

CANDIDATE'S NAME:

CANDIDATE'S SIGNATURE:

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525/1
CHEMISTRY
THEORY
PAPER 1
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3HOURS



NELSON MANDELA SECONDARY SCHOOL MASAKA
Uganda Advanced Certificate Of Education

CHEMISTRY
Paper One
(Theory)
3hours

INSTRUCTIONS TO CANDIDATES:

- *The paper is made up of six examination items set in two sections A and B.*
- *All items in section A are **compulsory**. Responses to this section **must** be written in the **gaps left**.*
- *Section B is partitioned into **two parts I and II**. You are required to respond to **one item** in each of the two parts. All items in section B carry **equal scores**.*
- *Any **extra** item responded to **will not** be scored.*
- *All the items in section B **must** be written in the response **booklets** given.*
- *Tidy and illustrated work is highly recommended.*

SECTION A (50scores)

(Compulsory)

Item 1

Sodium chloride is a nutritive salt used in homes as a food additive and preservative. In Uganda, the salt is chiefly mined from Lake Katwe with trace quantities of calcium and magnesium chlorides in concentrations 1M and 0.5M respectively.

Karibu is a foreign investor whose factory refines the salt (NaCl) from its impurities. The purification process is done by precipitation of the saturated solution using hydrogen chloride. Theoretically, the solubility product of sodium chloride is known to be 36.8Moldm^{-3} , the solubilities of Calcium chloride and magnesium chlorides are 81g l^{-1} and $8.0\text{g}/100\text{ml}$ respectively.

One day, the factory offices caught fire and almost all the important documents perished. This led the factory manager to be fired so that the new manager could be recruited. The new factory manager on his first attempt bubbled hydrogen chloride into a 300g l^{-1} solution of the salt but the salt failed to precipitate out which made him worried and uncomfortable at work. What else made him surprised and confused was the culture of his industrial workers to add excess aqueous ammonia to the remaining solution after precipitating out the sodium chloride salt. After treatment with excess ammonia, they pass the resultant mixture through a filtration system to obtain solid particles which are dried and later heated strongly to obtain a white solid powder which they add in excess to aqueous hydrogen chloride, the resultant solution is crystalized by evaporation to obtain solid X that is packed and sold for their side earning. The manager seeks to understand what is chemically going on and has consulted you as a knowledgeable chemist.

Task

- a) Help the manager to
 - i) Understand the meaning of a saturated solution, solubility of a salt and its solubility product. (3scores)
 - ii) Determine the solubility in gdm^{-3} of the salt obtained from Lake Katwe. (2scores)
 - iii) Determine the ionic product of the salt in the 300g l^{-1} solution. (4scores)
 - iv) Understand the chemistry behind the action of passing hydrochloric acid through a saturated solution of the sodium chloride salt. (3scores)
- b) Explain to the new manager why magnesium chloride and calcium chloride do not precipitate out in this industrial process? (Illustrate your response with explanations, expressions and calculations where necessary.) (7scores)
- c) Help the manager to understand the identity of the crystalline solid X (Show him the details of its formation). (6score)

Item 2

In Allan's medical research laboratory, culture solutions are made from buffers in which bacterial antigens are kept and related bacterial microbes are bred to promote specific vaccines for immunization of different bacterial ailments. A bacterial sample got from one patient was investigated to find out the suitable P^{H} conditions under which the bacteria survives mostly. The patient's blood was tested acidic with an unknown acid RCOOH at $\text{P}^{\text{H}}5$ and concentration 0.1M produced by the bacteria present. Spectral investigations showed that the molecular value of R is 15 consisting of 80% carbon and the rest being hydrogen. Further studies showed that the life of these bacteria is dependent of various P^{H} media according to the specific

chemical nature of the media fluid in which it breeds. In this laboratory, Benzoic acid is the only weak acid available for making the required buffer. However, it must be mixed with a special salt to ensure P^H stability on refilling the culture solutions. It should be always noted that the concentration of the salt to be used should equal to that of the $RCOO^-$ ions in the patient's blood and that, the concentration of Benzoic acid should equal to that of $RCOOH$ acid in the blood of the infected patients.

You are intending to become part of the research team and Doctor Allan is longing to experience your chemical analytical skills and values.

