UNIVERSITY OF SWAZILAND

SUPPLEMENTARY FINAL EXAMINATION

ACADEMIC YEAR 2009/2010

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.

ELECTRONIC CALCULATORS MAY BE USED

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Question one

a) Give the Rydberg equation and define all the parameters in it.

[6 marks]

b) Give three quantum numbers that are obtained from solving the Schrodinger equation. For each quantum number, state possible values that are allowed.

[4.5 marks]

c) Give the quantum number that determines the

i. shape of an orbital
ii. energy of an orbital
iii. orientation of an orbital

[1.5 marks]

d) Consider three one-electron species N^{6+}, B^{4+} and C^{5+}. With the help a brief explanation, answer the following questions:

i) Which one of the species has the smallest and which one has the largest most probable radius of the 1s orbital?

[4 marks]

ii) Which one of the species is expected to have the smallest energy gap and which one is expected to have the largest energy gap between any two shells?

[4 marks]

e) Sketch the angular part and the radial distribution function of the $5d_{zx}$ orbital

[5 marks]

Question Two

a) Consider the two atoms Ca and K.

i) Calculate the effective nuclear charge (Z_{eff}) for an electron in the 4s orbital of each of the atoms (K and Ca)

[6 marks]

ii) The first ionization energies, IE_1, of K and Ca are 418.8 and 589.8 $kJmol^{-1}$ respectively. Is the trend in these values consistent with the values of Z_{eff} you calculated in i) above? Explain your answer. **[2 marks]**

b) Consider the molecule XeO_2Cl_2.

i) Write three non-equivalent Lewis structures for the molecule

ii) Out of the structures in i) above, use formal charges to determine the most reasonable one

iii) Write the formula of the molecule in the form AB_xE_y and then determine, for the molecule, the

- overall geometry
- molecular geometry (or shape)
- hybridization of the Xe atom

[17 marks]

Question Three

a) One member of each of the following sets is not isoelectronic with the others. Which one in each set is <u>not isoelectronic</u> with the others?

i) $[NO_2]^+$, CO_2, $[NO_2]^-$ and $[N_3]^-$

ii) CO, NO^+, CN^- and NO

[4 marks]

b) Each of the following is a radical. For which does a Lewis structure **<u>incorrectly</u>** predict this property? Your answer should include Lewis structures of the molecules.

i) NO ii) O_2 iii) NF_2

[3 marks]

c) Draw two equivalent Lewis structures for the O_3 molecule and calculate the average bond order.

[3 marks]

d) Using **valence orbitals only,** prepare a molecular orbital energy level diagram for C_2, showing clearly how the atomic orbitals interact to form molecular orbitals. Use the diagram you have drawn to answer the following questions.

i) Write electron configurations for each of the species C_2, C_2^{2-} and C_2^{4-}.
ii) For each of the species in i) above, predict the bond order and the number of unpaired electrons
iii) Which of the species in i) above would you expect to have the shortest bond, and why?

[15 marks]

Question Four

a) For each of the following, give one example and a complex derived from it:

i) Group 13 halide
ii) Group 15 halide

[4 marks]

b) With the help of a balanced reaction equation, illustrate the synthesis of each of the following:

i) EtMgCl ii) CaH_2

[4 marks]

c) Briefly describe the difference between saline and molecular hydrides with respect to the following:

i) Nature of bonding
ii) Reaction with protic solvents
iii) Melting and boiling points

[6 marks]

d) What explanation can you give for the decrease in solubility of the alkaline earth metal sulphates in the sequence $CaSO_4 > SrSO_4 > BaSO_4$?

[4 marks]

e) Explain the fact that the maximum coordination number of Li^+ complexes is 4 whereas that of other group 1 ions, such as Na^+, can have coordination numbers as high as six. [Hint: Use hybridization schemes to illustrate your answer].

[7 marks]

Question Five

a) Sketch the Born-Haber cycle for the formation of LiH(s) from Li(s) and $H_2(g)$. Then calculate the electron affinity of the gaseous hydrogen atom from the following data:

Sublimation of Li(s) ..... +155 $kJmol^{-1}$
Ionization of Li(g) ..... +518 $kJmol^{-1}$
Dissociation of $H_2(g)$ ..... +432 $kJmol^{-1}$
Enthalpy of formation of LiH(s) ..... – 90 $kJmol^{-1}$
Lattice energy of LiH(s)..... -906 kJ mol^{-1}

[9 marks]

b) Cs metal crystallizes in a bcc lattice and has density of 1.873g.cm^{-3}. Calculate the radius of a cesium atom.

[13 marks]

c) Explain the fact that of all group 1 halides, lithium halides are the most soluble in **organic solvents**.

[3 marks]

Question Six

a) Complete and balance the following reactions:

i) $Cl_2O_7 + H_2O(l) \longrightarrow$

ii) $P_4O_{10} + H_2O(l) \longrightarrow$

iii) $SO_3 + H_2O(l) \longrightarrow$

iv) $CO_2 + H_2O(l) \longrightarrow$

v) $Be(OH)_2 + OH^-(aq) \longrightarrow$

vi) $N_2O_5(s) + H_2O(l) \longrightarrow$

vii) $I^- + Cl_2 \longrightarrow$

viii) $AlCl_3 + H_2O(l) \longrightarrow$

ix) $Mg + N_2 + heat \longrightarrow$

[18 marks]

b) For each of the following species, sketch the structure and indicate the coordination number around the central atom.

i) Ga_2H_6
ii) IF_7
iii) $[SiF_6]^{2-}$
iv) H_3BNH_3

[7 marks]

PERIODIC TABLE OF THE ELEMENTS

GROUPS

PERIODS	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 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									

TRANSITION ELEMENTS

* 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.

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	$\mathcal{R} = 1.097373177 \times 10^{-7}$ m^{-1}
Faraday's constant	$\mathcal{F} = 9.648670 \times 10^4$ 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	$\pi = 3.14159$
	$e = 2.7183$
	$\ln 10 = 2.3026$

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})	= 2.8591×10^{-3} kcal mol^{-1}
1 erg	= 2.390×10^{-11} kcal
1 centimeter (cm)	= 10^8 Å
	= 10^7 nm
1 picometer (pm)	= 10^{-2} Å
1 nanometer (nm)	= 10 Å