UNIVERSITY OF SWAZILAND

FINAL EXAMINATIONS

ACADEMIC YEAR 2013/2014

TITLE OF PAPER:	**INTRODUCTORY INORGANIC CHEMISTRY**
COURSE NUMBER:	**C201**
TIME ALLOWED:	**THREE (3) HOURS**
INSTRUCTIONS:	**THERE ARE SIX (6) QUESTIONS. ANSWER ANY FOUR (4) QUESTIONS. EACH QUESTION IS WORTH 25 MARKS.**

A PERIODIC TABLE AND A TABLE OF CONSTANTS HAVE BEEN PROVIDED WITH THIS EXAMINATION PAPER.

PLEASE DO NOT OPEN THIS PAPER UNTIL AUTHORISED TO DO SO BY THE CHIEF INVIGILATOR.

Question One

a) Based on the Bohr model, the radius r_n of an nth orbit is given by

$$r_n = -(\epsilon_0 n^2 h^2)/(\pi m_e e^2 Z)$$

For each of the species H, Li^{2+} and Be^{3+}, calculate

i) The radius of the smallest orbit

ii) The energy (in J) corresponding to the smallest orbit

[12]

b) Briefly explain why 4s, 4p, 4d, and 4f orbitals have the same energy in hydrogen-like atomic species, but have different energies in many-electron atomic species.

[5]

c) Write ground state electron configurations for the following species:

i) Bi^{3+}
ii) Te^{2-}
iii) Ag
iv) Fe^{2+}

[8]

Question two

a) Draw angular parts of **<u>any three</u>** orbitals corresponding to the subshell with n=4 and ℓ=2. The diagrams should include nodal planes if present.

[6]

b) Consider the species Sn and Sn^{2+}.

i) For each of the species, calculate the effective nuclear charge, Z_{eff}, for a valence electron.

ii) Based on your calculation, which one of the two species is expected to have a higher ionization energy? Explain.

[14]

c) Rationalize the difference in boiling points between members of the following pairs of substances:

i) HF (20 °C) and HCl (-85 °C)
ii) Ethylene glycol, $HOCH_2CH_2OH$, (198 °C) and, dimethoxyethane, $H_3COCH_2CH_2OCH_3$, (83 °C)

[5]

Question Three

a) Consider an orbital function whose **angular part is proportional to sinθsinφ**. Evaluate the function in the directions corresponding to the Cartesian coordinate axes and suggest the orientation of the angular part of the orbital. [Note: You are not required to sketch the shape of the orbital]

[10]

b) For each of the following species, write the ground state electronic configuration and indicate which electrons/orbitals are core and which ones are valence.

i) Fe ii) Te iii) Bi [9]

c) In each of the following pairs, select the better choice, and briefly explain your choice:

i) Higher IE: Ca or Ba
ii) Higher IE_1: N or O
iii) Higher EA_1: C or N
iv) Larger ionic radius: In^+ or In^{3+}

[6]

Question Four

a) For each of the molecular species given below, draw the Lewis structure, and then determine the electron-domain geometry and molecular geometry. Finally, determine the hybridization of the central atom.

i) IOF_5 (I is the central atom)
ii) XeO_3 (Xe is the central atom)

[9]

b) Prepare a molecular orbital energy level diagram for the heteronuclear diatomic molecule NO. Use the diagram to answer questions that follow.

i) NO^+ and NO^- are also known. Write electronic configurations of NO, NO^+ and NO^-.

ii) For each of the three species, predict the bond order and magnetic properties

iii) Which of the three would you expect to have the shortest bond? Why?

