UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2006

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 TABLE OF CONSTANTS AND A PERIODIC TABLE ARE ATTACHED

NON-PROGRAMMABLE ELECTRONIC CALCULATORS MAY BE USED

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QUESTION ONE

(a) Write a short account of photoelectric effect clearly indicating the properties of photoelectric emission. [5]

(b) The basic equation for the photoelectric effect is:

$KE = h\nu - W$, where W = work function.

The work function for caesium is 2.14 eV. What is the kinetic energy and the speed of the electrons emitted when the metal is irradiated with light of wavelength

(i) 200 nm (ii) 800 nm [5]

(c)

(i) Give the values of the quantum numbers for each electron in the valence shell of an atom of nitrogen. [3]

(ii) Draw the shapes of orbitals described by the sets of quantum numbers you have written in part (i). [4]

(d) An electron in the Be^{3+} ion falls from the energy level n = 3 to n = 1. Is radiation absorbed or emitted? Calculate the frequency and wavelength of the radiation. [5]

(e) Write out the ground-state electronic configurations and predict the number of unpaired electrons of each of the following species:

(i) Ti^{3+} (ii) Na^{-} (iii) Ca [3]

QUESTION TWO

Describe the following types of defects that can occur in the solid state. In each case indicate if any electrical conduction is possible and by what mechanism.

(i) Schottky defects [6]

(ii) Frenkel defects [6]

(iii) Metal excess defects [6.5]

(iv) Metal deficiency defects [6.5]

QUESTION THREE

(a) Determine the hybridization for the central atom in each of the following.
(i) BF_3 (ii) CO_2 (iii) OIF_5
In each case predict the geometry using the VSEPR theory. [9]

(b) The resonance forms of H_2 are shown below:

$$H_A^{(1)}H_B^{(2)} \leftrightarrow H_A^{(2)}H_B^{(1)} \leftrightarrow H_A^{(1)(2)}H_B \leftrightarrow H_AH_B^{(1)(2)}$$

P Q R S

Write down wave functions representing each of the resonance forms P, Q, R and S according to valence bond theory. [4]

(c) For the series of diatomics N_2^+, N_2 and N_2^- determine using molecular orbital energy level diagram of N_2:
(i) the bond orders
(ii) the trend in bond lengths
(iii) the trend in bond energies
(iv) magnetic properties [9]

(d) Sketch molecular orbitals that result from combination of $d_{x^2-y^2}$ and $d_{x^2-y^2}$ atomic orbitals on separate atoms. [3]

QUESTION FOUR

(a) The second ionization energies of some Period 4 elements are:

Ca	Sc	Ti	V	Cr	Mn
11.87	12.80	13.80	14.15	16.50	15.64 (eV)

Identify the orbitals from which ionization occurs in each case and account for the trend. [6]

(b) Consider the species Na^+ and Mg^{2+}. Select, giving reasons which one has
(i) higher ionic size. [2]
(ii) higher ionization energy. [2]

(c) Using Slater's rules, calculate the effective nuclear charge (Z^*) for the following electrons:
(i) the valence electron in Ca. [3]
(ii) the valence electron in Mn. [3]
(iii) the 3d electron in Mn. [3]

(d) Provide explanations for the following:
(i) Although oxygen and sulphur are in the same Group of the periodic table, oxygen forms only OF_2 while sulphur forms SF_2, SF_4 and SF_6. [3]
(ii) NH_3 has a larger bond angle than NF_3 [3]

QUESTION FIVE

(a) (i) What are the names of the following:
Na_2O; Na_2O_2; NaO_2

(ii) Which of the above compounds in (a) (i) is paramagnetic? Explain. [3]

(b) Explain the following concepts with relevant examples:

(i) hydrogen bonding. [2]

(ii) the diagonal relationship of elements. [5]

(c) Elements (P), (Q), (R), (S) and (T) all belong to the same period in the periodic table of elements. (P) combines with (Q) to form a gas QP_2 which turns lime water milky. (S) exists as a relatively unreactive diatomic gas, and its compound, SP_2 is a red-brown toxic gas. (R) is a reactive metal and combines with (P) to give the compound R_2P which dissolves in water to give a basic solution. (T) is an unreactive monoatomic gas. A total of 0.100 g of R_2P was dissolved in water, and the resulting solution required 26.63 ml of 0.2513 M HCl for neutralization.

(i) Identify, with reasons, the elements (P), (Q), (R), (S) and (T). [5]

(ii) Calculate the molar mass of the compound R_2P using the given titration data. [5]

(iii) Write the formula of the compound formed between (R) and (S), and write the equation of the reaction between the compound and water. [3]

(iv) If a small sample of compound R_2P is moistened with concentrated HCl and put into a Bunsen flame, what colour, if any, would be produced? [2]

QUESTION SIX

(a) (i) Mention ONE use of hydrogen. [1]

(ii) Give THREE methods of industrial production of hydrogen and ONE method of laboratory preparation. Write the reaction equation in each case. [4]

(iii) Describe the following types of hydrides:

(1) Ionic hydrides. [2]

(2) Covalent hydrides. [2]

(3) Metallic hydrides. [2]

(b) A white crystalline solid is either LiCl or KCl. Give FOUR tests, with relevant reaction equations where necessary, which would help to establish the identity of the solid. [10]