Task

Show the doctor your skills and abilities by

- Working out the K_a of the acid in the patient's blood. (8scores)
- Finding the molecular identity of R, hence the name and molecular/structural formula of the acid $RCOOH$ in the patient's blood. (5scores)
- Calculating the concentration of $RCOO^-$ ions and hence the concentration of the salt that should be used in the buffer culture solution. (5scores)
- Determining the P^H of the buffer culture solution. (7scores)

SECTION B (50scores)

Part 1

(Respond to only one item from this part)

Item 3

A pharmaceutical firm uses aluminium chloride to synthesize a hemostatic agent, a chemical used to stop bleeding during surgical operations in theatres. The aluminium metal powder is reacted with chlorine under special conditions to form the aluminium chloride. However, other metal elements can react with chlorine more easily. In the preparation cell are two identical metal powders in cans labeled X and Y. The details of the metals in the cans are summarized in terms of ionization energies as shown in table I below.

Table I

Ionization energy		1 st	2nd	3rd	4th
Energy values($KJmol^{-1}$)	X	578	1,817	2,745	11,600
	Y	738	1,451	7,733	10,542

Hakim, a new worker in the preparation cell is confused of which of the two metal cans is of aluminium power. As a chemistry student, you are aware that for Hakim to be able to analyze and identify the right aluminium can, he should know a lot about the chemistry of aluminium metal.

Task

Help Hakim to

- Write the electronic configurations of aluminium and its ion. (2scores)
 - Write the electronic configuration of the atom and the ion with which aluminium forms the hemostatic agent. (2scores)

- iii) Demonstrate how the compound in the hemostatic agent is formed. (2scores)
- iv) State the type of bond, physical properties and any other use of the compound in the hemostatic agent. (3scores)
- b) i) On the same axes, Plot the graph of energy values against ionization energies for both the metallic elements X and Y. (4scores)
- ii) Describe the trend in ionization energy values for each metallic element. (2scores)
- iii) According to your graph, which of the elements X and Y. (Explain) (2score)
- c) i) It is indicated that the remaining element after identifying aluminium is found in period 3 of the periodic table. Name the element, write its electronic configuration and show how it can form a compound with chlorine if mistakenly used instead of aluminium. (4scores)
- d) It is said that excess sodium hydroxide solution can be used to separate the two cations, aluminium and either X or Y in a solution mixture. One form insoluble precipitates in excess while the other forms soluble precipitates. Explain with equation(s) the difference in the observations. (4scores)

Item 4

Mr. Joseph intends to start a chemical factory that deals in production of acid for different purposes. His interest is in production of halic acid which is made by dissolving a hydrogen halide in water. The acid at the highest demand on the market is the strongest, and Mr. Joseph is confused of which acid to manufacture among the halic acids. The only information he has about halogens is about the boiling points of halogens F_2 , Cl_2 , Br_2 and I_2 . The man needs guidance and you were mentioned as one of the people with great knowledge about the chemistry of these halogens. Refer to table II below.

Table II

Halogen	F_2	Cl_2	Br_2	I_2
Boiling point($^{\circ}C$)	-188	-34	59	184

Mr. Joseph is confused of how to use the data he has and needs your assistance.

Task

Assist Mr. Joseph to;

- a) i) Plot a graph of boiling points against the halogens and describe the trend. (5scores)
- ii) Explain the trend in boiling points and comment on the matter states of the halogens basing on the data in the table/graph. (8scores)
- b) i) Write the outermost electronic configuration of each halogen. (2scores)
- ii) Using the outermost electronic shell, show how any one of the four halogens above forms a hydrogen halide. Name the type of bond that exists between the atoms in the formed compound and the type of intermolecular forces in its molecules. (3scores)
- c) Explain the trend in strength of the acids formed by the hydrogen halides. Hence, identify the halic acid that would be the most suitable to produce on market. (7scores)

Part II

(Respond to only one item from this part)

Item 5

A chemical industry dealing in production of an aromatic organic chloride from an organic substance P and an aliphatic alcohol R from an alkene Q hid its production schemes from the Uganda National Beaural of Standards (UNBS) for confidential purposes. A UNBS inspector landed on the production manual that contained the information as follows below.

