The Open University of Sri Lanka

Faculty of Natural Sciences

B.Sc/ B. Ed Degree Programme

Department	: Chemistry
Level	: 4
Name of the Examination	: Final Examination
Course Code and Title	**: CYU4300 - Inorganic Chemistry**
Academic Year	: 2024/2025
Date	: 02-December-2024
Time	: 1.30 – 3.30 p.m.
Duration	: 2 hours
Index number	:

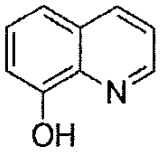
General Instructions

1. Read all the instructions **carefully** before answering the questions.
2. This question paper consists of 04 questions in 07 pages.
3. Answer all questions. Each question carries equal marks.
4. The answer to each question should commence from a new page.
5. Draw fully labeled diagrams where necessary.
6. Any unauthorized documents/mobile phones in your possession are a punishable offense.
7. Use blue or black ink to answer the questions.
8. Circle the number of questions you answered on the front cover of your answer script.
9. Clearly state your **index number in your answer script**.

Avogadro constant, L	$= 6.023 \times 10^{23}$ mol^{-1}	Gas constant, R	$= 8.314$ J K^{-1} mol^{-1}
Planck's constant, h	$= 6.63 \times 10^{-34}$ J s	Velocity of light, c	$= 3 \times 10^{8}$ m s^{-1}
Mass of an electron	= 0.0005 a.m.u	Mass of a proton	= 1.0073 a.m.u.
Mass of a neutron	= 1.0087 a.m.u.	1 a.m.u.	$= 1.661 \times 10^{-27}$ kg
1 MeV	$= 1.6022 \times 10^{-13}$ J	$\ln x$	$= 2.303 \log_{10} x$

01. Answer all parts (a) – (g)

(a) Deprotonation of 8-hydroxyquinoline (LOH) results in the monoanionic bidentate ligand, $\mathbf{LO^-}$. Two equivalents of this anion react with one equivalent of $PtCl_2$ to produce a neutral square-planar Pt(II) complex **A**.



LOH

i. Write a balanced equation for the above reaction.

ii. Draw and identify the structures of the geometrical isomers of **A**.

iii. Determine the effective atomic number (EAN) of Pt in **A**.

iv. Does it obey the EAN rule? Briefly explain your answer.

(25 Marks)

(b) Define the terms radioactivity and secular equilibrium in radioactive decay.

(7 Marks)

(c) Write **balanced equations** for the nuclear reactions described below.

i. $^{32}_{16}S(n,p)?$

ii. Two deuterium nuclei undergo fusion to form a tritium nucleus

(10 Marks)

(d) Giving reasons, predict the stability of the following nuclides. If unstable, provide the potential decay mode/s.

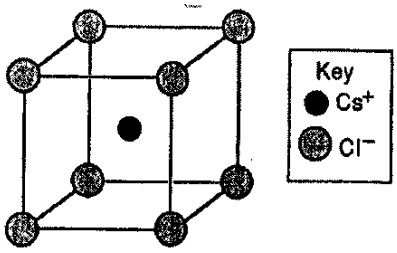
i. $^{17}_{10}Ne$ ii. $^{20}_{10}Ne$

(8 Marks)

(e) Compare crystalline and amorphous solids. Give an example for each solid type.

(6 Marks)

(f) Given below is the cubic unit cell of CsCl crystal.



i. What is the Bravais lattice type?

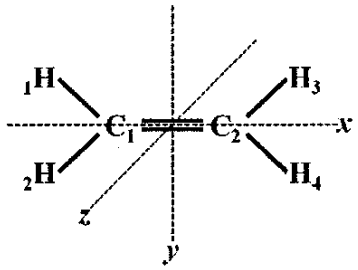
ii. Show that there is only one formula unit contained within the unit cell.

iii. Determine the coordination number of Cl^- ion. Hint: Count the number of counter-ions surrounding each Cl^- ion.

iv. Calculate the density of CsCl crystal in $g\ cm^{-3}$, if the unit cell length is 413 *pm*.

(19 Marks)

(g) The diagram below shows three designated axes of rotation for an ethylene molecule labeled x, y, and z. The x and y axes lie within the molecular plane, while the z axis is perpendicular to this plane, and all are represented by dot-dot lines.



i. State the order of each of the axes, x, y, and z.

ii. Giving reasons identify the principal rotation axis of the ethylene molecule.

iii. Locate the inversion center of the ethylene molecule.

iv. Draw the configuration that results when an inversion operation is applied to the ethylene molecule in the diagram above.

v. Using ethylene as an example, differentiate between the vertical plane (σ_v) and horizontal plane (σ_h).

(25 Marks)

02. Answer all parts (a) – (d)

(a) Write the molecular formulae of the following complexes.

i. Ionization isomer of $[CrBr(NH_3)_4(H_2O)]Cl$

ii. Linkage isomer of $[Fe(NO_2)(NH_3)_5]Cl$

iii. Hydrate isomer of $[MnCl(NH_3)_4(H_2O)]\cdot 2H_2O$

(18 Marks)

(b) The molecular formula of the **diamagnetic** complex **B** is $[NiCl_2(CO)(NH_3)]$.

i. Give the IUPAC name of **B**.

ii. According to the Valance Bond Theory (VBT), determine the hybridization of Ni in **B**.

iii. How would you prepare *cis*-$[NiCl_2(CO)(NH_3)]$ from $[NiCl_4]^{2-}$, if the *trans*-effect order is $CO > Cl > NH_3$. Give the formation steps.

