aquatic organisms, and wildlife, and can corrode infrastructure****. Mitigated by proper wastewater treatment before releasing it to surrounding water streams.*

$1di + 1de + 1dm = D_2 = 03\ Scores$

SECTION B

Part I

Attempt **One** *item in this section*

Item 3

A manufacturing company in Uganda, Victoria Industrial Chemicals Ltd, produces industrial grade materials for construction, ceramics, and high-temperature processes. The company has been advised that substances suitable for furnace linings, kiln refractory materials, and heat-resistant construction components must have high thermal stability and bonding character.

The engineering department is evaluating two types of available compounds from Period 3 elements: oxides and chlorides, to select the most suitable materials for industrial applications. The baseline requirement is that a suitable substance must remain solid above 1400 °C, must have strong ionic bonding, and be mechanically stable under operational conditions. The data provided for Period 3 oxides and chlorides are shown below:

period	**Period 3 chlorides and oxides**							
Chlorides Oxides	NaCl Na_2O	$MgCl_2$ MgO	$AlCl_3$ Al_2O_3	$SiCl_4$ SiO_2	PCl_3 P_4O_6	PCl_5 P_4O_{10}	S SO_3	Cl_2 Cl_2O_7
Melting pt of chlorides/°C	808	714	192	-68	-92	160	-76	-80
Melting pt of Oxides/°C	1275	2827	2007	1607	24	560	30	−91

The engineering team requires a comparative analysis of oxides and chlorides to determine which compounds are most suitable to serve the purpose.

They seek guidance on which properties make a substance "good", and how to evaluate *graphs* in melting points of the available compounds to explain *trends* in order to guide *selection* of suitable compounds for the intended industrial purpose, and to *predict* the likely melting point and industrial suitability of an oxide of element X between Al_2O_3 and SiO_2.

Task

As a chemistry student, make a write up you will use to help the company.

Item 4

Kilembe Kilembe Chemical Works Ltd, Kasese, is studying how bonding and molecular structure affect the properties and industrial uses of compounds in fertilizers, water purification, and plastics and ceramics manufacture. The compounds include water, ammonia, phosphorus trichloride, phosphorus pentachloride, carbon tetrachloride, tin(II) chloride, tin(IV) chloride, and nitrate ions. It was reported that some, like carbon tetrachloride and phosphorus trichloride, are liquids and insoluble in water, while water and ammonia are highly soluble with strong intermolecular attractions. Tin(II) chloride conducts electricity when molten, whereas tin(IV) chloride does not.

The manager seeks information on *molecular shape*, *bond type*, and *bond angle*, and how these explain bonding type *account for differences* in melting point, solubility, and electrical conductivity. *Compare* boiling points and solubility of water and ammonia to those of phosphorus trichloride, phosphorus pentachloride and carbon tetrachloride. *Compare* electrical conductivity and melting points of tin(II) and tin(IV) chloride. And evaluate environmental impacts of nitrate ions in fertilizers. You have been contacted for assistance.

Task;

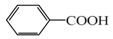
As a chemistry student, make a write up you will use to help the company.

Part II

Attempt **One** *item in this section*

ITEM 5

Nile Chemical Industries Ltd, a chemical manufacturing firm located in Jinja, produces a range of organic-based materials used in plastics, fuels, solvents, and disinfectants. In one of its experiments, 20.0 cm³ of a gaseous hydrocarbon W was exploded with 150 cm³ of excess oxygen. After complete combustion, the residual gas measured 110 cm³, and when concentrated potassium hydroxide solution was added, the volume further decreased to 30 cm³

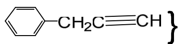
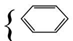
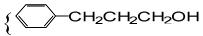
The company noted that ozonolysis of W produced only one compound and that W readily decolourised bromine water. These findings prompted the research team to seek a deeper understanding of W and its possible industrial applications in the synthesis of propan-1-ol, benzoic acid, {  }, 1,2-dibromopentane and 1-chlorobutane.

The company seeks a comprehensive evaluation: to determine the *formulae* of W, draw and name all possible *isomers*, *identify* W with reason(s), and illustrate the mechanism for the reaction between W and bromine water. Additionally, confirm the identity of the gas absorbed by potassium hydroxide solution, *predict* the functional groups of resulting organic compounds, describe *synthetic* pathways to related products, and assess the *environmental* impacts of producing above compounds in industry. You have been contacted for assistance.

Task:

As a student of Chemistry, prepare a presentation you will use upon invitation.

ITEM 6

Albertine Oil Fractionation Ltd, an industrial chemical company in the Albertine region, produces fuels, solvents, and organic feedstocks for plastics and chemical synthesis. During a research study, an organic compound P was isolated from a distillation fraction. Complete combustion of a sample of P yielded 8.8 g carbondioxide and 1.8 g water, while 0.100 g of P, vapourised at 273°C and 734 mmHg, occupied 4.46×10^{-2} dm³. Ozonolysis of P followed by hydrolysis produced a mixed Q of two different compounds, and P was observed to react readily with bromine and concentrated sulphuric acid. The company is exploring industrial applications of these compounds for synthesis of prop-2-yn-1-ylbenzene {  } a component in manufacture of new drugs, benzene {  }solvent, and {  }chemical feedstocks.

The manager seeks to know the formulae of P, all possible structural *isomers*, *identity* of P with reasons, deduce the structure and functional groups of mixture Q, illustrate *mechanisms* for reactions of P with *bromine* and *concentrated sulphuric acid*, , outline *synthetic* pathways from Albertine oil fractions P to synthesis industrial compounds stated, and evaluate the environmental impacts of producing compounds in industry and their mitigations. You have been invited to help the manager.

