UNIVERSITY OF SWAZILAND
SUPPLIMENTARY EXAMINATION
ACADEMIC YEAR 2011/2012

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) What is the total number of orbitals that are present in a shell of principal quantum number n? (Hint: Begin with n = 1, 2 and 3 to recognize the pattern).
[4]

b) For each of the species given below, draw the Lewis structure. Use the Lewis structure to determine the overall geometry and the molecular shape of the species. Then determine the hybridization scheme for the central atom in the molecule.

i) NO_3^- ii) SCl_4 iii) $XeOF_4$
[16]

c) Describe the nature of π bonding and structure of $P(SiH_3)_3$ molecule. Compare with the nature of bonding in $P(CH_3)_3$. **[5]**

Question Two

a) The Schrodinger equation may be written (in compact form) as

$$(KE + V)\psi = E\psi$$

What do the terms KE, V, ψ and E stand for?
[4]

b) Give the quantum numbers that are obtained from solving the Schrodinger equation.
[3]

c) In the hydrogen atom the 3s and 3p orbitals have identical energies, but in the chlorine atom the 3s orbital lies at a considerably lower energy. Explain.
[5]

d) The wave function of a certain orbital is roughly given by

$$\psi = (6-b)be^{-b/3}\cos\theta$$

where $b = zr/a_o$ and a_o is the Bohr radius.

Using the above function answer the following questions.

i) Pick out the radial part and the angular part of the function.
ii) Draw a rough sketch of the plot of the angular part of the function. Show how you figure out the shape of your plots. [Hint: Evaluate the angular function along the +x, -x, +y, -y, +z and –z directions].
[13]

Question Three

a) For each of the orbitals1s, $2p_y$ and $3d_{z^2}$ sketch

i) the radial function R(r) **[6]**

ii) The angular function **[7]**

b) Using Slater's rules, calculate Z_{eff} for the valence electron in i)Ca and ii) Sr. Electron configurations of Ca and Sr are $[Ar]4s^2$ and $[Kr]5s^2$ respectively. The first ionization potentials of Ca and Sr are 6.113 and 5.695 eV (1 eV = 1.602 x 10^{-19} J) respectively. Do their ionization energies seem to match the calculated effective nuclear charge values? Explain.

[12]

Question Four.

a) Illustrate, with the help of suitable orbital diagrams, how the LCAO approximation gives rise to **bonding** and **anti-bonding** orbitals for the following interactions:

i) an **s** orbital with an **s** orbital
ii) a **p** orbital with a **p** orbital to give π mo's

[Note that energy level diagrams are not required]

[7]

b) Using valence orbitals only, draw the molecular orbital energy-level diagram for the diatomic molecule B_2. The electron configuration of B is $[He]2s^22p^1$. Calculate the bond order of the molecule.

[8]

c) Use the energy-level diagram you have drawn in b) above to write an electron configuration for each of the species: i) C_2 ii) C_2^{2-} iii) C_2^{8-}. Which of these species do you expect to have any chance of existence? Give an explanation for your answer.

[10]

Question Five

(a) Sketch the Born-Haber cycle for the formation of a salt, $MX_2(s)$, from a metal, M(s), and a non-metal, $X_2(g)$

[10]

b) Calculate the lattice energy of calcium chloride, $CaCl_2(s)$, that is obtained by reacting Ca(s) with $Cl_2(g)$, using the following data:

Standard enthalpy of formation of $CaCl_2(s)$ ----------	-794 $kJmol^{-1}$
Heat of sublimation of Ca(s) ----------------------------	+193 $kJmol^{-1}$
Dissociation energy of $Cl_2(g)$ ---------------------------	+242 $kJmol^{-1}$
Ionization energy (I_1+I_2) of Ca(g) to $Ca^{2+}(g)$ ---------	+1725 $kJmol^{-1}$
Electron affinity of Cl(g) ------------------------------	-347 $kJmol^{-1}$

[4]

c) Rationalise the following:

i) Ionic radii of the group II elements are smaller than their corresponding atomic radii. [2]

ii) Compounds of Be are much more covalent than those of the other group II counterparts. [5]

iii) PCl_5 gas is known whereas NCl_5 is not. [4]

Question Six

a) A group 2 metal X occurs naturally in great abundance as the carbonate. Metal X reacts with cold water forming compound D, which is a strong base. Aqueous solutions of D are used in qualitative tests for CO_2. X combines with hydrogen gas, $H_2(g)$, to give a saline hydride, XH_2, that is used as a drying agent. Identify X and D. Write the equations for the reaction of X with H_2O and for the reaction of the hydride, XH_2, with H_2O. Write the equation of the reaction that takes place when an aqueous solution of D is used to test for CO_2.

