00747

THE OPEN UNIVERSITY OF SRI LANKA
B.Sc/B.Ed DEGREE/STAND ALONE COURSES IN SCIENCE - LEVEL 4
FINAL EXAMINATION – 2017/2018
INORGANIC CHEMISTRY CYU4300
INORGANIC CHEMISTRY CMU2122

25th September 2018 1.30 p.m. – 3.30 p.m.

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	= 1.0089 a.m.u.
1 a.m.u.	$= 1.661 \times 10^{-27}$ kg
1 MeV	$= 1.6021 \times 10^{-13}$ J

$$\ln x = 2.303 \log_{10} x$$

Answer **only FOUR** (04) questions.

Questions 1, 2, 3 and 4 are COMPULSORY for students registered for CYU4300. Questions 1 is COMPULSORY for students registered for CMU2122. Questions 5 and 6 are ONLY for students registered for CMU2122.

1. (a) (i) Give the IUPAC name of $[CoCl_2(gly)(NH_3)_2]$ (**A**)? ($gly^- = H_2NCH_2COO^-$)
(ii) Draw the structures of all the **geometrical** isomers of (**A**). (25 marks)

(b) Write nuclear equations for the processes described below:
(i) Carbon-11 is a positron emitter used in specific cases in Positron Emission Tomography (PET) to detect cancers.
(ii) Two deuterium nuclei undergo fusion to form a tritium nucleus. (08 marks)

(c) Complete the following nuclear equations and identify the nuclear reaction:
(i) ${}^{19}_{10}Ne \rightarrow {}^{19}_{9}F + ?$ (ii) ${}^{7}_{4}Be + ? \rightarrow {}^{7}_{3}Li$ (08 marks)

(d) Of the given pair of nuclides, identify the one that will be expected to be unstable and radioactive. Give reason(s) for your answer. (09 marks)

(i) $^{16}_{8}O$, $^{15}_{8}O$ (ii) $^{19}_{9}F$, $^{20}_{9}F$

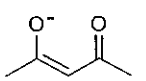
(e) An oxide of manganese crystallizes with a cubic unit cell that contains manganese ions at the corners and in the center. Oxide ions are located at the center of each edge of the unit cell. What is the formula of the compound? (5 marks)

(f) (i) Compute the Miller Indices for a plane intersecting at x = ¼ , y =1, and z =1/2
(ii) What relationship exist between (1 0 0) and ($\bar{1}$ 0 0) planes? Show using a unit cube. (8 marks)

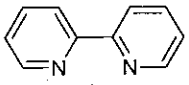
(g) X-rays of wavelength 0.0960 nm are diffracted by a metallic crystal, angle of first order (n=1), is measured to be 17.8. What is the distance (in pm) between the layers of atoms responsible for diffraction? Will the same result be obtained from a beam of radiation with 570 nm? Explain (12 marks)

(h) Define the following as applied in studying symmetry of molecules.
(i) Equivalent configuration
(ii) Identical configuration
(iii) Symmetry operation
(iv) Symmetry element (25 marks)

2. (a) (i) What is the **oxidation number** of Fe in $[FeSO_4(acac)(bipy)]$ (**B**)?



acac



bipy

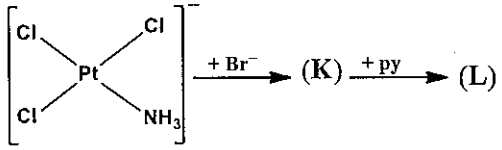
(ii) Give the IUPAC name of (**B**).
(iii) What is the **coordination number** of Fe in (**B**)?
(iv) Determine the Effective Atomic Number (EAN) of Fe in (**B**). (Atomic number of Fe is 26)
(v) Does it obey the EAN rule? (25 marks)

