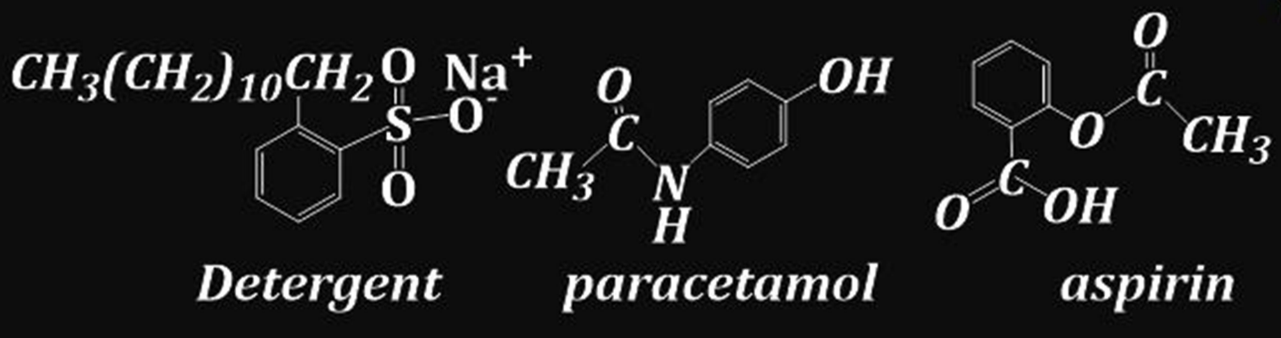
C.B.C U.A.C.E

CHEMISTRY HOLIDAY PACKAGE 2025

BY

Tr. Julius

2025



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U.A.C.E CHEMISTRY C.B.C 2025 SAMPLE ITEMS

S.5 CHEMISTRY END OF YEAR HOLIDAY PACKAGE TO BE COMPLETED 2025

Topic 1: Moles and Equations:

Item 1

According to the Ministry of Health Drug Quality Report (2024), several antibiotic samples from private clinics in central Uganda contained under-dosed active ingredients. Kampala Pharmaceutical Industries evaluated the stoichiometric efficiency of its production of amoxicillin ($C_{16}H_{19}N_3O_5S$).

Synthesis uses p-hydroxyphenylglycine ($C_8H_9NO_3$) and 6-aminopenicillanic acid ($C_8H_{11}N_2O_3S$):

Equation 1.1: $C_8H_9NO_3 + C_8H_{11}N_2O_3S \rightarrow C_{16}H_{19}N_3O_5S + H_2O$

A batch using *6.00 kg* of p-hydroxyphenylglycine yielded *7.80 kg* of amoxicillin.

To verify the identity of the product, chemists combusted a *1.0 g* sample and obtained *1.930 g* of carbon dioxide, *0.468 g* of water, *0.378 g* nitrogen dioxide and *0.176 g* Sulphur dioxide.

The oxygen used in producing the reagent contained isotopes O-16 (99.50%), O-17 (0.30%), and O-18 (0.20%).

A quality control solution of amoxicillin was prepared with a concentration of $0.250 moldm^{-3}$, and $2.50\times10^2 g$ of it was required. The minister has invited you for your assistance.

Task

As the learner of chemistry, help the minister to know;

(a) *(i)* ***The accurate relative atomic mass of oxygen.***
(ii) ***Whether Molecular formula of the product is consistent with amoxicillin.***

(b) ***The mass of amoxicillin expected from the 6.00 kg of reagent and hence advice the minister whether the production is efficient or not.***

(c) *(i)* ***How a solution of 0.250 $moldm^{-3}$ of amoxicillin is prepared for use.***
(ii) ***The volume of 0.250 $moldm^{-3}$ solution needed to obtain $2.50\times10^2 g$ of amoxicillin.***

(d) ***The environmental or health impact associated with the long term use of the product and its mitigation in Ugandan.***

Item 2

The Umeme Energy Outlook (2025) highlights Uganda's commitment to clean and renewable energy technologies to reduce reliance on fossil fuels and mitigate environmental pollution. At the Soroti Renewable Energy Hub, engineers are producing hydrogen gas via the electrolysis of water:

Equation 1.2: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g).$

During a trial, a 25 dm^3 electrolyser operating at room temperature produced 18.5 dm^3 of hydrogen gas. Gas chromatography analysis revealed 94% purity, with trace impurities including oxygen, nitrogen, and water vapor.

The hydrogen contains three isotopes: H-1: 99.98%, H-2 (deuterium): 0.015% and H-3 (tritium): 0.005%

A small portion of the hydrogen-storage residue was analysed and found to contain a polymer precursor composed of 7.50 g of carbon, 1.25 g of hydrogen and 10.0 g of oxygen with a molecular mass of 180.

This polymer is being investigated for potential use as a hydrogen storage medium, which could improve fuel cell efficiency in Uganda's transport and industrial sectors. The manager has invited you for assistance on the analysis.

Task

As a learner of chemistry, help the manager;

(a) *(i)* ***Calculate the accurate relative atomic mass of hydrogen.***
(ii) ***Determine the moles of hydrogen gas collected (1 mole of a gas at RTP occupies 24 dm³ mol⁻¹).***

(b) *(i)* ***Calculate the corresponding volume of oxygen formed and comment on whether the ratio supports the balanced equation.***
(ii) ***Calculate the actual moles of pure usable hydrogen.***
(iii) ***Suggest any other applications of one of the products above.***

(c) ***Determine the molecular formula of the polymer precursor.***

(d) ***Evaluate the environmental impacts associated with the fuel product above.***

Item 3

A 2024 NEMA Environmental Audit of the Kilembe copper mining region recorded high acidity in River Nyamwamba attributed to sulphur dioxide emissions. Dissolved sulphur dioxide forms sulphurous acid:

Equation 1.3: $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$

A 20.0 cm³ acid water sample required 13.6 cm³ of 0.050moldm⁻³ sodium hydroxide solution for neutralisation:

Equation 1.4: $H_2SO_3(aq) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + 2H_2O.$

Sulphur isotopes present were S-32 (94.99%) and S-34 (4.25%).

Sediment collected downstream contained an unknown sulphur-bearing compound with mass ratio: *S : O = 1.00 : 2.00*

Laboratory data suggested its relative molecular mass to be 63.84 and NEMA estimates monthly rainfall of 2.5×10^6 dm³ in the affected area the management of NEMA seeks analysis of the matter in order to best make informed decisions.