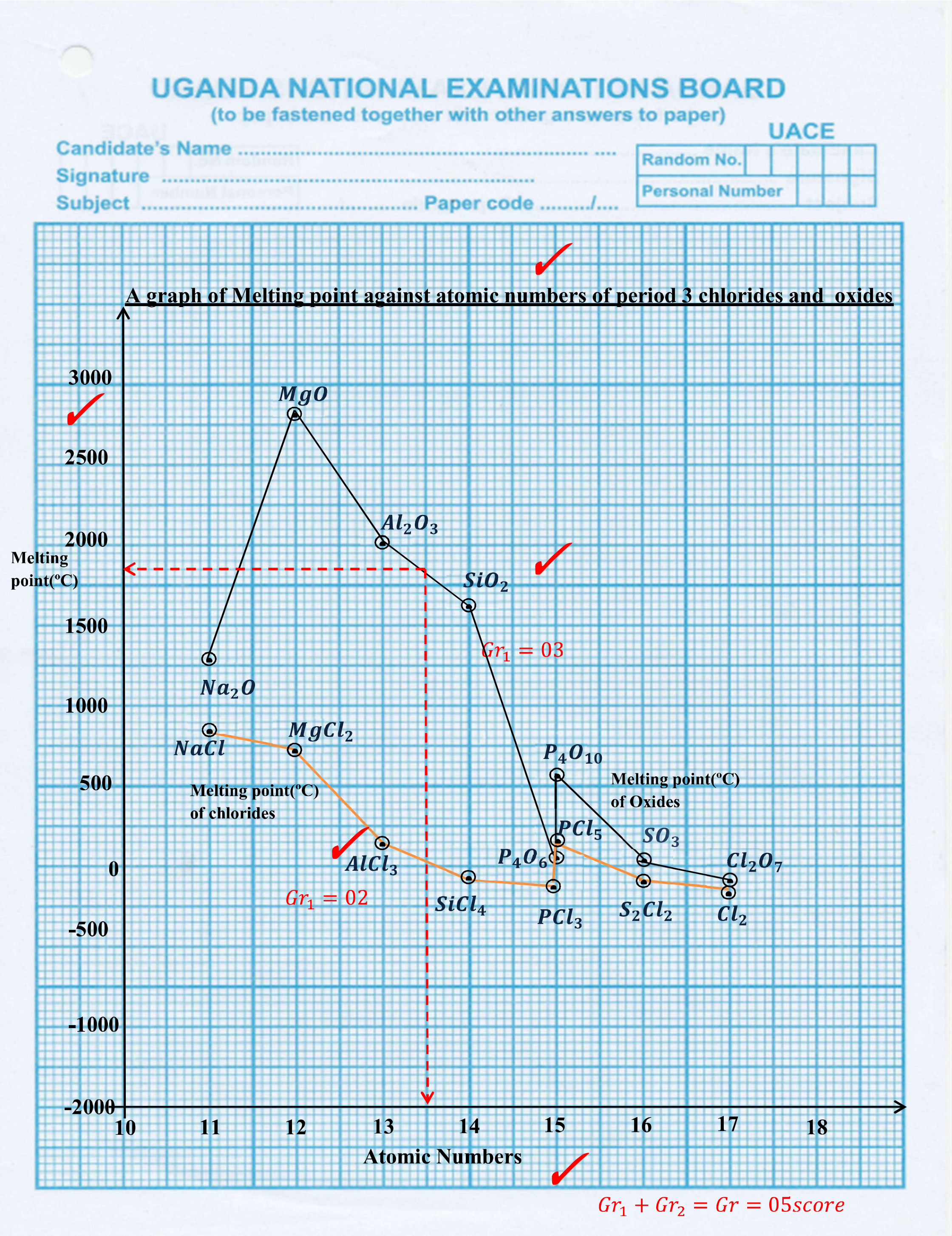
Task:

As a student of Chemistry, prepare a presentation you will use to help the company.

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	35.4 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 Te 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 Ti 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 68	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



3. **Trend in Melting points across period 3 oxides** R_2

Generally, melting point ***increases*** *from sodium oxide to magnesium oxide and then* ***reduces*** *to Chlorine (VII) oxide.* Tr_1

Reason;

Sodium oxide, magnesium oxide and aluminium oxide have ***giant ionic structures*** *whose ions are held by* ***strong ionic bonds****.* R_1 *Melting point increases from sodium oxide to magnesium oxide because magnesium oxide has a* ***higher product of charges*** *than sodium oxide.* R_1 R_1 *Melting point* ***decreases*** *from magnesium oxide to aluminium oxide because the* ***aluminium ion has a small ionic radius, very high charge density*** *and* ***high polarising power****, making aluminium oxide* ***less ionic****.* R_1 *Silicon(IV) oxide has a* ***giant covalent structure*** *in which each silicon atom is bonded to four oxygen atoms making* ***very many strong covalent bonds*** *that require a* ***high amount of energy to break****.* R_1 *Phosphorus pentoxide, sulphur trioxide and Chlorine(VII) oxide have* ***simple molecular structures*** *whose molecules are held by* ***weak van der waal's forces of attraction whose strength decreases with decrease in polarity of the molecules*** *as a result of increase in electronegativities of the atoms bonded to oxygen.* R_1

Irregularities;

MgO has ***higher melting point*** *than Na_2O becau it has* ***stronger ionic bonding*** *due to* ***smaller, doubly charged ions****, giving it a much* ***higher lattice energy*** *than Na_2O, whose ions carry only* ***single positive charges*** *and have larger interionic distances.* R_1

P_4O_{10} *has higher melting point than* P_4O_6*, beucause it has a* ***larger molecular size*** *and* ***stronger van der Waals forces*** *that* ***require more energy to be overcome*** *than those in the smaller* P_4O_6 *molecule.* R_1

Trend in Melting points across period 3 chlorides;

Melting point of the chlorides generally ***decrease*** *from sodium chloride to dichloride.* Tr_2

Reason;

Sodium chloride and magnesium chloride have ***giant ionic structures*** *held by* ***strong ionic bonds*** *which require a* ***high amount of energy to break****.* R_2 R_2 *The decrease in melting point from sodium chloride to magnesium chloride is because magnesium ion has a* ***smaller ionic radius****,* ***higher charge density*** *and* ***higher polarising power*** *than sodium ion making magnesium chloride* ***less ionic*** *than sodium chloride.* R_2 *Aluminium chloride has a* ***lower melting point*** *than magnesium chloride because among the cations, the aluminium ion has the* ***smallest ionic radius****, a* ***very high charge density*** *and* ***high polarising power****.* R_2 *Aluminium chloride is therefore predominantly* ***covalent****. Silicon tetrachloride is* ***covalent*** *and its molecules are held by* ***weak Van der Waals' forces of attraction that require a low amount of energy to break*** *hence a low melting point.* R_2 *Phosphorus trichloride has a* ***simple molecular structure*** *thus a low melting point.* R_2 *Disulphur dichloride and dichloride form simple molecular structures held by weak Van der Waals' forces of attraction.*

Irregularities;

*Phosphorus pentachloride has an **abnormally high** melting point because at ordinary temperatures it consists of PCl_4^+ + and PCl_6^+ ions hence exhibiting ionic character.*

$Tr_1 + Tr_2 + 4Tr_1 + 4Tr_2 = T_r = 08scores$

Evaluation and choice;

*Both period 3 **metal** oxides and chlorides exhibit **ionic** characters, due to their **very high melting points**, which indicate **strong electrostatic forces** between metal cations and chloride anions.*

However,

*The Period-3 **oxides** are far better substances for furnace linings, kiln refractories and heat-resistant construction than the chlorides because oxides such as **MgO (m.p. 2827 °C), Al_2O_3 (2007 °C)** and **SiO_2 (1607 °C) remain solid** well above the 1400 °C baseline and are **thermal dynamically stable**.*

*They have high melting points due to **very large lattice energies** and **strong network covalent bonding.***

Whereas;

*The metal **chlorides** (NaCl 808 °C),(MgCl₂ 714 °C),(AlCl₃ 192 °C), and the molecular chlorides of non-metals have **low melting points** and are **volatile** because they are **simple covalent molecules**; therefore they **fail the >1400 °C requirement** and unsuitable for high-temperature structural use.*

$1E_S + 3E_d = E_v = 04scores$

Prediction of melting point, nature and industrial suitability of chloride X;

*The oxide of element **X**, lying between Al₂O₃ and SiO₂ will likely have a melting point between 1607 °C and 2007°C, approximately 1850°C.*

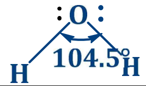
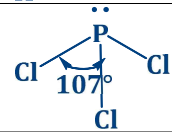
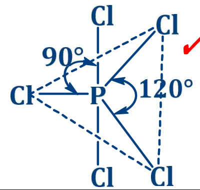
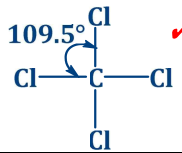
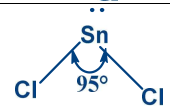
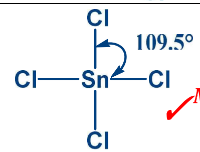
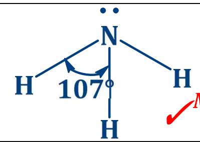
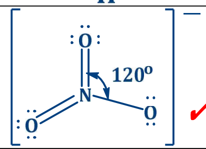
*Its bonding is expected to bean oxide with mixed **covalent and ionic** bonding rather than a purely ionic or simple molecular structure.*

