THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

032/1   **CHEMISTRY 1**

(For Both School and Private Candidates)

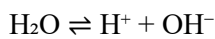**Time: 3 Hours**   **ANSWERS**   **Year: 2016**

Instructions

1. This paper consists of sections A, B and C with total of thirteen questions

2. Answer all questions.

I. Which of the following is true about the following equilibrium?

$H_2O \rightleftharpoons H^+ + OH^-$

A. Water molecules have stopped changing into ions.

B. Water molecules have all changed into ions.

C. Concentrations of water molecules and ions are equal.

D. Concentrations of water molecules and ions are constant.

E. Water molecules are moving slow.

In equilibrium, the rate of the forward reaction (ionization of water) equals the rate of the reverse reaction (recombination of ions), meaning that the concentrations of reactants and products remain constant over time.

Correct answer: D

II. The property of metal to be drawn into wires is called

A. Conductivity

B. Malleability

C. Ductility

D. Decorating

E. Expansion

The ability of a metal to be stretched into a wire without breaking is known as ductility.

Correct answer: C

III. If a steady current of 2 amperes was passed through an aqueous solution of iron (II) sulfate for 15 minutes, the mass of iron deposited at the cathode will be

A. 30 g

B. 56 g

C. 0.54 g

D. 28 g

E. 0.52 g

Using Faraday's laws of electrolysis:

$m = (ItM) / (nF)$,

where $I = 2A$, $t = 15$ min $= 900$ s, $M = 55.85$ g/mol (Fe), $n = 2$, and $F = 96500$ C/mol,

$m = (2 \times 900 \times 55.85) / (2 \times 96500) = 0.52$ g

Correct answer: E

IV. What will happen when zinc is placed in aqueous copper (II) sulfate?

A. Copper atoms are oxidized

B. Zinc atoms are oxidized

C. Copper ions are oxidized

D. Zinc ions are oxidized

E. Sulfur atoms are oxidized

Zinc is more reactive than copper, so it displaces copper from the solution by losing electrons (oxidation), forming Zn^{2+} ions.
   Correct answer: B

V. Which of the following pairs of gases can be prepared in the laboratory and collected over water?
   A. Oxygen and Ammonia
   B. Hydrogen and Hydrochloric acid
   C. Hydrogen and Oxygen
   D. Oxygen and Hydrogen chloride
   E. Hydrogen and Ammonia

   Gases collected over water should be insoluble or slightly soluble in water. Both oxygen and hydrogen fulfill this condition.
   Correct answer: C

VI. Two substances are allotropes of carbon if
   A. Both reduce heated iron (III) oxide to iron
   B. Have different crystalline structures
   C. Have equal masses
   D. Have equal shape
   E. Have the same arrangement of atoms

   Allotropes are different structural forms of the same element. Diamond and graphite, for example, have different crystalline structures.
   Correct answer: B

VII. The apparatus suitable for measuring specific volumes of liquids is called
   A. Burette
   B. Volumetric flask
   C. Pipette
   D. Measuring cylinder
   E. Graduated beaker

   A pipette is the most accurate for measuring specific liquid volumes.
   Correct answer: C

VIII. Which among the following reactions does $Cu^{2+} + Zn \rightarrow Zn^{2+} + Cu$ represent?
   A. Synthesis
   B. Precipitation
   C. Neutralization
   D. Displacement
   E. Decomposition

This is a single displacement reaction where zinc replaces copper in the solution.
Correct answer: D

IX. The occurrence of two or more compounds with the same molecular formula but different molecular structures is known as
  A. Amphoterism
  B. Isomerism
  C. Allotropy
  D. Polymorphism
  E. Isotopy

  Isomerism occurs when compounds have the same molecular formula but different structural arrangements.
  Correct answer: B

X. Which of the following sets of symbols represent isotopes of a single element?
  A. ^{40}K, ^{32}S, ^{35}Cl
  B. ^{1}H, ^{2}H, ^{3}H
  C. ^{12}C, ^{13}C, ^{14}C
  D. ^{35}Cl, ^{37}Cl, ^{39}K
  E. ^{23}Na, ^{24}Mg, ^{25}Mg

  Isotopes are atoms of the same element with the same atomic number but different mass numbers. Hydrogen (^{1}H, ^{2}H, ^{3}H) and Carbon (^{12}C, ^{13}C, ^{14}C) are examples of isotopes.
  Correct answer: C

2. Matching items
List A
(i) Atoms of the same element that contain different numbers of neutrons.
(ii) The elements that display both metallic and non-metallic characteristics.
(iii) Sub-atomic particle NOT found in the nucleus of the atom.
(iv) The number of protons found in the nucleus of the atom.
(v) The total number of protons and neutrons in the nucleus of the atom.
(vi) The number of unpaired electrons on an atom.
(vii) The elements which are incredibly stable and rarely react.
(viii) The non-metals that form diatomic molecules.
(ix) Sub-atomic particle with no charge.
(x) A group of atoms with unpaired electrons.