Task

As a learner of chemistry, help the management;

(a) *(i)* ***Calculate the accurate relative atomic mass of sulphur.***
(ii) ***Determine the molecular formula of the sulphur-oxygen compound in water.***

(b) *(i)* ***Know how a 0.050moldm⁻³ sodium hydroxide solution was prepared to be used.***
(ii) ***Calculate the concentration of the acid in the river sample.***

(c) *(i)* ***Determine the mass of Sulphur dioxide dissolved per litre of rainwater.***
(ii) ***Estimate the total monthly mass of Sulphur dioxide entering the environment.***

(d) ***Suggest the environmental impacts of the dissolved compound in water and how it can be mitigated.***

Item 4

The Agricultural Industrial Processing Report (2024) identifies significant stoichiometric inefficiencies during the *carbonation stage* at Kakira Sugar Works, where carbon dioxide is bubbled through lime treated cane juice to remove impurities. The process follows:

Equation 1.5: $Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

During a typical operating cycle, *4,500 dm^3* of carbon dioxide was supplied at *30 °C* and *1 atm*. From this operation, *235 g* of calcium carbonate was recovered. The lime solution used had a concentration of *1.50 $moldm^{-3}$.*

Isotopic analysis of calcium indicated Ca-40 (96.90%) and Ca-44 (2.10%).

In addition, an organic chemical impurity formed during juice clarification was isolated and on combustion of a *0.300 g* sample produced *0.660 g* of carbon dioxide and *0.270 g* of water and a molecular mass of *160.13g*.

Management at Kakira got so concerned and so seeks a full stoichiometric evaluation to improve process efficiency, optimise reagent use, and minimise environmental discharges associated with incomplete carbonation.

Task

As a learner of Chemistry, assist the management:

(a) (i) ***Calculate the accurate relative atomic mass of calcium.***

(ii) ***Determine the molecular formula of the impurity.***

(b) ***Calculate the moles of carbon dioxide supplied and hence determine the mass of calcium carbonate expected in the reaction in order to advise the company whether the precipitation is efficient or not.***

(c) (i) ***Briefly describe how 1.50 $moldm^{-3}$ calcium hydroxide solution is prepared for use***

(ii) ***Calculate the minimum volume of calcium hydroxide needed to react completely with the carbon dioxide supplied.***

(d) ***Analyse how important is the stoichiometric reaction above to the environment.***

TOPIC 2: ATOMIC AND ELECTRONIC STRUCTURE

Item 1

In 2025, Mulago National Referral Hospital upgraded its imaging department with a PET-CT scanner that uses Fluorine-18, a positron-emitter with a half-life of 110 minutes. Each radiopharmaceutical batch contains 2.4×10^9 nuclei of F-18, and the dose is normally administered 5.5 hours after preparation due to patient scheduling.

Because of international shortages, the hospital is considering Technetium-99m (gamma emitter) and Iodine-123 (electron-capture decay) as supplementary tracers.

The medical chemistry division must analyze the electron configurations of: Fluorine (Z = 9) and F^-, Technetium (Z = 43), Iodine (Z = 53) and I^- however they donot know how to do it. You have been invited by the hospital team to assist in this analysis.

Task

As a learner of chemistry, help the team;

- ***(a) Write the electronic configurations of the given atoms/ions and relate them to their biochemical reactivity.***
- ***(b) Determine the number of F-18 nuclei remaining after the delay before patient administration.***
- ***(c) Evaluate the suitability of F-18, Tc-99m and I-123 for different diagnostic imaging applications.***
- ***(d) Assess health and environmental risks associated with increasing weekly Tc-99m production and their mitigations.***

ITEM 2

The Ministry of Energy is conducting a feasibility study for a small modular nuclear reactor (SMR). Candidate fuels include Thorium (Z = 90) and Uranium (Z = 92), whose electron configurations determine their oxidation states in high-temperature fuel processing.

According to the feasibility report, Uranium-238 in fuel undergoes alpha decay to produce Thorium-234, which then undergoes beta decay to Protactinium-234.

For decay-rate analysis, a research test cell contains 6.0 g of Th-234, stored for 72 days, and the isotope has a half-life of 24 days.

Questions

- ***(a) Deduce the electron configurations of Th and U and explain their influence on oxidation states in fuel chemistry.***
- ***(b) Write the nuclear equations for the alpha decay of U-238 and beta decay of Th-234, explaining changes in nucleon numbers.***
- ***(c) Suggest the suitability of the substances towards their real life use.***
- ***(d) Determine the mass of Th-234 remaining after the specified storage period.***
- ***(e) Evaluate environmental challenges associated with incorporating radioisotopes into Uganda's future energy mix.***

Item 3

Following long-term phosphate-fertilizer use in Eastern Uganda, NEMA carried out a wetland contamination study. Samples showed that Radium-226 with a half-life of 1600 years, initially present at 5.0×10^6 atoms in the analysed sample. It was also found that accumulation of Radon-222, was by alpha decay of Ra-226.

Further analysis of the wetland revealed that there is contamination from transition-metal ions Fe^{2+}, Fe^{3+}, and Zn^{2+}, whose electron configurations determine their mobility in reducing wetland environments.

However, NEMA must model the remaining Ra-226 after 4800 years and evaluate ethical issues before publishing community-impact reports. You have been approached for help.

Task

As a learner of chemistry, help NEMA officers;

- ***(a) Write the electronic configurations of Fe^{2+}, Fe^{3+} and Zn^{2+} and analyse how these influence complex formation in wetland conditions.***
- ***(b) Write the nuclear equation for the decay of Ra-226 to Rn-222 and explain the rea life applications of the change in nucleon number.***
- ***(c) Determine the fraction of Ra-226 remaining after the period.***
- ***(d) Assess the environmental, public-health impacts, and mitigation measures NEMA must consider before releasing the radioactivity findings.***

Item 4

A steel-fabrication plant in Jinja conducts weld inspections using Cobalt-60, which emits gamma rays after beta decay. The Co-60 used has a half-life of 5.27 years and an initial activity of 4.8×10^8 disintegrations per second.

For safety audits, the plant must determine the remaining activity in Co-60 sources that have been stored for 15.8 years before disposal.

New technicians must also study the electron configurations of Cobalt (Z = 27), Co^{2+}, Co^{3+}, Nickel (Ni^{2+}), to understand corrosion resistance and alloy performance.

Task

As a learner of chemistry, help the manager;

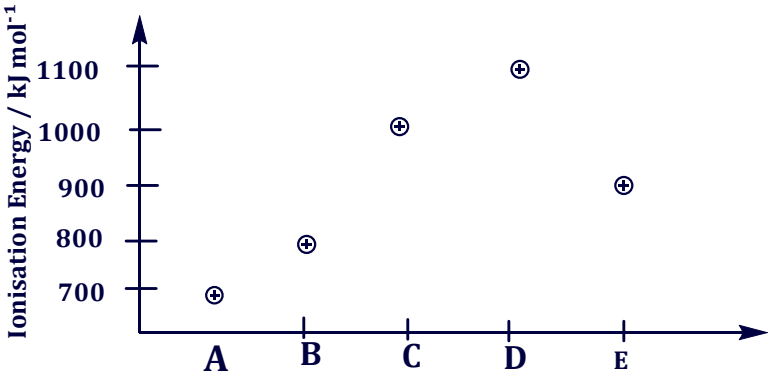
- ***(a) Write the electronic configurations of the given ions and explain how these electronic structures influence alloy behaviour.***
- ***(b) Write the nuclear equation for the β^- decay of Co-60 and explain the significance of the associated gamma emission in radiographic testing. (4 marks)***
- ***(c) Determine the activity of the Co-60 source after the stated storage duration.***
- ***(d) (i) Evaluate the industrial benefits of using Co-60 in manufacturing plants.***
  (ii) Suggest the environmental concerns and mitigations of using Co-60 in manufacturing plants.

