Name …… Combination …….

UGANDA ADVANCED CERTIFICATE OF EDUCATION

S.5 CHEMISTRY PAPER

EOT 2

Time: 2HRS 45 MINUTES

Instructions:

- This paper is made of two sections, A and B, with two parts in section B
- Attempt all items in section A and **ONLY** one item from each part of section B
- A total of four (4) items MUST be attempted

SECTION A

Item 1

In a rural community near a decommissioned industrial site, a local health officer discovers two abandoned metallic canisters labelled with radioactive hazard symbols. To manage the safety of the community, the officer enlists the help of a chemistry student to analyse the contents.

Canister A contains a pure transition metal, element X (atomic number 26). The community leaders worry about its potential reactivity if it leaks into the local water supply.

Canister B contains a radioactive isotope of element Y, which has an initial activity of 800 counts per minute (cpm). After 24 days, the activity drops to 100 cpm. The community fears long-term contamination and needs to understand how quickly this material decays to assess the risk of environmental accumulation.

Tasks:

a) Using the Aufbau principle, Pauli exclusion principle, and Hund's rule, write the full electronic configuration for element X and its common ion X^{2+}. Based on these configurations, predict the chemical reactivity of X.

b) Determine the half-life of the radioactive isotope in Canister B, showing all working steps.

c) Explain the nature of the decay observed in Canister B, and evaluate one potential environmental or health implication if this radioactive material is not managed correctly by the community.

Item 2

Cipla Quality Chemical Industries Ltd, located in Luzira Kampala, uses controlled amounts of heat during the purification stage of Artemether–Lumefantrine production. This heat is obtained from the exothermic combustion of ethanol. Recently, company purchased ethanol from a new supplier. Production engineers later observed that the reaction system was not reaching the expected temperature, suggesting a possible variation in the energy released during the combustion of the new ethanol batch. To verify, the Quality Control team carried out a calorimetry experiment using a spirit burner of the new ethanol sample and obtained the following textbook-standard data:

Mass of water used: 250 g

Initial temperature of water: 22.0 °C

Final temperature of water: 36.5 °C

Mass of ethanol before burning: 92.41 g

Mass of ethanol after burning: 91.21 g

Specific heat capacity of water: 4.18 J g^{-1} K^{-1}

Heat capacity of calorimeter: negligible

Task;

a) Explain what is meant by exothermic reaction and standard enthalpy of combustion.
b) Using a labelled diagram, describe how the experiment above was carried out to obtain the temperature rise.
c) Using the data provided, calculate the heat released when 1 mole of ethanol is completely burnt. (Relative atomic masses: C=12, H=1, O=16)
(i) Draw an energy profile diagram for the combustion of ethanol when the reaction is catalyzed.
(ii) Explain the effect of the catalyst on the above reaction.

SECTION B

Part 1

Item 3

A community-based research project in Mbarara is investigating the sustainable synthesis of industrial chemicals using hydrocarbons. The team has been supplied with propyne and 2-chloropropane as primary raw materials. The project coordinator is tasked with demonstrating how to transform these into specific useful products for local laboratories. They need to show that:

Propyne can be selectively converted into specific products through addition reactions. The choice of reaction conditions on 2-chloropropane dictates whether the final product is an alkene or an alcohol. The mechanisms of these reactions vary based on the reagents used (e.g., acidified water vs. halogen acids).

Task

a) Write equations and name the products formed when propyne reacts with:
   i) One mole of hydrogen bromide (HBr). **(1 score)**
   ii) Excess acidified water (H_2O/H^+) in the presence of a mercury(II) sulphate catalyst. And propose a suitable mechanism **(5 marks)**

b) Explain the mechanism for the reaction of propene with hydrogen bromide (HBr) using equations. **(3 scores)**

c) Propose the reagents and conditions required to convert 2-chloropropane into propene, and provide a brief explanation of why this reaction is classified as an elimination reaction. **(2 scores)**

d) Contrast the reaction of propene with hydrogen bromide and the reaction of 2-chloropropane with aqueous potassium hydroxide in terms of the reaction type and the nature of the intermediate species. **(2 scores)**

e) Synthesis 2-methylpropanoic acid from 2-methylpropene. **(2 scores)**

Item 4

A local manufacturing plant in Jinja has been using 2-bromo-2-methylbutane as a primary solvent for cleaning industrial machinery. Recently, the factory management proposed a transition to using this halogenated compound as a chemical feedstock to synthesise benzene for secondary production lines. However, residents living near the plant have raised concerns regarding the chemical waste being discharged into the nearby stream, specifically citing the pungent odour and the potential for long-term health and environmental damage.