Industrial suitability:

*such an oxide would be **suitable for high-temperature applications** (furnace linings, kiln refractories, and heat-resistant ceramics) because it meets the >1400 °C requirement and offers good thermal stability.*

$3Pr = P_r = 03scores$

4. Molecular shape, bond type, and bond angle;

Name of substance	Molecular structure	Name of molecular shape	Bond type	Bond angle
Water		*bent shape/ V-shape*	*Polar covalent*	104.5°
Phosphorus trichloride		*trigonal pyramidal*	*Polar covalent*	107°
Phosphorus pentachloride		*trigonal bipyramidal*	*Covalent*	90° and 120°.
Carbon tetrachloride		*tetrahedral*	*Non-polar covalent*	109.5°.
Tin(II) chloride		Bent shape/ V-shape	*Ionic with covalent character*	95°
Tin(IV) chloride		*tetrahedral*	*Pure covalent*	109.5°.
Ammonia		*trigonal pyramidal*	*Polar covalent*	107°
Nitrate ion		*trigonal planar*	*Covalent with resonance delocalization*	120°

$9Mi + 9Ni + 9Bi + 9Ai = V_p = 08scorers$

Account for differences in melting point, solubility, and electrical conductivity:

The **differences in solubility, melting point, and conductivity** among these compounds are due to the type of bonding and molecular structure.

Ionic compounds ($SnCl_2$, nitrate salts) have **high melting points** and **conduct electricity when molten or in solution**, while **covalent molecular compounds** (CCl_4, PCl_3, $SnCl_4$) have **low melting points**, are **non-conductors**, and are **insoluble** in water.

Hydrogen bonding in water and ammonia leads to **strong intermolecular attractions**, giving them higher boiling points than similar covalent molecules like PCl_3 and PCl_5.

$3R_3 = R_3 = 03scores$

Comparison of boiling points and solubility of water and ammonia to those of phosphorus trichloride, phosphorus pentachloride and carbon tetrachloride:

Water is a **bent polar molecule** with an angle of **104.5°**, and ammonia is **trigonal pyramidal** with an angle of **107°**; both have **polar covalent bonds** and form **hydrogen bonds** between molecules. Hydrogen bonding gives them **high boiling points** and makes them **highly soluble in water**.

In contrast, PCl_3 (trigonal pyramidal, 107°) and PCl_5 (trigonal bipyramidal, 90° & 120°) are **covalent** and **cannot form hydrogen bonds**. They have **low melting points** are **liquid or volatile solids**, and **do not dissolve** in water because they hydrolyse, producing **HCl** and **phosphoric acids**.

$3R_4 = R_4 = 03scores$

Comparison of electrical conductivity and melting points of tin(II) and tin(IV) chloride:

Tin(II) chloride ($SnCl_2$) is **ionic with some covalent character**, forming a **bent structure** (≈95°) and a **solid** at room temperature. It **conducts electricity when molten** because it contains **mobile ions (Sn^{2+} and Cl^-)**.

Tin(IV) chloride ($SnCl_4$), on the other hand, is **tetrahedral (109.5°)** and **purely covalent**, existing as a **molecular liquid** that **does not conduct electricity**. Its weak molecular forces give it a **lower melting point** than $SnCl_2$.

$3R_5 = R_5 = 03scores$

$R_3 + R_4 + R_5 = R = 09scores$

Evaluation of the environmental impacts of using nitrate ions in fertilizers:

In fertilizer use, **nitrate ions (NO_3^-)** improve plant growth.

However when overused, cause **environmental pollution** since Nitrates are **highly soluble** and can **leach into groundwater**, causing **eutrophication** and **oxygen depletion** in water bodies, leading to fish deaths and **blue-baby syndrome** in humans. Mitigated by controlled, fertilizer application, and use of organic manure.

$1di + 1de + 1dm = D_3 = 03\ Scores$

5. **Formulae of W ;**

$$C_xH_y(g) + \left(x + \tfrac{y}{4}\right) O_2(g) \longrightarrow xCO_2(g) + \tfrac{y}{2}H_2\,O(g)$$

$Volume\ of\ hydrocarbon = 20cm^3$

$Volume\ of\ carbon\ diode\ produced = 110 - 30 = \mathbf{80cm^3}$

$Volume\ of\ oxygen\ used\ up\ in\ reaction = original\ volume - volume\ unreacted$
$= 150 - 30 = \mathbf{120cm^3}$ — CA

$Volume\ of\ hydrocarbon \times x = volume\ of\ carbondioxide$

$\Rightarrow 20x = 80$

$\therefore x = {}^{80}/_{20} = \mathbf{4}$

$Also\ volume\ of\ hydrocarbon \times \left(x + \tfrac{y}{4}\right) = volume\ of\ oxygen\ used\ up$

$\Rightarrow 20\left(4 + \tfrac{y}{4}\right) = 120$

$\therefore\ y = (6 - 4) \times 4 = 8$ — CA

$\therefore$ ***The formula of W is C_4H_8*** — CA

Possible isomers, identity of W with reason(s)

$CH_3CH_2CH = CH_2$

$CH_3CH = CHCH_3$ — CA

Since ozonolysis of W produced only one compound, it indicates that it has a symmetrical carbon-carbon double bond.

$$CH_3CH = CHCH_3 \xrightarrow[2.\,H_2O,\,Zn,\,CH_3COOH]{1.\,O_3,\,CCl_4,\,<\,20^0C} 2CH_3CHO$$ ***, One compound produced is ethanal***

Therefore, W is $CH3CH = CHCH3$ but-2-ene — CA

Comfirmatory Test for Carbon dioxide; — I

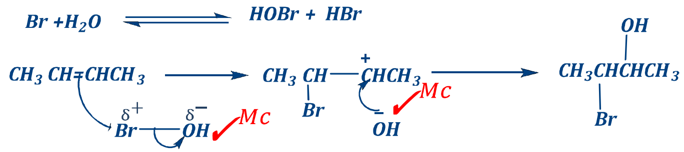
*If the gas is CO_2, KOH will absorb it so the **limewater remains clear** (no milky cloud), because CO_2 was removed by the KOH beforehand. But the gas is not absorbed by KOH, the limewater will still **go milky**.* — I

$5CA + 2I = F = 06\ Scores$

Mechanism for reaction between W and bromine water;

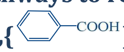
$$CH_3CH = CHCH_3 \xrightarrow{Br_2/H_2O} CH_3CHBrCH(OH)CH_3 + HBr$$

