UNIVERSITY OF SWAZILAND

FINAL EXAMINATION

ACADEMIC YEAR 2007/2008

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 PERIODIC TABLE AND A TABLE OF CONSTANTS HAVE BEEN PROVIDED WITH THIS EXAMINATION PAPER.

NON-PROGRAMMABLE ELECTRONIC CALCULATORS MAY BE USED

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

QUESTION ONE

(a) What postulates did Bohr advance in explaining how electrons are confined to orbitals instead of slowing down or being attracted towards the nucleus? [5]

(b) The transition from the n = 7 to the n = 2 level of hydrogen atom is accompanied by the emission of light slightly beyond the range of human perception. Determine the energy and the wavelength of this light. [5]

(c) Give all the quantum numbers of each of the valence electrons in chlorine. [3]

(d) Account for the following observations:

(i) Variation in electronegativity

F	Cl	Br	I
4.10	2.83	2.74	2.21

[3]

(ii) Variation in first ionisation energies of Group II metals ($kJmol^{-1}$)

Be	Mg	Ca	Sr
899	737	590	549

[3]

(e) If X, Y and Z represent elements of atomic number 9, 17 and 55 respectively, predict the **type of bonds** and the **formulas formed** between
(i) X and Y (ii) X and Z (iii) Y and Z [6]

QUESTION TWO

(a) Under what circumstances with regard to relative sizes of ions and degree of nonpolar character are Frenkel and Schottky defects likely? [6]

(b) Will Ge-doped Si be an n-type or p-type semiconductor? Justify your choice. [2]

(c) CdS is used as a photoconductor in light-meters. The band gap is about 2.4 eV. What is the shortest frequency of light that can promote an electron from the valence band to the conduction band in CdS? [2]

(d) The hardness of water may be 'temporary' or 'permanent'.
(i) What causes each of these conditions?
(ii) How is each condition treated? [8]

(e) On treatment with cold water, an element (A) reacted quickly liberating a colourless, odourless gas (B) and a solution (C). When carbon dioxide was bubbled through solution (C) an initial white precipitate (D) was formed, but this re-dissolved forming solution (E) when more carbon dioxide was added. Name the substances (A) to (E) and give balanced chemical equations for each of these reactions. [5]

(f) Account for the observation that Methanol, CH_3OH has a much higher boiling point than methyl mercaptan, CH_3SH. [2]

QUESTION THREE

(a) Determine the expected hybridisation of P, O and Sb in $Cl_3P\text{-}O\text{-}SbCl_5$. The P-O-Sb bond angle is 165°. [7]

(b) The hypofluorite ion, OF^- can be observed only with difficulty.
   (i) Draw a clearly labelled energy level molecular orbital diagram for this ion.
   (ii) Deduce the bond order.
   (iii) Deduce how many unpaired electrons are in this ion. [7]

(c) Sketch sigma bonding (σ) and antibonding (σ^*) molecular orbitals that result from the combination of s and p_x atomic orbitals on separate atoms. [3]

(d) For each of the following: Na, Al and S
   (i) write the formula of the most common oxide,
   (ii) classify each of the oxides as basic, acidic or amphoteric,
   (iii) write balanced equations for the reaction with water of the basic and acidic oxides in 3d (ii) above. [8]

QUESTION FOUR

(a) The second ionisation energy of carbon ($C^+ \rightarrow C^{2+} + e^-$) and the first ionisation energy of boron ($B \rightarrow B^+ + e^-$) both fit the reaction $1s^22s^22p^1 \rightarrow 1s^22s^2 + e^-$. Compare the two ionisation energies (24.383 and 8.298 eV, respectively) and explain the difference. [6]

(b) Which of the following pairs has the greater radius?
   (i) The element with atomic number 11 or the single positively charged ion formed by that element.
   (ii) The element with atomic number 14 or the element with atomic number 32.
   (iii) Phosphorus or sulphur. [6]

(c) Use Slater's rules to calculate the effective nuclear charge (Z*) in vanadium experienced by
   (i) one of the 4s electrons.
   (ii) one of the 3d electrons.
   (iii) Which type of electron is more likely to be lost when vanadium forms a positive ion? [7]

(d) Account for the following observations:
   (i) There is no reaction between NCl_3 and Cl_2 whereas PCl_3 reacts with Cl_2 to give PCl_5.
   (ii) Ionic compounds usually react rapidly whilst molecular covalent compounds usually react slowly. [6]

QUESTION FIVE

(a) Describe the difference in structure between $(BeH_2)_n$ and $(BeCl_2)_n$. [6]

(b) Orthoboric acid (or simply boric acid) may be written as H_3BO_3 or $B(OH)_3$.
- (i) How does it ionise in water and which way of writing the formula is the most helpful?
- (ii) How strong an acid is it?
- (iii) Why does glycerol enhance the acidic properties of orthoboric acid?
- (iv) Write a balanced equation for a neutralisation reaction with boric acid. [7]

(c) Boron halides are Lewis acids only but trivalent phosphorus compounds can serve as both Lewis acids and Lewis bases. Explain this observation. [6]

(d) Define the following terms:
(i) β decay (ii) nuclear fusion (iii) isotope [6]

QUESTION SIX

(a) Write the equations to show the reactions between Al and
(i) N_2 (ii) Cl_2 (iii) HCl (iv) NaOH (v) O_2 [5]

(b)
- (i) List three ways of making CO_2.
- (ii) Give three uses of CO_2.
- (iii) How can CO_2 be detected? [7]

(c) Using the data given below, predict the crystal structure of CsF:

Ion	Ionic Radius (pm)
Cs	181
F	119

[3]

(d) Arrange the following compounds in order of increase in lattice energy:
$Mg(OH)_2$, MgO, Al_2O_3, Na_2O, NaOH, $Al(OH)_3$
Justify your order. [5]

(e) The first element in each of the main groups in the periodic table shows anomalous properties when compared with the other members of the same group. Discuss this statement with particular reference to the element Li. [5]

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											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	28.086 **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								

Atomic mass →
Symbol →
Atomic No. →

TRANSITION ELEMENTS

***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	$2.997\ 924\ 58 \times 10^{8}$ 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 $< NO_2^- < CN^- < CO$