UNIVERSITY OF SWAZILAND

RE-SIT EXAMINATION

ACADEMIC YEAR 2017/2018

TITLE OF PAPER: Atomic Structure, Chemical Bonding and Chemistry of s- and p-Block Elements

COURSE CODE: CHE221

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS:

1. There are six (6) questions. Answer any four (4) questions. Each question is worth 25 marks.
2. Begin the solution to each question on a new page

A periodic table and a table of universal constants have been provided with this examination paper.

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Question One

a) Radiation of a certain wavelength (λ) excites a hydrogen atom originally in its ground state to the n=6 quantum level.

(i) Calculate the wavelength of the radiation.
(ii) How many emission lines would be observed? Use a suitable diagram to illustrate your answer.

[10]

b) Write a complete set of quantum numbers (n, ℓ, m_ℓ) that quantum theory allows for each of the following orbitals: (i) 2p (ii) 4f.

[5]

c) Write all the sets of quantum numbers that quantum theory allows for an electron in a 3d orbital.

[5]

d) Sketch orbital diagrams that correspond to the angular parts of the following orbitals, indicating the location of nodal planes, if any:

(i) $3d_{x^2-y^2}$ (ii) $6p_y$

[5]

Question Two

(a) Using orbital box diagrams, depict a **valence shell** electron configuration for each of the following ions: (i) Mg^{2+}, (ii) Ga^{2+}, (iii) Cl^-, and (iv) O^{2-}

[8]

(b) Using an orbital box diagram and noble gas notation, show the electron configuration of gallium, Ga. Give the set of quantum numbers for the highest energy electron.

[5]

(c) Answer the following questions:

i) Why is the radius of Li^+ so much smaller than the radius of Li? Why is the radius of F^- so much larger than the radius of F?

ii) Generally ionization energies increase from left to right on proceeding across the period, but this is not true on moving from magnesium (738 kJ/mol) to aluminium (578 kJ/mol). Explain this observation.

[6]

(d) One compound found in alkaline batteries is NiO(OH). When the battery is discharged NiO(OH) is transformed into $Ni(OH)_2$.

(i) Determine oxidation states of nickel in NiO(OH) and $Ni(OH)_2$.

(ii) Using orbital box diagrams, and the noble gas notation, show electron configurations of the nickel ions.

(iii) Are any of the ions paramagnetic? Explain your answer.

[6]

Question Three

a) For each of the molecules or ions below, where S is the central atom, draw a Lewis structure and determine the formal charge on each atom.

[6]

i) $OSCl_2$ ii) $[FSO]^{3-}$

b) Draw Lewis structures for each of the following molecules or ions. Describe the electron pair geometry and molecular geometry around the central atom.

i) SF_4 (S is the central atom)

ii) XeF_4 (Xe is the central atom)

[7]

c) Calcium carbide, CaC_2, contains the acetylide ion, C_2^{2-}. Sketch the molecular orbital energy level diagram for the ion. i) Give the electron configuration for the ion and for C_2^{4-}; ii) determine the bond order for the two ions; iii) Which functional group has the same bond order as C_2^{2-}? And which functional group has the same bond order as C_2^{4-}?

[12]

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]

c) Tungsten has a body-centered cubic lattice with all atoms at the lattice points. The edge length of the unit cell is 316.5 pm.

i) Calculate the volume of the unit cell
ii) Determine the number of tungsten atoms per unit cell
iii) Calculate the density of tungsten

[13]

Question Five

a) Consider the following oxoacids: HClO, $HClO_2$, $HClO_3$, $HClO_4$, $B(OH)_3$, and H_3PO_3.
i) Give the name of each of the acids
ii) Give the formula of the anhydride of each of the acids

[9]

b) Complete and balance the following reactions:

i) $B_2H_6 + H_2O(l) \rightarrow$
ii) $S + O_2(g) \rightarrow$
iii) $Na(s) + O_2(g) \rightarrow$
iv) $PCl_3(s) + Cl_2(g) \rightarrow$
v) $N_2(g) + O_2(g) \rightarrow$
vi) $In(s) + Br_2(l) \rightarrow$
vii) $Sn(s) + Cl_2(g) \rightarrow$
viii) $SiO_2(s) + HF(l) \rightarrow$

[16]

Question Six

a) Give examples of two basic oxides. Write equations illustrating the formation each oxide from its component elements. Write another chemical equation that illustrates the basic character of each oxide.

[5]

b) Place the following oxides in order of increasing basicity: CO_2, SiO_2, SnO_2. Explain your answer.

[3]

c) Write balanced chemical equations for the reaction of hydrogen gas with oxygen, chlorine and nitrogen gases. **[3]**

d) Elemental silicon is oxidized by O_2 to give an unknown A. The compound A dissolves in molten Na_2CO_3 giving B. When B is treated with aqueous hydrochloric acid, C is produced. Identify A, B and C. Give balanced chemical equations that lead to the formation of A, B and C.

[6]

e) The electrolysis of aqueous NaCl gives NaOH, Cl_2 and H_2. Write balanced half reactions taking place at the anode and at the cathode, and use the two reactions to write the net ionic equation.

[3]

f) Aluminium dissolves readily in hot aqueous NaOH to give the aluminate $[Al(OH)_4]^-$, and H_2. Write a balanced equation for this reaction. **[5]**

PERIODIC TABLE OF THE ELEMENTS

GROUPS

TRANSITION ELEMENTS

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 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	28.0855 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.

Fundamental Physical Constants (six significant figures)

Avogadro's number	N_A	$= 6.02214\times10^{23}$/mol
atomic mass unit	amu	$= 1.66054\times10^{-27}$ kg
charge of the electron (or proton)	e	$= 1.60218\times10^{-19}$ C
Faraday constant	F	$= 9.64853\times10^{4}$ C/mol
mass of the electron	m_e	$= 9.10939\times10^{-31}$ kg
mass of the neutron	m_n	$= 1.67493\times10^{-27}$ kg
mass of the proton	m_p	$= 1.67262\times10^{-27}$ kg
Planck's constant	h	$= 6.62607\times10^{-34}$ J·s
speed of light in a vacuum	c	$= 2.99792\times10^{8}$ m/s
standard acceleration of gravity	g	$= 9.80665$ m/s^2
universal gas constant	R	$= 8.31447$ J/(mol·K)
		$= 8.20578\times10^{-2}$ (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 = 1.01325×10^5 Pa
= 760 torr
1 bar = 1×10^5 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 = 1.602×10^{-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