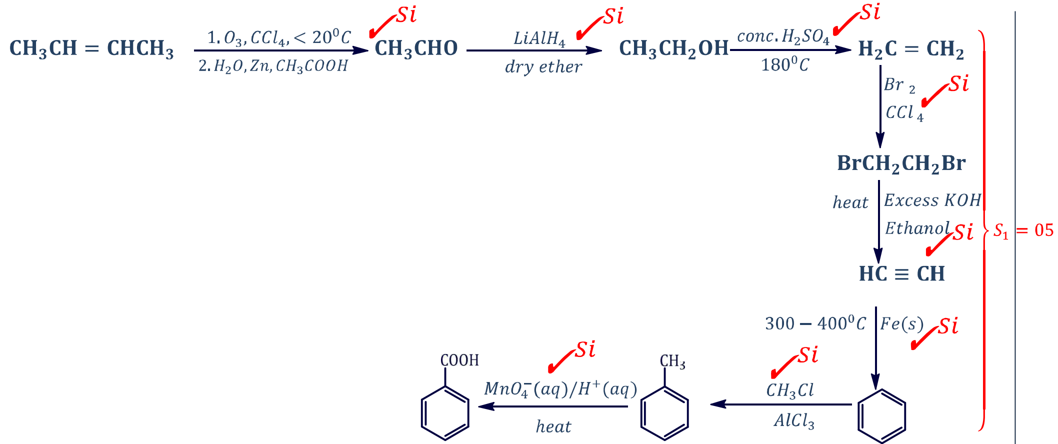
Mechanism



$2Mc = Mc = 02\ Scores$

Synthetic **pathways to related products;**

Benzoic acid,{  **};**



1,2-dibromopentane;

$CH_3CH = CHCH_3 \xrightarrow[2. H_2O, Zn, CH_3COOH]{1. O_3, CCl_4, < 20^0C} CH_3CHO \xrightarrow[dry\ ether]{LiAlH_4} CH_3CH_2OH \xrightarrow[180^0C]{conc. H_2SO_4} H_2C = CH_2 \xrightarrow{Br_2 / CCl_4} CH_2Br\,CH_2Br$

$\xrightarrow[heat]{Excess\ KOH/ethanol} HC \equiv CH \xrightarrow[CH_3CH_2CH_2Cl]{Na(s)/LiqNH_3} CH_3CH_2CH_2C \equiv CH \xrightarrow[lindlar's\ catalyst]{H_2} CH_3CH_2CH_2CH = CH_2 \xrightarrow[CCl_4]{Br_2} CH_3CH_2CH_2CHBrCH_2Br$ $S_2 = 05$

1-chlorobutane;

$CH_3CH = CHCH_3 \xrightarrow[warm]{H_2O/H^+} CH_3CH_2CH(OH)CH_3 \xrightarrow[180^0C]{conc.\ H_2SO_4} CH_3CH_2CH = CH_2 \xrightarrow[ROOR]{HCl} CH_3CH_2CH_2CH_2Cl$ $S_3 = 01$

$S_1 + S_2 + S_3 = S = 11\ Scores$

Environmental impacts of producing above compounds in industry;

When burnt, they give off poisonous gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to ***air pollution****,* ***acid rain****,* ***respiratory problems****, and* ***global warming****. The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid* ***open-air burning*** *and instead use* ***safe chemical disposal methods****.* dm

$1di + 1de + 1dm = D_3 = 03\ Scores$

6. **Formulae of P ;**

Mass of carbondiode formed $= 8.8g$ ***and mass of water formed*** $= 1.8$

mass of carbon $= \frac{12}{44} \times 8.8 = 2.4g$

mass hydrogen $= \frac{2}{18} \times 1.8 = 0.2g$

Element	C	H
%composition	2.4	0.2
Moles	$\frac{2.4}{12} = 0.2$	$\frac{0.2}{1} = 0.2$
Simplest ratio	$\frac{0.2}{0.2} = 1$	$\frac{0.2}{0.2} = 1$

CA

$\therefore$ *Empirical formula is* **CH**

Mass of p vaporised $= 0.100g$

At a Temperature $T = 273 + 273 = 546K$

At a Pressure $P = \left(\frac{734}{760} \times 1\right)\ atm$

At a Volume $V = 4.46 \times 10^{-2} dm^3$

Note: 1. *we use;* $R = 0.0821\ L \cdot atm/(mol \cdot K)$, *when, P is in atm and V is in litre/*dm^3
2. *we use;* $R = 8.314\ J/(molK)$, *when, P is in Pa and Volume is in* m^3

From ideal gas law $PV = nRT$

$$PV = \frac{m}{M_r}RT$$

$$\Rightarrow M_r = \frac{mRT}{PV} = \frac{0.100 \times 0.0821 \times 546}{\left(\frac{734}{760} \times 1\right) \times 4.46 \times 10^{-2}} = \frac{4.48266}{0.04307} \approx 104g$$ CA

$\therefore (CH)_n = 104$

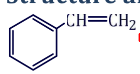
$(12 \times 1 \times n) + (1 \times 1 \times n) = 104$

$13n = 104$

$n = \frac{104}{13} = 8$

$\therefore$ *Molecular formula is* C_8H_8 CA

Structure and IUPAC Name;



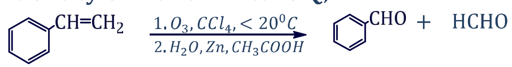
CA

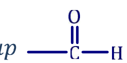
ethenylbenzene CA

Structural isomers;

P *has no other strural isomers.* I

Identity of P and mixture Q;

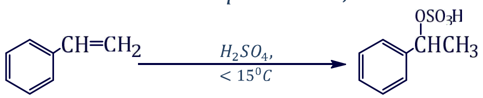


Q *is a mixture of benzylaldehyde and methanal with functional group*  I

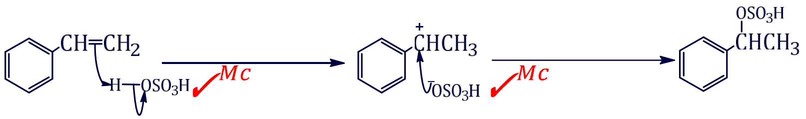
$5CA + 2I = F = 06$ *Scores*

Mechanisms for reactions of P with bromine and concentrated sulphuric acid;

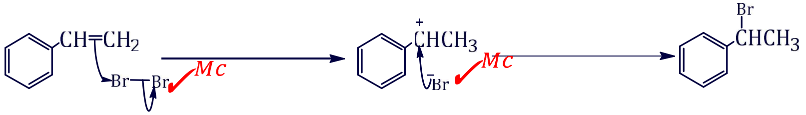
With concentrated sulphuric acid;



Mechanisim



With bromine;

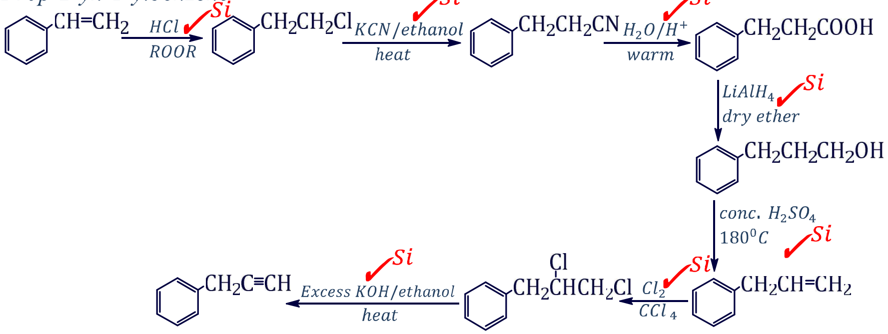


$M_C = 02$

$4Mc = Mc = 02$ *Scores*

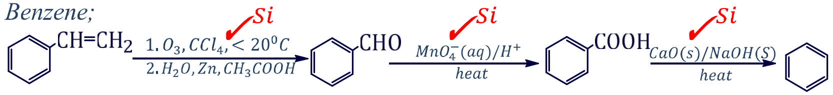
Synthetic pathways from Albertine oil fractions P to synthesis industrial compounds ;