As a consultant chemist, you are tasked to investigate the chemical behaviour of the solvent and the proposed synthetic pathway.

Tasks

a) Using 2-bromo-2-methylbutane as the substrate, propose the reaction mechanisms for:
   i) The formation of the major alkene product when treated with alcoholic potassium hydroxide at reflux.
   ii) The nucleophilic substitution reaction with aqueous potassium hydroxide.
   iii) The reaction between the compound and potassium cyanide and name the product
b) Outline the chemical pathway to synthesise benzene starting from a two-carbon halogenated alkane (e.g chloroethane), ensuring you show the necessary conditions for each step.
c) Evaluate the environmental and health implications of using and discharging alkyl halides like 2-bromo-2-methylbutane into the community ecosystem.

Part 2

Item 5

An environmental technician in Tororo is responding to a dilute sulfuric acid leak into a freshwater stream supplying a grazing area and a school. To neutralise the spill, the technician has access to Magnesium, Calcium, and Barium metals, with physical and atomic data supplied in Table 1 below.

Table 1: Physical and Atomic Properties of Selected Group 2 Elements

Element	**Atomic Radius (nm)**	**First Ionisation Energy (kJ/mol)**	**Solubility of Sulfate (g/100g water at 20°C)**
Magnesium	0.160	738	35.70000
Calcium	0.197	590	0.24000
Barium	0.217	503	0.00024

Field observations show:

- **Magnesium** reacts slowly at first but completely dissolves to neutralise the acid.
- **Calcium** reacts briefly, then stops as an insoluble white crust coats the metal.
- **Barium** reacts violently, but its dissolved ions are highly toxic to humans and livestock.

Task

(a) Using Table 1, explain how atomic properties govern the trend in reactivity of these metals with water, and explain why Calcium fails to complete the neutralisation reaction.

(b) Evaluate the health and environmental impacts of the untreated acid versus using toxic Barium, and recommend the best metal to safely resolve the spill.

Item 6

An environmental compliance officer inspecting an industrial park in Jinja is evaluating three Period 3 oxides produced across different manufacturing processes: **Magnesium oxide (MgO)**, **Silicon dioxide (SiO_2)**, and **Sulfur dioxide (SO_2)**. To determine safe handling measures, assess health hazards, and allocate these oxides to their correct industrial uses, the plant laboratory compiled the physical and chemical observations shown in Table 1.

Table 1: Physical and Chemical Observations of Selected Period 3 Oxides

Period 3 Oxide	Physical State at 25°C	Melting Point (°C)	Behaviour in Water	Reaction with 2 M NaOH(aq)	Reaction with 2 M HCl(aq)
Magnesium oxide (MgO)	White powder	2852	Slightly soluble; forms a weakly alkaline suspension (pH ~10)	No observable reaction	Dissolves readily to give a colourless solution
Silicon dioxide (SiO_2)	Hard crystalline solid	1710	Insoluble; no change observed	Dissolves only upon heating with concentrated alkali	No observable reaction
Sulfur dioxide (SO_2)	Colourless gas (pungent odour)	-73	Dissolves readily; forms an acidic solution (pH ~2)	Reacts rapidly to form a salt solution	No observable reaction

The factory intends to select one oxide for lining high-temperature steel-refining furnaces, another for manufacturing container glass, and must implement an emission-control plan for any oxide posing atmospheric and human respiratory hazards.

Task

(a) Analyse the observations in Table 1 by relating the melting points, physical states, and acid-base reactions of Magnesium oxide, Silicon dioxide, and Sulfur dioxide to their chemical bonding and structural types across Period 3.

(b) Evaluate the health and environmental risks posed by the escape of Sulfur dioxide into the surrounding environment, and recommend—with chemical justification—which of

the remaining oxides is most suitable for lining high-temperature furnaces and which is most suitable for glass production.

END

WE DON'T DREAM WHILE SLEEPING