UNIVERSITY OF SWAZILAND
FINAL EXAMINATIONS
ACADEMIC YEAR 2018/2019

TITLE OF PAPER: **Atomic Structure, Chem. Bonding and Chemistry of s- and p-Block Elements/Introductory Chemistry**

COURSE CODE: CHE221/C201

TIME ALLOWED: Three (3) Hours

INSTRUCTIONS:

THERE ARE TWO SECTIONS: SECTION A AND SECTION B. ANSWER ALL THE QUESTIONS IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A IS WORTH 40 MARKS AND EACH QUESTION IN SECTION B IS WORTH 20 MARKS.

THE ANSWER SHEET FOR SECTION A IS ATTACHED TO THE QUESTION PAPER. GIVE YOUR ANSWERS TO SECTION A QUESTIONS BY RECORDING ON THE ANSWER SHEET THE LETTER CORRESPONDING TO THE CORRECT ANSWER.

DETATCH THE ANSWER SHEET FROM THE QUESTION PAPER AND FILL IN ALL THE INFORMATION REQUIRED IN THE SPACES PROVIDED, BEFORE YOU LEAVE, PLACE THE ANSWER SHEET INSIDE THE UNISWA ANSWER BOOKLET CONTAINING YOUR ANSWERS TO SECTION B

A periodic table, a table of constants and a copy of Slater's Rules have been provided with this examination paper.

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

Question One

a) How many radial nodes and angular nodal planes do 3s, 3p, and 3d orbitals have? Show how you arrive at your answers. **[3]**

b) Use sketches of 2s, 3p and 4d orbitals to distinguish between (a) the radial functions and (b) the radial distribution functions. **[7]**

c) Given that radial the distribution function P(r) for a 1s orbital is proportional to the function $f(r) = r^2e^{-b}$, where $b = 2Zr/a_o$, show that the most probable radius occurs at $r_{max} = a_o/Z$ **[8]**

d) Given that the angular function of an orbital is proportional to $\cos^2\theta$, determine the orientation of the orbital. **[7]**

Question Two

a) In two dimension, sketch the angular parts of orbitals that transform as the functions given below. In each case label the drawing with the correct Cartesian coordinates and the + and – signs. **[7]**

i) x ii) yz iii) x^2-y^2

b) Give the ground-state electron configuration for each of the following:

i) P^{3-} ii) Co^{3+} iii) Eu **[6]**

c) For each of the species in b) above, state the number of unpaired electrons present. Show how you arrive at your answer. **[6]**

d) For each of the following species, state whether the bonding is ionic, polar covalent or non-polar covalent. Explain your answer.

i) $BeCl_2$ ii) BaO iii) PbI_2 iv) AsH_3 **[6]**

Question Three

a) The halogens react among themselves to form compounds, called "interhalogens". One of these compounds is iodine monochloride, ICl, in which the energies of molecular orbitals, arising from valence orbital interactions only, have been calculated and found to increase in the order $1\sigma < 2\sigma < 1\pi < 3\sigma < 2\pi < 4\sigma$.

i) Draw a schematic molecular orbital energy-level diagram for ICl, with all the molecular orbitals labelled. [Note: Energies of valence ao's increase in the order 3s (Cl)<3p(Cl)<5s(I)<5p (I)]. **[8]**

ii) Give the ground state electron configuration of ICl **[2]**

iii) For each of the molecular orbitals 1σ, 1π, and 2π, sketch the orbital diagram illustrating interaction of atomic orbitals (to form the molecular orbital). **[6]**

b) Consider the atomic species Sn and Sn^{2+}. For each of the species, calculate the effective nuclear charge for a valence electron. **[7]**

c) The first and third ionization energies of tin are 708 and 2943 kJ mol^{-1} respectively. Comment on these values, especially in light of effective nuclear charge values you calculated in b) above. **[2]**

Question Four

a) Give a sketch of the Born-Haber cycle for the formation of MgO(s) from the elements in their standard states. From the following data, calculate the electron affinity of an oxygen atom in gaining two electrons to give the oxide ion, O^{2-}:

Standard heat of formation of MgO(s) ....-600 kJ $mole^{-1}$
Lattice energy of MgO(s)..............................-3860 kJ $mole^{-1}$
Ionization energy of Mg(g) to give Mg^{2+} *(g)*.........+2170 kJ $mole^{-1}$
Dissociation energy of $O_2(g)$ ....+494 kJ $mole^{-1}$
Heat of sublimation of Mg(s) .... +150 kJ $mole^{-1}$

[12]

b) The radius a tungsten atom is 141 pm. Draw the bcc unit cell of tungsten metal.

i) Calculate the length (ℓ) of the unit cell of tungsten metal

ii) Calculate the volume of the unit cell

iii) Determine the number of tungsten atoms per unit cell

iv) Calculate the density of tungsten

v) If a carbon atom is placed at the centre of every face of the unit cell, what would be the formula of the resulting compound?