Prop-2-yn-1-ylbenzene



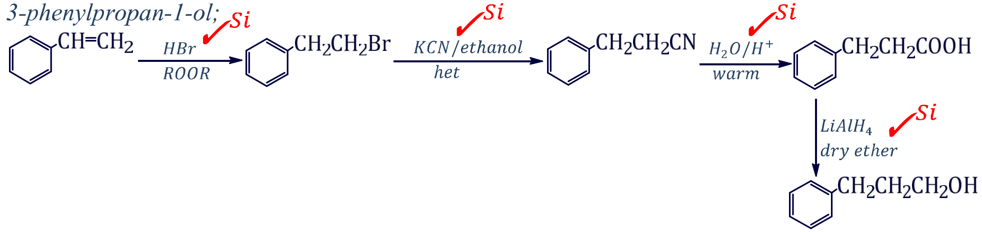
$S_1 = 05$

Benzene;



$S_3 = 01$

3-phenylpropan-1-ol;



$S_1 = 05$

$S_1 + S_2 + S_3 = S = 03$ *Scores*

Environmental impacts of producing above compounds in industry;

When burnt, they give off poisonous gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrogen chloride (HCl), and hydrogen bromide, hence lead to ***air pollution***, ***acid rain***, ***respiratory problems***, *and* ***global warming***. *The acid gases can also corrode metals and destroy plant leaves. Mitigated avoid* ***open-air burning*** *and instead use* ***safe chemical disposal methods.***

1di+1de+1dm=D₃=03 Scores

END
2025
It is All about mindset change

Candidate's Name: ……SAMPLE SCORE……………………………………………………..

Signature: …………………………….. | STREAM: | | | | | | | |

525/1
CHEMISTRY
March 2026
$2^1/_2$ hours

PRE-REGISTRATION ASSESSMENT 2026

Uganda Advanced Certificate of Education

S.6 CHEMISTRY

Paper 1

Set I

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

This paper has **two** *sections* **A** *and* **B.**

Section **A** *has two compulsory items while* **B** *has two parts* **Part I** *and* **Part II**

Each of part I and part II has two items, Answer only **one** *from each.*

Answers to Section **A** ***must*** *be written in the spaces provided and Section* **B** ***must*** *be written in the answer booklet(s) provided*

Answer four in all.

Where necessary use,

Molar gas volume at s.t.p = 22.4dm³

FOR EXAMINER'S USE ONLY		
ITEM	CODE	SCORE
1		
2		
3/4		
5/6		
TOTAL		

SECTION A

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

ITEM 1

PhosGuard Industries manufacture phosphorus-derived reagents used in water treatment to remove heavy metal poisoning. Part of their continuous firing reactor line handles phosphorus(V) chloride (PCl_5) as an intermediate. The safety team performs gas phase equilibrium checks to ensure plant safety and downstream water treatment compatibility.

A gas phase equilibrium test was carried out by introducing *3.60 moles* of phosphorus(V) chloride into a rigid vessel of volume *2.00 dm³* at a given temperature. Analysis showed 1% dissociation according to:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \quad \Delta H = +124\ kJ\ mol^{-1}.$$

Using this information, the equilibrium constant Kc can be determined.

In a follow-up process optimization test, the company introduces an additional 0.050 moles of chlorine gas (Cl_2) into the same system at the same temperature.

A treatment test was carried out where *0.208 g* of phosphorus(V) chloride (PCl_5) was completely hydrolysed in *1.00 dm³* of water, producing hydrochloric acid (HCl).

The acid produced supplies chloride ions (Cl^-), which are then used to react with lead(II) ions (Pb^{2+}) in wastewater to form a precipitate, equations involved;

$$PCl_5\,(g) + 4H_2O\,(l) \rightarrow H_3PO_4\,(aq) + 5HCl(aq)$$
$$Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)$$

A sample of wastewater contains 0.020 mol dm⁻³ Pb^{2+} ions. You have been contacted for help.

Task:

As a learner of chemistry, guide the company on how to:

(a) Calculate the equilibrium constant Kc and comment on the extent of the reaction.

	$PCl_5(g)$	$\rightleftharpoons$	$PCl_3(g)$	+	$Cl_2(g)$
Initial moles	**3.6**		**0**		**0**
Moles dissociated/formed	$3.6\,\alpha$		$3.6\,\alpha$		$3.6\,\alpha$ ✓CA
Moles at equilibrium	$\mathbf{3.6(1-\alpha)}$		$\mathbf{3.6\alpha}$		$\mathbf{3.6\alpha}$
~~***Concentration at equilibrium***~~	$\frac{3.6(1-\alpha)}{2.0}$		$\frac{3.6\alpha}{2.0}$		$\frac{3.6\alpha}{2.0}$

But $\alpha = {}^1/_{100} = \mathbf{0.01}$ ✓CA

$\therefore [PCl_5] = \frac{3.6(1-0.01)}{2.0} = \mathbf{1.782M}$ ✓CA; $[PCl_3] = \frac{3.6\times0.01}{2.0} = \mathbf{0.018M}$ ✓CA; $[Cl_2] = \frac{3.6\times0.01}{2.0} = \mathbf{0.018M}$ ✓CA

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}\ \frac{moldm^{-3}\times moldm^{-3}}{moldm^{-3}}$$

$$K_c = \frac{(0.018)^2}{1.782} = \mathbf{1.82\times10^{-4}\ moldm^{-3}}$$ ✓CA

∴The value of Kc is ***very small,*** *hence equilibrium lies to the* ***left*** *and the reaction proceeds to a* ***small extent.*** ✓CA

$7CA = C_1 = 03$ *scores;*

(b) Determine the new equilibrium concentrations of all species during optimization test, hence determine the direction in which the equilibrium shifts and explain your answer.

Moles of $PCl_5 = 3.6(1 - 0.01) = \mathbf{3.564}$; Moles of $PCl_3 = 3.6 \times 0.01 = \mathbf{0.036}$

Moles of $Cl_2 = 3.6 \times 0.01 = \mathbf{0.036}$; On addition of 0.050 moles of Cl_2 in the reaction vessel

$\therefore$ ***new $Cl_2 = 0.036 + 0.050 = 0.086$ moles***

Equilibrium shifts to the left to reduce excess Cl_2; *Let **x** be the amount reacting:*

	$PCl_3(g)$ +	$Cl_2(g)$ ⇌	$PCl_5(g)$
New Initial moles	**0.036**	**0.086**	**3.564**
Moles reacted/formed	x	x	x
Moles at equilibrium	$(0.036 - x)$	$(0.086 - x)$	$(3.564 + x)$
Concentration at equilibrium	$\frac{(0.036 - x)}{2.0}$	$\frac{(0.086 - x)}{2.0}$	$\frac{(3.564 + x)}{2.0}$

But Backward New $K_{C_{New}} = \frac{1}{K_C}$

$= \frac{1}{1.82 \times 10^{-4}} \quad \frac{1}{moldm^{-3}}$

$= \mathbf{5494.51\ mol^{-1}dm^{3}}$

$K_C = \frac{[PCl_5]}{[PCl_3][Cl_2]}$

$5494.51 = \frac{\frac{(3.564 + x)}{2.0}}{\left(\frac{(0.036 - x)}{2.0}\right)\left(\frac{(0.086 - x)}{2.0}\right)}$

