UNIVERSITY OF SWAZILAND

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.

NON-PROGRAMMABLE ELECTRONIC CALCULATORS MAY BE USED

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

Question one

a) What is the physical significance of a radial wave function R(r)?

[1 mark]

b) 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.

[4 marks]

c) 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 marks]

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

i) Re^{2+}

ii) Nd^{2+}

[8 marks]

e) Briefly state the de Broglie hypothesis. Your answer should include the appropriate equation. Briefly explain how the hypothesis has contributed to understanding of the properties of an electron.

[6 marks]

Question Two

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 marks]**

ii) Based on your calculated effective nuclear charges, which of the species is expected to have the lowest ionization energy? Explain. **[2 marks]**

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) Calculate the average I-O bond order.

[11 marks]

Question Three

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

a) F_2O (O is the central atom)
b) SF_4
c) BrF_5 (Br is the central atom)

[12 marks]

b) Consider the diatomic molecule SCl. Using valence atomic orbitals and valence electrons only, but excluding 3d orbitals, answer the following questions:

i) Prepare a molecular orbital energy level diagram for the molecule, **SCl.** [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 **SCl** and **SCl^-**. The electron configuration for **S is [Ne]$3s^23p^4$** and that of **Cl is [Ne]$3s^23p^5$**
iii) For each of the species (SCl and SCl^-), determine the number of unpaired electrons and indicate whether the species is paramagnetic or diamagnetic.
iv) For each of the species, 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 Four

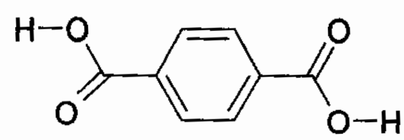
a) With the help of appropriate structures, suggest the nature of hydrogen bonding present in the following species:

i) Ethanol, CH_3CH_2OH

ii) $[NH_4][BH_4]$

iii) A compound containing H-bonds between RCOOH and $RCOO^-$

iv) 1,4-benzene dicarboxylic acid:



1,4-benzene dicarboxylic acid

[9 marks]

b) Use balanced equations to illustrate what happens when the following species are dissolved in water:

i) Diborane, B_2H_6

ii) $A\ell_4C_3$

iii) Mg_3N_2

[6 marks]

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) $Na^+(aq)$

[10 marks]

Question Five

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 marks]

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) $SiCl_4$ ii) PCl_5 iii) S_2Cl_2

[6 marks]

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

[9 marks]

Question Six

a) Identfy the species **A, B, C, D, E, F, G, H, I, J** and **K**:

i) $CaC_2 + \mathbf{A} \longrightarrow Ca(OH)_2 + \mathbf{B}$

ii) $\mathbf{C} + NH_3 \longrightarrow H_3NGaH_3$

iii) $\mathbf{D} + \text{heat} \longrightarrow B_2O_3 + \mathbf{E}$

iv) $Cl_2(aq) + \mathbf{F} \longrightarrow \mathbf{G} + Br_2(aq)$

v) $SiCl_4 + CH_3MgCl \longrightarrow \mathbf{H} + \mathbf{I}$

vi) $SiO_2 + \mathbf{J} \longrightarrow SiF_4 + \mathbf{K}$

[11 marks]

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

[6 marks]

c) A sodium chloride structure has 4 formula units per unit cell. A unit cell length of 564 pm for NaCl has been determined by x-ray diffraction studies. Determine the inter-ionic distance for NaCl, and calculate the volume, the mass and the density of the unit cell.

[8 marks]

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.

Derived SI Units

Physical quantity	Name of unit	Symbol for unit	Definition of unit
Energy	Joule	J	kg m^{2}s^{-2}
Force	Newton	N	kg m s^{-2} = J m^{-1}
Power	Watt	W	kg m^{2}s^{-3} = J s^{-1}
Pressure	Pascal	Pa	kg m^{-1}s^{-2} = N m^{-2}
Electric charge	Coulomb	C	A s
Electric potential difference	Volt	V	kg m^{2}s^{-3}A^{-1} = J A^{-1}s^{-1}, J/C
Electric resistance	Ohm	Ω	kg m^{2}s^{-3}A^{-2} = V A^{-1}
Electric capacitance	Farad	F	A^{2}s^{4}kg^{-1}m^{-2} = A s V^{-1}
Magnetic flux	Weber	Wb	kg m^{2}s^{-2}A^{-1} = V s
Inductance	Henry	H	kg m^{2}s^{-2}A^{-2} = V s A^{-1}
Magnetic flux density	Tesla	T	kg s^{-2}A^{-1} = V s m^{-2}
Frequency	Hertz	Hz	Hz = s^{-1}
Customary temperature, t	Degree Celsius	°C	t[°C] = T[K] − 273.15

Fundamental Constants

Quantity	Symbol	Value	SI unit
Speed of light in vacuum	c	2.997 925 × 10^8	m s^{-1}
Elementary charge	e	1.602 189 × 10^{-19}	C
Planck constant	h	6.626 18 × 10^{-34}	J s
Avogadro constant	N_A	6.022 04 × 10^{23}	mol^{-1}
Atomic mass unit	1u	1.660 566 × 10^{-27}	kg
Electron rest mass	m_e	0.910 953 × 10^{-30}	kg
Proton rest mass	m_p	1.672 649 × 10^{-27}	kg
Neutron rest mass	m_n	1.674 954 × 10^{-27}	kg
Faraday constant	F	9.648 46 × 10^4	C mol^{-1}
Rydberg constant	R_∞	1.097 373 × 10^7	m^{-1}
Bohr radius	a_0	0.529 177 × 10^{-10}	m
Electron magnetic moment	μ_e	9.284 83 × 10^{-24}	J T^{-1}
Proton magnetic moment	μ_p	1.410 617 × 10^{-26}	J T^{-1}
Bohr magneton	μ_B	9.274 08 × 10^{-24}	J T^{-1}
Nuclear magneton	μ_N	5.050 82 × 10^{-27}	J T^{-1}
Molar gas constant	R	8.314 41	J mol^{-1} K^{-1}
Molar volume of ideal gas (stp.)	V_m	0.022 413 8	m^3 mol^{-1}
Boltzmann constant	k	1.380 662 × 10^{-23}	J K^{-1}

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 wavenumber (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

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14 Si
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16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr

Periodic Table of the Elements

GROUP 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** 98.906*	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** ★ 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	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** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** 209.98*	85 **At** 209.99*	86 **Rn** 222.02*
87 **Fr** 223.02	88 **Ra** 226.03*	89 **Ac** ▲ 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (262)	108 **Hs** (269)	109 **Mt** (266)	110 (273)	111 (272)	112 (294)						

★Lanthanide series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92*	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
▲Actinide series	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** 244.06*	97 **Bk** 249.08*	98 **Cf** 252.08*	99 **Es** 252.08*	100 **Fm** 257.10*	101 **Md** 258.10*	102 **No** 259.10*	103 **Lr** 262.11*

Note: Atomic masses shown here are the 1993 IUPAC values with a maxium of five significant figures (T. B. Coplen *et al.*, *Inorg. Chim. Acta* 1994, *217*, 217).
An asterisk indicates the mass of a commonly known radioisotope. Numbers in parentheses are the mass numbers of the corresponding longer-lived isotope.