

**UNIVERSITY OF SWAZILAND**  
**SUPPLEMENTARY EXAMINATION**  
**ACADEMIC YEAR 2007/2008**

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**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.**

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**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) 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 ( $\text{m}^{-1}$ ) 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  $420 \text{ kJ mol}^{-1}$ . Calculate the wavelength of radiation which is just sufficient to excite electrons across the gap. [3]
- (d) Which type of semiconductor (n-type or p-type) are the following materials? Justify your choice in each case.
- (i) Si doped Ge
  - (ii) GaAs doped with Se [4]

### QUESTION THREE

- (a) Explain briefly 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  $\pi$  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 ( $\text{CH}_4$ ) is below that of the corresponding hydride of silicon ( $\text{SiH}_4$ ) but the boiling point of water ( $\text{H}_2\text{O}$ ) is above that of hydrogen sulphide ( $\text{H}_2\text{S}$ ). [4]
- (b)
- (i) Draw the structure of diborane,  $\text{B}_2\text{H}_6$ , and describe the bonding. [7]
  - (ii) Write a balanced chemical equation for the reaction between  $\text{B}_2\text{H}_6$  and  $\text{N}(\text{CH}_3)_3$ . [2]
- (c) Describe concisely the following:
- (i) Inert pair effect. [8]
  - (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  $1000^\circ\text{C}$ , a caustic white compound (W) was formed, which when heated with carbon at  $1000^\circ\text{C}$  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 was 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  $\text{Be}(\text{OH})_2$ . [2]
- (c)
- (i) What is an "alum"? [1]
  - (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)  $\alpha$  decay. [3]
  - (ii)  $\gamma$  radiation. [3]
  - (iii) nuclear fission. [3]
- (e)
- (i) Write equations showing how  $^{27}_{12}\text{Mg}$  and  $^{40}_{19}\text{K}$  undergo  $\beta$  decay and electron capture respectively. [2]
  - (ii) Complete the following reaction:  
 $^6_3\text{Li} + ^1_0\text{n} \rightarrow ? + ^3_1\text{H}$  [1]

# PERIODIC TABLE OF ELEMENTS

## GROUPS

PERIODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VII B	VIII B			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 H 1	9.012 He 2																
2	6.941 Li 3	9.012 Be 4																
3	22.990 Na 11	24.305 Mg 12																
<b>TRANSITION ELEMENTS</b>																		
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) Uuh 106	(262) Uns 107	(265) Uno 108	(266) Une 109	(267) Uun 110								

Atomic mass →  
Symbol ←→  
Atomic No. ←

*Lanthanide Series													
140.12	140.91	144.24	(145)	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04	174.97
Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
**Actinide Series													
232.04	231.04	238.03	237.05	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(260)
Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	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	$c$	$2.997\,924\,58 \times 10^8 \text{ m s}^{-1}$
Elementary charge	$e$	$1.602\,177 \times 10^{-19} \text{ C}$
Faraday constant	$F = N_A e$	$9.6485 \times 10^4 \text{ C mol}^{-1}$
Boltzmann constant	$k$	$1.380\,66 \times 10^{-23} \text{ J K}^{-1}$
Gas constant	$R = N_A k$	$8.314\,51 \text{ J K}^{-1} \text{ mol}^{-1}$ $8.205\,78 \times 10^{-2} \text{ dm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$ $6.2364 \times 10 \text{ L Torr K}^{-1} \text{ mol}^{-1}$
Planck constant	$h$ $\hbar = h/2\pi$	$6.626\,08 \times 10^{-34} \text{ J s}$ $1.054\,57 \times 10^{-34} \text{ J s}$
Avogadro constant	$N_A$	$6.022\,14 \times 10^{23} \text{ mol}^{-1}$
Atomic mass unit	$u$	$1.660\,54 \times 10^{-27} \text{ Kg}$
Mass		
electron	$m_e$	$9.109\,39 \times 10^{-31} \text{ Kg}$
proton	$m_p$	$1.672\,62 \times 10^{-27} \text{ Kg}$
neutron	$m_n$	$1.674\,93 \times 10^{-27} \text{ Kg}$
Vacuum permittivity	$\epsilon_0 = 1/c^2 \mu_0$ $4\pi\epsilon_0$	$8.854\,19 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$ $1.112\,65 \times 10^{-10} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$
Vacuum permeability	$\mu_0$	$4\pi \times 10^{-7} \text{ J s}^2 \text{ C}^{-2} \text{ m}^{-1}$ $4\pi \times 10^{-7} \text{ T}^2 \text{ J}^{-1} \text{ C}^{-2} \text{ m}^3$
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\,02 \times 10^{-24} \text{ J T}^{-1}$
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\,79 \times 10^{-27} \text{ J T}^{-1}$
g value	$g_e$	2.002 32
Bohr radius	$a_0 = 4\pi\epsilon_0\hbar/m_e e^2$	$5.291\,77 \times 10^{-11} \text{ m}$
Fine-structure constant	$\alpha = \mu_0 e^2 c/2\hbar$	$7.297\,35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4/8\hbar^3 c \epsilon_0^2$	$1.097\,37 \times 10^7 \text{ m}^{-1}$
Standard acceleration of free fall	$g$	$9.806\,65 \text{ m s}^{-2}$
Gravitational constant	$G$	$6.672\,59 \times 10^{-11} \text{ N m}^2 \text{ Kg}^{-2}$

## Conversion factors

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

f	p	n	$\mu$	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

$\Gamma^- < \text{Br}^- < \text{S}^{2-} < \text{Cl}^- < \text{NO}_3^- < \text{F}^- < \text{OH}^- < \text{EtOH} < \text{C}_2\text{O}_4^{2-} < \text{H}_2\text{O} < \text{EDTA} < (\text{NH}_3, \text{py}) < \text{en} < \text{dipy} < \text{NO}_2^- < \text{CN}^- < \text{CO}$