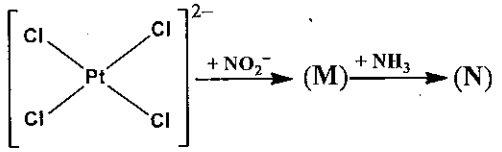
(b) (i) Draw the structures of all the **geometrical** isomers of $[CoF(en)(CO)_2]$ (**C**) if the geometry of (**C**) is **trigonal bipyramidal**. (en = ethylenediamine)
(ii) Comment on the optical isomerism of (**C**). (25 marks)

(c) (i) Arrange the following ligands in order of increasing Crystal Field Strength.
I^-, CN^-, H_2O and NH_3
(ii) According to the Crystal Field Theory what is the *d*-electron configuration of iron in $K_2[Fe(NH_3)_2(CN)_4]$ (**D**)? (Atomic number of Fe is 26).
(iii) Calculate the Crystal Field Stabilisation Energy in kJ mol^{-1} if Δ_o = 300 kJ mol^{-1}.
(iv) Calculate the Total Stabilisation Energy in kJ mol^{-1} if the pairing energy is 150 kJ mol^{-1}.

(v) Comment on the spin only magnetic moment (μ_s) of (**D**). (30 marks)

(d) Identify (**K**), (**L**), (**M**) and (**N**) if the *trans*-effect order is
$NO_2^- > Br^- > Cl^- > NH_3$. (py = pyridine) (20 marks)

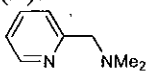




Note: Indicate *cis-trans* isomerism and the **charge** of (**K**), (**L**), (**M**) and (**N**), if any.

3. (a) (i) Comment on the molar conductivity of $Na_3[FeCl_6]$.
(ii) Using Valence Bond Theory predict the hybridization of iron in $Na_3[FeCl_6]$ if the magnetic moment of the complex is 5.9 B.M. (20 marks)

(b) (i) One mole of the ligand $C_8H_{12}N_2$ (**E**) reacts with a mole of $PtCl_2$ to give an 16e-neutral Pt(II) complex (**F**). Draw the structure of (**F**).



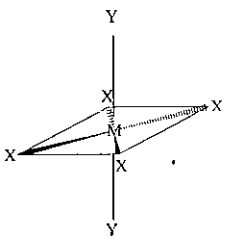
(E)

(ii) In methanol, (**F**) reacts with another mole of (**E**) to give the Pt(II) salt (**G**). With an excess of $AgNO_3$, a mole of (**G**) gives two moles of AgCl. Write the **molecular formula** of (**G**).
(iii) **Draw** and **identify** the two isomers of (**G**). (20 marks)

(c) $[PdCl_2(PPh_3)_2]$ oxidatively adds one mole of Cl_2 to give a neutral octahedral complex (**X**). What is the molecular formula of (**X**)? (10 marks)

(d) (i) Define the terms 'half-life' and 'activity' of a radionuclide.
(ii) Calculate the activity of 1 μg of pure *plutonium-239* ($t_{1/2}$= 24000 y) in Becquerel (Bq).
(iii) At 12.00 noon, a patient was injected with a sample labeled with 50 μCi of *fluorine-18* ($t_{1/2}$ = 110 min). The patient was imaged at 1.15 p.m. Assuming that none of the activity was excreted, how much activity remained at the time of imaging? (50 marks)

4. (a) Consider the MX_4Y_2 molecule which has square bipyramidal geometry as shown in the figure. M-Y bond length is twice as



that of the M-X bond. The electronegativities of the atoms M, X and Y are very different from each other.

(i) Locate all the rotational axis of symmetry in the molecule and deduce their orders.

(ii) Giving reasons identify the principal axis of the molecule.

(iii) Giving reasons state whether the molecule has a permanent dipole moment or not.

(iv) Locate all the symmetry planes of the molecule.

(v) Giving reasons, classify them at vertical, dihedral or horizontal planes.

(50 marks)

(b) The ratio of **tetrahedral holes** to **each anion** in a cubic closed packed array of anions is 2:1 whereas for **octahedral holes** it is 1:1.
Rutile (molar mass = 79 g mol^{-1}), is a mineral that contains titanium and oxygen. Its structure can be described as a closed packed array of oxide ions with titanium ions in only half of the octahedral holes.

