

2411/302
INORGANIC CHEMISTRY
June/ July 2022
Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ANALYTICAL CHEMISTRY

INORGANIC CHEMISTRY

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

Non-programmable scientific calculator.

This paper consists of TWO sections; A and B.

Answer ALL the questions in section A and any THREE questions from section B in the answer booklet provided.

Each question in section A carries 4 marks while each question in section B carries 20 marks.

Maximum marks for each part of a question are as shown.

Candidates should answer the questions in English.

This paper consists of 8 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

SECTION A (40 marks)

Answer ALL the questions in this section.

1. A piece of rock was found to contain three isotopes of element X. Table I shows the experimental data of the isotopes obtained from a mass spectrometer.

Table 1

m/z	24.0	25.0	26.0
Relative abundance	64.2	20.3	15.5

- (a) Calculate the relative atomic mass of X. (2 marks)
- (b) Name the element X. (1 mark)
- (c) Give a reason why the relative atomic mass of X in the periodic table is different from the answer in (a). (1 mark)
2. Complete table II with the required information about period 3 oxides. (4 marks)

Table II

	Sodium oxide	Silicon dioxide	Phosphorus (V) oxide	Sulphur dioxide
Physical state at room temperature				
Type of bonding present				

3. The elements lithium, potassium and caesium were placed in water in separate large beakers.
- (a) Describe the observed reaction of each element. (3 marks)
- (b) State how it can be shown that an alkaline solution is formed when caesium reacts with water. (1 mark)
4. Explain how it can be demonstrated that aluminium oxide contains ions. (4 marks)
5. When an aqueous solution containing $[Cr(H_2O)_6]^{3+}$ ions is warmed in the presence of Cl^- ions, $[Cr(H_2O)_5Cl]^{3+}$ ions are formed and the colour of the solution changes.
- (a) Name this type of reaction. (1 mark)
- (b) Explain why the colours of the complex ions are different. (3 marks)

6. (a) Complete the following nuclear equations:
- (i) ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + \text{---} + 2\gamma$; (1 mark)
- (ii) ${}_{96}^{244}\text{Cm} + {}_2^4\text{He} \rightarrow {}_{97}^{245}\text{Bk} + {}_1^1\text{H} + \text{---}$; (1 mark)
- (iii) ${}_{19}^{40}\text{K} \rightarrow {}_{18}^{40}\text{Ar} + \text{---}$. (1 mark)
- (b) Name the decay process in (iii). (1 mark)
7. (a) Write the electronic configuration for S^{2-} . (2 marks)
- (b) Sodium sulphide, Na_2S , is a high melting point solid which conducts electricity when molten. Carbon disulphide, CS_2 , is a liquid which does not conduct electricity. State the type of bonding in Na_2S and CS_2 . (2 marks)
8. (a) Write the electronic arrangement of Fe^{2+} ion. (1 mark)
- (b) Explain why iron is placed in the d-block of the periodic table. (1 mark)
- (c) Explain the difference in the chemical properties of isotopes of iron. (2 marks)
9. (a) Aluminium oxide is amphoteric. Write a chemical equation for the reaction between aluminium oxide and:
- (i) hydrochloric acid; (1 mark)
- (ii) excess aqueous sodium hydroxide. (1 mark)
- (b) Name the type of bonding in aluminium oxide. (1 mark)
- (c) State one property of aluminium oxide which makes it resistant to corrosion in water. (1 mark)
10. (a) Calculate the time required for a 75.0 mg sample of iodine -131 to decay to 12.5 mg given that the half-life of $\text{I}-131$ is 8.05 days. (3 marks)
- (b) Describe the change occurring in the nucleus when an electron is captured. (1 mark)

SECTION B (60 marks)

Answer any THREE questions from this section.

