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 = 22.4dm^3

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.

	$PCl_5(g)$ ⇌	$PCl_3(g)$ +	$Cl_2(g)$
Initial moles	**3.6**	**0**	**0**
Moles dissociated/formed	$3.6\,\alpha$	$3.6\,\alpha$	$3.6\,\alpha$
Moles at equilibrium	$\mathbf{3.6(1-\alpha)}$	$\mathbf{3.6\alpha}$	$\mathbf{3.6\alpha}$ ✓CA
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

$$\therefore [PCl_5] = \frac{3.6(1-0.01)}{2.0} = \mathbf{1.782M}\ ✓CA; \quad [PCl_3] = \frac{3.6\times0.01}{2.0} = \mathbf{0.018M}\ ✓CA; \quad [Cl_2] = \frac{3.6\times0.01}{2.0} = \mathbf{0.018M}\ ✓CA$$

$$K_C = \frac{[PCl_3][Cl_2]}{[PCl_5]} \quad \frac{moldm^{-3}\times moldm^{-3}}{moldm^{-3}}$$

$$K_C = \frac{(0.018)^2}{1.782} = \mathbf{1.82\times10^{-4}\ moldm^{-3}}$$ ✓CA

∴*The value of Kc is **very small,** hence equilibrium lies to the **left** and the reaction proceeds to a **small extent.*** ✓CA

$7CA = C_1 = 03\ scores;$

Turn Over

(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*

$\therefore \mathbf{new\ Cl_2 = 0.036 + 0.050 = 0.086\ moles}$

Equilibrium shifts to the left to reduce excess $\mathbf{Cl_2}$; *Let* $\mathbf{x}$ *be the amount reacting*:

	$PCl_3(g)$	+ $Cl_2(g)$	$\rightleftharpoons PCl_5(g)$
New Initial moles	$\mathbf{0.036}$	$\mathbf{0.086}$	$\mathbf{3.564}$
Moles reacted/formed	$\mathbf{x}$	$\mathbf{x}$	$\mathbf{x}$
Moles at equilibrium	$\mathbf{(0.036-x)}$	$\mathbf{(0.086-x)}$	$\mathbf{(3.564+x)}$
Concentration at equilibrium	$\mathbf{\frac{(0.036-x)}{2.0}}$	$\mathbf{\frac{(0.086-x)}{2.0}}$	$\mathbf{\frac{(3.564+x)}{2.0}}$

$But\ Backward\ New\ K_{C_{New}} = \frac{1}{K_C}$

$= \frac{1}{1.82 \times 10^{-4}} \quad \frac{1}{moldm^{-3}}$

$= \mathbf{5494.51\ mol^{-1}dm^3}$

$\mathbf{K_C} = \frac{\mathbf{[PCl_5]}}{\mathbf{[PCl_3][Cl_2]}}$

$$5494.51 = \frac{\frac{(3.564+x)}{2.0}}{\left(\frac{(0.036-x)}{2.0}\right)\left(\frac{(0.086-x)}{2.0}\right)}$$

$5494.51[(0.036-x)(0.086-x)] = 2(3.564+x)$

$5494.51(0.003096 + x^2 - 0.122x) = 2(3.564+x)$

$17.01 + 5494.51x^2 - 670.33x = 7.128 + 2x$

$5494.51x^2 - 672.33x + 9.882 = 0$

$$x = \frac{672.33 \pm \sqrt{(672.33)^2 - 4(5494.51)(9.882)}}{2(5494.51)}$$

$x = 0.105\ or\ 0.0171$

x must be less than $\mathbf{0.036}$ *and* $\mathbf{0.086}$

(cannot exceed initial moles),

$\therefore \mathbf{x = 0.0171\ moles}$

At new equilibrium;

$[PCl_5] = \frac{(3.564 + 0.0171)}{2.0} = \mathbf{1.791 moldm^{-3}}$;

$[PCl_3] = \frac{(0.036-0.0171)}{2.0} = \mathbf{0.00945 moldm^{-3}}$;

$\mathbf{[Cl_2]} = \frac{(0.086-x)}{2.0} = \mathbf{0.0345\ moldm^{-3}}$

$\therefore$ ***Equilibrium shifts to the left to reduce excess*** $\mathbf{Cl_2}$ ***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.*

$F = 03\ scores$;

Turn Over

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: $\boldsymbol{PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl}$

$$1\ mole\ of\ PCl_5\ produces\ 5\ moles\ of\ Cl^-$$

$$0.0010\ moles\ of\ PCl_5\ produce\ \frac{(0.0010 \times 5)}{1} = \mathbf{0.0050\ moles\ of\ Cl^-}$$

From equation: $\boldsymbol{Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)}$

$$2\ moles\ of\ Cl^-\ react\ with\ 1\ mole\ of\ Pb^{2+}$$

$$0.0050\ moles\ of\ Cl^-\ react\ with\ \frac{0.0050}{2} = \mathbf{0.0025\ moles\ of\ Pb^{2+}}$$

$$1000\ cm^3\ a\ sample\ of\ wastewater\ contains\ \mathbf{0.020\ moles\ of\ Pb^{2+}}$$

$$\therefore \mathbf{chloride\ ions\ remove\ only\ 0.0025\ moles}$$

$$\therefore \mathbf{chloride\ ions\ are\ not\ sufficient\ to\ completely\ remove\ Pb^{2+}}$$

