UNIVERSITY OF SWAZILAND

FINAL EXAMINATION

ACADEMIC YEAR 2010/2011

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.

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Question One

a) For an electron in the nth shell of a hydrogen-like atomic species, its energy is given by

$$E_n = -\left(\frac{m_e Z^2 e^4}{8\varepsilon_0^2 h^2}\right)\left(\frac{1}{n^2}\right)$$

i) Define each of the parameters in the expression

ii) Derive the expression for the change in energy when such a species decays from an an excited state having principal quantum number $n = n_1$ to a lower state having $n = n_2$.

iii) Derive the expression for the wave number corresponding to the emitted radiation in ii) above.

[6 mks]

b) An atom is observed to emit radiation at 100 nm, 125 nm and 500 nm. Theoretical considerations indicate that there are only two excited states involved.

i) With the help of a suitable energy level diagram, explain why the three lines are observed.

ii) How far above the ground state is the energy (in J) of the highest state?

[9 mks]

c) Write the ground state electron configuration, and determine the number of unpaired electrons, for each of the following species:

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

[10 mks]

Question two

a) Draw angular parts of **any three** of orbitals corresponding to n = 4 and ℓ = 2. The diagrams should include nodal planes if present.

[9 mks]

b) Consider a zinc atom, Zn, and its ion, Zn^{+}.

i) For each of the species, calculate the effective nuclear charge, Z_{eff}, for an electron in the 4s orbital.

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

[10 mks]

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 ethylene glycol dimethyl ether, $CH_3OCH_2CH_2OCH_3$, (83 °C) **[6 mks]**

Question Three

a) For the 7f set of orbitals, determine the number of radial nodes and sketch the radial distribution function. **[4 mks]**

b) Consider the following observed trends:

Compound	Interionic distance, d (pm)	Lattice Energy, ΔH_L ($kJmol^{-1}$)
LiF	201	-1004
CsCl	395	-527
MgO	210	-3933

Briefly explain the changes in ΔH_L upon moving from LiF to
i) CsCl
ii) MgO **[6 mks]**

c) Sketch the Born-Haber cycle for the formation of $CaI_2(s)$ from constituent elements and calculate the lattice energy from the following data:

Standard enthalpy of formation of $CaI_2(s)$ .... -535 $kJmol^{-1}$
Heat of sublimation of Ca(s) .... +193 $kJmol^{-1}$
Ionization of Ca(g) to $Ca^{2+}(g)$ ....+ 1725 $kJmol^{-1}$
Heat of sublimation of $I_{2(s)}$ .... +62 $kJmol^{-1}$
Dissociation energy of $I_2(g)$...+149 $kJmol^{-1}$
Electron affinity of I(g) .... -308 $kJmol^{-1}$

[10 mks]

d) Consider the oxides SnO_2 and Cu_2O. For each of the oxides,

i) Determine the oxidation number of the metal ion
ii) Write the electron configuration of the metal ion. **[5 mks]**

Question Four

a) For each of the molecular species given below, draw the **Lewis structure**, and then determine the **overall geometry** and **molecular shape**. Finally, determine the **hybridization** of the central atom.

i) IF_5 (Iodine is the central atom)
ii) XeO_2F_2 (Xenon is the central atom) **[9 mks]**

b) Consider the molecule, SO_3, which is obtained by oxidizing sulphur.

i) Write three non-equivalent Lewis structures for the molecule.
ii) Use formal charges to suggest the Lewis structure of lowest energy

[8 mks]

c) Niobium oxide crystallizes in the ***sodium chloride*** system.

i) Sketch the unit cell
ii) How many niobium atoms and how many oxygen atoms belong to the unit cell?
iii) Calculate the mass of a unit cell of the compound.

[8 mks]

Question Five

a) Consider carbon monoxide, CO, which is isoelectronic with N_2. Experimentally, it is found that the highest energy electrons reside in a σ-type MO.

i) Draw an **energy level diagram** for CO. Write the electron configuration for the molecule and calculate the bond order.

ii) Would you expect the π_{2p} **MO's** to have equal atomic orbital contributions from C and O atoms? If not, which atom is expected to have greater contribution? Explain.

iii) Sketch orbital diagrams showing how pi-type p orbitals overlap to give bonding (π_{2p}) and anti-bonding (π^*_{2p}) MO's. [Note that an energy level diagram is **NOT** required here).

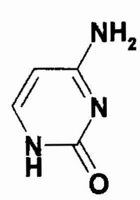
iv) Use the **energy level diagram** you have drawn for CO in i) above to write the electronic configuration for the diatomic molecule NO. Calculate the bond order for NO.

v) State which one, of the two molecules, is expected to

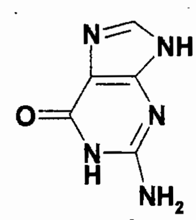
- have a stronger bond
- be paramagnetic
- have a lower first ionization energy.