$5494.51[(0.036 - x)(0.086 - x)] = 2(3.564 + x)$

$5494.51(0.003096 + x^2 - 0.122x) = 2(3.564 + x)$

$17.01 + 5494.51x^2 - 670.33x = 7.128 + 2x$

$5494.51x^2 - 672.33x + 9.882 = 0$

$x = \frac{672.33 \pm \sqrt{(672.33)^2 - 4(5494.51)(9.882)}}{2(5494.51)}$

$x = 0.105\ or\ 0.0171$

*x must be less than **0.036** and **0.086***

(cannot exceed initial moles),

$\therefore x = \mathbf{0.0171\ moles}$

At new equilibrium;

$[PCl_5] = \frac{(3.564 + 0.0171)}{2.0} = \mathbf{1.791 moldm^{-3}}$;

$[PCl_3] = \frac{(0.036 - 0.0171)}{2.0} = \mathbf{0.00945 moldm^{-3}}$;

$[Cl_2] = \frac{(0.086 - x)}{2.0} = \mathbf{0.0345\ moldm^{-3}}$

$\therefore$ ***Equilibrium shifts to the left to reduce excess Cl_2 introduced at equilibrium***

9CA = C_2 = 06 scores;

(c) Explain what would happen to the equilibrium position, the equilibrium constant (Kc) and the speed of attainment of equilibrium when the following changes are made:

i. Increasing the temperature

*According to´Le Chatelier's principle, the forward reaction is **endothermic (ΔH = +124 kJ/mol)**. Increasing temperature adds heat to the system, therefore the equilibrium shifts **from left to right** to absorb the added heat, producing more PCl_3 and Cl_2. The value of **Kc increases** because equilibrium constant depends on temperature and increases for endothermic reactions. The **rate of attainment of equilibrium increases** since higher temperature increases kinetic energy and collision frequency of molecules.* *F = 03 scores;*

ii. Decreasing the pressure

*According to Le Chatelier's principle, the reaction involves an **increase in number of gas molecules (1 mole → 2 moles)**. Decreasing pressure shifts equilibrium **from left to right**, favouring the side with more gas molecules to increase pressure. The value of **Kc remains unchanged** because pressure does not affect equilibrium constant. The **rate of attainment of equilibrium decreases** since fewer particles per unit volume result in fewer effective collisions.*

F = 03 scores;

iii. Adding helium gas at constant volume

*According to´Le Chatelier's principle, helium is an **inert gas** and does not take part in the reaction. Adding helium at constant volume does **not change the concentration or partial pressure of reacting gases**, therefore the **equilibrium position remains unchanged**. The value of **KcK_cKc remains unchanged**, and the **rate of attainment of equilibrium remains unchanged** since there is no effect on reacting particles.*

F = 03 scores;

(d) Advise the company on how to optimize operating conditions (temperature, pressure, concentration) in order to, control equilibrium effectively, improve production efficiency and ensure safety in handling phosphorus(V) chloride

- *High temperature increases yield of products but excessive heat may be dangerous, therefore moderate temperature should be used.*
- *Low pressure favors forward reaction but must be controlled to avoid gas leakage.*
- *Continuous removal of Cl_2 shifts equilibrium to the right increasing production.*
- *Proper monitoring and closed systems prevent leakage of toxic gases like chlorine and phosphorus(V) chloride.*

04 scores;

(e) Calculate the maximum number of moles of Pb^{2+} ions that can be precipitated by the chloride ions present, Comment whether chloride ions are sufficient to completely remove Pb^{2+} ions from the wastewater.

Molar mass of $PCl_5 = 208.5g$

$0.208\ g\ contain\ \frac{0.208}{208.5} = 0.0010\ moles\ of\ PCl_5$

From equation: $\boldsymbol{PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl}$

$1\ mole\ of\ PCl_5\ produces\ 5\ moles\ of\ Cl^-$

$0.0010\ moles\ of\ PCl_5\ produce\ \frac{(0.0010 \times 5)}{1} = \boldsymbol{0.0050\ moles\ of\ Cl^-}$

From equation: $\boldsymbol{Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)}$

$2\ moles\ of\ Cl^-\ react\ with\ 1\ mole\ of\ Pb^{2+}$

$0.0050\ moles\ of\ Cl^-\ react\ with\ \frac{0.0050}{2} = \boldsymbol{0.0025\ moles\ of\ Pb^{2+}}$

$1000\ cm^3$ *a sample of wastewater contains* $\boldsymbol{0.020\ moles\ of\ Pb^{2+}}$

∴ chloride ions remove only 0.0025 moles

∴ chloride ions are not sufficient to completely remove Pb^{2+}

(f) Suggest possible environmental impacts PhosGuard Industries should beware of and propose appropriate mitigation measures.

Leakage of chlorine gas during processing can cause ***respiratory problems*** *and* ***air pollution*** *since it is highly* ***toxic,*** *hence hazardous to human* ***health****. This can be mitigated by* ***installing gas scrubbers*** *and ensuring closed systems.*

Discharge of ***acidic solutions*** *into water bodies can* ***lower pH*** *and* ***harm aquatic life****. This is controlled by* ***neutralizing the effluents*** *before discharge.*

Improper disposal of lead compounds can cause environmental contamination specifically ***soil pollution reduced fertility, plant yield associated food poisoning****. This can be mitigated by proper collection, recycling, and safe disposal of sludge.*

Item 2

A chemical processing plant plans to scale up production of propan-2-ol, an important solvent used in sanitizers. Plant managers are evaluating two possible preparation routes, and the management wants a full thermochemical assessment before commissioning either pathway. Major preparation involves hydrogenation of Propanone:

$$CH_3C(=O)CH_3 + H_2(g) \longrightarrow CH_3CH(OH)CH_3(l)$$

Alternatively, propan-2-ol can be obtained from hydration of propene:

$$CH_3CH = CH_2(g) + H_2O(l) \longrightarrow CH_3CH(OH)CH_3(l)$$

The thermochemical department has supplied the following bond energies and auxiliary standard enthalpy information for use:

Bond / Data	C=O	C=C	C–C	C–H	C–O	O–H	H–H
Value (kJ·mol⁻¹)	715.41	614.28	345.01	414.50	351.11	464.23	436.43

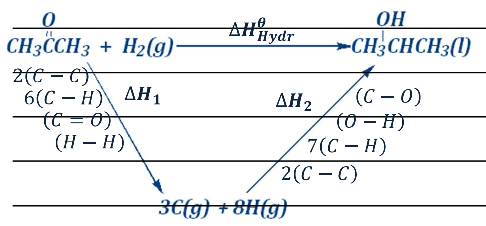
To inform decision making for the best preparation reaction the manager has been advised by the expert that the best reaction must be feasible therefore you have been contacted for help.

Task:

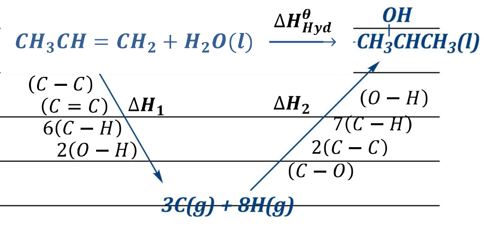
As a learner of chemistry, help the manager

(a) For each route, construct a Hess's law energy cycle, using the thermochemical data.

