UNIVERSITY OF SWAZILAND

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

NON-PROGRAMMABLE ELECTRONIC CALCULATORS MAY BE USED

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QUESTION ONE

(a) The photoelectric effect is the basis of the spectroscopic technique known as photoelectron spectroscopy. An X-ray photon of wavelength 10^{-7} cm is directed onto a piece of potassium metal. If one-fifth of the photon energy is used up for working against electrostatic forces

(i) what will be the maximum wavelength of light that can produce photoelectric current for potassium metal? [3]

(ii) what will be the velocity of the ejected electron for that maximum wavelength? [3]

(b) Calculate the wave numbers in reciprocal meters (m^{-1}) for the first and last lines in the Brackett and Pfund series of the hydrogen atom. Hence calculate the energy in joules associated with these lines. [8]

(c) Various quantum numbers are needed to describe the state of an electron in an atom.

(i) What are these quantum numbers?

(ii) What properties of electrons or atomic orbitals are determined by these quantum numbers? [5]

(d) If X, Y, and Z represent elements of atomic numbers 8, 17 and 56, 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) Show by means of a diagram, and a simple calculation, the value of the radius ratio r^+/r^- which permits a salt to adopt a cation coordination number of three. [3]

(b) Using the data given below, predict the crystal structure of MgS:

<u>Ion</u>	<u>Ionic Radius (pm)</u>
Mg	86
S	170

[3]

(c)

(i) In terms of band theory, explain the difference in the electrical conductivities of a conductor, an insulator and a semi-conductor. [12]

(ii) The energy gap in a semiconductor is 420 $kJmol^{-1}$. Calculate the wavelength of radiation which is just sufficient to excite electrons across the gap. [3]

(d) Decide whether each of the following materials is an n-type or a p-type semi-conductor.

(i) Si doped Ge (ii) GaAs doped with Se [4]

QUESTION THREE

(a) What is meant by each of the following terms?
   (i) Hybridization.
   (ii) Linear Combination of Atomic Orbitals (LCAO) method. [4]

(b) What are the geometric arrangements of sp^3d^2 and sp^3d hybrid orbitals? Give one example of a molecule which has a central atom with sp^3d^2 and another with sp^3d hybrid orbitals. [3]

(c) Draw the molecular orbital diagrams for O_2 and OF and determine the
   (i) bond orders (ii) number of unpaired electrons
   (iii) magnetic properties [12]

(d) Sketch π bonding and antibonding molecular orbitals that result from combination of the following atomic orbitals on separate atoms aligned along their z-axes.
   (i) p_x and p_y (ii) p_x and d_{xy} [6]

QUESTION FOUR

(a) (i) Define ionisation energy. [1]
   (ii) Explain the following observations:
      (1) the ionisation energy of oxygen is less than that of nitrogen even though oxygen is more electronegative and smaller than nitrogen. [3]
      (2) the first ionisation energy of potassium is less than that of calcium, but the second ionisation energy of potassium is greater than that of calcium. [3]

(b) Which of the following pairs has the greater radius:
   (i) the element with atomic number 18 or the element with atomic number 19;
   (ii) the element with atomic number 22 or the most likely ion of that element;
   (iii) the element with atomic number 35 or the most probable ion formed by that element?
   Explain the basis for your choices. [6]

(c) Using Slater's rules calculate the effective nuclear charge experienced by an electron in
   (i) the 4s orbital in Cr. (ii) the 3d orbital in Cr.
   From which orbital would an electron be removed to form the Cr^+ ion? [6]

(d) Explain or account for the following:
   (i) Boron halides are Lewis acids only, but trivalent phosphorus compounds can serve both as Lewis acids and Lewis bases. [3]
   (ii) Although nitrogen and phosphorus are in the same group of the periodic table their chlorides NCl_3 and PCl_3 produce totally different products on hydrolysis. [3]

QUESTION FIVE

(a) Explain or account for the following:

(i) the reactivity and nature of products for the reaction of lithium through caesium with oxygen. [4]

(ii) the boiling point of methane (CH_4) is below that of the corresponding hydride of silicon (SiH_4) but the boiling point of water (H_2O) is above that of hydrogen sulphide (H_2S). [4]

(b)

(i) Draw the structure of diborane, B_2H_6, and describe the bonding. [7]

(ii) Write a balanced chemical equation for the reaction between B_2H_6 and $N(CH_3)_3$. [2]

(c) Give a brief account on each of the following:

(i) Inert pair effect. (ii) Oxides of phosphorus. [8]

QUESTION SIX

(a) On treatment with cold water, an element (P) reacted quietly, liberating a colourless, odourless gas (Q) and a solution (R). The gas (Q) reacts with lithium metal to give a solid product (S) which effervesced with water to give a strongly basic solution (T). When carbon dioxide was bubbled through solution (R), an initial white precipitate (U) was formed, but this re-dissolved to form a solution (V). Precipitate (U) gives off a gas with dilute hydrochloric acid, and produced a deep red colouration to a Bunsen flame. When (U) was heated with carbon at 1000 °C, a caustic white compound (W) was formed, which when heated with carbon at 1000 °C gave a solid (X) which has some commercial importance.

(i) Identify with reasons the compounds (P) to (X).

(ii) Write balanced equations for each of the reactions described above.

(iii) A total of 1.000 g of (P) was added to water and the solution is made up to 250 mL in a volumetric flask. If 25.00 mL of the resulting solution is titrated with 0.0250 M HCl, calculate the volume of HCl required for neutralization. [10]

(b) Write a balanced reaction equation to show the amphoteric nature of $Be(OH)_2$. [2]

(c)

(i) What is an "alum"?

(ii) Give the formulae of TWO alums. Choose one of the alums, and describe simple chemical tests to identify the ions in the compound. Write equations for your tests where possible. [6]

(d) Define the following terms:

(i) α decay. (ii) γ radiation. (iii) nuclear fission. [3]

(e)

(i) Write equations showing how ${}^{27}_{12}Mg$ and ${}^{40}_{19}K$ undergo β decay and electron capture respectively. [2]

(ii) Complete the following reaction:

$${}^{6}_{3}Li + {}^{1}_{0}n \rightarrow ? + {}^{3}_{1}H$$ [1]

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	$2.997\ 924\ 58 \times 10^{8}$ 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