“P will be obtained from limestone (calcium carbonate) and coke (carbon) as the primary raw materials. P has molecular mass 78, 92.31% of which is carbon and the rest being hydrogen while Q has molecular mass 56 with 85.71% carbon and the rest being hydrogen.”

The manual further revealed that,

”P is reacted with chlorine in presence of anhydrous aluminium chloride to form the aromatic chloride. The resultant inorganic product of this reaction is not wasted, but is rather directly reacted with Q in either presence or absence of an organic peroxide depending on the chemical market demand. Q is isomeric with three compounds among which only one is the desirable. One of the two undesirable isomers is said to have a very low boiling point and hence forms a very volatile type of alcohol that is uneasy to store for longer. The second undesirable isomer is neglected just because it forms only one type of alcohol yet the desirable one form two isomeric alcohols. The resultant compound from the later reaction of Q under the organic peroxide is passed through alcoholic sodium hydroxide to obtain the final desired alcohol.”


The UNBS inspectorate failed to interpret and understand what the production manual described and so, you have been consulted as an authority of chemical analysis.

Task

Help the inspectorate to.

- a)
 - i) Determine the molecular and structural identity of compound P. (5scores)
 - ii) Explain and illustrate the course of production of P from the primary raw materials as described in the manual. (4scores)
- b) Show how the aromatic chloride is obtained from P(indicate acceptable mechanism for the reaction) (3scores)
- c)
 - i) Name and write the molecular and structural formulae of the three isomers of Q. (4¹/₂scores)
 - ii) Identify the undesirable isomer whose alcohol is very volatile and explain why. (2scores)
- d) Explain how the inorganic product formed with the aromatic chloride is used to convert the desirable isomer of Q into a desirable chloride(show acceptable mechanism where possible)
 - i) In presence of a peroxide. (3scores)
 - ii) In absence of a peroxide. (3scores)
- e) Show how the isomeric chlorides obtained in di) and dii) above are converted to the desirable isomeric alcohols. (5¹/₂scores)

Item 6

In Nyanza textile industry is a section that is responsible for production of textile dye and printing paste. The production of a dye or a paste involves the use of an alkyl benzene  as a solvent for dissolving the dyes, where R is an alkyl group.

The supplier of this solvent was banned from further production of the chemical due to some amendments in production standards and now the textile has been in insufficiency of the solvent until an industrial chemist was deployed to join the production team. The industrial chemist was tasked to locally synthesize the solvent. He started by exploding 20cm³ of an unknown hydrocarbon T with 100cm³ of excess oxygen which gave 70cm³ of residual gases (this excludes water vapor). The volume of the residual gas got reduced by 85.7% when it was bubbled through aqueous potassium hydroxide. The chemist told the industrial directors that the purpose of all this is to confirm the identity of hydrocarbon T that he was not sure of. After identifying T, he confirmed that it was the appropriate one to synthesize the required solvent. The chemist wanted to chlorinate T using Hydrogen chloride in presence of organic peroxide and the use the result to synthesize the required alkyl benzene.

As they got concerned with financial accountability, the directors suggested elimination of the organic peroxide because it was very costly yet it never participated directly in the reactions. It was wastage according to them but the chemist insisted that the product that will be formed will not be the one needed. However, he supported their low accountability by suggesting that the excess product of T with hydrogen bromide in presence of peroxide can be recycled back to hydrocarbon T for continuous production. The directors are wondering how this chemist does his things and are worried if he doesn't financially fake them and you are consulted for clarification.

Task

Help the directorate to

- a) i) Show how the molecular and structural identity of T was found. **(5scores)**
- iii) Explain the mechanism that is involved in brominating T in presence of the organic peroxide according to the chemist. Name the product of the reaction. **(4scores)**
- iv) Show and explain how the required alkyl benzene was synthesized from the resultant compound in a) iii) above. (Include reagents, conditions and mechanisms for the reaction) and hence name the alkyl benzene. **(5scores)**
- v) Explain what would be formed instead if the organic peroxide was eliminated as was first suggested by the industrial directorate. (Show the acceptable mechanisms) and hence name the unrequired aromatic compound that would be formed. **(5scores)**
- b) Explain the route process that you would recommend to be followed so as to recycle the excess products suggested by the chemist in favor of financial accountability back to T. **(6scores)**