UNIVERSITY OF SWAZILAND

SUPPLEMENTARY FINAL EXAMINATION

ACADEMIC YEAR 2008/2009

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) The second ionization energy of helium is almost exactly four times the ionization energy of H, and the third ionization energy of Li is almost exactly nine times the ionization energy of hydrogen:

$H(g) \longrightarrow H(g)^{+} + e^{-}$ $\quad IE(H) = 1.3120 \times 10^{6}\ kJ.mol^{-1}$

$He^{+}(g) \longrightarrow He^{+}(g) + e^{-}$ $\quad IE_2(He) = 5.2504 \times 10^{6}\ kJ.mol^{-1}$

$Li^{2+}(g) \longrightarrow Li^{3+}(g) + e^{-}$ $\quad IE_3(Li) = 11.8149 \times 10^{6}\ kJ.mol^{-1}$

Explain this trend on the basis of the Bohr equation for energy levels of single electron systems. **[5 marks]**

b) (i) Calculate Z^{*} for a 6*s* electron and a 5d electron in Platinum.

(ii) Based on your Z* values, which one of the two orbitals is expected to lie lower in energy? Explain your answer.

[5 marks]

c) For which of the following species can the Bohr theory be used to estimate energy level?

i) He ii) Be^{2+} iii) Be^{4+} iv) H^{-}

[4 marks]

d) On the same axis set, sketch approximate (i.e. qualitative) representations of the function $4\pi r^2[R(r)]^2$ for 1s orbital of H and B^{4+}. Indicate the positions of the most probable values, r_p, in the diagram. Explain any differences between the two representations. **[5 marks]**

e) Give the name and symbol for each of the atoms whose **ground state electron configurations in their outer shells** are given below:

i) $3s^2 3p^6 4s^2$
ii) $4s^2 4p^6 4d^{10v} 5s^2 5p^3$
iii) $6s^2 6p^6$

[6 marks]

Question Two

(a) Magnesium oxide and sodium fluoride have the same arrangement of ions in the solid state. Explain the observation that MgO is nearly twice as hard as NaF and has a much higher melting point than NaF (2800° compared to 993°). **[4 marks]**

b) Write down a reaction equation that defines the process to which each of the following refers:

i) IE_4 of Sn
ii) Overall process corresponding to ($IE_1 + IE_2 + IE_3$) of aluminium, Al

[3 marks]

c) EA_1 and EA_2 for O atom are -141 and +798 $kJmol^{-1}$ respectively. Write the equation for each individual process as well as the overall process and, determine the value of ΔH_{EA} for the overall process.

[3 marks]

d) Explain the following:

i) There is a decrease in first ionization energy on moving from N to O
ii) The substantial decrease in first ionization energy observed between Mg and Ca, is not observed on moving from Al to Ga
iii) In water, Li is as strong a reducing agent as cesium
iv) Elements with a large difference in electronegavity will tend to form ionic bonds with one another

[12 marks]

e) The C-C bond length in ethane is 154 pm and that of the Cl-Cl is 198.8 pm. Estimate the length of the C-Cl bond in chloroethane.

[3 marks]

Question Three

a) Sketch simple orbital diagrams to illustrate the following bonding interactions:

i) A p_π-p_π interaction
ii) A p_π-d_π interaction
iii) π interactions in H-C≡C-H

[5 marks]

b) Construct an MO diagram for the formation of O_2; show only the participation of valence orbitals of the oxygen atoms. Use the diagram to answer the following questions:

i) Rationalize the following trend in O-O bond distances: O_2, 121 pm; O_2^+, 112 pm; O_2^-, 134 pm; O_2^{2-}, 149 pm
ii) Which of the species in i) above are paramagnetic?

[8 marks]

c) Consider the species SO_3 and SO_3^{2-}. For each of the species:

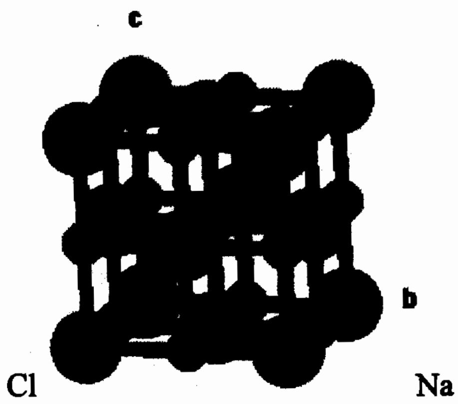
i) write four non-equivalent Lewis structures
ii) determine the best Lewis structure
iii) determine the average bond order for the best Lewis structure
iv) give the hybridization of the central atom

[12 marks]

Question Four

a) Determine the number formula units in the unit cell of sodium chloride (shown below). [Note: Sodium ions are represented by the small grey spheres].

[4 marks]



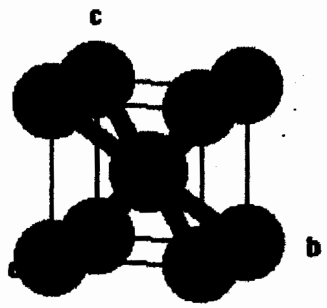
b) Give an outline of the Born-Haber cycle depicting the formation of a metal halide, $MX_2(s)$, starting with a metal M(s) and a halogen $X_2(g)$. Calculate the electron affinity of X(g) from the following data:

Standard heat of formation of $MX_2(s)$	-798 $kJmol^{-1}$
Heat of sublimation of M(s)	+193 $kJmol^{-1}$
Dissociation energy of $X_2(g)$	+242 $kJmol^{-1}$
Ionization energy of M(g) to $M^{2+}(g)$	+1725 $kJmol^{-1}$
Lattice energy of $MX_2(s)$	-2260 $kJmol^{-1}$

[9 marks]

c) Calculate the inter-ionic distance (in Å) in CsI which crystallizes in CsCl system (**1 formula unit per unit cell**) and has density 4.51 $g.cm^{-3}$. [Note: The CsCl structure is shown below where the cesium ion is represented by the black sphere at the centre of the cube].