Item 5

A mining company in Karamoja recently reported that a newly discovered ore contains two major elements, P and Q. Laboratory analysis indicated that Element P has atomic number 20 while Element Q has atomic number 17. During purification, engineers observed that P forms a P^{2+} ion readily, while Q forms a Q^- ion.

A temperature reactivity study carried out at the site showed that when P was heated from 20 °C to 200 °C, its reaction rate with oxygen increased linearly. Meanwhile, Q reacted vigorously with hydrogen at room temperature.

A simplified graph showing first ionisation energies of a set of period-3 elements (A–E), including analogues of P and Q, is provided below.



Task

(a) ***Write the electronic configurations of P, P^{2+}, Q and Q^{-}.***
(b) ***Using these configurations, explain why P forms P^{2+} and Q forms Q^{-} ions.***
(c) ***Using the graph, identify which element (A–E) most closely resembles Q. Give a reason.***
(d) ***Explain the trend observed in the ionisation energies of A–E using electronic structure.***
(e) ***Predict which element (P or Q) will form an ionic bond more readily with oxygen in the purification process. Give a reason.***
(f) ***Comment on the relative reactivity of P and Q as observed in the scenario, using their electron structures.***
(g) ***Suggest some environmental impacts associated with the long term use of the subsatnces.***

Item 6

A regional hospital in Mbale uses a radioisotope, X-131, for thyroid imaging. X-131 is a β-emitter used for diagnostic scans. A patient receives an administered dose containing 64 MBq of X-131. After treatment, nuclear technicians record the activity of the isotope stored in the decay room to monitor safe handling and disposal. The measured decay data are shown below:

Time, t (hours)	0	4	8	12	16	20	24	28
Activity, A (MBq)	64	45	32	22	16	11	8	6

Technicians suspect that the isotope follows first-order decay and recommend plotting the data to estimate the decay constant (λ). The hospital safety officer reminds all staff that although X-131 is highly effective for thyroid diagnostics, unnecessary exposure to ionising radiation must be minimized. You have been invited for assistance.

Task

As a learner of chemistry, help the hospital team;

(a) State the electronic configuration of a neutral iodine atom (Z = 53).
(b) Explain whether formation of the isotope X-131 affects its electronic configuration.
(c) Using the data provided:
(a) ***Plot a suitable graph to determine the decay constant (λ) of X-131.***
(b) ***From your graph, determine the half-life of the isotope.***
(d) Calculate the time required for the activity to fall to 4 MBq.
(e) Explain any other application and environmental impacts of using such radioisotopes.
(f) State one safety precaution that hospital staff must follow when handling β-emitting materials.

Item 7

A food-processing plant in Jinja uses a gamma-emitting radiotracer, Y-198, to test for leakage and flow uniformity in automated beverage-filling lines. The isotope emits γ-radiation and is detected

by automated sensors as it moves through the pipe network. After each test run, residual tracer is collected in a shielded storage container until it decays to a safe disposal level.

Due to concerns about long exposure times for technicians, the plant requests a decay analysis. A sample of Y-198 was placed in the decay chamber and its activity recorded at regular intervals. The measurements are shown below:

Time, *t* (hours)	6	10	14	18	22	26	30	34
Activity, *A*(MBq)	120	92	70	53	40	30	23	17

Engineers believe Y-198 undergoes first-order decay and would want to estimate the decay constant (λ). They also request chemical support to explain whether the isotope's electronic configuration changes during radioactive decay. They have approached you for assistance.

Task

As a learner of chemistry, help the Engineering team;

(a) ***State the electronic configuration of a neutral atom of Y (atomic number = 79).***

(b) ***Explain whether forming the isotope Y-198 changes the electronic configuration of element Y.***

(c) (i) ***Analyze the data to determine the decay constant λ of Y-198.***

(ii) ***Determine the half-life of the isotope.***

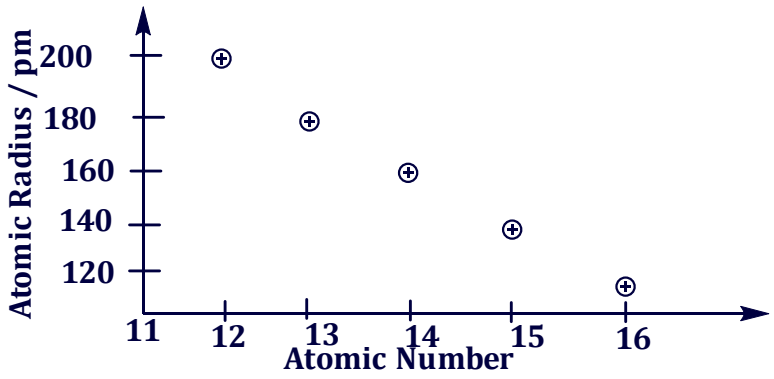
(d) ***Calculate the time required for the activity to fall to 8 MBq.***

(e) ***Explain any other industrial application and environmental concerns and safety measure associated with the use of the substance in food-processing industries.***

Item 8

An agricultural chemistry research station in Soroti analyzed soils from two farms, identifying high levels of Elements R and S. Element R has atomic number 13, while Element S has atomic number 16. Soil tests showed that R^{3+} ions strongly bind to clay particles, whereas S forms S^{2-} ions that readily form compounds used in fertilisers.

A graph of atomic radius (pm) against atomic number for a section of period-3 elements is provided:



Task

As a leaner of chemistry, help the research team;

(a) ***Write electronic configurations for R, R^{3+}, S and S^{2-}.***

(b) ***Using the graph, explain the trend in atomic radius from Z = 11 to 16.***

(c) ***Predict the relative reactivity of R and S in forming their common ions in soil.***

(d) ***Explain how the electron configuration of S^{2-} makes it useful in fertiliser compounds.***

(e) ***Evaluate one environmental implication of excessive accumulation of R^{3+} or S^{2-} ions in farmland.***

Item 9

A factory producing metallic cans in Jinja uses a γ-emitting source, Y-60, for thickness monitoring. Y-60 has an initial activity of 500 MBq and a half-life of 5.3 years. The detector records the count rate passing through each can; lower count rate indicates a thicker wall. Technicians observed that after 10.6 years, the activity of Y-60 had decreased significantly, causing unreliable readings. However they are unaware on how deal with these changes. They have contacted you for your assistance.