List B
A. Atomic number
B. Electron

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C. Radical
D. Metalloids
E. Isotopes
F. Mass number
G. Neutron
H. Allotropes
I. Noble gases
J. Period
K. Group
L. Proton
M. Valence
N. Atomic radii
O. Halogens

(i) E
(ii) D
(iii) B
(iv) A
(v) F
(vi) M
(vii) I
(viii) O
(ix) G
(x) C

3. (a) Give the meaning of the following terms:

(i) Soil pH.
Soil pH refers to the measure of acidity or alkalinity of the soil, expressed on a scale from 0 to 14. A pH below 7 indicates acidic soil, while a pH above 7 indicates alkaline soil. The pH level affects nutrient availability and microbial activity in the soil.

(ii) Liming.
Liming is the process of applying lime (calcium-containing compounds such as calcium carbonate) to the soil to reduce its acidity and increase its pH. This practice improves soil fertility, enhances microbial activity, and promotes better plant growth.

(b) (i) Explain why sulphur and its compounds are removed from fuels before they are burned.

Sulphur and its compounds are removed from fuels before combustion to prevent the release of sulphur dioxide (SO_2) into the atmosphere. Sulphur dioxide is a major pollutant that causes acid rain, which

damages crops, forests, and aquatic life. It also contributes to respiratory problems in humans and corrodes buildings and infrastructure. Removing sulphur from fuels helps in reducing environmental pollution and health hazards.

(ii) Describe how sulphur dioxide is changed into sulphur trioxide. Give the reaction conditions and the equation(s).
Sulphur dioxide is converted into sulphur trioxide through the Contact Process, which involves the oxidation of sulphur dioxide in the presence of a vanadium (V) oxide (V_2O_5) catalyst at around 450°C and 1-2 atm pressure. The reaction is as follows:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$
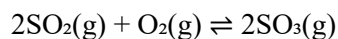
This reaction is exothermic, and the equilibrium yield of sulphur trioxide increases at lower temperatures, but a moderate temperature of about 450°C is used to balance the reaction rate and yield.
4. (a) Differentiate dilute hydrochloric acid from dilute sulphuric acid.

Dilute hydrochloric acid (HCl) contains hydrogen chloride gas dissolved in water, whereas dilute sulphuric acid (H_2SO_4) is a solution of sulphuric acid in water. Hydrochloric acid forms chloride salts when it reacts with metals, while sulphuric acid forms sulphate salts. Additionally, hydrochloric acid is a monoprotic acid, meaning it donates one hydrogen ion (H^+) per molecule, whereas sulphuric acid is diprotic, meaning it donates two hydrogen ions (H^+) per molecule.

(b) John measured the volume of gas produced when 3 g of two chemicals X and Y were added separately to hydrogen peroxide under identical conditions. His results for the experiment are represented on the graph below.
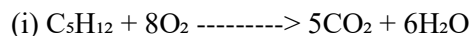
(i) Why does Steven think that John's conclusion is wrong?

Steven thinks that John's conclusion is wrong because the volume of gas produced depends not only on the catalyst's efficiency but also on factors such as reaction conditions, surface area, and concentration. John might not have considered all these variables before concluding that Y is a better catalyst than X.

(ii) After the experiment, Steven recovered 5 g of X and 1 g of Y from the two experiments. He claimed that this shows that John was wrong. Does Steven's claim hold true? Give a reason.

Yes, Steven's claim holds true because catalysts are not consumed in a chemical reaction. If Y was a better catalyst, it should have remained unchanged like X. The significant loss of Y indicates that it might have reacted with the hydrogen peroxide instead of acting as a true catalyst, which contradicts John's conclusion.

5. (a) Give the name of the type of reaction represented by each of the following chemical equations:

(i) $C_5H_{12} + 8O_2 \text{---------}> 5CO_2 + 6H_2O$

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Combustion reaction. A combustion reaction occurs when a hydrocarbon reacts with oxygen to produce carbon dioxide and water. It is an exothermic reaction, meaning it releases energy in the form of heat and light. In this case, pentane (C_5H_{12}) undergoes complete combustion in excess oxygen.

