UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION

ACADEMIC YEAR 2012/2013

TITLE OF PAPER: INTRODUCTORY INORGANIC CHEMISTRY

COURSE NUMBER: C201

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. **There are six (6) questions. Answer any four (4) questions. Each question is worth 25 marks.**
2. **Begin the solution to each question on a new page**

A periodic table, a table of constants and a copy of Slater's Rules 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) Define, **or** state, **or** illustrate using a suitable diagram, each of the following:

i) The Bohr radius

ii) The de Broglie wavelength

iii) The most probable radius of a 1s orbital in a hydrogen atom

[6]

b) Define each of the following:

i) An orbital **[2]**

ii) The effective nuclear charge **[2]**

iii) Bond order. **[2]**

c) Give all the quantum numbers and their possible values for an electron in a **6h** orbital. **[3]**

d) Sketch the energy-level diagram of the molecule that forms when a hydrogen atom and a helium atom combine. Label the atomic and molecular orbitals, give the electron configuration and calculate the bond order of the molecule.

[6]

e) The beryllium compound BeH_2 exists as a polymer. Draw the structure of BeH_2. What is special about this structure? [**4**]

Question Two

a) If a wave function of a hydrogen atom is given by

$$\psi = (27-18b + 2b^2)\exp(-b/3)$$

where $b=Zr/a_o$, give the expression for each of the following:

i) radial part

ii) angular part

iii) radial distribution function.

[5]

b) For the wavefunction of a **$6d_{x^2-y^2}$** orbital, sketch the diagram corresponding to

i) radial part
ii) radial distribution function
iii) angular part

[6]

c) For each of the following species, write the electron configuration and determine the number of unpaired electrons present:

i) Cr   ii) P^{3-} iii) Co^{2+} iv) Mo^{2+}

[14]

Question Three

a) Consider the species Ga, Ga^+ and Ga^{2+}.

i) For each of the species above, calculate the effective nuclear charge for an electron in the valence shell **[12]**

ii) Based on your calculated effective nuclear charges, which of the species is expected to have the lowest ionization energy? Explain. **[3]**

b) Consider the molecule IO_2F_3, where iodine, I, is the central atom.

i) Draw at least three non-equivalent Lewis structures of the molecule
ii) Use formal charges to determine which one of the structures you have drawn is the most reasonable.
iii) For the most reasonable structure, calculate the average **I-O** bond order.

[10]

Question Four

a) For each of the following species, determine the molecular geometry and suggest an appropriate hybridization scheme for the central atom:

i) F_2O (O is the central atom)
ii) SF_4 (S is the central atom)
iii) BrF_5 (Br is the central atom)

[12]

b) Consider a diatomic molecule NO. Using valence atomic orbitals and valence electrons only, answer the following questions:

i) Prepare a molecular orbital energy level diagram for the molecule, **NO.** [Note that the diagram should not be filled with any electrons at this point].
ii) Use the diagram in i) above to give electron configurations for **NO** and **NO^+**.
iii) For each of the species (NO and NO^+), indicate whether the species is paramagnetic or diamagnetic. Briefly explain your answer.
iv) For each of the two species above, calculate the bond order, and indicate which one is expected to have a stronger bond and which one is expected to have a shorter bond

[13 marks]

Question Five

h) Complete the following equations:

i) $CaC_2 + H_2O \longrightarrow$

ii) $Ca + H_2 \longrightarrow$

iii) $Cl_2(aq) + Br^- \longrightarrow$

[7]

c) For each of the following, sketch the structure and indicate the coordination number around the Lewis acid:

i) $[BF_4]^-$ ii) $Be^{2+}(aq)$ iii) SiF_6^{2-}

iv) $Na^+(aq)$

[12]

b) Give an outline of the Born-Haber cycle for the formation of indium chloride, $InCl_3(s)$.

[6]

Question Six

a) For each of the groups (of the periodic table) given below, state the common oxidation state(s) which occur in oxides, and give the formula, M_xO_y, of each of such oxides:

i) group 1 ii) group 2 iii) group 13 iv) group 14 v) group 15

[10]

b) Give a balanced equation for a reaction that is expected to take place when each of the following chlorides is added to water:

i) CaH_2 ii) PCl_5

[4]

c) Give one example of an oxide and write a balanced reaction equation to illustrate its property as indicated below.

i) An acidic oxide that is soluble in water and show how it reacts with water

ii) A basic oxide that is soluble in water and show how it reacts with water

i) An amphoteric oxide and show how it reacts with an acid and a base

[11]

PERIODIC TABLE OF THE ELEMENTS

GROUPS

TRANSITION ELEMENTS

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											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	186.207 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	164.930 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.

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.

PHYSICAL AND CHEMICAL CONSTANTS

Avogadro's number	N_A	$= 6.022045 \times 10^{23}$ mol^{-1}
Electron charge	e	$= 4.8030 \times 10^{-10}$ abs esu
		$= 1.6021892 \times 10^{-19}$ C
Electron mass	m_e	$= 9.1091 \times 10^{-31}$ kg
		$= 5.4860 \times 10^{-4}$ amu
		$= 0.5110$ MeV
Proton mass	m_p	$= 1.6726485 \times 10^{-27}$ kg
		$= 1.007276470$ amu
Gas constant	R	$= 8.31441$ J mol^{-1} K^{-1}
		$= 1.9872$ cal mol^{-1} K^{-1}
		$= 0.08206$ L atm mol^{-1} K^{-1}
Ice point		$= 273.15$ K
Molar volume		$= 22.414 \times 10^{3}$ cm^{3} mol^{-1}
		$= 2.2414 \times 10^{-2}$ m^{3} mol^{-1}
Planck's constant	h	$= 6.626176 \times 10^{-34}$ J s
		$= 6.626176 \times 10^{-27}$ erg s
Boltzmann's constant	k	$= 1.380662 \times 10^{-23}$ J K^{-1}
Rydberg constant	$\mathfrak{R}$	$= 1.097373177 \times 10^{-7}$ m^{-1}
Faraday's constant	$\mathfrak{F}$	$= 9.648670 \times 10^{4}$ C mol^{-1}
Speed of light	c	$= 2.99792458 \times 10^{8}$ m s^{-1}
Bohr radius	a_0	$= 0.52917706 \times 10^{-10}$ m
Other numbers	π	$= 3.14159$
	e	$= 2.7183$
	$\ln 10$	$= 2.3026$

CONVERSION FACTORS

1 cal	= 4.184 joules (J)
1 eV/molecule	= 96.485 kJ mol^{-1}
	= 23.061 kcal mol^{-1}
1 kcal mol^{-1}	= 349.76 cm^{-1}
	= 0.0433 eV
1 kJ mol^{-1}	= 83.54 cm^{-1}
1 wave number (cm^{-1})	$= 2.8591 \times 10^{-3}$ kcal mol^{-1}
1 erg	$= 2.390 \times 10^{-11}$ kcal
1 centimeter (cm)	$= 10^{8}$ Å
	$= 10^{7}$ nm
1 picometer (pm)	$= 10^{-2}$ Å
1 nanometer (nm)	= 10 Å