Task

As a leaner of chemistry, the research team;

(a) ***Determine the remaining activity after 10.6 years.***

(b) ***Explain why γ-radiation is suitable for thickness monitoring.***

(c) ***State the electronic configuration of cobalt (Z = 27), the element from which Y-60 is produced.***

(d) ***Comment on the effect of radioactive decay on the electronic configuration of the cobalt nucleus.***

(e) ***State one industrial application and one health or environmental impact of using γ-sources.***

TOPIC 3: BONDING AND STRUCTURE

ITEM 1

At the Uganda Heart Institute, biomedical engineers are redesigning sensors used for monitoring electrical signals during cardiac examinations. Five materials have been recommended by an expert to be evaluated whether sodium chloride (NaCl) can be used in electrolyte gels, aluminium metal (Al) can be used for electrode pads, glucose ($C_6H_{12}O_6$) is present in physiological fluids, water (H_2O) can be the main solvent in body tissues, and ethanol (C_2H_6O) can be the main agent in cleaning solutions for bloods.

The institute seeks to know the *bonding* of all four substances. Relate these features to *electrical conductivity, solubility,* and *mechanical properties*. Justify the *suitability* of each material for its application. Compare the molecular structure and shape using VSEPR for water and ethanol to explain their difference in *Polarity, Solvation and Boiling point* in order to predict if substances fit there purposes.
The research committee invites you to assist in this program.

Task

As a learner of chemistry, write a presentation you will use upon invitation.

ITEM 2

The Nile Breweries maintenance division is reviewing cleaning chemicals used for internal washing of stainless-steel beverage pipelines. Their evaluation focuses on four substances: carbon dioxide (CO_2) used for pressure cleaning, ammonia (NH_3) used in detergent solutions, oxygen gas (O_2) used in aeration systems, and ethanol (C_2H_5OH) used as a sterilizing agent.

The company wishes to understand the *bonding and molecular structure* of the four substances, analyze how their *polarity*, *shape* and *intermolecular forces* affect their behavior in industrial cleaning, include a *VSEPR* explanation for ammonia and ethanol to predict bond angles and polarity, and evaluate which chemical would offer the safest and most effective cleaning performance for beverage pipelines. You have been invited for assistance.

Tasks:

As a learner of chemistry, write a presentation you will use upon invitation.

ITEM 3

During an environmental audit in Jinja Municipality, inspectors investigated pollutants released from informal metal working garages. Four major substances were identified: sulphur dioxide (SO_2) produced from burning sulphur, nitrogen monoxide (NO) emitted from welding equipment, calcium ions (Ca^{2+}) washed from metal finishing waste, and magnesium hydroxide ($Mg(OH)_2$) formed when workshop ash mixes with rainwater. Reports reveal that SO_2 forms acidic solutions, NO readily forms nitrogen dioxide in air, Ca^{2+} precipitates with carbonates in soil, and $Mg(OH)_2$ is a solid with limited solubility. Environmental officers seek to analyze the *bonding, structure*, and *polarity* of all four pollutants. Discuss the environmental significance of molecular geometry using *VSEPR* for *SO_2* and *NO*. Explain how these features influence solubility, mobility, and

reactivity, and propose scientifically appropriate strategies for reducing the environmental impact of these substances.

Task

As a learner of chemistry, write a presentation you will use upon invitation.

ITEM 4

A renewable energy company in Tororo is testing materials for a low cost rechargeable battery system to be distributed in rural households. The study compares the suitability of four substances: graphite, sodium chloride (NaCl), magnesium oxide (MgO), and distilled water a used in preparing battery electrolytes.

Engineers note that graphite is good for electrodes, NaCl only good for electrolytes, MgO is good for higher temperature environments and water stabilizes ions but may corrode metallic parts.

The design team requests a scientific evaluation to analyze the *bonding and structure* of all four substances. Relate these features to *conductivity*, *thermal stability* and *reactivity*, include VSEPR diagram for water to explain hydrogen bonding and its significance as a solvent. And justify which materials are most suitable for incorporation into a durable, efficient, and affordable rural battery system.

Task

As a learner of chemistry, write a presentation you will use upon invitation.

TOPIC 4: PERIODICITY 1

ITEM 1

A pharmaceutical company in Kampala is designing a new antacid tablet. The effectiveness of antacids depends on the solubility and reactivity of metal oxides and hydroxides with water, which neutralize stomach acid. The company has been advised by an expert to use substance with a high solubility as it implies faster reaction with water. The chemists are comparing Group 2 oxides and Period 3 oxides to select the most effective and safe compound. The measured solubility in water at 25°C (g/100 mL) is shown below:

Group/period	Group II oxides				Period 3 oxides			
Atomic Number	12	20	38	56	11	12	13	14
Oxide	MgO	CaO	SrO	BaO	Na_2O	MgO	Al_2O_3	SiO_2
Solubility (g/100 mL)	0.008	0.185	0.95	3.89	0.9	0.008	0.0001	0.00005

The company manager seeks to have a comprehensive report on the data; by *analyzing plots* of solubility of oxides against the elements on the same axes, explaining *trends* in solubility, *evaluating* which oxide(s) is/are the most suitable for inclusion in a safe, effective antacid tablet and *predicting* the solubility and application of an oxide that might exist between CaO and SrO, with reason. In order to best inform decisions for a proper antacid table. In need, he has contacted you for assistance.

Task:

As a learner of chemistry, make a write up to best inform the manager.

ITEM 2

A hospital in Gulu is investigating metal chlorides to use as electrolytes in IV solutions. Stability and hydration behaviour are crucial for patient safety. The hospital has been advised by the expert that substances better for formulations are highly soluble but with a lower hydration energy when reacted with water during administering. Chemists tested Group 2 and Period 3 chlorides for enthalpy of hydration (kJ/mol):

Group/period	Group II chlorides				Period 3 chlorides			
Atomic Number	12	20	38	56	11	12	13	14
Chloride	$MgCl_2$	$CaCl_2$	$SrCl_2$	$BaCl_2$	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$
ΔHhyd (kJ/mol)	–1922	–1577	–1443	–1305	–406	–1922	–3250	–10

The hospital team seeks to have a comprehensive report on the data; by *analyzing plots* of hydration enthalpy against the elements on the same axes, explaining *trends* in hydration enthalpy, *evaluating* which chloride(s) is/are the most suitable for safe use in IV solutions, balancing solubility and hydration energy and *predicting* the likely hydration enthalpy and application of the chloride that might exist between $CaCl_2$ and $SrCl_2$, and explain its suitability. In order to best inform decisions for a proper electrolyte. You have been contacted you for help.

Task:

As a learner of chemistry, make a write up to help the hospital team.

