UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATIONS

ACADEMIC YEAR 2015/2016

TITLE OF PAPER:	INTRODUCTORYINORGANIC 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 physical significance of a radial wave function R(r)?

[1]

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]

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]

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]

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]

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]**

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

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. **[11]**

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]

b) Consider the diatomic molecule C_2. Using <u>valence atomic orbitals and valence electrons only</u>, answer the following questions:

i) Prepare a molecular orbital energy level diagram for the molecule, $\mathbf{C_2}$. [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 $\mathbf{C_2}$ and $\mathbf{C_2^{2-}}$.

iii) For each of the species, 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]

Question Four

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

i) Hydrogen fluoride, HF

ii) CH_3OH

iii) A carboxylic acid RCOOH

iv) $CH_3C(=O)NH_2$, an amide

[9]

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

i) K_2O

ii) $A\ell_4C_3$

iii) Cl_2O_7

[6]

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]

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 **[6]**

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) HCl(g) **[6]**

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

[13]

Question Six

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

i) CaC_2 + **A** ⟶ $Ca(OH)_2$ + **B**

ii) **C** + H_2 ⟶ CaH_2

iii) **D** + heat ⟶ BaO + **E**

iv) $Cl_2(aq)$ + **F** ⟶ **G** + $Br_2(aq)$

v) $SiCl_4 + H_2O$ ⟶ **H** + **I**

vi) **J** + **K** ⟶ $Ca(OH)_2 + AsH_3$

[11]

b) Give an outline of the Born-Haber cycle for the formation of indium chloride, $InCl_3(s)$. **[8]**

c) From a theoretical approach, give three factors that contribute to lattice energy of an ionic compound. Briefly **explain how** each factor affects lattice energy.

[6]

C201: Slater's Rules:

1) Write the correct electron configuration for the atom and organize the orbitals into groupings as follows:

(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 zero to shielding.

3) All other electrons in the same grouping (or same principal quantum number, **n**) 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* (**n-1**)*of the principal quantum number shield to an extent of 0.85 units of nuclear charge per electron. All electrons with two less values* (**n-2**) *of the principal quantum number shield to an extent of 1.00 units per electron.*

5) If the electron of interest is a *d* or an *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:

$Z_{eff} = Z - S$

where

Z_{eff} = effective nuclear charge

Z = atomic number

S = shilelding constant

Fundamental Physical Constants (six significant figures)

Avogadro's number	N_A	$= 6.02214 \times 10^{23}$/mol
atomic mass unit	amu	$= 1.66054 \times 10^{-27}$ kg
charge of the electron (or proton)	e	$= 1.60218 \times 10^{-19}$ C
Faraday constant	F	$= 9.64853 \times 10^{4}$ C/mol
mass of the electron	m_e	$= 9.10939 \times 10^{-31}$ kg
mass of the neutron	m_n	$= 1.67493 \times 10^{-27}$ kg
mass of the proton	m_p	$= 1.67262 \times 10^{-27}$ kg
Planck's constant	h	$= 6.62607 \times 10^{-34}$ J·s
speed of light in a vacuum	c	$= 2.99792 \times 10^{8}$ m/s
standard acceleration of gravity	g	$= 9.80665$ m/s^2
universal gas constant	R	$= 8.31447$ J/(mol·K)
		$= 8.20578 \times 10^{-2}$ (atm·L)/(mol·K)

Rydberg constant = 1.097 x 10^7 m^{-1}

SI Unit Prefixes

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

Conversions and Relationships

Length
SI unit: meter, m

1 km	= 1000 m
	= 0.62 mile (mi)
1 inch (in)	= 2.54 cm
1 m	= 1.094 yards (yd)
1 pm	$= 10^{-12}$ m = 0.01 Å

Volume
SI unit: cubic meter, m^3

1 dm^3	$= 10^{-3}$ m^3
	= 1 liter (L)
	= 1.057 quarts (qt)
1 cm^3	= 1 mL
1 m^3	= 35.3 ft^3

Pressure
SI unit: pascal, Pa

1 Pa	= 1 N/m^2
	= 1 kg/m·s^2
1 atm	$= 1.01325 \times 10^5$ Pa
	= 760 torr
1 bar	$= 1 \times 10^5$ Pa

Mass
SI unit: kilogram, kg

1 kg	$= 10^3$ g
	= 2.205 lb
1 metric ton (t)	$= 10^3$ kg

Energy
SI unit: joule, J

1 J	= 1 kg·m^2/s^2
	= 1 coulomb·volt (1 C·V)
1 cal	= 4.184 J
1 eV	$= 1.602 \times 10^{-19}$ J

Math relationships

$\pi = 3.1416$

volume of sphere $= \frac{4}{3}\pi r^3$

volume of cylinder $= \pi r^2 h$

Temperature
SI unit: kelvin, K

0 K	= −273.15°C
mp of H_2O	= 0°C (273.15 K)
bp of H_2O	= 100°C (373.15 K)
T (K)	$= T$ (°C) + 273.15
T (°C)	$= [T$ (°F) − 32]$\frac{5}{9}$
T (°F)	$= \frac{9}{5}T$ (°C) + 32

PERIODIC TABLE OF THE ELEMENTS

GROUPS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PERIODS	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	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				TRANSITION ELEMENTS							26.982 Al 13	28.0855 Si 14	30.9738 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18
4	39.0983 K 19	40.078 Ca 20	44.956 Sc 21	47.88 Ti 22	50.9415 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	92.9064 Nb 41	95.94 Mo 42	98.907 Tc 43	101.07 Ru 44	102.906 Rh 45	106.42 Pd 46	107.868 Ag 47	112.41 Cd 48	114.82 In 49	118.71 Sn 50	121.75 Sb 51	127.60 Te 52	126.904 I 53	131.29 Xe 54
6	132.905 Cs 55	137.33 Ba 56	138.906 *La 57	178.49 Hf 72	180.948 Ta 73	183.85 W 74	186.207 Re 75	190.2 Os 76	192.22 Ir 77	195.08 Pt 78	196.967 Au 79	200.59 Hg 80	204.383 Tl 81	207.2 Pb 82	208.980 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	(223) Fr 87	226.025 Ra 88	(227) **Ac 89	(261) Rf 104	(262) Ha 105	(263) Unh 106	(262) Uns 107	(265) Uno 108	(266) Une 109									

* Lanthanide series	140.115 Ce 58	140.908 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.925 Tb 65	162.50 Dy 66	164.930 Ho 67	167.26 Er 68	168.934 Tm 69	173.04 Yb 70	174.967 Lu 71
** Actinide series	232.038 Th 90	231.036 Pa 91	238.029 U 92	237.048 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

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.