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P525/1
CHEMISTRY
JUL / AUG, 2026
2¾ Hours

BIOCHEM SERIES 2026

Uganda Advanced Certificate of Education
CHEMISTRY
PAPER 1
TIME: 2 HOURS 45 MINUTES

INSTRUCTIONS TO CANDIDATES:

- *The paper consists of section **A** and **B**.*
- *Section B consists of two parts **I** and **II***
- *Answer all items in section **A** and **two** items from section **B**.*
- *Respond to **one** from each part.*
- *Illustrate your answers with equations where applicable.*

TURN OVER

SECTION A

(Attempt all items in this section)

Item one.

The government is encouraging the use of clean energy technologies as part of its efforts to reduce greenhouse gas emissions. A renewable-energy company is currently investigating the production of hydrogen fuel for use in fuel-cell-powered charging stations. Hydrogen is considered a promising alternative fuel because it can generate electricity without producing carbon dioxide.

Before constructing a pilot production plant, the company is evaluating a reaction that produces hydrogen gas from two aqueous reactants, X and Y.

X and Y react according to the following equation:

$$2X(aq) + Y(aq) \longrightarrow H_2(g) + WZ(aq)$$

A series of experiments conducted on the reaction above revealed the result summarized in Table 1 and Table 2 below:

Table 1: Initial rate data

Experiment	[X] (mol dm^{-3})	[Y] (mol dm^{-3})	Initial rate (mol dm^{-3} s^{-1})
1	0.10	0.10	2.0×10^{-3}
2	0.20	0.10	8.0×10^{-3}
3	0.30	0.10	1.8×10^{-2}
4	0.10	0.20	4.0×10^{-3}

Table 2: Thermochemical data

Species	ΔH_f^{θ} (kJ mol^{-1})
X(aq)	−120
Y(aq)	−250
WZ(aq)	−670

The company is currently unsure how this interpret the data and proceed with their plans. They have been advised that a rate constant above 2.0×10^{-2} mol dm^{-3} s^{-2} and an enthalpy of reaction more negative than −150 kJ mol^{-1} represent an efficient production process.

Furthermore, the company lacks knowledge on how to increase the rate of hydrogen production. They intend to establish production units in remote communities where efficiency, safety, and sustainability are critical.

You and your teacher recently visited the company, and they provided you with details regarding their reactions and future plans.

Task

(a) Analyse the data provided and use it to comment on whether the reaction can actually be used for electricity generation and help the company assess the efficiency of the production process.

(b) Explain the conditions the company should optimise to increase the production rate of the fuel.

(c) Analyse the importance of these laws in the scenario for real-life applications and make a recommendation regarding the qualities of a good fuel that the company should consider.

Item 2

A chemical company in Kasese district intends to produce sulphuric acid to support the manufacture of phosphate fertilizers for farmers in Uganda. Sulphuric acid is produced industrially using the Contact Process.

Before installing a full-scale plant, the company's laboratory team carried out two pilot experiments

Experiment 1

A 2.0 dm^3 reaction vessel was filled with 3.0 moles of sulfur dioxide gas and 2.0 moles of oxygen gas. The mixture was heated to 450 °C in presence of vanadium(V) catalyst. At equilibrium, 1.8 moles of sulfur trioxide had been formed according to the following equation:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -197 \text{ kJ mol}^{-1}$$

Experiment 2

The Sulphur trioxide gas from Experiment 1 was absorbed in concentrated sulphuric acid to form oleum, which was then carefully diluted with water to form 98 % concentrated sulfuric acid.

For fertilizer processing, the company prepares a working solution by diluting 5.0 cm^3 of 98% sulphuric acid in distilled water to make 500 cm^3 of dilute solution.

The company has been advised that an equilibrium constant, K_c value greater than 3.60 mol^{-1} dm^3 in sulphur trioxide synthesis would represent optimal production efficiency and the pH of the resultant diluted sulphuric acid solution should be below 0.54 for efficient fertilizer production. *(Density of sulphuric acid is 1.84 g cm^{-3}, H=1, S=32, O=16)*

The company also wants to investigate the conditions that affect the rate and yield of sulfuric acid production.

Tasks:

As a learner of chemistry;

(a) Analyse the data provided and use it to comment on the production efficiency of the company.

(b) Explain the ways the company would use to increase the amount of sulphuric acid produced during the production process.

(c) Explain other real-life applications of the principles used in the company.