(i) Compute the formula of rutile **with given information**.

(ii) What is the percent by mass of titanium in rutile?

(iii)What is the oxidation number of titanium?

Relative Atomic mass O = 16 and Ti = 47 (25 marks)

(c) The edge length of the unit cell of Nickel is 0.3524 nm. The density of nickel is 8.90 g/cm^3. Does Nickel crystallizes in a simple cubic structure? Explain. Avogadro number = 6.023×10^{23}, Molar mass of Nickel = 58.693 g mol^{-1} (25 marks)

Questions 5 and 6 are ONLY for students registered for CMU2122

5. (a) (i) State the Jahn Teller Theorem. (py = pyridine)

(ii) The molecular structure of $[Cu(py)_6]^{2+}$ showed four Cu-N bonds with a bond length of 210 pm and two Cu-N bonds with a bond length of 270 pm. Determine the number of *d*-electrons in the d_z^2 and d_{x2-y2} orbitals? (20 marks)

(b) (i) Show that $\beta_2 = K_1K_2$ for the equilibrium $M + 2L \rightleftharpoons ML_2$, β_2 is the overall formation constant ; K_1 and K_2 are the stepwise formation constants for the intermediates ML and ML_2, respectively.

(ii) If β_2 is $10^{6.0}$ and $\log K_2$ is 2.0. Calculate the stepwise formation constant K_1.

(20 marks)

(c) $[MeCo(CO)_4]$ undergoes an **migratory insertion** reaction to give a 16e Co(I) complex (**Y**). What is the molecular formula of (**Y**)? (10 marks)

(d) Predict, giving reasons, the mode/s of decay that each of the following radionuclides may undergo. Write nuclear equation(s) for such decay process(es).

(i) $^{18}_{9}F$ (ii) $^{22}_{9}F$ (30 marks)

(e) Write the principles behind radio carbon dating. Comment on its limitations. (20 marks)

6. (a) The edge length of the unit cell of Nickel is 0.3524 nm. The density of nickel is 8.90 g/cm^3. Does Nickel crystallizes in a simple cubic structure? Explain. Avogadro number = 6.023×10^{23}, Molar mass of Nickel = 58.693 g mol^{-1} (25 marks)

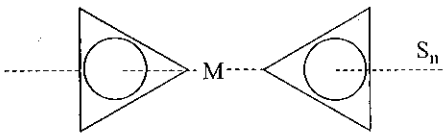
(b) Use a proper diagram to explain the co-existence of Fe^{2+} and Fe^{3+} in a FeO lattice. (25 marks)

(c) If nitrogen, vanadium and zirconium were present as impurities in a sample of titanium metal, which is most likely to form an interstitial impurity? a substitutional impurity? Explain. (25 marks)

Use information in table below to arrive at your answer.

Element	atomic radius/pm
nitrogen	56
vanadium	171
zirconium	206
titanium	176

(d) Un unstable organometallic ion has two (aromatic) $[C_3H_3]^-$ ions attached to a central metal ion, M; see the figure. The three C nuclei in $[C_3H_3]^-$ form an equilateral triangle.



The planes of the two $[C_3H_3]^-$ ions are parallel to each other and are in their staggered conformation. The M nucleus is sandwiched in the middle between these two ions. The axis that passes through the centres of the $[C_3H_3]^-$ ions, perpendicular to the plane of each ion and passing through the M nucleus is an improper axis of rotation, S_n.

(i) Define the following as applied in studying the symmetry of molecules.
   (α) Improper rotational operation.
   (β) Improper (symmetry) axis of rotation.

(ii) Using Neumann projection formulae determine the order of the improper axis of rotation, S_n, of the above mentioned ion.

(iii) Using Neumann projection formulae to represent the resultant configurations after symmetry operations and performing the symmetry operations on the above mentioned ion, show that $S_n^2 = C_{n/2}^1$. (50 marks)
