UNIVERSITY OF SWAZILAND

FINAL EXAMINATION

ACADEMIC YEAR 2008/2009

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

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Question one

Which of the two electronic configurations has a lower energy: (i) $[Ar]3d^4 4s^2$ (ii) $[Ar]3d^5 4s^1$? Identify this element and discuss Hund's rule as it applies to this case.

[4 marks]

b) When the 116^{th} element is discovered, what would be its probable electronic configuration? Which group would it belong to?

[4 marks]

c) The radial function R(r) for a 2p orbital in a hydrogen atom is $K\ r\ \exp(-r/2a_o)$, where K is a constant and a_o is the Bohr radius.

i) Give the expression for the radial distribution function?

ii) What is the most probable radius, r_p? Express r_p in terms of the Bohr radius a_o.

[6 marks]

d) Estimate the energy of radiation emitted from a one-electron cation with Z=74 when the electron drops from the N shell to the M shell

[4 marks]

e) Give limits of values of each of the polar coordinates r, θ, φ in three-dimensional space around the nucleus of an atom. **[3 marks]**

f) For the $4dx^2\text{-}y^2$ atomic orbital, sketch:

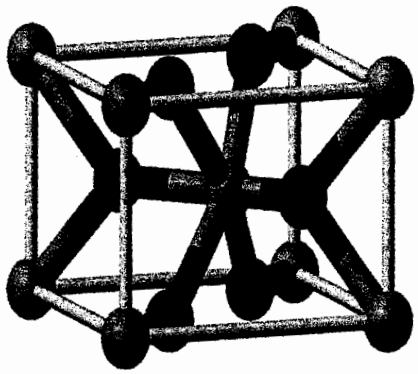
i) the radial distribution function, P(r)

ii) the angular part, A(θ, φ), of the orbital

[4 marks]

Question Two

a) Determine the number of formula units per unit cell of a titanium oxide whose unit cell has a rutile structure which is sketched below. [Note: oxide ions are represented by black spheres] **[5 marks]**



b) Outline the Born-Haber cycle and calculate the lattice energy of RbF(s) given the following data:

Sublimation of Rb(s) ..... +86 $kJmol^{-1}$
Ionization energy of Rb(g) ..... +402 $kJmol^{-1}$
Dissociation energy of $F_2(g)$ ..... +155 $kJmol^{-1}$
Electron affinity of F(g) ..... –346 $kJmol^{-1}$
Enthalpy of formation of RbF(s) ..... – 548 $kJmol^{-1}$

[10 marks]

c) Gold crystallizes in the fcc system, which has **4 lattice points** per unit cell. The radius of the atom is 1.44 Å. Calculate the

i) length of one side of the unit cell
ii) volume of the unit cell
iii) mass of the unit cell
iv) density of gold

[10 marks]

Question Three

a) Assuming the internuclear axis coincides with the z axis, sketch molecular orbitals arising from the following combinations of atomic orbitals:

i) d_{z^2} with d_{z^2} (both bonding and antibonding)
ii) p_y with d_{yz} (both bonding and antibonding) **[4 marks]**

b) Consider the diatomic molecule C_2:

i) Prepare a molecular orbital energy level diagram for this molecule
ii) Use the diagram in i) above to give electron configurations for the ions C_2^{2-}, C_2^{4-} and C_2^{6-}
iii) Calculate the bond order for each of the ions
iv) List the ions in order of expected bond length, starting with the smallest.

[12 marks]

c) (i) Write three **non-equivalent** Lewis structures of SO_3F^-, where sulphur is the central atom. Use formal charges to determine the best Lewis structure.

(ii) Determine the hybridization of the S atom and the average S-O bond order in the best Lewis structure.

[9 marks]

Question Four

a) On the basis of electron configuration, explain why:

i) Sulphur has a lower electron affinity than chlorine
ii) Iodine has a lower electron affinity than bromine
iii) Sulphur has a lower ionization energy than phosphorus

[6 marks]

b) Electron configurations for **Ce, Pr, and Nd** are, respectively, **$[Xe]4f^15d^16s^2$, $[Xe]4f^36s^2$, $[Xe]4f^46s^2$.**

(i) Use Slater's rules to calculate the effective nuclear charge, Z*, for a 4f electron in **Ce, Pr** and **Nd**.

(ii) Are your calculated values consistent with the expected trend? Explain your answer.

[12marks]

c) Explain the fact that SF_6 is known but OF_6 is not. Your answer should include hybridization scheme of SF_6.