[10]

b) Consider the compounds $BaSO_4$, BCl_3, PCl_3, $Mg(OH)_2$, SrH_2, $SiCl_4$, $Ca(NO_3)_2$ and KCl. Indicate which ones of the above compounds (when mixed with water)

i) are sparingly soluble
ii) are soluble without reaction
iii) react with water

For each of the species which react with water, write the balanced reaction equation involved.

[9]

c) For each of the compounds given below, indicate whether the compound will produce an acidic, neutral or a basic solution when it is dissolved in water. Give the formulas of the major species that are formed upon dissolution of the compound.

i) Na_2O ii) NaCl iii) SO_3

[6]

Useful relations

At 298.15 K, $RT = 2.4790$ kJ mol^{-1} and $RT/F = 25.693$ mV

1 atm = 101.325 kPa = 760 Torr (exactly)

1 bar = 10^5 Pa

1 eV = $1.602\ 18 \times 10^{-19}$ J = 96.485 kJ mol^{-1} = 8065.5 cm^{-1}

1 cm^{-1} = 1.986×10^{-23} J = 11.96 J mol^{-1} = 0.1240 meV

1 cal = 4.184 J (exactly)

1 D (debye) = $3.335\ 64 \times 10^{-30}$ C m

1 T = 10^4 G

1 Å (ångström) = 100 pm

1 M = 1 mol dm^{-3}

General data and fundamental constants

Quantity	Symbol	Value
Speed of light	c	$2.997\ 925 \times 10^8$ m s^{-1}
Elementary charge	e	$1.602\ 177 \times 10^{-19}$ C
Faraday constant	$F = eN_A$	9.6485×10^4 C mol^{-1}
Boltzmann constant	k	$1.380\ 66 \times 10^{-23}$ J K^{-1}
		8.6174×10^{-5} eV K^{-1}
Gas constant	$R = kN_A$	$8.314\ 51$ J K^{-1} mol^{-1}
		$8.205\ 78 \times 10^{-2}$ dm^3 atm K^{-1} mol^{-1}
Planck constant	h	$6.626\ 08 \times 10^{-34}$ J s
	$\hbar = h/2\pi$	$1.054\ 57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\ 14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\ 54 \times 10^{-27}$ kg
Mass of electron	m_e	$9.109\ 39 \times 10^{-31}$ kg
Vacuum permittivity	ε_0	$8.854\ 19 \times 10^{-12}$ J^{-1} C^2 m^{-1}
	$4\pi\varepsilon_0$	$1.112\ 65 \times 10^{-10}$ J^{-1} C^2 m^{-1}
Bohr magneton	$\mu_B = e\hbar/2m_e$	$9.274\ 02 \times 10^{-24}$ J T^{-1}
Bohr radius	$a_0 = 4\pi\varepsilon_0\hbar^2/m_e e^2$	$5.291\ 77 \times 10^{-11}$ m
Rydberg constant	$R_\infty = m_e e^4/8h^3 c\varepsilon_0^2$	$1.097\ 37 \times 10^5$ cm^{-1} = 1.09737×10^7 m^{-1}

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^3	10^6	10^9

The Periodic Table

Period	1	2	3	4	5	6	7	8	9	10	11	12	13/III	14/IV	15/V	16/VI	17/VII	18/VIII
1									1 H 1.008									2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	La-Lu	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 210.0	85 At 210.0	86 Rn 222.0
7	87 Fr 223.0	88 Ra 226.0	Ac-Lr	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	......								
	s block		d block										p block					

Lanthanides	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 146.2	61 Pm 144.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu 239.1	95 Am 241.1	96 Cm 244.1	97 Bk 249.1	98 Cf 252.1	99 Es 252.1	100 Fm 257.1	101 Md 258.1	102 No 259.1	103 Lr 262.1
	f block														