SECTION B

(Attempt two items; one from each part)

PART I

Item 3

Water treatment and waste management systems are key in improving public health and environmental sustainability. A rapidly growing municipality in Uganda relies on chlorine for disinfecting drinking water, but recent expansion plans have raised concerns about the safe handling, storage, and disposal of chemicals used in water treatment and nearby industries.

Several industries operating within the municipality use or produce substances containing chlorine. These include

- Sodium chloride (NaCl)
- Aluminium chloride ($AlCl_3$)
- Tin(IV) chloride ($SnCl_4$)
- Chlorine (Cl_2)

During stakeholder meetings, engineers, environmental officers, and public health officials observed that these substances behave very differently during storage, transport, and use. For example, some exist as solids with very high melting, while others are gases or volatile liquids. Some react readily with water to produce solutions that corroded the metal structures with the plant, while others dissolve with little or no chemical change. Similarly, when treated with sodium hydroxide during waste treatment, they undergo entirely different reactions. The stakeholders failed to understand these differences in behaviour.

To make informed decisions about chemical selection, handling, and disposal, the municipality needs to understand the above behaviors of the compounds but lack the skills and knowledge. This understanding would be used to develop guidelines for chemical use in water treatment, industrial processes, and environmental management.

The stakeholders have invited a nearly by school of which you are among the learners.

Task.

(a) Help the municipality to analyse and understand the behaviors of the compounds.

(b) Assess the use of chlorine by the municipality.

Item 4

Various oxides are used in industries to manufacture a wide range of products, such as cement, fertilizers, and ceramics. However, their properties significantly impact heating requirements, worker safety, and environmental pollution, particularly during industrial processing.

Farmers living near a certain factory recently reported crop damage and accelerated corrosion of iron sheets. Simultaneously, workers and engineers raised concerns regarding irritating oxide fumes and the high temperatures required to process certain oxide materials. In response to these concerns, the District Science and Environment Committee organised a joint industrial inspection involving chemists, environmental officers, and Senior Six chemistry learners from a neighboring school.

One of the industries visited utilizes oxides formed by Period 3 elements. During the inspection and testing, the learners observed that some oxides reacted vigorously with water to form corrosive solutions, while others dissolved only in alkaline solutions. The learners are keen to understand the reasons behind these differences.

The District Committee has requested that the learners prepare a scientific report to help industries improve safety, reduce pollution, and select appropriate oxide materials for industrial use. The data in Table 4 below outlines one of the properties of the selected oxides currently used in the factories visited.

Table 4

Oxide	Na_2O	MgO	Al_2O_3	SiO_2	SO_3
Melting point (°C)	1275	2827	2007	1607	30

Task:

As one of the Senior Six learners:

(a) Explain why some oxides produce fumes while others require very high temperatures to process.

(b) Analyse and explain the observed reactions of the oxides during inspection and testing.

(c) Assess the environmental, health, or industrial implications associated with the production and use of these oxides, and recommend suitable safety measures.

PART II

Item 5

Organic compounds have a wide range of uses and can be converted into other useful substances through different chemical reactions. Recently, employees at a newly established chemical manufacturing company, which uses propan-1-ol and ethyne as raw materials to produce customer-required products, observed that these two compounds behave differently when heated. They do not understand why. The quality assurance team advised the staff that understanding the behaviour of organic compounds when exposed to heat is important, as it helps prevent potential explosions and other associated hazards.

A group of chemistry students who visited the factory during a science innovation exhibition became interested in how these simple organic compounds could be converted into more useful industrial products. During discussions with the industrial chemists, the students learnt that the company was particularly interested in improving the conversion of propan-1-ol into ethanol, and ethyne into 1-phenylethanol, because these products are needed in the manufacture of other goods. The students wondered how these transformations can be achieved.

To expand their production line, the company's director recently imported two additional raw materials: ethanal and benzene. The company has been advised to convert these into the more profitable products, ethanal 2,4-dintrophenylhydrazone and benzene sulphonic acid, respectively. This is because these two compounds are in high demand in the neighbouring industries as important precursors. However, the company's manager needs to understand how these conversions can be effectively carried out to minimize any potential dangers associated with the processes.

The students, company workers, and the company director have approached you for assistance.

Task:

(a) Prepare a write-up that will assist the learners, the company's workers, and the company's director.

(b) Evaluate the industrial importance and safety concerns associated with the raw materials in the above industrial processes.

Item six.