11. (a) Sketch a cross-section of a p-orbital. (1 mark)
- (b) Explain why hydrogen sulphide (H_2S) is a gas at room temperature and pressure whereas water (H_2O) is a liquid under the same conditions. (4 marks)
- (c) HF and HCl are molecules having polar covalent bond with boiling points of 293 K and 188 K respectively.
- (i) State the property of the atoms which causes the bond to be polar. (1 mark)
- (ii) Explain in terms of the intermolecular forces present in each compound, why HF has a higher melting point than HCl. (3 marks)
- (d) Determine which of the species Na^+ , K^+ , Mg^{2+} , Ca^{2+} , S^{2-} , Ar are isoelectronic. (6 marks)
- (e) A sample of strontium has a relative atomic mass of 87.8 and consists of three isotopes, ^{86}Sr , ^{87}Sr and ^{88}Sr . The ratio of abundances of the isotopes ^{86}Sr : ^{87}Sr in this sample is 1:1.
- (i) State why the isotopes of strontium have similar chemical properties. (1 mark)
- (ii) Calculate the percent abundance of the ^{88}Sr isotope in this sample. (4 marks)
12. Y and Z are metals in the same group of the S-block in the periodic table. Aqueous solutions of a salt of each metal were added to three aqueous laboratory reagents. The observations are as shown in table III.

Table III

	$\text{H}_2\text{SO}_{4(\text{aq})}$	$\text{NaOH}_{(\text{aq})}$	$\text{Cl}_{2(\text{aq})}$
Salt of Y	White precipitate	No visible reaction	Orange brown solution
Salt of Z	No visible reaction	White precipitate	Orange brown solution

- (a) Identify with reasons metal Y and Z. (6 marks)
- (b) Write ionic equations for the reactions between:
- (i) salt of Y with dilute sulphuric acid; (1 mark)
- (ii) salt of Z with aqueous sodium hydroxide. (1 mark)

- (c) Explain what happens when aqueous chlorine is added to the solution of the salts Y and Z. (4 marks)
- (d) Describe a test that would be carried out to confirm identity of the anions of bromine and iodine. (8 marks)

13. (a) Differentiate between chemical reactions and nuclear reactions. (6 marks)

(b) Technetium-99 is prepared from ^{98}Mo . Molybdenum-98 combines with a neutron to give molybdenum-99, an unstable isotope that emits a β -particle to yield an excited form of technetium-99, represented as $^{99}\text{Tc}^*$. This excited nucleus relaxes to the ground state, represented as ^{99}Tc by emitting a γ -ray. The ground state of ^{99}Tc then emits a β -particle. Write equations for these nuclear reactions. (8 marks)

(c) The mass of ^7_3Li nucleus is 7.016005 amu. Given that the mass of a proton is 1.007276 amu and that of a neutron is 1.008665 amu, calculate the:

- (i) mass defect in kg. (3 marks)
- (ii) binding energy per nucleon in Joules. (2 marks)
- (iii) binding energy per mole. (1 mark)

$$c = 2.998 \times 10^8 \text{ m/s}$$

$$1 \text{ kg} = 6.022 \times 10^{26} \text{ amu}$$

$$1 \text{ J} = 1 \text{ kg.m}^2/\text{s}^2$$

$$\text{Avogadro's number} = 6.02 \times 10^{23} \text{ nuclei/mole}$$

14. (a) Explain the following observations:

- (i) scandium is a transition metal but zinc is not; (3 marks)
- (ii) d-block elements exhibit a large number of oxidation states in their compounds. (2 marks)

(b) Iron forms several complex ions in which the oxidation state is +3.

- (i) Write the electronic configuration of Fe^{3+} . (1 mark)
- (ii) Describe using ionic equation, including state symbols, the reaction that takes place when excess sodium hydroxide is added to an aqueous solution containing $\text{Fe}^{3+}_{(aq)}$. (4 marks)
- (iv) Hexacyanoferrate (II) ion, $[\text{Fe}(\text{CN})_6]^{3-}$, is one of the complex ions formed in which cyanide ions, CN^- , act as ligands. Explain why a cyanide ion can act as a ligand. (2 marks)

- (c) Table IV shows the electronegativity values of some elements.

Table IV

Element	H	Li	P	C	Cl	O	F
Electronegativity	2.1	1.0	2.06	2.50	2.83	3.5	4.0

- (i) Define 'electronegativity'. (2 marks)
- (ii) Explain which bond between P-F and P-Cl is more polar. (4 marks)
- (d) Nitrogen, phosphorus and arsenic are in group V of the periodic table. The boiling points of their hydrides are as shown in table V. Explain the following observations:

- (i) boiling point of PH_3 is lower than that of NH_3 ; (2 marks)
- (ii) boiling point of PH_3 is lower than that of AsH_3 . (2 marks)

Table V

Element	Hydride	Boiling point/ $^{\circ}\text{C}$
N	NH_3	-33
P	PH_3	-88
As	AsH_3	-55