ITEM 3

A renewable energy company in Namanve industrial park is developing low cost rechargeable batteries for rural households. The engineers are comparing metal oxides as candidate anode or cathode materials. Thermal stability is crucial because battery performance drops if the oxide decomposes at operational temperatures. They measured decomposition temperatures of oxides (°C):

Group/period	Group II oxides				Period 3 oxides			
Atomic Number	12	20	38	56	11	13	14	15
Oxide	MgO	CaO	SrO	BaO	Na_2O	Al_2O_3	SiO_2	P_4O_{10}
Decomposition Temp (°C)	2800	2572	2531	1923	1132	2072	1713	340

The ideal battery oxide should have a decomposition temperature above 2500°C for long term efficiency. The company manager seeks to have a comprehensive report on the data; by *analyzing plots* of decomposition temperature against the atomic numbers on the same axes, explaining *trends* in decomposition temperature, *evaluating* which oxide(s) is/are the most suitable for efficient, durable battery materials, and *predicting* the likely decomposition temperature of an oxide between CaO and SrO and justify its suitability for battery use. In order to best inform decisions for a proper electrolyte. You have been contacted you for help.

Task:

As a learner of chemistry, make a write up to help the company manager.

ITEM 6

A solar energy company in Mbale industrial area is developing molten salt batteries. High ionic conductivity is needed for efficient charge transport. Engineers tested Group 2 and Period 3 chlorides at 300°C and recorded conductivity (S/m):

Group/period	Group II chloride				Period 3 chloride			
Atomic number	12	20	38	56	11	12	13	14
Chloride	$MgCl_2$	$CaCl_2$	$SrCl_2$	$BaCl_2$	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$
Conductivity (S/m)	6.8	7.7	8.3	9.1	7.6	6.8	2.3	0

The most efficient electrolyte must have conductivity ≥ 8 S/m.

The company manager seeks to have a comprehensive report on the data; by *analyzing plots* of ionic conductivity against the atomic numbers on the same axes, explaining *trends* in ionic conductivity, *evaluating* which chloride(s) is/are the most battery electrolytes, and *predicting* the conductivity of a chloride between $CaCl_2$ and $SrCl_2$, and justify its use with reason. In order to best inform decisions for a proper battery electrolyte. You have been contacted you for help.

Task:

As a learner of chemistry, make a write up to help the company manager.

ITEM 7

A water treatment plant in Jinja studies Group 2 and Period 3 elements for removal of dissolved salts and heavy metals. Smaller atomic radius enhances adsorption and reactivity in flocculation processes. The measured atomic radii (pm) are:

Group/period	Group II elements				Period 3 elements						
Atomic number	12	20	38	56	11	12	13	14	15	16	17
Element	Mg	Ca	Sr	Ba	Na	Mg	Al	Si	P	S	Cl
Atomic Radius (pm)	160	197	215	222	186	160	143	118	110	104	99

The plant manager seeks to have a comprehensive report on the data; by *analyzing plots* of atomic radii against the atomic numbers on the different axes, explaining *trends* in atomic radii, *evaluating* which element(s) is/are the most suitable for water treatment, and *predicting* the likely atomic radius and adsorption efficiency of an element between Ca and Sr, and justify your prediction. In order to best inform decisions for a flocculant in water treatment. You have been contacted you for help

Task:

As a learner of chemistry, make a write up to help the company manager.

ITEM 8

A soil remediation project in Mbale aims to select elements capable of oxidising pollutants. Higher electronegativity favours electron withdrawal from contaminants. Engineers studied Group 2 and Period 3 elements and measured Pauling electronegativity values:

Group/period	Group II elements				Period 3 elements						
Atomic number	12	20	38	56	11	12	13	14	15	16	17
Element	Mg	Ca	Sr	Ba	Na	Mg	Al	Si	P	S	Cl
Electronegativity value	1.31	1	0.95	0.89	0.93	1.31	1.61	1.9	2.1	2.5	3.0

The project manager seeks to have a comprehensive report on the data; by *analyzing plots* of electronegativity against the atomic numbers on the different axes, explaining *trends* in electronegativity highlighting the diagonal relationship between Mg and Al., *evaluating* which element(s) is/are most suitable for removal of contaminants, and *predicting* the likely electronegativity of an element between Ca and Sr, and explain its likely usefulness and justify your prediction. In order to best inform decisions for removal of contaminants. You have been contacted you for help

Task:

As a learner of chemistry, make a write up to help the company manager.

ITEM 9

A metal processing plant in Jinja studies Group 2 and Period 3 elements for the extraction of metals via electrolysis. The plant expert team from U.S.A advised the plant manager that metals with lower first ionisation energy are easier to extract in order to minimize costs on electricity bills so that profit can be maximized. In order for the plant to repond to the adivice the plant manager acquired several substances that can have to be first tested for their suitability. They measured their first ionisation energies (kJ/mol) and obtained the following values:

Group/Period	Group II elements				Period 3 elements			
Atomic Number	12	20	38	56	11	12	13	14
Element	Mg	Ca	Sr	Ba	Na	Mg	Al	Si

First Ionisation Energy (kJ/mol)	737	590	549	502	496	737	578	786

For the manager to best inform decision of the best choice of the substance, he must first have a comprehensive study on the data by; *analyzing plots* of first ionisation energy against atomic number of the elements for Group 2 and Period 3 on the same axes. Analyzing *trends*, irregularities and diagonal relationship of the elements if any, *Evaluating* the most suitable element(s) for efficient industrial extraction using electrolysis. And *predicting* the first ionisation energy of an element between Ca and Sr, and explain its likely ease of extraction.

Task:

As a learner of chemistry, make a write up to help the plant manager.

ITEM 10

A steel manufacturing company in Tororo examines Group 2 and Period 3 elements for alloy production. Metals with higher electropositivity are more reactive and form stronger bonds with other metals. Measured Pauling electropositivity values:

Group/Period	Group II elements				Period 3 elements			
Atomic Number	12	20	38	56	11	12	13	14
Element	Mg	Ca	Sr	Ba	Na	Mg	Al	Si
Electropositivity value	1.31	1.0	0.95	0.89	0.93	1.31	1.61	1.9

For the manager to best inform decision of the best choice of the substance, he must first have a comprehensive study on the data by; *analyzing plots* of electropositivity values against atomic number of the elements for Group 2 and Period 3 on the same axes. Analyzing *trends*, irregularities and diagonal relationship of the elements if any, *Evaluating* the most suitable element(s) for alloy production, balancing reactivity and stability. And *predicting* the electropositivity of an element between Ca and Sr, and justify its potential in industrial applications.

Task:

As a learner of chemistry, make a write up to help the company manager.

TOPIC 5: THERMOCHEMISTRY

ITEM 1 section A type

A green energy investment project in Hoima plans to deploy small generator units in rural trading centres. Engineers must choose between two possible fuels: methane extracted from biogas digesters, and ethanol produced from molasses.

