2411/302
INORGANIC CHEMISTRY
Oct./Nov. 2021
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 shown.
Candidates should answer the questions in English.

This paper consists of 9 printed pages.

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

Turn over

SECTION A (40 marks)

Answer ALL the questions in this section.

1. Figure 1 shows the behaviour of the three fundamental particles in an electric field.

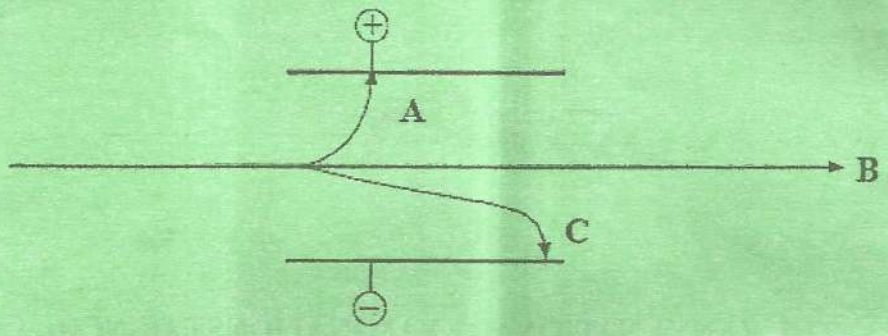

Fig. 1

(a) Identify the particles **A**, **B** and **C**. (1 mark)

(b) Explain the shapes and directions of the paths followed by the fundamental particles as they pass through the electric field. (3 marks)

2. Table I shows the first ionization energies of sodium, potassium and rubidium.

Table I

Element	First ionization energy (kJ/mol)
Sodium	494
Potassium	418
Rubidium	402

(a) Write the full electronic configuration of a rubidium atom. (1 mark)

(b) Explain why the first ionization energy of rubidium is lower than the first ionization energy of sodium. (3 marks)

3. (a) Old samples of magnesium oxide are usually contaminated with magnesium carbonate. State how this contamination occurs. (1 mark)

(b) An excess of hydrochloric acid was added to the old sample in (a). Explain why the resulting solution contained only one dissolved compound of magnesium. (3 marks)

4. When sodium chlorate (I) $(NaClO)$, is heated, sodium chlorate (V) and sodium chloride are formed.

(a) Write the ionic equation for this reaction. (1 mark)

(b) Name the type of a reaction in (a). (1 mark)

(c) State a chemical test for chlorine. (2 marks)

5. Vanadium (V) oxide is used as a heterogeneous catalyst in the contact process.

(a) Define 'heterogeneous catalyst'. (1 mark)

(b) State the essential feature of vanadium chemistry which enables vanadium (V) oxide to function as a catalyst. (1 mark)

(c) Using equations, describe how vanadium (V) oxide is involved in the contact process. (2 marks)

6. Complete the following nuclear equation:

(a) $^{252}_{98}Cf + \quad \rightarrow {}^{257}_{103}Lr + 5{}^{1}_{0}n$ (1 mark)

(b) Krypton-85 is used in indicator lights of appliances. The half-life of Krypton-85 is 11 years. Determine how much a 2.00 mg sample remains after 33 years. (3 marks)

7. Magnesium sulphide has the same crystal structure as sodium chloride. Draw the crystal structure of magnesium sulphide clearly labelling the formula of each species present. (4 marks)

8. (a) Write the full electronic configuration of the Ni^{2+} ion. (1 mark)

(b) Explain in terms of structure and bonding, why nickel has a high melting point. (2 marks)

(c) State why nickel is ductile. (1 mark)

9. Three containers labelled **A**, **B** and **C** contain aqueous solutions of sodium chloride, sodium iodide and silver nitrate. However, it is not known which solution is in which container. The solutions are mixed together as shown in table II and the observations recorded as shown.

Table II

Experiment	**Observation**
Solution in **A** added to solution in **B**	Yellow precipitate formed
Solution in **A** added to solution in **C**	No change
Solution in **B** added to solution in **C**	White precipitate formed

(a) Identify the solution contained in **B**. (1 mark)

(b) Give a reason for the answer in (a). (1 mark)

(c) Explain how the results can be used to identify the solution contained in **A** and **C**. (2 marks)

10. State the changes that occur to the atomic number and mass of a nucleus during each of the following decay activities:

(a) an α-particle is emitted. (2 marks)

(b) a β-particle is emitted. (2 marks)

SECTION B (60 marks)

*Answer any **THREE** questions from this section.*

11. (a) A mass spectrometer can be used to determine the relative atomic mass of silicon.

(i) State how a solid sample of silicon is made into silicon ions in a mass spectrometer. (2 marks)

(ii) Describe how silicon ions are separated in a mass spectrometer. (3 marks)

(b) The mass spectrum of a silicon sample showed the presence of three isotopes; ^{28}Si, ^{29}Si and ^{30}Si. The percentage of ^{28}Si present was 92.2% and the mass spectrum showed that the percentage of ^{29}Si present was twice that of ^{30}Si. Calculate the relative atomic mass of this silicon sample (5 marks)

(c) (i) Sketch a cross-section of a d-orbital. (1 mark)

(ii) An electron is in one of the 3d orbitals. Give the possible values of n, l and m_l for this electron. (3 marks)

(d) Table III shows the properties of $NaCl$, $MgCl_2$, $SiCl_4$ and PCl_3.