(ii) $2Pb(NO_3)_2 -----> 2PbO + 4NO_2 + O_2$
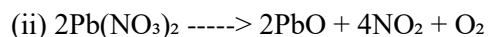
Thermal decomposition reaction. Decomposition reactions occur when a single compound breaks down into two or more simpler substances upon heating. Here, lead(II) nitrate decomposes into lead(II) oxide, nitrogen dioxide, and oxygen gas when heated. The brown gas observed in this reaction is nitrogen dioxide (NO_2).

(iii) $Zn + CuSO_4 --------> ZnSO_4 + Cu$
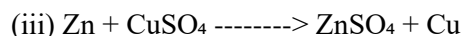
Displacement reaction. A displacement reaction occurs when a more reactive element replaces a less reactive element from its compound. Zinc is more reactive than copper, so it displaces copper from copper(II) sulfate solution, forming zinc sulfate and depositing copper metal.

(b) 25 cm³ samples of water A, B, C, and D were tested with soap solution. The volume of soap solution required to produce a lather that lasted for a minute was recorded. Fresh samples of each were boiled and tested again with soap solution. The results are shown in Table 1.

Table 1

Water sample	Volume of soap solution required (cm³) before boiling	Volume of soap solution required (cm³) after boiling
A	5.0	5.0
B	1.0	0.0
C	11.0	8.0
D	9.0	9.0

(i) Which sample probably contains temporary hardness of water only?

Sample B contains temporary hardness only because after boiling, the volume of soap solution required reduces to zero. This means that the dissolved salts responsible for hardness were removed upon boiling. Temporary hardness is usually caused by the presence of dissolved calcium bicarbonate ($Ca(HCO_3)_2$), which decomposes upon heating to form insoluble calcium carbonate, removing hardness.

(ii) Which sample probably contains both permanent and temporary hardness of water? Give a reason for your answer.

Sample C contains both permanent and temporary hardness. This is because before boiling, a large volume of soap solution was required (11.0 cm³), and after boiling, the volume decreased but still remained

significant ($8.0\ \text{cm}^3$). This shows that boiling removed some of the hardness (temporary hardness), but some still remained (permanent hardness), which is due to dissolved sulfates and chlorides of calcium and magnesium that do not decompose upon heating.

6. (a) Write the structural formula for the following compounds:

(i) But-2-ene

But-2-ene is an alkene with the molecular formula C_4H_8. The structure consists of four carbon atoms in a chain with a double bond between the second and third carbon atoms.
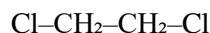
CH_3–CH=CH–CH_3
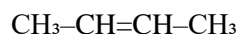
(ii) Pent-2-yne

Pent-2-yne is an alkyne with the molecular formula C_5H_8. The structure consists of five carbon atoms with a triple bond between the second and third carbon atoms.

CH_3–$C{\equiv}C$–CH_2–CH_3

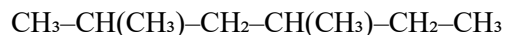(iii) 1,2-Dichloroethane

1,2-Dichloroethane is a halogenoalkane with two chlorine atoms attached to different carbon atoms in an ethane structure.

Cl–CH_2–CH_2–Cl

(iv) 2,4-Dimethylhexane

2,4-Dimethylhexane is an alkane with six carbon atoms in the main chain and methyl groups attached to the second and fourth carbon atoms.

CH_3–$CH(CH_3)$–CH_2–$CH(CH_3)$–CH_2–CH_3

(b) Briefly explain what will be observed when silver nitrate solution is added to an aqueous solution of sodium chloride.

When silver nitrate solution ($AgNO_3$) is added to sodium chloride solution ($NaCl$), a white precipitate of silver chloride ($AgCl$) is formed. This is because silver nitrate reacts with chloride ions in solution to form insoluble silver chloride.

$AgNO_3 + NaCl \text{--------> } AgCl \text{ (white precipitate)} + NaNO_3$

7. (a) Determine the empirical formula of a substance that has the following composition by mass: 49.5% manganese and 50.5% oxygen.

Step 1: Convert percentages to moles.

Moles of Mn = 49.5 ÷ 54.94 = 0.9
Moles of O = 50.5 ÷ 16 = 3.16

Step 2: Divide by the smallest value.

Mn = 0.9 ÷ 0.9 = 1
O = 3.16 ÷ 0.9 = 3.5

Step 3: Multiply by 2 to get whole numbers.