[13]

Question Five

a) For each of the following species, determine domain geometry, molecular geometry and hybridization of atomic orbitals around the central atom.

i) SOF_4 ii) IF_5

[9]

b) Consider the molecule XeO_3F_2, where Xe is the central atom.

i) Write at least four non-equivalent Lewis (i.e. resonance) structures.

ii) Use formal charges to determine which one of the structures from i) above is expected to be the most stable.

[10]

c) Use appropriate diagrams to illustrate the nature of hydrogen bonding interactions in the following systems:

i) Acetic acid (CH_3COOH)

ii) A liquid mixture of chloform ($CHCl_3$) and propanone (i.e. CH_3COCH_3)

iii) Liquid HF

[6]

Question Six

a) Give complete reaction equations for the following processes:

i) The reaction of SiF_4 with H_2O
ii) Synthesis of calcium carbide
iii) Reaction of aluminium carbide with water
iv) Reaction of Li_3N with water
v) The production of nitric acid
vi) The reaction of P_4O_{10} with water

[14]

b) Draw a Lewis structure for each of the following :

(i) Molecule of phosphorus P_4

(ii) Molecule of sulphur S_8.

[5]

c) Which of the following schemes for the repeating pattern of close-packed planes are not ways of generating close-packed lattices? Explain your answer.

i) ABCABBC .... ii) ABAC..... iii) ABAA.... iv) ABCBC .....

[6]

Commonly Used Physical Constants

Constant	Symbol	Value
acceleration due to gravity	g	9.8 m s^{-2}
atomic mass unit	amu, m_u or u	1.66 x10^{-27} kg
Avogadro's Number	**N**	**6.022 x 10^{23} mol^{-1}**
Bohr radius	a_o	0.529 x 10^{-10} m
Boltzmann constant	k	1.38 x 10^{-23} J K^{-1}
electron charge to mass ratio	$-e/m_e$	-1.7588 x 10^{11} C kg^{-1}
electron classical radius	r_e	2.818 x 10^{-15} m
electron mass energy (J)	m_ec^2	8.187 x 10^{-14} J
electron mass energy (MeV)	m_ec^2	0.511 MeV
electron rest mass	m_e	9.109 x 10^{-31} kg
Faraday constant	F	9.649 x 10^{4} C mol^{-1}
fine-structure constant	α	7.297 x 10^{-3}
gas constant	R	8.314 J mol^{-1} K^{-1}
gravitational constant	G	6.67 x 10^{-11} Nm^2kg^{-2}
neutron mass energy (J)	m_nc^2	1.505 x 10^{-10} J
neutron mass energy (MeV)	m_nc^2	939.565 MeV
neutron rest mass	m_n	1.675 x 10^{-27} kg
neutron-electron mass ratio	m_n/m_e	1838.68
neutron-proton mass ratio	m_n/m_p	1.0014
permeability of a vacuum	μ_o	4π x 10^{-7} N A^{-2}
permittivity of a vacuum	ε_o	8.854 x 10^{-12} F m^{-1}
Planck constant	h	6.626 x 10^{-34} J s
proton mass energy (J)	m_pc^2	1.503 x 10^{-10} J
proton mass energy (MeV)	m_pc^2	938.272 MeV
proton rest mass	m_p	1.6726 x 10^{-27} kg
proton-electron mass ratio	m_p/m_e	1836.15
Rydberg constant	R_H	1.0974 x 10^{7} m^{-1}
speed of light in vacuum	C	2.9979 x 10^{8} m/s
Electronic Charge	e	1.602 x 10^{-19} C

Periodic Table of the Elements

Main Group Representative Elements (groups 1A–2A; 3A–8A)

Metals | Metalloids | Nonmetals

Transition metals (groups 3B–2B)

	1A[a] 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.00794																	2 He 4.002602
2	3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.0067	8 O 15.9994	9 F 18.998403	10 Ne 20.1797
3	11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.065	17 Cl 35.453	18 Ar 39.948
4	19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.64	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
5	37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc [98]	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.293
6	55 Cs 132.90545	56 Ba 137.327	71 Lu 174.967	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
7	87 Fr [223.02]	88 Ra [226.03]	103 Lr [262.11]	104 Rf [261.11]	105 Db [262.11]	106 Sg [266.12]	107 Bh [264.12]	108 Hs [269.13]	109 Mt [268.14]	110 Ds [281.15]	111 Rg [272.15]	112 Cn [285]	113 [284]	114 Fl [289.2]	115 [288]	116 Lv [293]	117 ** [294]	118 [294]

Lanthanide series	57 La 138.9055	58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.259	69 Tm 168.93421	70 Yb 173.04
Actinide series	89 Ac [227.03]	90 Th 232.0381	91 Pa 231.03588	92 U 238.02891	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]

[a] The labels on top (1A, 2A, etc.) are common American usage. The labels below these (1, 2, etc.) are those recommended by the International Union of Pure and Applied Chemistry (IUPAC).

Except for elements 114 and 116, the names and symbols for elements above 113 have not yet been decided.

Atomic weights in brackets are the names of the longest-lived or most important isotope of radioactive elements.

Further information is available at http://www.webelements.com

** Discovered in 2010, element 117 is currently under review by IUPAC.