[20 mks]

b) Structural formulas of cytosine and guanine are given below. Show how the two molecules may interact with each other giving rise to three hydrogen bonds at the same time. Indicate the location of partial charges (δ^+ and δ^-) on the atoms participating in hydrogen bonding. **[5 mks]**



cytosine



guanine

Question Six

a) Explain the fact that the highest fluoride compound for nitrogen is NF_3 whereas phosphorous readily forms PF_5.

[4 mks]

b) Give reasons why hydrogen might be placed in group 1 or group 17 of the periodic table.

[6 mks]

c) Complete and balance the following reactions:

i) $BeO + OH^-(aq) + H_2O(\ell) \rightarrow$

ii) $Mg_3N_2(s) + H_2O(\ell) \rightarrow$

iii) $CaH_2(s) + H_2O(\ell) \rightarrow$

iv) $Al_2O_3(s) + H_2SO_4(aq) \rightarrow$

[8 mks]

d) Predict whether each of the following is acdic, basic, amphoteric or neutral. Give a brief explanation for your answer.

i) CO_2 ii) $Al(OH)_3$ iii) CaO iv) N_2O

[7 mks]

PERIODIC TABLE OF ELEMENTS

GROUPS

Atomic mass → 10.811
Symbol → **B**
Atomic No. → 5

TRANSITION ELEMENTS

PERIODS	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	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	28.086 **Si** 14	30.974 **P** 15	32.06 **S** 16	35.453 **Cl** 17	39.948 **Ar** 18
4	39.098 **K** 19	40.078 **Ca** 20	44.956 **Sc** 21	47.88 **Ti** 22	50.942 **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	92.906 **Nb** 41	95.94 **Mo** 42	98.907 **Tc** 43	101.07 **Ru** 44	102.91 **Rh** 45	106.42 **Pd** 46	107.87 **Ag** 47	112.41 **Cd** 48	114.82 **In** 49	118.71 **Sn** 50	121.75 **Sb** 51	127.60 **Te** 52	126.90 **I** 53	131.29 **Xe** 54
6	132.91 **Cs** 55	137.33 **Ba** 56	138.91 ***La** 57	178.49 **Hf** 72	180.95 **Ta** 73	183.85 **W** 74	186.21 **Re** 75	190.2 **Os** 76	192.22 **Ir** 77	195.08 **Pt** 78	196.97 **Au** 79	200.59 **Hg** 80	204.38 **Tl** 81	207.2 **Pb** 82	208.98 **Bi** 83	(209) **Po** 84	(210) **At** 85	(222) **Rn** 86
7	223 **Fr** 87	226.03 **Ra** 88	(227) ****Ac** 89	(261) **Rf** 104	(262) **Ha** 105	(263) **Unh** 106	(262) **Uns** 107	(265) **Uno** 108	(266) **Une** 109	(267) **Uun** 110								

***Lanthanide Series**	140.12 **Ce** 58	140.91 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.96 **Eu** 63	157.25 **Gd** 64	158.93 **Tb** 65	162.50 **Dy** 66	164.93 **Ho** 67	167.26 **Er** 68	168.93 **Tm** 69	173.04 **Yb** 70	174.97 **Lu** 71
****Actinide Series**	232.04 **Th** 90	231.04 **Pa** 91	238.03 **U** 92	237.05 **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

( ) indicates the mass number of the isotope with the longest half-life.

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	$2.997\ 925 \times 10^8$	$m\ s^{-1}$
Elementary charge	e	$1.602\ 189 \times 10^{-19}$	C
Planck constant	h	$6.626\ 18 \times 10^{-34}$	J s
Avogadro constant	N_A	$6.022\ 04 \times 10^{23}$	mol^{-1}
Atomic mass unit	1u	$1.660\ 566 \times 10^{-27}$	kg
Electron rest mass	m_e	$0.910\ 953 \times 10^{-30}$	kg
Proton rest mass	m_p	$1.672\ 649 \times 10^{-27}$	kg
Neutron rest mass	m_n	$1.674\ 954 \times 10^{-27}$	kg
Faraday constant	F	$9.648\ 46 \times 10^4$	$C\ mol^{-1}$
Rydberg constant	R_∞	$1.097\ 373 \times 10^7$	m^{-1}
Bohr radius	a_0	$0.529\ 177 \times 10^{-10}$	m
Electron magnetic moment	μ_e	$9.284\ 83 \times 10^{-24}$	$J\ T^{-1}$
Proton magnetic moment	μ_p	$1.410\ 617 \times 10^{-26}$	$J\ T^{-1}$
Bohr magneton	μ_B	$9.274\ 08 \times 10^{-24}$	$J\ T^{-1}$
Nuclear magneton	μ_N	$5.050\ 82 \times 10^{-27}$	$J\ T^{-1}$
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	$1.380\ 662 \times 10^{-23}$	$J\ K^{-1}$

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