A cooperative of young entrepreneurs in Uganda plans to establish a small agroprocessing and chemical manufacturing enterprise. The enterprise intends to produce and market a range of products, including: a fruit-flavored beverage made from locally grown pineapples and mangoes, a fragrance additive for soaps and cosmetics, a cleaning solvent for industrial and laboratory use, and a biofuel additive to improve fuel combustion efficiency.

Before production begins, the entrepreneurs must select suitable organic compounds and production methods. The compounds considered for use are:

- Ethene (C_2H_4)
- Ethanol (C_2H_5OH)
- Ethanoic acid (CH_3COOH)
- Propan-1-ol (C_3H_7OH)
- Ethyl ethanoate ($CH_3COOC_2H_5$)

During preliminary trials, they observe that some compounds evaporate quickly, while others remain liquid for long periods; they are unsure why this occurs.

At the enterprise, benzene is reacted with a warm mixture of concentrated nitric acid and concentrated sulphuric acid, while propan-1-ol is heated with ethanoic acid in presence of sulphuric acid. The workers are eager to understand how these reactions proceed to yield the desired products.

Workers at the enterprise also discovered that several products can be made from the same starting materials. As a result, they are considering preparing propyl benzoate and an azo-dye from ethene, but they lack the necessary expertise.

Furthermore, the workers at enterprise lack an understanding of the which organic compounds are most suitable for the specific applications required in the production of these various goods.

Task:

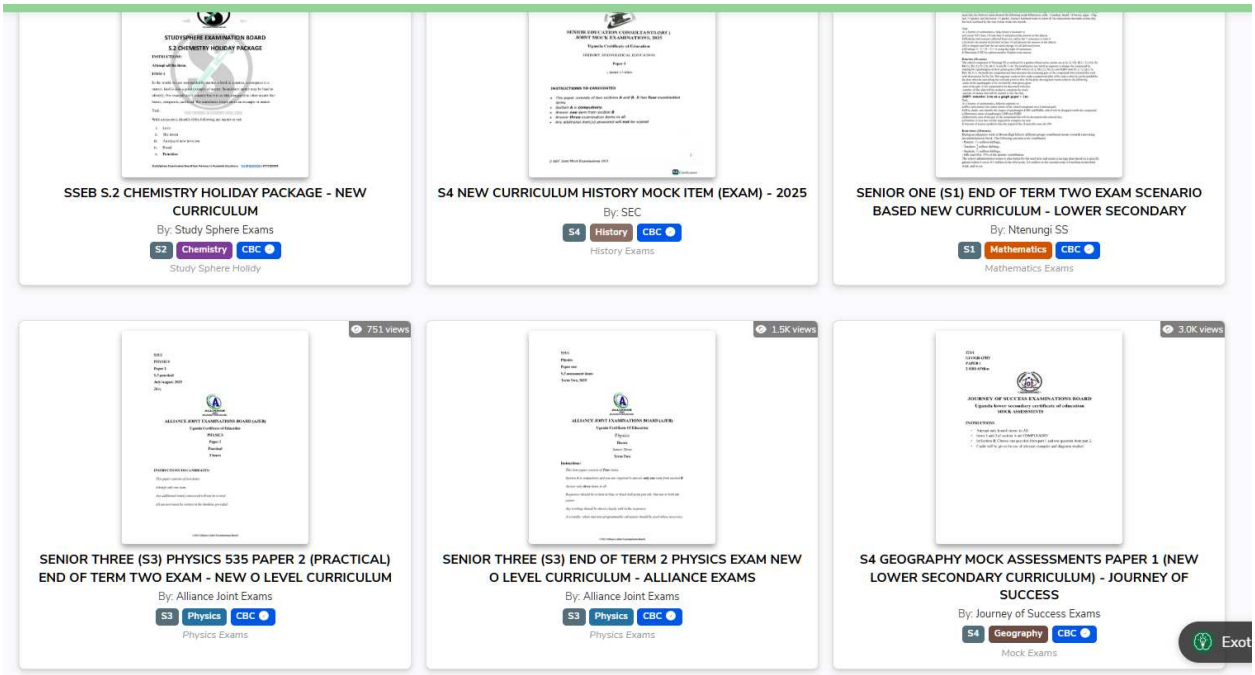
(a) Explain the differences in the evaporation behaviour of the compounds considered for use.

(b) Help the workers in the cooperative solve their other challenges.

(c) Assess the suitability of one of these compounds for use in the production of a specified product the company intends to make.

END

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