(27 Marks)

(c) The neutral weak-field ligand L forms complex ions $[CrL_4]^{2+}$ and $[CrL_6]^{2+}$.

i. State the **four** assumptions of the crystal field theory (CFT).

ii. Using CFT, predict which compound, $[CrL_4]^{2+}$ or $[CrL_6]^{2+}$, is more stable. Assume that $\Delta_t = 0.5\ \Delta_o$.

iii. Calculate the spin-only magnetic moment (μ_s) of $[CrL_6]^{2+}$.

(35 Marks)

(d) i. Write **two** characteristics of an **oxidative addition** reaction. Give an example.

ii. The square-planar $[Ni(NH_3)_4]^{2+}$ complex undergoes **mono substitution** reaction with Cl^-. Write the balanced equation for this reaction.

iii. If the above reaction proceeds via an **associative** mechanism, write the molecular formula of the intermediate formed.

iv. What can you say about the geometry of the intermediate formed?

(20 Marks)

03. Answer all parts (a) – (d)

(a) i. List **three** factors of ligands that affect the stability of a complex.

ii. Write the relationship between the **overall stability constant**, β_N, of a metal complex, $[ML_N]^{m+}$, and the **stepwise formation constants**, K_1, K_2, K_3,….,K_N.

iii. Overall stability constants for the formation of $[NiL_3]^{2+}$ and $[NiL_4]^{2+}$ are $10^{6.7}$ and $10^{7.9}$, respectively. Calculate the K_4 value for the following reaction.

$$[NiL_3]^{2+} + L \rightarrow [NiL_4]^{2+}$$

iv. The stability constant for the formation of $[CuL_4]^{2+}$ is $10^{9.5}$. What can you say about the relative stabilities of $[NiL_4]^{2+}$ and $[CuL_4]^{2+}$?

(35 Marks)

(b) An octahedral complex with empirical formula $CoCl_3 \cdot 4NH_3$ shows a molar conductivity typical for a 1:1 electrolyte. What is the molecular formula of the complex? **Draw and identify** the **two** isomers.

(15 Marks)

(c) Nuclear fuel is material used in nuclear power stations to produce heat to power turbines. Heat is created when nuclear fuel undergoes nuclear fission. One common isotope that is used as nuclear fuel is plutonium-239. When one plutonium-239 atom is hit by a slow-moving neutron, it splits, creating xenon-134, zirconium-103, and high-energy neutrons. The atomic masses of ^{239}Pu, ^{134}Xe, ^{103}Zr, and ^{1}n are 239.052163, 133.905395, 102.92660, and 1.008665 a.m.u., respectively.

i. What is meant by *nuclear fission*?

ii. Explain how energy is released by a nuclear fission reaction.

iii. Write a balanced equation for the nuclear reaction described above.

iv. Determine the mass defect (in a.m.u.) that occurs during the fission of one plutonium-239 atom.

v. Calculate the amount of energy (MeV) released.

(40 Marks)

(d) A tiny piece of paper (produced from formerly living plant matter) taken from the Dead Sea Scrolls (some ancient religious manuscripts found on the northern shore of the Dead Sea)

has a carbon-14 content 0.795 times that found in plants living today. Estimate the age of the scroll. Half-life of carbon-14 is 5720 years.

(10 Marks)

04. Answer all parts (a) – (e)

(a) The underlying principle of X-ray crystallography is that the crystalline atoms cause a beam of X-rays to diffract into many specific directions. By measuring the angles and intensities of these diffracted beams, a crystallographer can produce a 3D picture of the density of electrons within the crystal.

i. Write down the Bragg equation and define each term in it.

ii. X-rays are diffracted by a gold sample. The θ angle was 32.29° for the {220} planes. What is the wavelength of the X-rays used? (The distance between two adjacent planes is 144 *pm*; assume first-order diffraction).

iii. Sketch a cubic unit cell and in it show the (220) plane.

(30 Marks)

(b) The formation of F-centers is a non-stoichiometric defect.

i. Distinguish between a stoichiometric and a non-stoichiometric defect. Give an example for each defect with clear diagrams.

ii. List **two** properties associated with the formation of F-centers. Explain your answers.

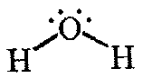
iii. Describe the defect responsible for the beautiful red color of the Ruby gem.

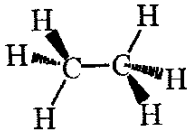
(20 Marks)

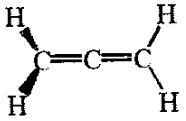
(c) Using NH_3 as an example, discuss the difference between the terms symmetry element and symmetry operations concerning those present in NH_3.

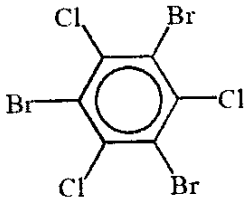
(10 Marks)

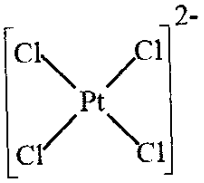
(d) Indicate all the symmetry **elements other than E** present in the following molecules.

i. 

ii. 

iii. 

iv. 

v. 

(25 Marks)

(e) Using BF_3 as an example, predict which single symmetry operation is equivalent to the following combined operations.

i. σ_h followed by S_3^1

ii. C_3^1 followed by S_3^2

iii. σ_h followed by C_3^3

(15 Marks)

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Periodic Table of Elements

1																	18
1 H 1.008	2	atomic number Symbol atomic weight										13	14	15	16	17	2 He 4.003
3 Li 6.94	4 Be 9.01											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	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	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 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	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 95.95	43 Tc -	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	57-71	72 Hf 178.5	73 Ta 180.9	74 W 183.8	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 -	85 At -	86 Rn -
87 Fr -	88 Ra -	89-103	104 Rf -	105 Db -	106 Sg -	107 Bh -	108 Hs -	109 Mt -	110 Ds -	111 Rg -	112 Cn -	113 Nh -	114 Fl -	115 Mc -	116 Lv -	117 Ts -	118 Og -