[7 marks]

Question Five

a) How do anhydrous $CaCl_2$ and CaH_2 function as drying agents?

[3 marks]

b) Give a balanced chemical equation depicting reaction between:

i) Strontium peroxide and hydrochloric acid
ii) Aluminium hydroxide and potassium hydroxide
iii) Potassium superoxide and water
v) BCl_3 and CH_3CH_2OH
v) B_2H_6 and O_2

[8 marks]

c) The values of the lattice energies of MgO, CaO and SrO are -3795, -3414 and -3220 kJ mol^{-1} respectively. Show that this trend in values is consistent with the Kapustinski equation.

[8 marks]

d) Consider the salts Na_2CO_3, Cs_2CO_3, Na_2SO_4, Li_2CO_3, Li_2Cl and LiF.

(i) Which ones are readily soluble in water?

(ii) Using LiCl and LiF as examples, discuss factors that contribute to the solubility of a salt.

[6 marks]

Question Six

a) Consider the molecules BF_3, B_2H_6 and Al_2Cl_6.

i) BF_3 has triangular planar geometry and has a p_π orbital that does not participate in σ-bonding. Use suitable diagrams to illustrate how this orbital gives rise to delocalized pi bonding in BF_3.

[5 marks]

ii) Draw the structure of B_2H_6 and indicate the **two types of bonding** present. **[3 marks]**

iii) Draw the structure of Al_2Cl_6 and indicate the **two types** of bonds present

[2 marks]

b) **Y** is an element that belongs to group 2 and reacts with **hot water** to form **A** and a gas **B**, but the element does not react with cold water. **Y** reacts with hot air to form compounds **C** and **D**. Compound **C** is commonly used as a refractory material. **Y** is a strongly electropositive metal such that it reacts with $AgNO_3$ to form Ag and compound **E**. The oxide of **Y** reacts with hydrogen peroxide, H_2O_2, to form peroxide, **F**.

i) Identify the element **Y** and the compounds **A**, **B**, **C**, **D**, **E**, and **F**.

ii) Give the reaction equations that lead to the formation of **A**, **B**, **C**, **D**, **F** and **E**. [It is not necessary to balance the equations].

[15 marks]

~~~~~~~~~~~~~~~~~~~~#END OF EXAM#~~~~~~~~~~~~~~~
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PERIODIC TABLE OF THE ELEMENTS

GROUPS

PERIODS	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1.008 H																	4.003 He
2	6.941 Li	9.012 Be											10.811 B	12.011 C	14.007 N	15.999 O	18.998 F	20.180 Ne
3	22.990 Na	24.305 Mg											26.982 Al	28.0855 Si	30.9738 P	32.06 S	35.453 Cl	39.948 Ar
4	39.0983 K	40.078 Ca	44.956 Sc	47.88 Ti	50.9415 V	51.996 Cr	54.938 Mn	55.847 Fe	58.933 Co	58.69 Ni	63.546 Cu	65.39 Zn	69.723 Ga	72.61 Ge	74.922 As	78.96 Se	79.904 Br	83.80 Kr
5	85.468 Rb	87.62 Sr	88.906 Y	91.224 Zr	92.9064 Nb	95.94 Mo	98.907 Tc	101.07 Ru	102.906 Rh	106.42 Pd	107.868 Ag	112.41 Cd	114.82 In	118.71 Sn	121.75 Sb	127.60 Te	126.904 I	131.29 Xe
6	132.905 Cs	137.33 Ba	138.906 *La	178.49 Hf	180.948 Ta	183.85 W	186.207 Re	190.2 Os	192.22 Ir	195.08 Pt	196.967 Au	200.59 Hg	204.383 Tl	207.2 Pb	208.980 Bi	(209) Po	(210) At	(222) Rn
7	(223) Fr	226.025 Ra	(227) **Ac	(261) Rf	(262) Ha	(263) Unh	(262) Uns	(265) Uno	(266) Une									

TRANSITION ELEMENTS

* Lanthanide series	140.115 Ce	140.908 Pr	144.24 Nd	(145) Pm	150.36 Sm	151.96 Eu	157.25 Gd	158.925 Tb	162.50 Dy	164.930 Ho	167.26 Er	168.934 Tm	173.04 Yb	174.967 Lu
** Actinide series	232.038 Th	231.036 Pa	238.029 U	237.048 Np	(244) Pu	(243) Am	(247) Cm	(247) Bk	(251) Cf	(252) Es	(257) Fm	(258) Md	(259) No	(260) Lr

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.