(c) Explain the following observations:

(i) Beryllium salts are acidic. [2]

(ii) Aluminium hydroxide is amphoteric. [2]

PERIODIC TABLE OF 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	VIIIB			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										Atomic mass → **Symbol** → Atomic No. →	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	28.086 **Si** 14	30.974 **P** 15	32.06 **S** 16	35.453 **Cl** 17	39.948 **Ar** 18
4	39.098 **K** 19	40.078 **Ca** 20	44.956 **Sc** 21	47.88 **Ti** 22	50.942 **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	92.906 **Nb** 41	95.94 **Mo** 42	98.907 **Tc** 43	101.07 **Ru** 44	102.91 **Rh** 45	106.42 **Pd** 46	107.87 **Ag** 47	112.41 **Cd** 48	114.82 **In** 49	118.71 **Sn** 50	121.75 **Sb** 51	127.60 **Te** 52	126.90 **I** 53	131.29 **Xe** 54
6	132.91 **Cs** 55	137.33 **Ba** 56	138.91 ***La** 57	178.49 **Hf** 72	180.95 **Ta** 73	183.85 **W** 74	186.21 **Re** 75	190.2 **Os** 76	192.22 **Ir** 77	195.08 **Pt** 78	196.97 **Au** 79	200.59 **Hg** 80	204.38 **Tl** 81	207.2 **Pb** 82	208.98 **Bi** 83	(209) **Po** 84	(210) **At** 85	(222) **Rn** 86
7	223 **Fr** 87	226.03 **Ra** 88	(227) ****Ac** 89	(261) **Rf** 104	(262) **Ha** 105	(263) **Unh** 106	(262) **Uns** 107	(265) **Uno** 108	(266) **Une** 109	(267) **Uun** 110								

***Lanthanide Series**	140.12 **Ce** 58	140.91 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.96 **Eu** 63	157.25 **Gd** 64	158.93 **Tb** 65	162.50 **Dy** 66	164.93 **Ho** 67	167.26 **Er** 68	168.93 **Tm** 69	173.04 **Yb** 70	174.97 **Lu** 71
****Actinide Series**	232.04 **Th** 90	231.04 **Pa** 91	238.03 **U** 92	237.05 **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

( ) indicates the mass number of the isotope with the longest half-life.

General data and fundamental constants

Quantity	Symbol	Value
Speed of light	c	2.997 924 58 X 10^{8} m s^{-1}
Elementary charge	e	1.602 177 X 10^{-19} C
Faraday constant	$F = N_A e$	9.6485 X 10^{4} C mol^{-1}
Boltzmann constant	k	1.380 66 X 10^{23} J K^{-1}
Gas constant	$R = N_A k$	8.314 51 J K^{-1} mol^{-1}
		8.205 78 X 10^{-2} dm^3 atm K^{-1} mol^{-1}
		6.2364 X 10 L Torr K^{-1} mol^{-1}
Planck constant	h	6.626 08 X 10^{-34} J s
	$\hbar = h/2\pi$	1.054 57 X 10^{-34} J s
Avogadro constant	N_A	6.022 14 X 10^{23} mol^{-1}
Atomic mass unit	u	1.660 54 X 10^{-27} Kg
Mass		
electron	m_e	9.109 39 X 10^{-31} Kg
proton	m_p	1.672 62 X 10^{-27} Kg
neutron	m_n	1.674 93 X 10^{-27} Kg
Vacuum permittivity	$\varepsilon_o = 1/c^2\mu_o$	8.854 19 X 10^{-12} J^{-1} C^2 m^{-1}
	$4\pi\varepsilon_o$	1.112 65 X 10^{-10} J^{-1} C^2 m^{-1}
Vacuum permeability	μ_o	4π X 10^{-7} J s^2 C^{-2} m^{-1}
		4π X 10^{-7} T^2 J^{-1} C^{-2} m^3
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	9.274 02 X 10^{-24} J T^{-1}
nuclear	$\mu_N = e\hbar/2m_p$	5.050 79 X 10^{-27} J T^{-1}
g value	g_e	2.002 32
Bohr radius	$a_o = 4\pi\varepsilon_o\hbar/m_e e^2$	5.291 77 X 10^{-11} m
Fine-structure constant	$\alpha = \mu_o e^2 c/2h$	7.297 35 X 10^{-3}
Rydberg constant	$R_\infty = m_e e^4/8h^3 c\varepsilon_o^2$	1.097 37 X 10^{7} m^{-1}
Standard acceleration of free fall	g	9.806 65 m s^{-2}
Gravitational constant	G	6.672 59 X 10^{-11} N m^2 Kg^{-2}

Conversion factors

1 cal	4.184 joules (J)	1 erg	1 X 10^{-7} J
1 eV	1.602 2 X 10^{-19} J	1 eV/molecule	96 485 kJ mol^{-1}
			23.061 kcal mol^{-1}

f	p	n	μ	m	c	d	k	M	G	**Prefixes**
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}	

Spectrochemical Series

$I^- < Br^- < S^{2-} < Cl^- < NO_3^- < F^- < OH^- <$ EtOH $< C_2O_4^{2-} < H_2O <$ EDTA $< (NH_3$, py) < en < dipy $< NO_2^- < CN^- <$ CO