(i) Hydrogenation of propanone



(ii) Hydration of propene



(b) Use the energy cycles above to calculate the enthalpy change for:

(i) Hydrogenation of propanone

$$\Delta H^{\theta}_{Hydr} = \Sigma \text{ bond energies broken} - \Sigma \text{ bond energies made}$$

$$\Delta H^{\theta}_{Hydr} = \Delta H_1 - \Delta H_2$$

$$\Delta H^{\theta}_{Hydr} = [2(C-C) + 6(C-H) + (C=O) + (H-H)] - [2(C-C) + 7(C-H) + (O-H) + (C-O)]$$

$$\Delta H^{\theta}_{Hydr} = [2 \times 345.01 + 6 \times 414.50 + 715.41 + 436.43] - [2 \times 345.01 + 7 \times 414.50 + 464.23 + 351.11]$$

$$= 4328.86 - 4406.86$$

$$\therefore \Delta H^{\theta}_{Hydr} = -78\ kJmol^{-1};\ \therefore \textit{Reaction is exothermic}$$

(ii) Hydration of propene

$$\Delta H^{\theta}_{Hydr} = \Sigma \text{ bond energies broken} - \Sigma \text{ bond energies made}$$

$$\Delta H^{\theta}_{Hydr} = \Delta H_1 - \Delta H_2$$

$$\Delta H^{\theta}_{Hydr} = [(C-C) + (C=C) + 6(C-H) + 2(O-H)] - [2(C-C) + 7(C-H) + (O-H) + (C-O)]$$

$$\Delta H^{\theta}_{Hydr} = [345.01 + 614.28 + 6 \times 414.50 + 2 \times 464.23] - [2 \times 345.01 + 7 \times 414.50 + 464.23 + 351.11]$$

$$= 4374.75 - 4406.86$$

$$\therefore \Delta H^{\theta}_{Hydr} = -32.11\ kJmol^{-1};\ \therefore \textit{Reaction is exothermic}$$

(c) Evaluate which preparation route is more feasible for large scale production of propan-2-ol in the factory.

According to thermochemical principles, a more feasible reaction is one that is ***more exothermic (more negative ΔH)*** *since it releases more energy and is energetically favorable. Hydrogenation:* ***ΔH = –78.0 kJ mol^{-1}*** *while Hydration:* ***ΔH = –32.11 kJ mol^{-1}***

∴Hydrogenation of propanone is more feasible; This is because it releases ***more heat energy****, making it more favorable for large-scale production.*

(d) Predict any major environmental impact arising from the process and propose a realistic mitigation measure for the impact.

Hydrogenation involves the use of hydrogen gas which is ***highly flammable****. Leakage during processing can cause explosions and fire outbreaks, posing danger to workers and the environment. This can be mitigated by* ***using airtight reactors and regular monitoring of pipelines****.*

Industrial processes may release ***volatile organic compounds (VOCs)*** *which contribute to air pollution. This can be controlled by installing* ***gas capture and treatment systems*** *to reduce emissions.*

SECTION B

Part I

Attempt **One** *item in this section*

Item 3

Your chemistry class has been invited by a chemical plant management near Lake Victoria to assist in identifying ways of optimizing the production of key industrial compounds including sodium oxide, magnesium oxide and silicon dioxide used in glassmaking and ceramics. The plant management has observed inconsistencies in melting points and reactivity, which are affecting product quality and safety. You are tasked with conducting a scientific investigation to analyze periodic trends of the elements, compound properties, and molecular structures to recommend improvements.

Important chemical data of the findings about the elements and their compounds is provided in the table below to assist in the analysis.

Element	Atomic Number	Atomic Radius (pm)	Ionisation Energy (kJ/mol)	Melting Point (°C)	Oxide Melting Point (°C)
Sodium (Na)	11	186	496	98	1275
Magnesium (Mg)	12	160	738	650	2800
Aluminium (Al)	13	143	578	660	2072
Silicon (Si)	14	118	786	1410	1710

Phosphorus (P)	15	110	1012	44	580
Sulphur (S)	16	104	1000	115	Gas/Sublimes
Chlorine (Cl)	17	99	1251	-101	Gas/Gas

Task

As a chemistry learner, write a report about the periodic trends of the elements and their oxides, and recommend improvements to the plant's production processes.

Item 4

Uganda faces persistent challenges in rural electrification. Many communities rely on unreliable and costly energy sources like diesel generators, kerosene lamps, and car batteries. A Ugandan company is developing solar-powered micro-grids and has invited your chemistry class to help identify suitable materials for solar batteries and wiring. These materials must be affordable, corrosion-resistant, and durable under Uganda's rural conditions.

The company is investigating elements similar to those in Periods 2 and 3 of the Periodic Table. The measured properties of selected elements are shown below:

Element	Atomic Radius (pm)	First Ionization Energy (kJ/mol)	Electronegativity (Pauling)	Typical Bonding Type
Li	145	520	1.0	Metallic
Mg	130	730	1.5	Metallic
Al	110	1000	2.5	Metallic
Si	95	1250	3.0	Covalent
P	85	1500	3.5	Covalent

Task

As a chemistry learner;

Use your understanding of atomic structure, periodic trends, chemical bonding and the information provided to propose suitable materials for solar batteries and wiring in Uganda's rural micro-grid systems

Part II

Attempt **One** *item in this section*

ITEM 5

A certain town in central Uganda faces growing concerns over water pollution from agro-processing industries, especially during the cocoa harvest season. Wastewater from cocoa processing plants often contains organic matter including acids, and amines that can harm aquatic life if released untreated.

A group of entrepreneurs is setting up a small plant to process cocoa husks, a by-product of cocoa bean production, into value-added products. Chemical analysis of the husks shows that they contain ethanol (from natural fermentation), ethanoic acid, small amounts of amines

(from protein breakdown), and aromatic aldehydes such as vanillin(4-hydroxy-3-methoxybenzaldehyde).

To address the water pollution challenge and create additional revenue streams, the team plans to:

1. Determine the relationship between the structure of vanillin and ethanoic acid, and their solubility.
2. Convert ethanol into amines for use in water treatment and cosmetics.
3. React ethanoic acid with ethanol to produce an ester for fragrances, and study its reaction mechanism.
4. Evaluate the use of the esters and amines in producing fragrances and cosmetics

You have been tasked by your teacher to design feasible chemical processes, explain the underlying organic chemistry, and propose sustainable solutions to help the plant reduce environmental harm while maintaining profitability.

ITEM 6

In southwestern Uganda, a small cosmetics start-up is producing herbal skin-care creams using locally sourced plant oils, such as shea butter and sunflower oil. The production process generates significant amounts of waste plant oils and fats. These wastes are currently disposed of into nearby drainage systems, causing blockages and foul smells, which has led to complaints from the community and environmental authorities.

The company has approached a team of A-level chemistry students in your school to:

1. Analyse the composition of these waste materials, their functional groups and physical properties,
2. Explore possible chemical processes to convert them into valuable products and their mechanisms,
3. Design a synthetic route to convert compound C into compound D
4. Propose a sustainable chemical process to convert waste A into a useful, marketable product that reduces environmental harm.

Analysis of a sample of the waste oil revealed the presence of a mixture of the following compounds:

Compound	Structure (condensed)
A	$CH_3(CH_2)_{14}COOCH_2CH(OH)CH_2OH$
B	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
C	$CH_3CH_2CH_2OH$
D	CH_3COCH_3

Tasks:

As a chemistry learner, give written presentation that addresses the company's challenges and outlines scientifically sound, sustainable solutions.