Mn = 1 × 2 = 2
O = 3.5 × 2 = 7

Empirical formula = Mn_2O_7

(b) Give one reason why aluminium is chosen to make each of the following items:

(i) Cooking foil

Aluminium is lightweight, non-toxic, and has high thermal conductivity, which allows efficient heat transfer while cooking. It is also resistant to corrosion.

(ii) Overhead electric cables

Aluminium is a good conductor of electricity, lightweight, and has a high strength-to-weight ratio. It is used in overhead electric cables because it is cheaper and lighter than copper.

(iii) Window frames

Aluminium is strong, lightweight, and resistant to corrosion. This makes it suitable for making durable window frames that require minimal maintenance.

8. (a) Identify and state the environmental problem caused by the gas which is released from the blast furnace in the extraction of iron from its oxide.

The gas released from the blast furnace is carbon dioxide (CO_2), which contributes to global warming and climate change. Excessive CO_2 in the atmosphere leads to the greenhouse effect, which increases Earth's temperature and disrupts ecosystems.

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(b) (i) Draw a labelled diagram of a simple electrolytic cell which shows how copper is purified.

An electrolytic cell for copper purification consists of:
- Anode (Impure copper)
- Cathode (Pure copper)
- Electrolyte (Copper sulfate solution)

(ii) Write balanced ionic equations to show the electrode reactions which occur when copper is purified.

At the anode: $Cu \longrightarrow Cu^{2+} + 2e^-$ (Copper dissolves into solution)
At the cathode: $Cu^{2+} + 2e^- \longrightarrow Cu$ (Copper is deposited as pure metal)

9. (a) Name two elements which are expected to show similar chemical reactions with magnesium. What is the basis for your choice?

Calcium (Ca) and Barium (Ba), because they belong to the same Group 2 (alkaline earth metals) in the periodic table and have similar valency and chemical properties.

(b) State the main raw material and the process involved in the manufacture of the following products:

(i) Wood charcoal
Raw material: Wood
Process: Carbonization (heating wood in the absence of oxygen)

(ii) Coke
Raw material: Coal
Process: Destructive distillation (heating coal in the absence of air)

(iii) Lampblack
Raw material: Hydrocarbon oils
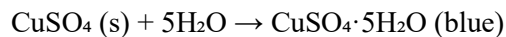Process: Incomplete combustion (burning oil with limited oxygen supply)

10. (a) Give two chemical tests of water and the expected result to be observed.

(i) Anhydrous copper(II) sulfate test

Procedure: Add a few drops of water to anhydrous copper(II) sulfate.

Expected result: The white anhydrous copper(II) sulfate will turn blue, indicating the presence of water.

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Equation:
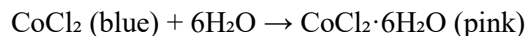$CuSO_4 (s) + 5H_2O \rightarrow CuSO_4 \cdot 5H_2O$ (blue)

(ii) Cobalt(II) chloride paper test

Procedure: Dip dry cobalt(II) chloride paper into the sample of water.

Expected result: The blue cobalt(II) chloride paper turns pink, confirming the presence of water.

Equation:
$CoCl_2$ (blue) $+ 6H_2O \rightarrow CoCl_2 \cdot 6H_2O$ (pink)

(b) A student tested five solutions M, N, O, P, and Q with a universal indicator solution to find their pH values. The following results were obtained:

M: pH 14
N: pH 5
O: pH 7
P: pH 1
Q: pH 9

(i) Which of the above solutions was neutral?

Solution O, because it has a pH of 7, which indicates neutrality.

(ii) Which of the above solutions was a strong acid?

Solution P, because it has a pH of 1, indicating a highly acidic solution.

(iii) Which of the above solutions was a strong alkali?

Solution M, because it has a pH of 14, indicating a strong base.

(iv) Which of the above solutions was a weak acid?

Solution N, because it has a pH of 5, indicating a weak acid.

11. (a) State the meaning of the following and give one example in each case.

(i) Amphoteric oxide

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An amphoteric oxide is an oxide that can react with both acids and bases to form salt and water. These oxides exhibit both acidic and basic properties.
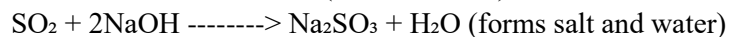Example: Aluminium oxide (Al_2O_3)

$Al_2O_3 + 6HCl$ ----------> $2AlCl_3 + 3H_2O$ (acts as a base)
$Al_2O_3 + 2NaOH + 3H_2O$ -------------> $2NaAl(OH)_4$ (acts as an acid)

(ii) Acidic oxide

An acidic oxide is an oxide of a non-metal that reacts with water to form an acid or with a base to form a salt.

