



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION

INORGANIC CHEMISTRY (PST1144)

Main Examination Paper

NOVEMBER 2024

This Examination Paper consists of 7 pages

Time Allowed:

3 hours

Total Marks:

100

Special Requirements:

Chemistry Data Booklet, Calculator

Internal Examiner:

Mr SA Phiri

External Examiner:

Dr SJ Mpofu

INSTRUCTIONS

1. SECTION A: Answer **both** questions.
2. SECTION B: Answer any **three (3)** questions on separate answer sheets.
3. Each question carries **20marks**.
4. Use of calculators is permissible.
5. Important data is at the back.

MARK ALLOCATION

QUESTION		MARKS
SECTION A	1	20
	2	20
SECTION B	3	20
	4	20
	5	20
	6	20
TOTAL		100

SECTION A

1. a) Deduce the electronic configuration of
 - i. $_{28}\text{Ni}$
 - ii. $_{58}\text{Ce}$. [4]
- b) Explain the following:
 - i. Why an anion is larger than its neutral atom. [3]
 - ii. Why a cation is smaller than its neutral atom. [3]
 - iii. Calculate the effective nuclear charge for:
 1. The electron in the periphery of Nitrogen ($Z = 7$). [5]
 2. One of the 4f electrons of Cerium ($Z = 58$). [5]
2. a) Describe the observations made when Bromine is reacted with:
 - i. Sodium thiosulphate
 - ii. Tin (II) oxide
 - iii. Ferrous (II) sulphate [6]
- b) Aqueous aluminium chloride is added to sodium hydrogen carbonate and a fizzy effect is observed together with a white precipitate.
 - i. Write an equation that resulted in a fizzy effect. [4]
 - ii. Using equations explain how the reaction occurred. [6]
- c) State and describe two uses of silicon. [4]

SECTION B

3. a) **M** and **N** are oxides of Period 3 elements. Oxide **M** is a solid with a high melting point. It does not conduct electricity when solid but does conduct electricity when molten or when in solution. Oxide **M** reacts with water forming a solution with a high pH.

Oxide **N** is a colourless gas at room temperature. It dissolves in water to give a solution with a lower pH.

- Identify **M**.
- State the type of bonding present in **M** and explain its electrical conductivity.
- Write an equation for the reaction of **M** with water.
- Identify **N**.
- State the type of bonding present in **N** and explain its electrical conductivity.
- Write an equation for the reaction of **N** with water. [10]

b) **W** is a hydroxide of a Period 3 element. It is insoluble in water but dissolves in both aqueous sulphuric acid and aqueous sodium hydroxide.

- Give the name used to describe this behaviour of the hydroxide.
- Describe this term.
- Write equations for the reactions occurring.
- Suggest why **W** is insoluble in water. [10]

4. a) Given the table below.

Elements	Metallic radii/Nm	Ionic radii/nm
Beryllium	0.112	0.030
Magnesium	0.160	0.065
Calcium	0.197	0.094
Strontium	0.215	0.110
Barium	0.211	0.134

Give an account for the following:

- Why the metallic radius increases down the group?
- Why are the ionic radii smaller than the atomic radii?
- K^+ and Ca^{+2} are isoelectric but Ca^{+2} is smaller.
- Explain the term isoelectronic.
- Why is the radius for K^+ larger than that of Ca^{+2} ? [10]

b) i. Which of the ions in the table has the least hydration energy? Give reasons for your answer. [5]

ii. Deduce the electronic configuration for Ba using energy levels. Account for your answer using the s.p.d.f notation. [3]

c) Predict the metallic nature of the elements moving down the group. [2]

5. a) The table below lists the boiling points of the Group IV chlorides.

Compound	Boiling point/ ^o C
CCl ₄	76
SiCl ₄	57
GeCl ₄	87
SnCl ₄	114

i. Draw a graph using the given data (b.p. on the y-axis and the chloride on the x-axis). [4]

ii. Use your graph to predict the boiling point of PbCl₄ would be if it did not decompose. [2]

iii. Account for the variations in boiling points. [4]

b) SiCl₄ reacts vigorously with water whereas CCl₄ is inert.

i. Give a reason for this difference in reactivity.

ii. Write an equation for the reaction between SiCl₄ and water.

iii. Suggest with a reason, whether you would expect GeCl₄ to react with water. [6]

c) Use E⁰ values suggest what happens when and aqueous iron (III) nitrate is separately added to solutions of:

i. Tin (II) nitrate.

ii. Lead (II) nitrate. [4]

6. The successive ionisation energies for four elements are as follows:

580 1800 2700 11600 14800 18400 23300

1010 1900 2900 5000 6300 21300 25400

1140 2100 3500 4800 5800 8500 9900

1000 2300 3400 4600 7000 8500 27100

a) Draw ionisation energy diagrams for each element. [8]

b) Suggest the groups in which each element belongs to. [4]

c) Give a reason for your answer. [4]

d) Deduce the outer shell electronic configuration of each element. [4]