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	35.4 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 Te 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 Ti 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 68	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

ITEM 3

Periodic Trends and Compound Properties

- ***Atomic radius decreases across Period 3 (Na → Cl)*** *due to increasing nuclear charge while electrons are added to the same shell. This leads to* ***smaller atoms with stronger bonding****, influencing the stability and melting points of oxides.*
- ***Ionisation energy increases across the period (Na → Cl)****. Sodium and magnesium have low ionisation energy, making them highly reactive metals. Silicon has intermediate ionisation energy, while phosphorus, sulphur, and chlorine are non-metals and more likely to gain or share electrons.*
- ***Melting points of elements:***
  - *Sodium (98°C) → low due to weak metallic bonding.*
  - *Magnesium (650°C) and Aluminium (660°C) → higher due to stronger metallic bonding.*
  - *Silicon (1410°C) → very high due to giant covalent structure.*
  - *Phosphorus (44°C), Sulphur (115°C), Chlorine (-101°C) → low due to simple molecular structures with weak intermolecular forces.*
- ***Oxide properties:***
  - *Sodium oxide (Na_2O) and magnesium oxide (MgO) are* ***ionic oxides****, with high melting points.*
  - *Aluminium oxide (Al_2O_3) is an* ***amphoteric oxide****, with moderate melting point.*
  - *Silicon dioxide (SiO_2) is a* ***giant covalent oxide****, with a very high melting point.*
  - *Phosphorus and sulphur oxides →* ***molecular****, low melting points.*
- ***Explanation of inconsistencies:*** *Differences in melting points and reactivity arise from* ***variation in bonding type, lattice strength, and molecular structure****. Ionic compounds (Na_2O, MgO) require high temperatures for lattice formation, covalent networks (SiO_2) require strong energy input, and molecular oxides have low melting points, leading to inconsistency if a uniform process is used.*

Recommendations for Production Optimization

- ***Temperature control***
  - *Sodium oxide, magnesium oxide, and silicon dioxide require* ***different melting and reaction temperatures****. MgO requires very high temperatures, Na_2O requires moderate temperatures, and SiO_2 requires high but controlled heating. This ensures* ***consistent quality and avoids decomposition****.*
- ***Separation of production units:***

  - *Ionic, covalent, and molecular compounds should be processed in* ***different reactors*** *to prevent contamination and optimize reaction conditions.*
- ***Raw material purity:***
  - *Impurities affect bonding, melting points, and reactivity, leading to* ***inconsistent products****. Using* ***high-purity feedstock*** *ensures quality and predictable outcomes.*
- ***Monitoring and automation:***
  - *Installing* ***sensors for temperature, pressure, and reaction progress*** *ensures proper control, enhances efficiency, and reduces human error.*
- ***Worker safety and handling:***
  - *Automated handling systems and protective equipment minimize exposure to hot oxides and reactive chemicals.*

Environmental and Safety Impacts with Mitigation

- ***High-temperature processing of MgO and SiO_2*** *can cause* ***fire hazards and burns to workers*** *since molten oxides are extremely hot.* ***Mitigation:*** *Install heat shields, protective equipment, and automated handling systems.*
- ***Leakage of sodium oxide or magnesium oxide dust*** *can cause* ***respiratory problems and irritation*** *since the oxides are caustic.* ***Mitigation:*** *Use closed systems, dust extractors, and proper ventilation.*
- ***Discharge of acidic or alkaline effluents*** *can* ***alter pH in nearby water bodies****, harming aquatic life and reducing water quality.* ***Mitigation:*** *Neutralize effluents before discharge and monitor pH regularly.*
- ***Contamination from raw material impurities*** *(e.g., heavy metals) can cause* ***soil pollution, reduced fertility, and accumulation in food chains****, posing health hazards.* ***Mitigation:*** *Use high-purity raw materials, proper waste collection, and safe disposal methods.*
- ***Dust and gas exposure*** *from production may cause* ***respiratory problems and air pollution****.* ***Mitigation:*** *Ensure* ***air filtration, gas scrubbers, and closed systems*** *to protect workers and the environment.*

ITEM 4:

- ***Atomic radius decreases from Li (145 pm) to P (85 pm)*** *due to increasing nuclear charge while electrons are added to the same energy level. This causes a* ***stronger attraction between the nucleus and outer electrons****, pulling them closer. As a result, atoms become smaller and their outer electrons are held more tightly. This leads to* ***stronger bonds and more compact structures****, making elements like silicon form* ***rigid, durable materials****.*

- ***Ionisation energy increases from Li (520 kJ/mol) to P (1500 kJ/mol)*** *because electrons are held more strongly as atomic size decreases. This means metals like lithium and magnesium lose electrons easily, forming positive ions, while non-metals resist electron loss. The ease of electron loss in metals explains their ability to provide* ***mobile charge carriers****.*
- ***Electronegativity increases across the period****, meaning atoms increasingly attract electrons in a bond. Elements like silicon and phosphorus strongly attract electrons, leading to the formation of* ***covalent bonds****. These bonds involve sharing of electrons and result in* ***stable, corrosion-resistant structures****.*
- ***Bonding type changes from metallic (Li, Mg, Al) to covalent (Si, P)*** *across the period. In metallic bonding, positive metal ions are surrounded by a 'sea of delocalised electrons' which are free to move, allowing metals to conduct electricity efficiently. In contrast, covalent bonding involves strong sharing of electrons between atoms, forming* ***giant structures (as in silicon)*** *that are hard, stable, and resistant to heat. These properties make covalent materials ideal for* ***solar panels and electronic components****.*

Proposed Materials for Wiring

- ***Aluminium for wiring*** *is suitable because it has* ***metallic bonding with delocalized electrons****, allowing efficient electrical conductivity. It is also* ***lightweight and relatively resistant to corrosion****, making it ideal for rural installations.*
- ***Magnesium can support alloy formation*** *to improve strength, since pure metals may be too soft. Alloys enhance* ***durability and mechanical strength*** *under harsh rural conditions.*
- ***Lithium is not suitable for wiring*** *despite being a metal because it is* ***too reactive and soft****, making it unsafe and less durable.*

Proposed Materials for Solar Batteries

- ***Lithium is suitable for batteries*** *because it has* ***low ionisation energy****, meaning it loses electrons easily to form ions, enabling efficient energy storage and release in electrochemical cells.*
- ***Silicon is suitable for solar cells*** *because it forms a* ***giant covalent structure****, making it stable, durable, and capable of controlling electron flow (semiconductor properties).*
- ***Phosphorus can be used as a dopant in silicon****, improving electrical conductivity by increasing charge carriers in solar cells.*

Impacts that can arise due to poor matera selection in Rural Conditions

- ***Corrosion of metals in humid rural environments*** *can reduce efficiency and lifespan of wires since moisture promotes oxidation. This is mitigated by* ***using corrosion-resistant materials like aluminium and protective coatings****.*
- ***High temperatures and sunlight exposure*** *can degrade weak materials, reducing durability of solar systems. This is mitigated by* ***using strong covalent materials like silicon which withstand high temperatures****.*
- ***Use of reactive metals like lithium in batteries*** *can cause fire hazards if not properly handled since lithium reacts vigorously with water and air. This can be mitigated by* ***using sealed battery systems and proper insulation****.*
- ***Poor conductivity materials*** *can lead to energy losses during transmission, reducing efficiency of rural electrification systems. This is mitigated by* ***using metals with high electrical conductivity such as aluminium****.*
- ***Material cost constraints in rural areas*** *can limit implementation of electrification systems. This is mitigated by* ***using affordable and abundant materials like aluminium and silicon*** *instead of expensive alternatives.*