THE OPEN UNIVERSITY OF SRI LANKA
B.Sc./B.Ed. DEGREE/STAND ALONE COURSES IN SCIENCE - Level 4
FINAL EXAMINATION PAPER – 2023/2024
INORGANIC CHEMISTRY CYU4300

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14th October 2023   Time Duration = 2 h   1.30 pm – 3.30 pm

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Avogadro constant, L $= 6.023 \times 10^{23} \text{ mol}^{-1}$
Gas constant, R $= 8.314 \text{ J K}^{-1}\text{mol}^{-1}$
Planck's constant, h $= 6.63 \times 10^{-34} \text{ J s}$
Velocity of light, c $= 3 \times 10^{8} \text{ m s}^{-1}$
Mass of an electron $= 0.0005 \text{ a.m.u.}$
Mass of a proton $= 1.0073 \text{ a.m.u.}$
Mass of a neutron $= 1.0089 \text{ a.m.u.}$
1 a.m.u. $= 1.661 \times 10^{-27}\text{ kg}$
1 MeV $= 1.6021 \times 10^{-13} \text{ J}$

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

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

1. (a) Consider the complex $[CrBr_2(en)_2]$ **(A)**. (Z of Cr = 24) (en = $H_2NCH_2CH_2NH_2$)
    (i) Write the IUPAC name of **(A)**?
    (ii) Determine the Effective Atomic Number (EAN) of Cr in **(A)**.
    (iii) Does it obey the EAN rule?
    (iv) Draw the **structures** of the two **optical** isomers of **(A)**.   (25 marks)

   (b) (i) Define the terms *radioactivity* and *activity* of a radionuclide.
       (ii) Calculate the activity of 1 mole of pure ^{14}C ($t_{1/2}$ = 5730 years) in Bq.   (13 marks)

   (c) Write **balanced equations** for the nuclear reactions described below.
       (i) $^{10}_{5}B(n, \alpha)$?
       (ii) A uranium-235 atom undergoes induced nuclear fission when
            bombarded with a low-energy neutron to produce barium-141,
            kripton-94 and high-energy neutrons.   (6 marks)

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(d) **Giving reasons**, predict the stability of the following nuclides.
  If unstable, provide the potential decay mode/s.　　　　　　　(6 marks)
  　(i) $^{22}_{9}F$　　　(ii) $^{16}_{8}O$

(e) The diagram below shows the **cubic** unit cell of an alloy (a metal made by
  combining two or more metallic elements) containing gold and copper.
  (i) Define the term *unit cell*.
  (ii) What is the Bravais lattice type of this structure?
  (iii) What is the coordination number of Au? *Hint:* Count the number of
  　neighboring Cu atoms around Au?
  (iv) What is the chemical formula of this alloy?
  (v) Pure gold (100% gold by weight) is 24 carats. What carat gold is this alloy?
  　Atomic masses of Au and Cu are 196.97 and 63.55 gmol^{-1}, respectively.
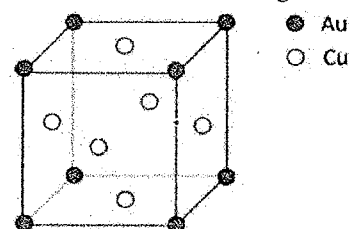
　　　　　　　　　　　　　　　　　　　　　　(25 marks)

(f)　(i) Define the term n-fold axis of rotation (C_n).
  (ii) Identify all the rotation axes available in the following molecules.
  　1) H_2O　　2) BCl_3　　3) XeF_4　　4) Benzene
  (iii) Identify the **principal** rotation axis of the molecules XeF_4 and Benzene.　　(25 marks)

2. (a) Draw all **geometrical** isomers of $[Ru(NH_3)_2(CO)(en)]$ (**B**) with the
  　　trigonal bipyramidal geometry. (en = $H_2NCH_2CH_2NH_2$)　　(20 marks)

  (b) (i) Write the **molecular formula** of the octahedral complex
  　　　pentaammine(nitro)iron(II) chloride (**C**).
  　(ii) What are the **types of isomerism** shown by (**C**).
  　(iii) Draw the **structures** of all the isomers of (**C**).
  　(iv) Suggest a value for the molar conductivity of (**C**) in $m^2\Omega^{-1}mol^{-1}$.　　(25 marks)