[16]

Question Five

a) Give structural formulas of the following species and indicate the coordination number(s) around central atom(s).

i) $BeCl_2$

ii) B_2H_6

iii) $[SiF_6]^{2-}$

[8]

b) Write balanced reaction equations for the following:

i) Reaction of $GeCl_4$ with water

ii) Reaction of SiF_4 with H_2SO_4

iii) Reaction of $SiCl_4$ with NaOH

[6]

c) Give an outline the Born-Haber cycle for the formation of MgO(s) starting with constituent elements in their standard states. Then calculate the electron affinity of the oxygen atom in gaining two electrons to give the oxide O^{2-}, from the following data:

Standard enthalpy of formation of MgO(s) .... $-600 kJmol^{-1}$

Heat of sublimation of Mg(s) .... $+150 kJmol^{-1}$

Ionization of Mg(g) to $Mg^{2+}(g)$ .... $+2170 kJmol^{-1}$

Dissociation energy of $O_2(g)$ .... $+494 kJmol^{-1}$

Lattice energy of MgO(s) .... $-3860 kJmol^{-1}$

[11]

Question Six

a) Indicate whether the following oxides are expected to be acidic, basic or amphoteric. Give a chemical equation or, if necessary, two chemical equations to illustrate each of your answers.

i) BaO ii) Cl_2O_7 iii) Al_2O_3.

[12]

b) Give four commonly used products which contain group 1 metal ions.

[4]

c) Complete and balance the following reactions:

i) $Na + O_2 + \text{heat} \rightarrow$
ii) $Ca + H_2 \rightarrow$
iii) $Na_2O_2(s) + H_2O(l) \rightarrow$
iv) $Li(s) + N_2 \rightarrow$

[6]

d) The manufacture of sodium metal (Na) involves electrolysis of molten sodium chloride. Give half reactions that take place at the anode and cathode.

[3]

PERIODIC TABLE OF THE ELEMENTS

GROUPS

PERIODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 H 1																	4.003 He 2
2	6.941 Li 3	9.012 Be 4											10.811 B 5	12.011 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.180 Ne 10
3	22.990 Na 11	24.305 Mg 12	TRANSITION ELEMENTS										26.982 Al 13	28.0855 Si 14	30.9738 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18
4	39.0983 K 19	40.078 Ca 20	44.956 Sc 21	47.88 Ti 22	50.9415 V 23	51.996 Cr 24	54.938 Mn 25	55.847 Fe 26	58.933 Co 27	58.69 Ni 28	63.546 Cu 29	65.39 Zn 30	69.723 Ga 31	72.61 Ge 32	74.922 As 33	78.96 Se 34	79.904 Br 35	83.80 Kr 36
5	85.468 Rb 37	87.62 Sr 38	88.906 Y 39	91.224 Zr 40	92.9064 Nb 41	95.94 Mo 42	98.907 Tc 43	101.07 Ru 44	102.906 Rh 45	106.42 Pd 46	107.868 Ag 47	112.41 Cd 48	114.82 In 49	118.71 Sn 50	121.75 Sb 51	127.60 Te 52	126.904 I 53	131.29 Xe 54
6	132.905 Cs 55	137.33 Ba 56	138.906 *La 57	178.49 Hf 72	180.948 Ta 73	183.85 W 74	188.207 Re 75	190.2 Os 76	192.22 Ir 77	195.08 Pt 78	196.967 Au 79	200.59 Hg 80	204.383 Tl 81	207.2 Pb 82	208.980 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	(223) Fr 87	226.025 Ra 88	(227) **Ac 89	(261) Rf 104	(262) Ha 105	(263) Unh 106	(262) Uns 107	(265) Uno 108	(266) Une 109									

* Lanthanide series	140.115 Ce 58	140.908 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.925 Tb 65	162.50 Dy 66	184.930 Ho 67	167.26 Er 68	168.934 Tm 69	173.04 Yb 70	174.967 Lu 71
** Actinide series	232.038 Th 90	231.036 Pa 91	238.029 U 92	237.048 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103

Numbers below the symbol of the element indicates the atomic numbers. Atomic masses, above the symbol of the element, are based on the assigned relative atomic mass of ^{12}C = exactly 12; ( ) indicates the mass number of the isotope with the longest half-life.