The project team requires a thermochemical assessment of which fuel delivers higher energy output, greater thermal efficiency, and lower environmental burden. To guide the decision, the technical department provides the following standard thermochemical data:

Standard enthalpies of formation of methane, ethanol, carbondioxide and liquid water are *–74.8, –277.0, –393.5 and –285.8kJ mol⁻¹* respectively.

Standard enthalpies of complete combustion of methane and ethananol are;

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \qquad respectively$$

Measured activation energies for combustion of methane and ethanol are; 252 kJ mol⁻¹ and 186 kJ mol⁻¹ respectively.

The management has asked you, a learner of chemistry, to interpret the data and recommend the most suitable fuel.

Task

As a learner of chemistry, help the project manager;

(a) Calculate enthalpy of combustion of CH_4 and C_2H_5OH

(b) Sketch energy profile diagram for the combustion of CH_4 and C_2H_5OH on the same axes, clearly indicating ΔH and Ea for each reaction and state category of the reactions.

(c) Using the enthalpy data, calculate:

(i) the heat released per gram of CH_4 and per gram of C_2H_5OH.

(ii) the volume of carbon dioxide produced per kJ of energy released for each fuel at s.t.p.

(d) Using your diagrams and calculations, explain which fuel requires a lower activation barrier and discuss the implication on ignition and efficiency.

(e) Evaluate which fuel is more suitable for long term rural energy use, giving scientific reasons.

(f) Predict the environmental impact of using either ethanol is sourced from renewable biomass versus methane is sourced from landfill biogas and suggest their realistic mitigations.

ITEM 2

ITEM 1 Section A type

A car service company in Kampala is evaluating petrol (C_8H_{18}) and diesel ($C_{12}H_{26}$) engines for urban transport. Engineers want to understand which fuel provides higher energy output, better thermal efficiency, and a lower environmental impact per unit energy. The technical department provides the following thermochemical information about the fuels and products as below;

Reaction	ΔH^{θ}_f (kJ·mol⁻¹)
$C_8H_{18}(l) \rightarrow 8\,C(s) + 9\,H_2(g)$	+208.4
$C_{12}H_{26}(l) \rightarrow 12\,C(s) + 13\,H_2(g)$	+249.0
$C(s) + O_2(g) \rightarrow CO_2(g)$	–393.5

$H_2(g) + ½\,O_2(g) \rightarrow H_2O(l)$	–285.8

Measured activation energies for combustion of petrol and diesel are 310 and 295 kJ·mol^{-1} respectively. For better car servicing due to increasing growth of new competitive companies aiming at energy efficient fuel and protecting the against environmental impacts, the manager has invited you for assistance in in order to guide solid decision making.

Task

As a learner of chemistry, help the analyst to:

(a) Calculate the enthalpy of combustion of petrol and diesel.

(b) Draw a labelled energy profile for the combustion of petrol and diesel on the same axes.

(c) Using the enthalpy data, calculate:

(i) The heat released per gram of petrol and per gram of diesel.

(ii) The volume of carbon dioxide produced per kJ of energy released for each fuel at s.t.p.

(d) Using your cycle and calculations, explain which fuel requires a lower activation barrier and discuss the implications for ignition, engine start-up, and efficiency.

(e) Evaluate which fuel is more suitable for urban transport, giving scientific reasons.

(f) Predict the environmental impact of using petrol versus diesel in cars and suggest one realistic mitigation measure for the major environmental impact identified.

ITEM 3

A chemical-processing company in Jinja plans to scale up production of propan-2-ol, an important solvent used in pharmaceuticals, cosmetics, and sanitizers. Engineers are evaluating two possible preparation routes, and the management wants a full thermochemical assessment before commissioning either pathway. Major preparation involves hydrogenation of Propanone:

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

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

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

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

Bond / Data	Value (kJ·mol^{-1})
C=O	715
C=C	614
C–C	345
C–H	414
C–O	351
O–H	464
H–H	436

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
(ii) Hydration of propene
(c) Evaluate which preparation route is more feasible for large scale production of propan-2-ol in the factory.
(d) Predict any major environmental impact arising from the process and propose a realistic mitigation measure for the impact.

ITEM 4

A chemical manufacturing company in Tororo Industrial Park plans to expand its product line of industrial salts used in water treatment, pharmaceuticals, and battery electrolytes. Two candidates have been proposed for large-scale manufacture:
Option A: Magnesium Chloride ($MgCl_2$)
Option B: Aluminium Chloride ($AlCl_3$)
The technical and procurement teams note that both compounds dissolve in water, but their overall stability, energy demands, and environmental impacts differ significantly. Since energy costs in Uganda have risen, management requires a full thermochemical comparison before selecting the more stable and cost-effective product. To guide the decision, the R&D laboratory has provided the following thermochemical data.

A. Data for Magnesium Chloride		**B. Data for Aluminium Chloride**	
Enthalpy change	**(kJ·mol⁻¹)**	**Enthalpy change**	**(kJ·mol⁻¹)**
$\boldsymbol{Standard\ enthalpy\ of\ formation\ of\ MgCl_2(s)}$	–641.62	$\boldsymbol{2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)}$	–1049
$\boldsymbol{Lattice\ energy\ of\ MgCl_2(s)}$	+2495.6	$\boldsymbol{HCl(g) \rightarrow HCl(aq)}$	–74.8
$\boldsymbol{Hydration\ energy\ of\ Mg^{2+}(aq)}$	–1926	$\boldsymbol{H_2(g) + Cl_2(g) \rightarrow 2HCl(g)}$	–184.5
$\boldsymbol{Hydration\ energy\ of\ Cl^{-}(aq)}$	–378	$\boldsymbol{AlCl_3(s) \rightarrow AlCl_3(aq)}$	–323
$\boldsymbol{Enthalpy\ of\ formation\ of\ HCl(g)}$	–92.32		
$\boldsymbol{Enthalpy\ of\ solution\ of\ HCl(g\ \rightarrow\ aq)}$	–74.8		
$\boldsymbol{Required\ equation}$ $\boldsymbol{Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)}$		$\boldsymbol{Required\ equation}$ $\boldsymbol{2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)}$	

For the manager to choose the best substance for use in the industry, he must first analyze the thermochemical data. However he does not know how to do that therrreforer he has invited you for assistance.

Task:

As a learner of chemistry, help the manager;

(a) Calculate the enthalpy change for the required reaction in;
(i) option A.
(ii) option B.
(c) Advise the company on which product is better for large scale industrial production in Uganda.
(d) Suggest any applications of any of the energy processes the company is investigating.
(d) Suggest any environmental impacts associated with long term use of each of the substances and their mitigations.

