JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES

UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

3RD YEAR 1ST SEMESTER 2016/2017 ACADEMIC YEAR

MAIN CAMPUS

COURSE CODE: SCH 306

COURSE TITLE: INORGANIC CHEMISTRY III

EXAM VENUE: CHEM LAB **STREAM: (BSc.)**

DATE: 27/04/16 **EXAM SESSION: 2.00 – 4.00 PM**

TIME: 2 HOURS

Instructions:

1. **Answer question 1 (compulsory) and ANY other 2 questions.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

Section A, Answer <u>all</u> the questions (30 marks)

Question 1

a) Scandium (Sc) is the first 3d-element and its electron configuration is $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^2$, $3d^1$ or [Ar]$4s^2$ $3d^1$ and it belongs to group 3. Complete the table below for the other 3*d* –elements (6 marks)

	Element	Z	Element Name	Configuration	Group no.
a	Sc	21			
b	Ti	22			
c	V	23			
d	Cr	24			
e	Fe	26			
f	Co	27			
g	Ni	28			
h	Cu	29			
i	Zn	30			

b) Give an explanation why the electronic configuration of Cr and Cu are written as [Ar]$4s^1$ $3d^5$ and [Ar]$4s^1$ $3d^{10}$. (1 mark)

c) All the 3-*d* elements are coloured except Sc and Zn, give an explanation why the two are not coloured. (1 mark)

d) The electronic configuration of V and Cr can also be represented as shown below. Complete the table and use these orbital arrangement of electrons to explain the paramagnetic property of V and Cr. (4 marks)

		3d					4S
V	[Ar]	↑	↑	↑			↓↑
Cr	[Ar]	↑	↑	↑	↑	↑	↑
Cu							
Ni							
Fe							
Mn							

e) Determine the oxidation and coordination numbers of each of the metal at the centres of the following complexes. (4 marks)

i. $[Fe(OH)(H_2O)_5]SO_4$

ii. $[CoCl(CN)(NO_2)(NH_3)_3]$

iii. $[CoCl(NH_3)_5](NO_3)_2$

iv. $K_3[Fe(CN)_5NO]$

f) Draw the structures of the following compounds/complex ions. (6 marks)

i. $[Ag(NH_3)_2]^+$
ii. $[Ni(CO)_4]$
iii. $[Ni(CN)_4]^{2-}$
iv. [Fe(CO)5]
v. $[Cr(NH3)_6]^{3+}$
vi. $[Co(C_2O_4)_3]^{3-}$

g) Give the composition of the following alloys of steel. (4 marks)

i. Stainless steel
ii. Tungsten steel
iii. Cobalt steel
iv. Manganese steel:

h) Identify the shapes of the following molecules. (4 marks)

i. HCl
ii. BF_3
iii. CH_4
iv. PCl_5

Section B. Answer any <u>TWO</u> questions

Question 2.

a) Coordination complex metal ions in aqueous solutions are hydrated (the aqua species) and are denoted as $M^{2+}(aq)$ where this often represents the hexa-aqua ion $[M(H_2O)_6]^{z+}$. Consider the addition of a neutral ligand L to the solution, and the formation of a series of complexes.

$[M(H_2O)_5L]^{Z+}$, $[M(H_2O)_4L_2]^{Z+}$, $[M(H_2O)_4L_2]^{Z+}$…….$[ML_6]^{Z+}$

In the formation of the complex $[ML_6]^{Z+}$ from $[M(H_2O)_5L]^{Z+}$, each displacement of a coordinated water molecule by ligand L has a characteristic stepwise stability constant K_1, K_2, K_3, K_4, K_5 and K_6.

$K_1 = [M(H_2O)_5L^{Z+}] / [M(H_2O)_6{}^{Z+}] [L]$.