[12 marks]



Question Five

a) A compound **A** was isolated from the reaction between a **group 1** metal **M** and **O_2**. Compound **A** reacts with water to give only **MOH**, while **M** reacts in a controlled manner with water giving **MOH** and another product **B**.

i) Suggest the identities of **M**, **A** and **B**.
ii) Write equations for the reactions described
iii) Compare the reaction between M and O_2 with that between the other group 1 metals and O_2.

[8 marks]

b) With the help of a balanced reaction equation as an example, illustrate how Li, in some instances, does not resemble the other group 1 metals but resembles Mg. Give a brief explanation for this type of behaviour. **[6 marks]**

c) For each of the following, draw a likely structure, state the geometry and the coordination number around the central atom: **[6 marks]**

i) The dimer of $BeCl_2$ (present in vapour phase below 1020 K)
ii) $BeCl_2.2Et_2O$ (formed when $BeCl_2$ is dissolved in ether)

d) Explain each of the following:

i) $Be(OH)_2$ is virtually insoluble in water , but is soluble in aqueous solution containing excess hydroxide ions.
ii) The Be^{2+} ion forms the tetrahedral complex ion, $[Be(OH_2)_4]^{2+}$, while the Mg^{2+} ion forms octahedral complex ion, $[Mg(OH_2)_6]^{2+}$.

[5 marks]

Question Six

a) With the help of chemical reactions, give an outline of basic steps involved in the extraction of the following metals.

i) Boron from borax **[5 marks]**

ii) Aluminium from bauxite **[8 marks]**

b) Identify the boron compounds **A**, **C**, **D** and **E** in the following equations: **[6 marks]**

$$BF_3 + LiBH_4 \longrightarrow \textbf{A (gas)}$$

$$\textbf{A} + H_2O \longrightarrow \textbf{C}$$

$$\textbf{C} \xrightarrow{\Delta} \textbf{D}$$

$$\textbf{C} + OH^- \longrightarrow \textbf{E}$$

c) Aluminium metal reacts with $Hg(CH_3)_2$ to form Hg and trimethylaluminium which is covalent and exists as a dimer.

(i) Give a balanced equation for the reaction. **[2 marks]**

(ii) Describe the probable structure of the aluminium compound and the type of bonding present in the structure. **[4 marks]**

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Fundamental Constants

Quantity	Symbol	Value	SI unit
Speed of light in vacuum	c	$2.997\,925 \times 10^{8}$	m s^{-1}
Elementary charge	e	$1.602\,189 \times 10^{-19}$	C
Planck constant	h	$6.626\,18 \times 10^{-34}$	J s
Avogadro constant	N_A	$6.022\,04 \times 10^{23}$	mol^{-1}
Atomic mass unit	1u	$1.660\,566 \times 10^{-27}$	kg
Electron rest mass	m_e	$0.910\,953 \times 10^{-30}$	kg
Proton rest mass	m_p	$1.672\,649 \times 10^{-27}$	kg
Neutron rest mass	m_n	$1.674\,954 \times 10^{-27}$	kg
Faraday constant	F	$9.648\,46 \times 10^{4}$	C mol^{-1}
Rydberg constant	R_H	$1.097\,373 \times 10^{7}$	m^{-1}
Bohr radius	a_0	$0.529\,177 \times 10^{-10}$	m
Electron magnetic moment	μ_e	$9.284\,83 \times 10^{-24}$	J T^{-1}
Proton magnetic moment	μ_p	$1.410\,617 \times 10^{-26}$	J T^{-1}
Bohr magneton	μ_B	$9.274\,08 \times 10^{-24}$	J T^{-1}
Nuclear magneton	μ_N	$5.050\,82 \times 10^{-27}$	J T^{-1}
Molar gas constant	R	8.314 41	J mol^{-1} K^{-1}
Molar volume of ideal gas (stp.)	V_m	0.022 413 8	m^3 mol^{-1}
Boltzmann constant	k	$1.380\,662 \times 10^{-23}$	J K^{-1}

Periodic Table of the Elements

GROUP 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** 98.906*	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** ★ 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** 209.98*	85 **At** 209.99*	86 **Rn** 222.02*
87 **Fr** 223.02	88 **Ra** 226.03*	89 **Ac** ▲ 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (262)	108 **Hs** (269)	109 **Mt** (266)	110 (273)	111 (272)	112 (294)						

★Lanthanide series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92*	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
▲Actinide series	90 **Th** 232.04*	91 **Pa** 231.04*	92 **U** 238.03	93 **Np** 237.05*	94 **Pu** 239.05*	95 **Am** 241.06*	96 **Cm** 244.06*	97 **Bk** 249.08*	98 **Cf** 252.08*	99 **Es** 252.08*	100 **Fm** 257.10*	101 **Md** 258.10*	102 **No** 259.10*	103 **Lr** 262.11*

Note: Atomic masses shown here are the 1993 IUPAC values with a maxium of five significant figures (T. B. Coplen *et al.*, *Inorg. Chim. Acta* 1994, *217*, 217). An asterisk indicates the mass of a commonly known radioisotope. Numbers in parentheses are the mass numbers of the corresponding longer-lived isotope.