Important Data

DATA	E°/V
$\text{ZnO (s)} + \text{H}_2\text{O (l)} + 2\text{e} \leftrightarrow \text{Zn (s)} + 2\text{OH}^- \text{ (aq)}$	-1.260
$\text{Zn}^{2+} \text{ (aq)} + 2\text{e} \leftrightarrow \text{Zn (s)}$	-0.762
$\text{BrO}^- \text{ (aq)} + \text{H}_2\text{O (l)} + 2\text{e} \leftrightarrow \text{Br}^- \text{ (aq)} + 2\text{OH}^- \text{ (aq)}$	+0.761
$\text{Hg}^{2+} \text{ (aq)} + \text{e} \leftrightarrow \text{Hg (l)}$	+0.851
$\text{Sn}^{4+} \text{ (aq)} + 2\text{e} \leftrightarrow \text{Sn}^{2+} \text{ (aq)}$	+0.150
$\text{Cu}^{2+} \text{ (aq)} + 2\text{e} \leftrightarrow \text{Cu (s)}$	+0.342
$\text{Pb}^{4+} \text{ (aq)} + 2\text{e} \leftrightarrow \text{Pb}^{2+} \text{ (aq)}$	+1.690
$\text{Br}_2 \text{ (g)} + 2\text{e} \leftrightarrow 2\text{Br}^- \text{ (aq)}$	+1.066
$\text{S}_4\text{O}_6^{2-} \text{ (aq)} + 2\text{e} \leftrightarrow 2\text{S}_2\text{O}_3^{2-} \text{ (aq)}$	+0.090
$\text{Hg}_2\text{Cl}_2 \text{ (s)} + 2\text{e} \rightarrow 2\text{Hg (l)} + 2\text{Cl}^- \text{ (aq)}$	+0.268
$\text{SO}_4^{2-} \text{ (aq)} + 4\text{H}^+ \text{ (aq)} + 2\text{e} \leftrightarrow \text{SO}_2 \text{ (g)} + 2\text{H}_2\text{O (l)}$	+0.172
$\text{Cr}_2\text{O}_7^{2-} \text{ (aq)} + 14\text{H}^+ \text{ (aq)} + 6\text{e} \leftrightarrow 2\text{Cr}^{3+} \text{ (aq)} + 7\text{H}_2\text{O (l)}$	+1.332
$\text{Fe}^{3+} \text{ (aq)} + \text{e} \leftrightarrow \text{Fe}^{2+} \text{ (aq)}$	+0.771

$$R = 8.314 \text{ JK}^{-1} \text{ mol}^{-1}$$

$$F = 96500 \text{Cmol}^{-1}$$

$$1 \text{atm} = 760 \text{ Torr} = 760 \text{mmHg} = 101325 \text{Pa} = 101.325 \text{KPa}$$

$$h = 6.626 \times 10^{-34} \text{J}$$

$$c = 3 \times 10^8 \text{ms}^{-1}$$

$$g = 9.81 \text{ms}^{-2}$$

$$L = 6.02 \times 10^{23} \text{mol}^{-1}$$

$$e = -1.60 \times 10^{-19} \text{C}$$

$$\text{specific heat capacity of water} = 4.18 \text{kJkg}^{-1} \text{K}^{-1}$$

$$\text{molar gas volume } (V_m) = 22.4 \text{dm}^3 \text{mol}^{-1} \text{ @ stp}$$

$$= 24 \text{dm}^3 \text{mol}^{-1} \text{ under room conditions}$$

$$K_{\text{W}(\text{H}_2\text{O})} = 1.0 \times 10^{-14} \text{mol}^2 \text{dm}^{-6} \text{ @ } 25^\circ \text{C}$$

$$m_p = 1.67 \times 10^{-27} \text{kg}$$

$$m_n = 1.67 \times 10^{-27} \text{kg}$$

$$m_e = 9.11 \times 10^{-31} \text{kg}$$

END OF PAPER

1 H Hydrogen 1.008																	2 He Helium 4.003	
3 Li Lithium 6.94	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180	
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.085	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948	
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.97	35 Br Bromine 79.904	36 Kr Krypton 83.798	
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium [97]	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.904	54 Xe Xenon 131.293	
55 Cs Cesium 132.905	56 Ba Barium 137.327	* 57 - 70	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	78 Ir Iridium 192.217	79 Pt Platinum 195.084	80 Au Gold 196.997	81 Hg Mercury 200.592	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	** 89 - 102	103 Lr Lawrencium [262]	104 Rf Rutherfordium [267]	105 Db Dubnium [270]	106 Sg Seaborgium [269]	107 Bh Bohrium [270]	108 Hs Hassium [270]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [281]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [293]	118 Og Oganesson [294]

*Lanthanide series

57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.045
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**Actinide series

89 Ac Actinium [227]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium [247]	98 Cf Californium [251]	99 Es Einsteinium [252]	100 Fm Fermium [257]	101 Md Mendelevium [258]	102 No Nobelium [259]
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