ITEM 5

Uganda's National Pharmaceutical Manufacturing Initiative (NPMI) is expanding its capacity to produce critical drug precursors locally. The new plant aims to reduce import dependence by producing high purity chemical intermediates for domestic drug formulation. Two strategic starting chemicals are under consideration *ethanol* (C_2H_5OH) and *phenol* (C_6H_5OH) for the production from elements.

$$\boldsymbol{2H_2(g) + 2C(s) + O_2(g) \rightarrow C_2H_5OH(l)}$$

$$6C(s) + 3H_2(g) + 72O_2(g) \rightarrow C_6H_5OH(s)$$

High grade ethanol is required for fabricating *NOZIN®,* a topical antiseptic formulation, used to reduce nasal colonization of microbial infections. Phenol is used in synthesizing *DIFLUNISAL®*, a non-steroidal anti-inflammatory drug (NSAID) used for treatment of inflammation, osteoarthritis and rheumatoid arthritis. The thermochemical data below were available to guide analysis;

$$C_2H_5OH(l) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l) \quad \Delta H_1 = -875\,kJmol^{-1}$$
$$C_6H_5OH(s) + 7O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l) \quad \Delta H_2 = -3050\,kJmol^{-1}$$
$$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H_3 = -394.51\,kJmol^{-1}$$
$$H_2(g) + 12O_2(g) \rightarrow H_2O(l) \quad \Delta H_4 = -285.8\,kJmol^{-1}$$

Therefore, to guide the selection of better production line the analyst must ensure that either ethanol or phenol manufacture must therefore be efficient, stable, and cost effective because the demand in infection-control products is steadily increasing.

Task:

As a learner of chemistry, help the production manager;

(a) ***Draw a labelled Hess energy cycle diagram for the formation of;***
   (i) Ethanol from its elements.
   (ii) Phenol from its elements.

(b) ***Calculate the standard enthalpy of formation of:***
   (i) Ethanol from its elements.
   (ii) Phenol from its elements.

(c) ***Advise the manager on which production line the pharmaceutical plant should prioritize, with reason.***

(d) ***Suggest environmental impacts associated with the long term use of the suggested chemical product and sate their mitigations.***

ITEM 6

A company that manufactures medical battery packs for portable diagnostic equipment is assessing two electrolyte salts sent in as samples by suppliers *Cadmium iodide (CdI_2)* and *Lithium oxide (Li_2O)* proposed as electrolyte raw materials for high capacity prototype cells.

The material largely depends on its solution which cools the electrolyte managing battery temperature under heavy use or raises electrolyte temperature accelerating degradation promoting high costs of maintenance. The plant's analytical laboratory has supplied the thermochemical data which must be analyzed before decision is made.

Cadmium iodide	**(kJ·mol⁻¹)**	**Lithium oxide**	**(kJ mol⁻¹)**
$Cd(s) \rightarrow Cd(g)$	**+177.0**	$2Li(s) + 12O_2(g) \rightarrow Li_2O(s)$	**−596**
$½\ I_2(g) \rightarrow I(g)$	**+151.0**	$Li(s) \rightarrow Li(g)$	**+161**
$Cd(g) \rightarrow Cd^+(g)$	**+867.8**	$Li(g) \rightarrow Li^+(g) + e^-$	**+519**
$Cd^+(g) \rightarrow Cd^{2+}(g)$	**+1631.4**	$O_2(g) \rightarrow 2O(g)$	**+496**
$I(g) \rightarrow I^-(g)$	**−295.0**	$O(g) + e^- \rightarrow O^-(g)$	**−141.4**
$Cd(s) + I_2(g) \rightarrow CdI_2(s)$	**−201.0**	$O^-(g) + 2e^- \rightarrow O^{2-}(g)$	**+798**
$Cd^{2+}(g) \rightarrow Cd^{2+}(aq)$	**−1760.0**	$Li^+(g) \rightarrow Li^+(aq)$	**−544**
$I^-(g) \rightarrow I^-(aq)$	**−295.0**	$O^{2-}(g) \rightarrow O^{2-}(aq)$	**−1450**

The plant's process team needs a thermochemical assessment before selecting the more efficient, stable and safe electrolyte to adopt. You have been contacted for assistance.

Task:

As a learner of chemistry, help the process team;

(a) ***Analyse the data to construct an energy level diagram for the changes in the:***
(i) Formation of Cadmium iodide.
(ii) Formation of Lithium oxide.

(b) ***Use the energy cycles constructed to calculate Lattice energy hence enthalpy of solution for;***
(i). Cadmium iodide.
(ii). Lithium oxide.

(c) ***(i) Evaluate and advise the manager which substance is most suitable for cells, giving reasons.***
(ii). State any other important industrial use of the process chosen.

(d) ***Suggest the possible impacts and mitigations of the substance chosen to the environment.***

ITEM 7

Environmental chemists working with the National Environmental Management Authority (NEMA) were investigating pollution around an old metal processing site in Karamoja region in Uganda. Residents had reported a persistent rotten egg smell and several unexplained small fires near abandoned metal scrap waste heaps.

On inspection, the team discovered that aluminium scraps had reacted with sulfur rich soil to form aluminium sulfide (Al_2S_3) a compound that releases toxic hydrogen sulfide when it rains and also found grey carbide residues that released ethyne gas on contact with water. Tests confirmed the presence of calcium carbide (CaC_2), previously used in welding.

When a salt is *less stable* during solution, it dissolves violently with side reactions in water giving off high solution enthalpy, posing high risk of environmental contamination.

To assess their stability, chemists were given the following thermochemical data:

Aluminium sulfide	**(kJ/mol)**	**Calcium carbide**	**kJ/mol)**
$2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$	–724.0	$Ca(s) + 2C(s) \rightarrow CaC_2(s)$	–60
$Al(s) \rightarrow Al(g)$	+326.4	$Ca(s) \rightarrow Ca(g)$	+178
$Al(g) \rightarrow Al^+(g + e^-$	+577.4	$Ca(g) \rightarrow Ca^+ + e^-$	+590
$Al^+(g) \rightarrow Al^{2+}(g) + e^-$	+1816.6	$Ca^+ \rightarrow Ca^{2+} + e^-$	+1145
$Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$	+2740	$2C(s) \rightarrow 2C(g)$	+1434
$S(s) \rightarrow S(g)$	+278.8	$2C(g) \rightarrow C_2(g)$	–614
$S(g) + e^- \rightarrow S^-(g)$	–200.4	$C_2(g) + e^- \rightarrow C_2^-$	–315
$S^- + e^- \rightarrow S^{2-}(g)$	+334.1	$C_2^-(g) + e^- \rightarrow C_2^{2-}(g)$	+410
$Al^{3+}(g) \rightarrow Al^{3+}(aq)$	-4690	$Ca^+(g) \rightarrow Ca^{2+}(aq)$	–505
$S^-(g) \rightarrow S^{2-}(aq)$	–1700	$C_2^{2-}(g) \rightarrow C_2^{2-}(aq)$	-2900

The environmental team needed scientifically grounded analysis to guide disposal strategies and advise local authorities on the safest material handling practices. You have been approached for assistance.