Table III

Group	**1**	**2**	**14 (4)**	**15 (5)**
Chloride	$NaCl$	$MgCl_2$	$SiCl_4$	PCl_3
Electrical conductivity (Liquid)	good	good	poor	poor
Melting point	high	high	low	low

Explain the following properties shown in table III in terms of bonding and structure:

(i) electrical conductivity; (3 marks)

(ii) melting point. (3 marks)

12. (a) Describe how a flame test can be used to identify a white solid that is suspected to be either a magnesium or a potassium compound. (4 marks)

(b) (i) Write a chemical equation for the reaction between magnesium sulphide with water. (1 mark)

(ii) Give the observations made in the reaction in b (i). (2 marks)

(c) When barium sulphide is added to water, a similar reaction to that in (b) occurs.

(i) State the observations made in this reaction. (2 marks)
(ii) Give a reason for the answer in c (i). (2 marks)
(iii) Write a chemical equation for the chemical reaction in (c). (1 mark)

(d) Silicon has a structure similar to that of diamond. The Si-Si-Si bond angle is 109.5°.

(i) State the name of the shape that has this angle. (1 mark)
(ii) Explain why silicon is a very poor conductor of electricity. (1 mark)
(iii) Explain why the bonding between each atom is covalent. (3 marks)

(e) Determine the oxidation state of:

(i) phosphorous in Na_3PO_4; (1 mark)
(ii) nitrogen in $N_2H_5^+$; (1 mark)
(iii) Sulphur in $S_2O_8^{2-}$. (1 mark)

13. (a) Complete the following nuclear equations:

(i) $^{239}_{94}P_u + \square \longrightarrow {}^{242}_{96}C_m + {}^{1}_{0}n$ (1 mark)

(ii) $^{14}_{7}N + {}^{4}_{2}He \longrightarrow \square + {}^{1}_{1}H$ (1 mark)

(iii) $^{235}_{92}U \longrightarrow \square + {}^{135}_{55}C_s + 4\,{}^{1}_{0}n$ (1 mark)

(iv) $^{7}_{3}L_i + \square \longrightarrow 2\,{}^{4}_{2}H_e$ (1 mark)

(b) One of the nuclei: Chromium −53; Manganese −51 and iron −59 decays by positron emission.

(i) Describe a positron. (2 marks)

(ii) With explanation, identify the nuclei that is most likely to decay by positron emission. (5 marks)

(c) The mass of the atom $^{23}_{11}Na$ is 22.9898 amu. Calculate the:

(i) mass defect in kg; (5 marks)
(ii) binding energy per atom in MeV; (2 marks)
(iii) binding energy per nucleon. (2 marks)

Mass of neutron	=	1.008665 amu
Mass of proton	=	1.007825 amu
1 MeV	=	1.6022×10^{13}J
1 amu	=	1.661×10^{-27} kg
Speed of light, C	=	3.00×10^{8} m/s

14. (a) Explain why:

(i) d-block elements exhibit high enthalpies of atomisation; (3 marks)
(ii) melting and boiling points of d-block elements are high; (4 marks)
(iii) d-block elements form a large number of complex compounds. (3 marks)

(b) A sample of iron is heated with steam of dry hydrogen chloride. A chloride of iron that contains Fe^{2+} is formed. This chloride dissolves in water to form a pale green solution that contains the hexaaquairon (II) complex ion.

(i) Write the electronic configuration of Fe^{2+}. (1 mark)
(ii) Draw the shape of the hexaaquairon (II) complex ion. (2 marks)
(iii) State the observation made when aqueous sodium hydroxide is added to a solution containing $Fe^{2+}_{(aq)}$. (1 mark)
(iv) Write an ionic equation with state symbols for the reaction in b (iii). (1 mark)

(c) Copper forms compounds containing Cu^{2+} or Cu^{+} ions but zinc only forms compounds containing Zn^{2+} ions.

(i) Explain why copper is a transition element while zinc is not. (3 marks)

(ii) List **two** differences between compounds containing Cu^{2+} and Zn^{2+} (2 marks)

15. (a) Describe Newland's law of octaves. (4 marks)

(b) Consider the following species: N^{3-}, O^{2-}, F^{-}, Na^{+}, Mg^{2+} and Al^{3+}.

(i) State **one** common property of the species. (1 mark)
(ii) Arrange the species in order of increasing ionic radii. (2 marks)
(iii) Give a reason for the answer in b (ii). (4 marks)

(c) Explain why the orders of increasing reactivity among group I elements is $Li < Na < K < R_b < C_s$ whereas that among group 17 (7) is $F > Cl > Br > I$. (4 marks)

(d) (i) Arrange the elements B, C, N, F and Si in order of their non-metallic character. (1 mark)

(ii) Explain the answer in (d) (i). (4 marks)

Periodic Table of the Elements

1A 1																	8A 18
1 H 1.008	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3B 3	4B 4	5B 5	6B 6	7B 7	8	8B 9	10	1B 11	2B 12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc [98]	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra [226]	89 Ac [227]	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [269]	109 Mt [268]	110 Ds [281]	111 Rg [272]	112 Cn [285]	113 [284]	114 Fl [289]	115 [288]	116 Lv [293]	117 [294]	118 [294]

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm [145]	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]

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