Example: Sulfur dioxide (SO_2)

$SO_2 + H_2O$ -------> H_2SO_3 (sulfurous acid)
$SO_2 + 2NaOH$ --------> $Na_2SO_3 + H_2O$ (forms salt and water)

(b) A student investigated the different reactivity of a set of metals by placing pieces of each metal in metal nitrate solution. Table 2 shows some of the results.
Table 2

Solution	Aluminium	Barium	Lithium	Magnesium
Aluminium nitrate	X	✓	✓	✓
Barium nitrate	X	X	✓	✓
Lithium nitrate	X	X	X	✓
Magnesium nitrate	X	X	X	X

Where: ✓ = reaction observed and X = no reaction.

(i) Use the results given to arrange the metals in order of reactivity, starting with the most reactive metal.

The reactivity of a metal can be determined based on whether it reacts in another metal's solution. If a reaction occurs, the metal is more reactive than the one in solution.

From the table:
- Barium reacts with lithium and magnesium, making it more reactive than lithium and magnesium.
- Lithium reacts with magnesium but not barium, meaning it is less reactive than barium but more than magnesium.
- Magnesium only reacts with lithium nitrate, indicating it is the least reactive.
- Aluminium does not react with any solution, meaning it is the least reactive in this set.

Order of reactivity (most to least reactive):
Barium > Lithium > Magnesium > Aluminium

(ii) Use the reactivity series to complete Table 2.

By comparing with the standard reactivity series, potassium and sodium would be more reactive than lithium, while zinc and iron would be less reactive than magnesium but more reactive than aluminium.

12. Explain five methods to prevent terrestrial pollution.

(i) Proper waste disposal

Properly managing waste through recycling, composting, and proper landfills reduces soil and water contamination. Industries should dispose of hazardous materials in designated facilities.

(ii) Afforestation and reforestation

Planting trees helps prevent soil erosion, reduces land degradation, and absorbs pollutants from the soil and air. Deforestation should be minimized to maintain ecological balance.

(iii) Reducing the use of chemical fertilizers and pesticides

Excessive use of chemical fertilizers and pesticides leads to soil pollution and contaminates water sources. Using organic fertilizers and biological pest control reduces environmental impact.

(iv) Reducing industrial emissions and waste

Industries should treat their solid, liquid, and gaseous waste before releasing them into the environment. Advanced filtration and waste recycling techniques should be employed.

(v) Promoting sustainable agriculture

Practices such as crop rotation, contour farming, and agroforestry reduce soil degradation and pollution. Avoiding excessive use of monoculture also helps maintain soil fertility.

13. 0.48 g of a metal, M, was placed in a test tube and hot copper(II) sulfate solution was added to it and stirred until the reaction stopped. The metal (M) displaced copper from copper(II) sulfate solution. Copper was filtered, washed with water, dried at 100°C and the mass found to be 1.27 g. Given that the balanced chemical reaction that occurred is:
$M + CuSO_4 ----------> MSO_4 + Cu$
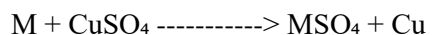
(a) (i) Calculate the number of moles of copper that were formed and the number of moles of M that were used in the reaction.

Moles of copper = Mass / Molar mass
Molar mass of Cu = 63.5 g/mol

Moles of Cu = 1.27 g / 63.5 g/mol
= 0.02 moles

From the equation, 1 mole of M displaces 1 mole of Cu, so:
Moles of M used = 0.02 moles

(ii) Calculate the relative atomic mass of M and hence identify metal M.

Relative atomic mass = Mass of M / Moles of M
= 0.48 g / 0.02 moles
= 24 g/mol

Since the relative atomic mass is approximately 24, the metal is Magnesium (Mg).

(b) State the appearance of the metal formed (Cu).

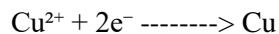Copper appears as a reddish-brown solid that is deposited at the bottom of the test tube.
(c) With ionic equations, explain why the reaction can be considered to involve both oxidation and reduction.

The reaction is a redox reaction because oxidation and reduction occur simultaneously.

Oxidation (M loses electrons):
$M \longrightarrow M^{2+} + 2e^-$

Reduction (Cu^{2+} gains electrons):
$Cu^{2+} + 2e^- \longrightarrow Cu$

Since metal M loses electrons (oxidation) and copper ions gain electrons (reduction), the reaction involves both oxidation and reduction.