(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:

$$CH_3\overset{O}{\overset{\|}{C}}CH_3 + H_2(g) \longrightarrow CH_3\overset{OH}{\overset{|}{C}}HCH_3(l)$$

Alternatively, propan-2-ol can be obtained from hydration of propene:

$$CH_3CH = CH_2(g) + H_2O(l) \longrightarrow CH_3\overset{OH}{\overset{|}{C}}HCH_3(l)$$

The thermochemical department has supplied the following bond energies and auxiliary standard enthalpy information for use:

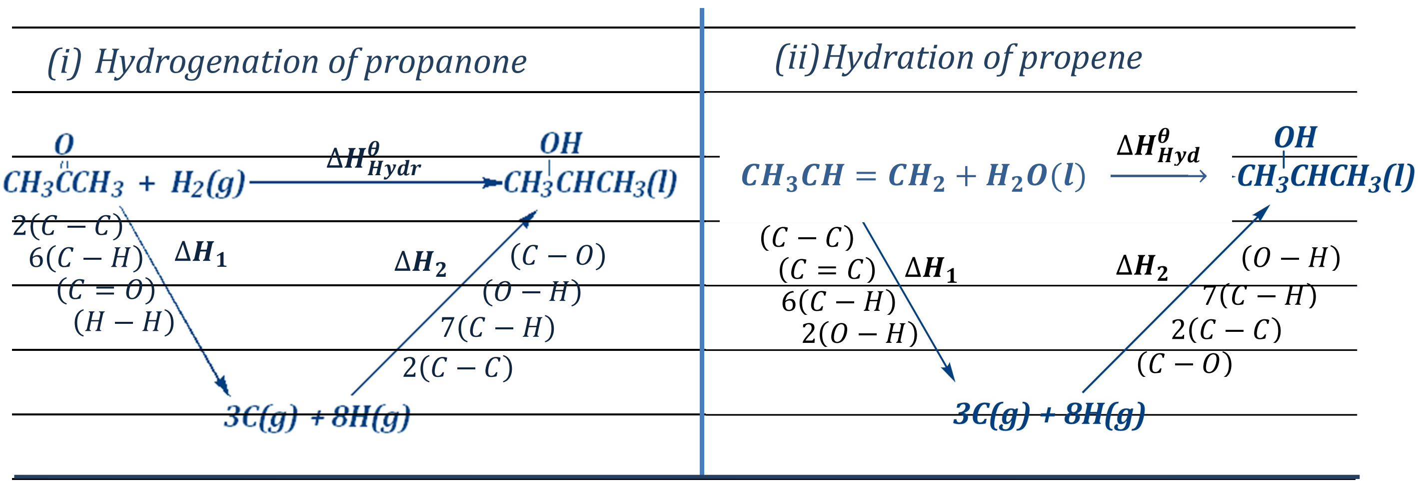
Bond / Data	C=O	C=C	C–C	C–H	C–O	O–H	H–H
Value (kJ·mol⁻¹)	715.41	614.28	345.01	414.50	351.11	464.23	436.43

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.



(b) Use the energy cycles above to calculate the enthalpy change for:

(i) Hydrogenation of propanone

Turn Over

$$\Delta H^{\theta}_{Hydr} = \Sigma\ bond\ energies\ broken - \Sigma\ bond\ energies\ made$$

$$\Delta H^{\theta}_{Hydr} = \Delta H_1 - \Delta H_2$$

$$\Delta H^{\theta}_{Hydr} = [2(C-C) + 6(C-H) + (C=O) + (H-H)] - [2(C-C) + 7(C-H) + (O-H) + (C-O)]$$

$$\Delta H^{\theta}_{Hydr} = [2 \times 345.01 + 6 \times 414.50 + 715.41 + 436.43]$$
$$- [2 \times 345.01 + 7 \times 414.50 + 464.23 + 351.11]$$

$$= 4328.86 - 4406.86$$

$$\therefore \boldsymbol{\Delta H^{\theta}_{Hydr} = -78\ kJmol^{-1}};\ \therefore \textbf{\textit{Reaction is exothermic}}$$

(ii) Hydration of propene

$$\Delta H^{\theta}_{Hydr} = \Sigma\ bond\ energies\ broken - \Sigma\ bond\ energies\ made$$

$$\boldsymbol{\Delta H^{\theta}_{Hydr} = \Delta H_1 - \Delta H_2}$$

$$\Delta H^{\theta}_{Hydr} = [(C-C) + (C=C) + 6(C-H) + 2(O-H)] - [2(C-C) + 7(C-H) + (O-H) + (C-O)]$$

$$\Delta H^{\theta}_{Hydr} = [345.01 + 614.28 + 6 \times 414.50 + 2 \times 464.23] - [2 \times 345.01 + 7 \times 414.50 + 464.23 + 351.11]$$

$$= 4374.75 - 4406.86$$

$$\therefore \boldsymbol{\Delta H^{\theta}_{Hydr} = -32.11\ kJmol^{-1}};\ \therefore \textbf{\textit{Reaction is exothermic}}$$

(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.*