And the overall stability constant β will be given by

$\beta_6 = [ML_6]^{Z+} / [M(H_2O)_6{}^{Z+}] [L]^6$. The relationship between K and β is given by

$\beta_6 = K_1 * K_2 * K_3 * K_4 * K_5 * K_6$

Use this information to answer the following questions

Results of a pH study using a glass electrode (in 2M NH_4NO_3) aqueous solution gave values of the stepwise stability constants (at 300 K) of $[Ni(H_2O_{6-x}(NH_3)_x)^{2+}$ (x = 1-6) as log K_1 = 2.8, log K_2 = 2.2, log K_3 = 1.7, log K_4= 1.3, log K_5 = 0.7 and log K_6 = 0.1. Calculate:

i. β_6 for $[Ni(NH_3)_6)^{2+}$ (4 marks)
ii. ΔG_1 (300_K) (2 marks)
iii. If the value of ΔH_1 (300K) = -15.8 $kjmol^{-1}$ calculate ΔS_1 (300K) (4 marks)

Take R = 8.314 $jk^{-1}mol^{-1}$

b) Transition metals form colored compounds and complexes. These colors can vary depending on the charge on the metal ion and the number and type of groups of atoms (ligands) attached to the metal ion. In aqueous solutions, the ions form complexes with different colors. Give an explanation for the coloration.
(6 marks)

c) Give the IUPAC names of the following complex anions. (4 marks)

i. $[TiCl_5]^-$
ii. $[VCl_6]^{2-}$
iii. $[MnO_4]^-$
iv. $[Fe(CN)_6]^{4-}$

Question 3

a) Give the IUPAC names of the following complex complexes. (8 marks)

i. $[V(NH_3)_6]^{3+}$
ii. $[MnBr(CO)_5]$ $[Fe(OH)(H_2O)_5]SO_4$
iii. $[CoCl(CN)(NO_2)(NH_3)_3]$
iv. $[TiCl_5]^-$
v. $[VCl_6]^{2-}$
vi. $[MnO_4]^-$
vii. $[Fe(CN)_6]^{4-}$

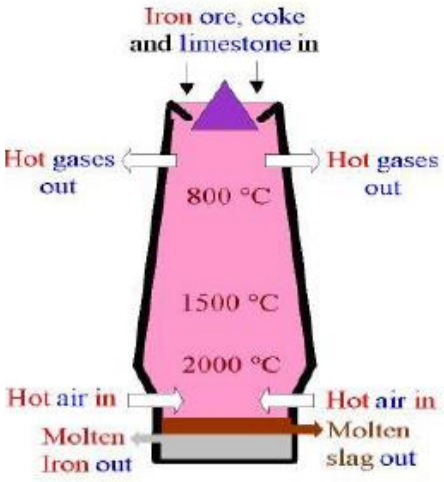
d) Give complete balanced chemical equations for the following reactions of *d*-block elements. (6 marks)

i. $Sc(s) + O_2(g) \rightarrow$
ii. $V(s) + O_2(g) \rightarrow$
iii. $Cr(s) + O_2(g) \rightarrow$
iv. $Cr(s) + 2\,HCl(aq) \rightarrow$
v. $Fe(s) + 2\,HCl(aq) \rightarrow$
vi. $Co(s) + 2\,HCl(aq) \rightarrow$

e) Extraction of copper from sulphide ores consists of four main stages under the pyrometallurgical method namely, mining, milling, smelting, and refining. Briefly describe the smelting and refining stages. (6 marks)

Question 4

a) Iron is one of the most important metals. It occurs in nature as oxides or sulphides for example haematite Fe_2O_3; magnetite Fe_3O_4; iron pyrites FeS_2. Iron is obtained by the reduction of its oxides with carbon monoxide. The iron ore contains haematite, *i.e.* Fe_2O_3. Reduction of Fe_2O_3 to Fe by carbon monoxide takes place in a blast furnace at temperatures as high as 800-2000 ^oC as shown below. Give the balanced chemical equation of all the reactions in this process starting from generation of CaO. (7 marks)



b) The commonest ore of copper is chalcopyrite ($CuFeS_2$). Copper can be extracted by two principal methods, Pyrometallurgical method and Hydrometallurgical method. Give a brief description of these two methods.
(6 marks)

c) Give the catalyst used in the following reactions. (5 marks)

i. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

ii. $2\ SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

iii. $RCH{=}CH_2 + H_2 \rightarrow RCH_2CH_3$

iv. $2\ H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

v. $2\ KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$

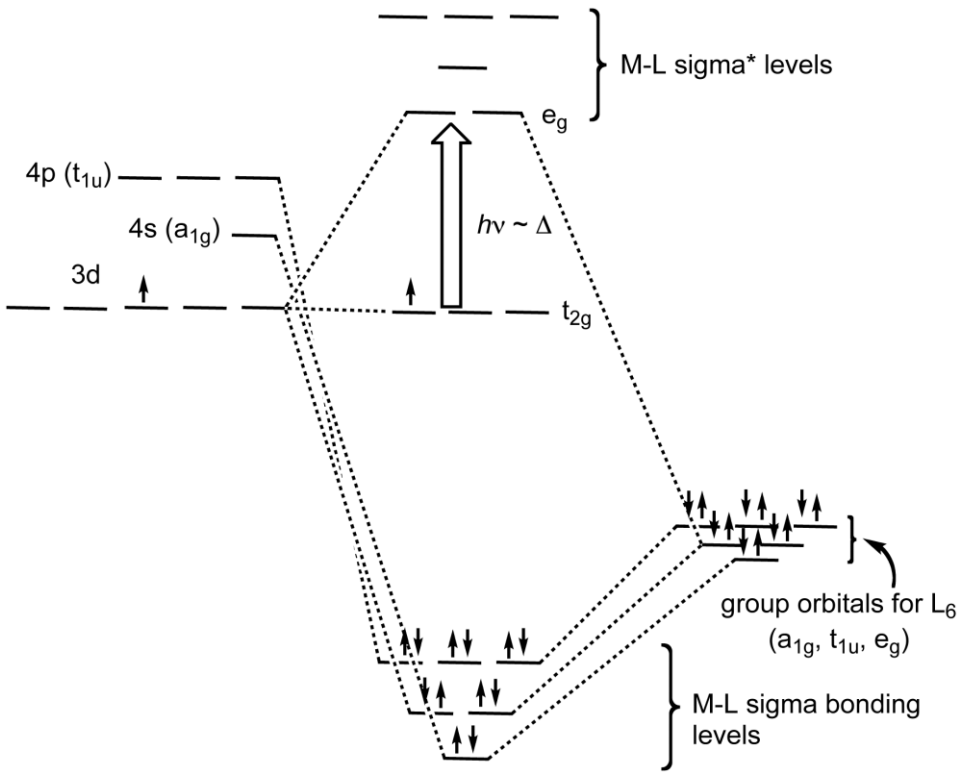
f) Divalent (M^{2+}) and trivalent (M^{3+}) transition metal centres form octahedral hexaaqua-complexes of the type $[M(H2O)6]^{n+}$, Give the structural formula of this complex. (2 marks)

Question 5

a) Transition elements (3-*d* elements) have various industrial uses. Give at least one function of each of the following elements. (10 marks)

	Element	Z	
a	Sc	21	
b	Ti	22	
c	V	23	
d	Cr	24	
e	Fe	25	
f	Co	26	
g	Ni	27	
h	Cu	28	
i	Zn	29	

b) Ligand field theory (LFT) describes the bonding, orbital arrangement, and other characteristics of coordination complexes. It represents an application of molecular orbital theory to transition metal complexes. A transition metal ion has nine valence atomic orbitals - consisting of five *n*d, one *(n+1)*s, and three *(n+1)*p orbitals. These orbitals are of appropriate energy to form bonding interaction with ligands (see the figure below).

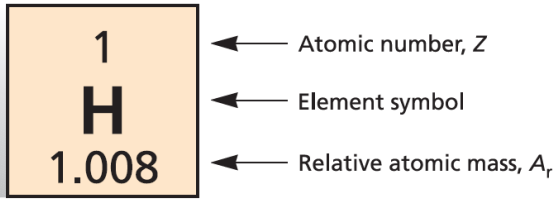


Using this information, give a brief description of the following bonding theories.

i. σ-Bonding (sigma bonding) (3 marks)
ii. π-bonding (pi bonding) (3 marks)

c) Define the following terms (4 marks)
   i. Ligand :
   ii. Oxidation number:
   iii. Coordination number:
   iv. Paramagnetic

Periodic table



1	2											13	14	15	16	17	18
1 H 1.008																	2 He 4.00
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 47.90	23 V 50.94	24 Cr 52.01	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.54	30 Zn 65.41	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	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 95.94	43 Tc 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	La–Lu	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po 210	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226.03	Ac–Lr	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [277]	109 Mt [268]	110 Ds [271]	111 Rg [272]	112 Uub [285]						

Lanthanoids	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 146.92	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinoids	89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 239.05	95 Am 241.06	96 Cm 244.07	97 Bk 249.08	98 Cf 252.08	99 Es 252.09	100 Fm 257.10	101 Md 258.10	102 No 259	103 Lr 262