SOURCE: International Union of Pure and Applied Chemistry, I. Mills, ed., *Quantities, Units, and Symbols in Physical Chemistry*, Blackwell Scientific Publications, Boston, 1988, pp 86-98.

PHYSICAL CONSTANTS

Speed of light in a vacuum	c_0	2.99792458×10^{8} m s^{-1}
Permittivity of a vacuum	ϵ_0	$8.854187816 \times 10^{-12}$ F m^{-1}
	$4\pi\epsilon_0$	1.11264×10^{-10} c^2 N^{-1} m^{-2}
Planck constant	h	$6.6260755(40) \times 10^{-34}$ J s
Elementary charge	e	$1.60217733(49) \times 10^{-19}$ C
Avogadro constant	N_A	$6.0221367(36) \times 10^{23}$ mol^{-1}
Boltzmann constant	k	$1.380658(12) \times 10^{-23}$ J K^{-1}
Gas constant	R	8.314510(70) J K^{-1} mol^{-1}
Bohr radius	a_0	$5.29177249(24) \times 10^{-11}$ m
Rydberg constant	R_∞	$1.0973731534(13) \times 10^{7}$ m^{-1} (infinite nuclear mass)
	R_H	$1.09677759(50) \times 10^{7}$ m^{-1} (proton nuclear mass)
Bohr magneton	μ_B	$9.2740154(31) \times 10^{-24}$ J T^{-1}
	π	3.14159265359
Faraday constant	F	$9.6485309(29) \times 10^{4}$ C mol^{-1}
Atomic mass unit	m_u	$1.6605402(10) \times 10^{-27}$ kg
Mass of the electron	m_e	$9.1093897(54) \times 10^{-31}$ kg or $5.48579903(13) \times 10^{-4}$ m_u
Mass of the proton	m_p	1.007276470(12) m_u
Mass of the neutron	m_n	1.008664904(14) m_u
Mass of the deuteron	m_d	2.013553214(24) m_u
Mass of the triton	m_t	3.01550071(4) m_u
Mass of the α-particle	m_α	4.001506170(50) m_u

CONVERSION FACTORS

To convert from units in the first column to units in columns 2 through 4, multiply by the factor given. For example, 1 eV = 96.4853 kJ/mol.

	cm^{-1}	**eV**	**kJ/mol**	**kcal/mol**
cm^{-1}	1	1.239842×10^{-4}	11.96266×10^{-3}	2.85914×10^{-3}
eV	8065.54	1	96.4853	23.0605
kJ/mol	83.5935	1.036427×10^{-2}	1	0.239006
kcal/mol	349.755	4.336411×10^{-2}	4.184	1

SOURCE: International Union of Pure and Applied Chemistry, I. Mills, ed., *Quantities, Units, and Symbols in Physical Chemistry*, Blackwell Scientific Publications, Boston, 1988, pp. 81-2, 85, inside back cover.

UNIVERSITY OF SWAZILAND
CHEMISTRY DEPARTMENT

Compiled by Dr. N D Silavwe

Slater's Rules:

1) Write the electron configuration for the atom using the following design;

(1*s*)(2*s*,2*p*)(3*s*,3*p*) (3*d*) (4*s*,4*p*) (4*d*) (4*f*) (5*s*,5*p*) etc

2) Any electrons to the right of the electron of interest contributes no shielding. (Approximately correct statement.)

3) All other electrons in the same group as the electron of interest shield to an extent of 0.35 nuclear charge units

4) If the electron of interest is an *s* or *p* electron: All electrons with one less value of the principal quantum number shield to an extent of 0.85 units of nuclear charge. All electrons with two less values of the principal quantum number shield to an extent of 1.00 units.

5) If the electron of interest is an *d* or *f* electron: All electrons to the left shield to an extent of 1.00 units of nuclear charge.

6) Sum the shielding amounts from steps 2 through 5 and subtract from the nuclear charge value to obtain the effective nuclear charge.