UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2007

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) The entrance doors at airports are often controlled by photoelectric cells. What is the maximum wavelength of light that could be used for such systems with cesium cathodes if electrons are ejected from cesium with a kinetic energy of 9.6×10^{-20} J upon irradiation with 500 nm light? [6]

(b) The He^{+} ion is a one electron-system similar to hydrogen, except that Z = 2. Consider the third and fifth energy levels in the species He^{+}.
- (i) Calculate the frequency of the radiation which this species would absorb in going from the lower of these levels to the upper level.
- (ii) Assuming circular orbits of the simple Bohr theory, calculate the ratio of the radii of the orbits associated with these levels.
- (iii) Calculate the first ionisation potential of He^{+}. [9]

(c) Write out the ground-state electronic configurations and predict the number of unpaired electrons of each of the following species:
(i) Cu^{2+} (ii) Mn^{3-} (iii) V [3]

(d) Calculate the de Broglie wavelength of an electron moving at one-tenth the speed of light. [2]

(e) What is an orbital? Draw the shapes of the orbitals with n = 3 [5]

QUESTION TWO

(a) Relate the tendency of atoms to gain or lose electrons to the types of bonds they form. [8]

(b) If Ge is added to GaAs, the Ge is about equally distributed between the Ga and As sites.
- (i) Which sites would the Ge prefer if Se is added also?
- (ii) Would GaAs doped with Se be an n-type or p-type semiconductor? [4]

(c) The promotion of an electron from the valence band into the conduction band in pure TiO_2 by light absorption requires a wavelength of less than 350 nm. Calculate the energy gap in eV between the valence and conduction bands. [2]

(d) Distinguish intrinsic from extrinsic semiconduction and give an example of each in actual compounds. [8]

(e)
- (i) Complete the following reaction:
  $^{232}_{90}Th + ? \rightarrow {}^{1}_{0}n + {}^{235}_{92}U$ [1]
- (ii) Write equations showing how
  - (1) $^{238}_{92}U$ undergoes α decay.
  - (2) $^{13}_{7}N$ undergoes β^{+} emission. [2]

QUESTION THREE

(a) Determine the hybridization for the central atom in each of the following.
(i) BeF_2 (ii) $TeCl_4$ (iii) $OPCl_3$
In each case predict the geometry using the VSEPR theory. [9]

(b) Assuming that the available atomic orbitals for boron and nitrogen are of equal energy (which is a large assumption),
(i) Give the molecular-orbital energy level diagram for the molecule BN, showing the distribution of electrons in the molecular orbitals available.
(ii) What are the bond orders in these species:
(1) BN (2) BN^{2-} [7]

(c) Sketch π bonding and antibonding molecular orbitals that result from combination of the following atomic orbitals on separate atoms:
(i) p_x and p_x
(ii) p_x and d_{xz} [6]

(d) In which of the following covalent compounds is the central atom obeying the octet rule?
(i) CH_4 (ii) H_2S (iii) ClF_3 [3]

QUESTION FOUR

(a) The ionization energies for Cl^-, Cl and Cl^+ are 343, 1250 and 2300 $kJmol^{-1}$, respectively. Explain these differences. [6]

(b) In each of the following pairs, which is the larger ion? Explain.
(i) S^{2-}, Br^-
(ii) Fe^{2+}, Co^{3+}
(iii) O^{2-}, Se^{2-} [6]

(c) Using Slater's rules, determine the effective nuclear charge (Z*) for the following electrons:
(i) The outermost electron in an oxygen atom.
(ii) A 3d electron in a nickel atom.
(iii) A 4s electron in a nickel atom. [7]

(d) Provide explanations for the following:
(i) Water readily decomposes BCl_3 whereas it has no effect on CCl_4.
(ii) Ionic compounds have high melting points while molecular covalent compounds have low melting points. [6]

QUESTION FIVE

(a) Give equations to show the reaction of hydrogen with:
  (i) N_2 using a catalyst of activated Fe at 380-450 °C and 200 atmospheres pressure.
  (ii) CO over a Cu/Zn catalyst at 300 °C. [4]

(b) Account for the following:
  (i) The variation in boiling points of the Group VIA hydrides whose values are 100, –60, –42 and –2.3 °C for H_2O, H_2S, H_2Se and H_2Te respectively.
  (ii) The trend in the bond angles for the hydrides of the Group VA elements which are as follows:
  NH_3, 106.6°; PH_3, 93.6°; AsH_3, 91.8°; SbH_3, 91.3°. [10]

(c) (i) What products are formed when Li, Na, and K are each burnt in oxygen?
  (ii) How do these products react with water? [6]

(d) On the basis of inductive effect, the Lewis acidity of the boron halides is expected to be $BF_3 > BCl_3 > BBr_3$. Experimentally, the opposite is observed. Explain this anomaly. [5]

QUESTION SIX

(a) A total of 0.4008 g of an alkaline earth metal element (A) reacts with oxygen to give 0.5608 g of an alkaline oxide (B). The metallic element (A) reacts with nitrogen gas to form the compound (C) and with hydrogen gas to form the compound (D). On reacting the compound (D) with water, a gas (E) was given off and a sparingly soluble compound (F) was formed. Compound (F) is also obtained when oxide (B) is dissolved in water. Compound (F) gave a strongly basic aqueous solution, which can be neutralised with hydrochloric acid to form the salt (G). When a sample of the salt (G) was moistened with nitric acid and introduced into a Bunsen burner flame, a red colour was imparted into the Bunsen flame. Bubbling carbon dioxide gas through a solution of compound (F) gave a milky solution of compound (H), which finally became a clear solution of compound (I) as more carbon dioxide passed through the solution.
  (i) Calculate the molar mass of the element (A) and hence identify the element (A). [3]
  (ii) Identify, with reasons, the compounds (B) to (I). [4]
  (iii) Write balanced equations for all the reactions involved. [4]
  (iv) Calculate the volume of 0.750 M HCl required to neutralise the strongly basic solution obtained from 0.5608 g of the metal oxide (B). [4]

(b) Compare and contrast the structures of trimethylamine and trisilylamine. [4]

(c) (i) How would you prepare CO in the laboratory?
  (ii) Give the uses of CO.
  (iii) How can CO be detected? [6]

General data and fundamental constants

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

Conversion factors

1 cal	4.184 joules (J)	1 erg	1×10^{-7} J
1 eV	$1.602\,2 \times 10^{-19}$ 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

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.