  (c) (i) List **three** factors which influence the crystal field splitting strength.
  　(ii) According to CFT, what is the *d*-electron configuration
  　　　(Number of t_{2g} and e_g electrons) of Fe in $[FeCl_4]^{2-}$?
  　　　(Assume chloride as a **weak field** ligand, Group number of Fe is 8).
  　(iii) Calculate the Crystal Field Stabilization Energy (**CFSE**) in kJ mol^{-1}
  　　　if $\Delta_t = 180$ kJ mol^{-1}.
  　(iv) Calculate the Total Stabilization Energy (**TSE**) in kJ mol^{-1}
  　　　if Pairing Energy = 100 kJ mol^{-1}.
  　(v) Calculate the **spin only magnetic moment** (μ_s) of $[FeBr_4]^-$.　　(35 marks)

(d) The **octahedral** complex (**D**) with the empirical formula $CrCl_3 \cdot 3NH_3 \cdot 3H_2O$
does **not** conduct electricity.
(i) What is the molecular formula of (**D**)?
(ii) **Draw** and **identify** the **structures** of the two isomers of (**D**).
(iii) Comment on optical isomerism of isomers of (**D**).   (20 marks)

3. (a) Identify (**P**), (**Q**) and (**R**).
$[MeCo(CO)_3]$ undergoes an **oxidative addition** reaction with MeBr to give a **neutral**,
octahedral Co(III) complex (**P**). (**P**) undergoes a **reductive elimination** reaction
to give an **alkane** (**Q**) and a **square planar** Co(I) complex (**R**).   (20 marks)

(b) A **neutral mononuclear** 16e-complex (**Y**), contains a nickel(II) centre which is
coordinated **only** to bromide and ammine (NH_3) ligands. The Group number of Ni is 10.
(i) What is the **molecular formula** of (**Y**)?
(ii) Comment on the possible **geometries** of (**Y**) and draw the **structures** of all
three·isomers of (**Y**).
(iii) If (**Y**) is a diamagnetic compound. Using Valence Bond Theory,
determine the hybridization of nickel in (**Y**).   (30 marks)

(c) Hydrogen fusion in the Sun produces an enormous amount of energy. The overall
reaction consumes **four** Hydrogen atoms and produces **one** Helium atom. The power
output of the Sun due to this fusion reaction is 4×10^{26} watts (1 watt = 1 J/s).
Atomic masses of ^1H and ^4He are 1.007825 and 4.002603 **a.m.u.** respectively.
(i) What is meant by *nuclear fusion*?
(ii) Explain how energy is released by a nuclear fusion reaction.
(iii) Determine the mass defect (in kilograms) that occurs during the formation
of one He atom in the Sun (one fusion reaction).
(iv) Calculate the amount of energy released in one fusion reaction.   (30 marks)

(d) Geological dating based on ^{87}Rb: ^{87}Sr ratio is regarded as the most accurate
method for the age determination of rocks. ^{87}Rb is a β emitter with
a half-life of 4.8×10^8 years.
(i) Determine the decay constant in the unit of per year (y^{-1}).
(ii) A certain rock is found to have an ^{87}Rb: ^{87}Sr mass ratio of 1.00:0.004.
What is the age of the rock?   (20 marks)

4. (a) (i) Sketch a sodium chloride lattice with a **Schottky** defect.
(ii) Will such a crystal preserve charge neutrality? Explain your answer.
(iii) In contrast to the above lattice, the sodium chloride lattice with
*F-centers* show paramagnetism. Explain.   (15 marks)

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(b) (i) Why X-rays are used in crystal structure determination?

(ii) Write down the **Bragg** equation and define each term in it.

(iii) A Strontium sample is irradiated with 0.154 nm X-rays. The first order scattering angle is 14.7°.

How far apart are atomic layers responsible for this effect?　　　　(20 marks)

(c) Clearly **show your work** for the following questions related to Miller planes.

(i) Work out the Miller indices of the shaded plane below.
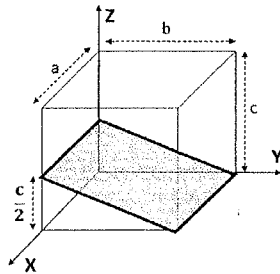
(ii) Sketch a cubic unit cell and in it show the (412) plane.　　　　(15 marks)

(d) (i) Distinguish the symmetry element and symmetry operation using suitable examples.

(ii) Identify the symmetry elements present in the following molecules.

1) NH_3　　　　　　2) Staggered conformation of ethane

3) C_2H_2　　　　　　4) CO_3^{2-}

(iii) Using $[PtCl_4]^{2-}$ as an example, show what operation has the same effect as each.

1) S_4^2　　　　2) C_4^2　　　　3) σ^2　　　　4) i^2　　　　(50 marks)

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