Task:

As a learner of chemistry, help the process team:

(a) Analyse the data to construct a born haber cycle for:
(i) Formation of aluminium sulfide
(ii) Formation of calcium carbide

(b) Using the energy cycles constructed, calculate the lattice energy and enthalpy of solution of;
(i) aluminium sulfide.
(ii) calcium carbide.

(c) (i) Evaluate and advise the manager which substance has less effects to the environment, giving reasons

(ii) State any other industrial use of the substance you recommend.

(d) Suggest the environmental impacts and mitigation measures associated with the gaseous product given out in the side reaction with water of the substance chosen.

TOPIC6 : ORGANIC CHEMISTRY 1

ITEM 1 section B type

Hoima District Hospital, aiming to minimise reliance on imported medical reagents, has launched a pilot project transforming bromoethane into health related organic compounds. The programme targets products used in antiseptics, topical cleaning agents, medical plastics, diagnostic solvents, and disinfectant formulations

Proposed Synthetic Routes from the available substance involves conversion to; *Ethyl propanoate* a topical cleaning agent, *polystyrene* a medical plastic, *propanone* a diagnostic solvent, and *benzyl aldehyde* a disinfectant formulation.

The management must, *analyse the four synthetic pathways* by identifying the functional *groups in the final products*, and provide the *IUPAC names* of one selected intermediates from each route, *Classify the types of reactions* throughout the pathways with reason, and *explain step by step, with equations*, how bromoethane is transformed into the final useful products. *Write the mechanisms for key reactions*, including *esterification* to yield ethyl propanoate, the *last step in the formation of propanone*. Finally, *evaluate any environmental or health impacts* associated with long-term exposure to compounds from the pathway you selected and suggest one mitigation measure for each impact. You have been contacted for help.

Task:

As a learner of chemistry, write a presentation you will use upon invitation.

ITEM 2

A small chemical plant near a rural community recently discharged an unknown hydrocarbon into a drainage channel used by households and livestock. Environmental officers collected the sample, labelled G, and performed preliminary tests.

The molecular formula of G is C_4H_6, and when treated with silver nitrate solution in ammonia, a white precipitate was formed. Further tests with bromine water and acidified potassium manganate(VII) indicate that G contains unsaturation.

The environmental chemistry team is tasked with identifying G and investigating its chemical properties. They also need to predict its likely reactions in both laboratory and environmental conditions, explore possible synthetic routes from simple alkenes such as *but-1-ene*, *ethanol* and a metal residue *calcium carbide*, and assess potential *environmental and health impacts*. The team is particularly interested in the mechanism of how G reacts with *water* in the presence of *sulphuric acid and mercury(II) sulfate*, with *hydrogen bromide to yield* 1-bromo compound, *bromine liquid* and potassium manganate(VII) using equations. Safe handling and mitigation strategies are also to be considered.

Before any decision is made the team must know: *structure* , *functional group* and possible *isomerism* of compound. Apply correct *IUPAC names* to G and all related products formed in laboratory reactions. Predict major products at each reaction stage based on organic reactivity and *mechanism* for key reactions. Explain stepwise reaction *pathways* leading for mation of G, *classifying type* of reaction at each stage, and evaluate the environmental and health impacts associated with G and its derivatives while proposing mitigation strategies.

Task:

As a learner of chemistry, make a write up to help the team inform their decision making.

ITEM 3

During routine air quality monitoring at a large paints and resins factory in Namanve Industrial Park, engineers detected the presence of an unknown aromatic hydrocarbon vapor escaping from

one of the towers. Analysis showed that the vapor effuses 0.691 times as rapidly as carbon dioxide. The compound readily decolorized alkaline potassium permanganate(VII) and burned smoky flame,
The analytical wished to collect this vapor and intend to use as feedstock that can be transformed through different synthetic routes into;

Polystyrene a polymer (packaging)**,**

2-phenylethan-1-amine (perfume),

Sodium dodecyl benzene sulphonate (detergent)**,**

1-ethyl-2-iodobenzene (pharmaceutical drug)

By exploiting these transformations, the factory can maximize innovation, expand product lines, and increase profitability.
Management seeks a comprehensive chemical assessment to guide safety, by *analyzing* the effusion data to determine the molar mass of the vapor and confirm its *identity*. Draw and name all possible structural *isomers* of the compound. Classify its major reactions, and explain the *mechanisms* involved in its reactions with *bromine*, *concentrated nitric acid*, and *ethonylchloride*. Outline feasible *synthetic pathways* from the compound to four important products indicating reagents and conditions. Finally, evaluate the *environmental and health impacts* of using the compound and propose appropriate mitigation strategies.
Task:
As a learner of chemistry, make a write up to help the management.
ITEM 4
A chemical manufacturing plant producing specialty flame-retardant polymers has recently synthesized a brominated organic compound Y, intended as a starting material for high value polymers and pharmaceutical intermediates.
For quality control, 1.363 g of Y was completely combusted, giving 1.10 g of carbon dioxide and 0.45 g of water. In a separate experiment, 0.35 g of Y was vaporized, occupying 39.5 cm^3 at 20°C and 750 mmHg. When Y was heated with alcoholic potassium hydroxide, the resulting vapor decolorized bromine liquid and formed a white precipitate with ammoniacal silver nitrate.
Correct identification of the compound is critical, as it will be used in the synthesis of; *propene gas* for polymers, *chloropentane* for pharmaceuticals, *hexanal* for preserving fresh

apples, and *polythene* for food storage.

Understanding the how to determine the *molecular formula* of Y. Identify the *functional group* present and draw all possible structural *isomers* of Y. Predict the *types of reactions* that Y can undergo and illustrate the *mechanisms* for at least two reactions *(e.g., nucleophilic substitution and elimination).* Outline *synthetic pathways* from Y to stated useful compounds, indicating reagents and conditions at each step. Finally, evaluate the *environmental and health impacts* of handling Y and its derivatives, and propose appropriate mitigation will help the plant optimise profit maximization. You have been invited for assistance.
Task
As a learner of chemistry, make a write up to help the management.

TOPIC 7: EQUILIBRIA I -IONIC EQUILIBRA AND SOLUBILITY

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).

(b) How the equilibrium system is affected by:

- ***i. Passing equilibrium mixture through hydrochloric acid.***
- ***ii. Introducing a catalyst.***
- ***iii. Increasing temperature.***
- ***iv. Increasing pressure.***

(c) Calculate the pH of the solution obtained. ($\boldsymbol{K_b = 1.8 \times 10^{-5} moldm^{-3}}$).

(d) How the buffer system works.

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

ITEM 2

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).

(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.***
- ***ii. introducing a catalyst.***
- ***iii. increasing temperature.***
- ***iv. increasing pressure.***

(c) Calculate the pH of the solution obtained

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

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

END MERRY CHRISTMAS AND HAPPY NEW YEAR 2026

“One thing that you can't fake is chemistry.”