



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

INORGANIC CHEMISTRY FOR ENGINEERS

SCH 1241

SECOND SEMESTER EXAMINATION PAPER

March 2025

This examination paper consists of 5 pages

Time Allowed:	3 hours
Total Marks:	100
Special Requirements:	Periodic Table, Data Booklet, calculator
Internal Examiner:	Miss E. Bere
External Examiner:	Prof. G. Mehlana

### INSTRUCTIONS

1. Answer **ALL** questions from **Section A** and **ANY THREE** questions from **Section B**.
2. Section A carries 40 marks and each question in Section B carries 20 marks.
3. Use of calculators is permissible

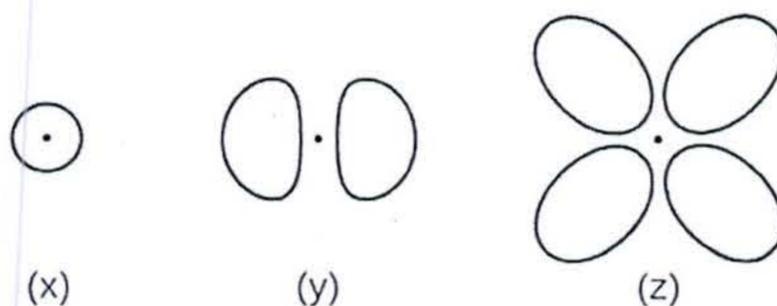
### MARK ALLOCATION

QUESTION	MARKS
1.	40
2.	20
3.	20
4.	20
5	20
TOTAL	100

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## SECTION A

- 1 a) Which elements have the following ground state electronic configurations?
- i)  $1s^2 2s^2 2p^6 3s^2 3p^4$
  - ii)  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$
  - iii)  $[\text{Kr}] 5s^2 4d^{10} 5p^3$
  - iv)  $[\text{Xe}] 6s^2 4f^{14} 5d^6$
  - v)  $[\text{Xe}] 6s^2$  [5]
- b)
  - i) Define the term *Electron affinity* [1]
  - ii) Using O as an example, and Slater's rule, show whether the atom is likely to form a cation or an anion. [10]
- c) Consider the orbitals shown in outline below;



- i) What are the possible  $l$  and  $m$  values for each type of orbital?
  - ii) How many orbitals of each type are found in a shell with  $n = 2$ ? [9]
- d) Name and draw structures of the following complexes:
- i)  $[\text{CoCl}_4]^{2-}$
  - ii)  $[\text{Ni}(\text{NH}_3)_6]^{2+}$  [4]
- e) What are the geometries of the following two complexes?
- i)  $[\text{AlCl}_4]^-$
  - ii)  $[\text{Ag}(\text{NH}_3)_2]^+$  [2]
- d)
  - i) Calculate the wavelength of electromagnetic radiation emitted by an electron as it relaxes from  $n = 3$  to  $n = 1$ . [3]
  - iii) Discuss the origin, application and limitations of Rydberg's equation [4]
- e) Naturally occurring magnesium is a mixture of three isotopes:  
 $78.99\% \text{}^{24}\text{Mg}$ ,  $10.00\% \text{}^{25}\text{Mg}$ , and  $11.01\% \text{}^{26}\text{Mg}$   
 The atomic masses are respectively 23.9850 amu, 24.9858 amu, and 25.9826.  
 Calculate the average molar mass of magnesium. [2]

[Total 40 marks]

## SECTION B

2. a) Draw feasible Lewis structures for the following;
- i)  $\text{NO}^+$ ,
  - ii)  $\text{H}_2\text{O}_2$ ,
  - i)  $\text{ClO}^-$ , and
  - ii)  $\text{CCl}_4$  [4]
- b) Using Hydrogen as an example, discuss the similarities and differences between atomic and molecular orbitals. [10]
- c) Calculate the spin only magnetic moment in  $\mu\text{B}$  for the complex  $[\text{Mn}(\text{Br})_4]^{2-}$ . Also predict the geometry of the complex. [6]

[Total 20 marks]

3. a) Use the molecule  $\text{CH}_4$  and partial orbital diagrams to describe the hybridisation model for bond formation. What are the advantages and disadvantages of hybridisation? [10]
- b) Methane can undergo a substitution reaction with bromine.
- (i) Write a balanced equation for this reaction
  - (ii) Using appropriate data from the table of bond enthalpies below, calculate the enthalpy change of reaction for the bromination of methane. [6]

bond	Average bond enthalpy / kJ mol <sup>-1</sup>
C-H	+413
H-H	+435
C-Br	+280
Br-Br	+193
H-Br	+366
C-C	+347

- c) Two solutions, one orange and one blue each contain a cobalt complex; one has chloride ions as ligands, while the other has ammonia ligands. Deduce which solution is expected to be orange [4]

[Total 20 marks]

4. a) What is meant by the term 'diamagnetism?' [1]
- b) Describe how you would experimentally determine the magnetism of an element or compound [4]
- c) Using molecular orbital theory and bond order, which of the following would you expect to exist naturally and be diamagnetic?
- i)  $\text{N}_2^-$
  - ii)  $\text{O}_2^-$
  - iii)  $\text{Be}_2^+$  [15]

[Total 20 marks]

5. Give the name and find the ligand field stabilization energy (in terms of  $D_q$ ) for the complexes below. Are any of them Jahn Teller active?

- i)  $[\text{Cr}(\text{NH}_3)_6]^{3+}$
- ii)  $[\text{Cu}(\text{NH}_3)_4(\text{OH}_2)_2]^{2+}$
- iii)  $[\text{Ti}(\text{OH}_2)_6]^{3+}$
- iv)  $[\text{Co}(\text{CN})_6]^{3-}$
- v)  $[\text{Ni}(\text{NH}_3)_4\text{Cl}_2]$

[20]

[Total 20 marks]

END OF QUESTION PAPER

GENERAL DATA AND FUNDAMENTAL CONSTANTS

$1 \text{ amu} = 1.6606 \times 10^{-24} \text{ g}$	$1 \text{ electron volt} = 1.6022 \times 10^{-19} \text{ J}$ $= 96.485 \text{ kJ mol}^{-1}$
$N_A = 6.022 \times 10^{23} \text{ particles mol}^{-1}$	$\pi = 3.1416$
$R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$ $= 1.987 \text{ cal mol}^{-1} \text{ K}^{-1}$ $= 8.3145 \text{ J mol}^{-1} \text{ K}^{-1}$ $= 8.3145 \text{ kPa dm}^3 \text{ mol}^{-1} \text{ K}^{-1}$	$R_H = 1.09737 \times 10^7 \text{ m}^{-1}$ $= 1.09737 \times 10^5 \text{ cm}^{-1}$  (Rydberg constant)
$h = 6.6262 \times 10^{-34} \text{ J s.}$ $= 6.6262 \times 10^{-27} \text{ erg s.}$	$m_e = 9.10938 \times 10^{-31} \text{ kg}$
$C = 2.9979 \times 10^8 \text{ m s}^{-1}.$	$F = 9.64853 \times 10^4 \text{ C mol}^{-1}$
$e = 1.60219 \times 10^{-19} \text{ coulomb}$	$\epsilon_0 = 8.85419 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$
	$4\pi\epsilon_0 = 1.11265 \times 10^{-10} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$

## Periodic Table of the Elements

1 H 1.0																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	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 (277)	109 Mt (268)	110 Ds (281)	111 Uuu (272)	112 Uub (285)		114 Uuq (289)		116 Uuh (289)		

	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)	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 (260)

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