UNIVERSITI SAINS MALAYSIA

First Semester Exams
Academic Session 2005/2006

November 2005

KTT 111 – Inorganic Chemistry I

Time: 3 hours

Make sure this question paper contains NINE printed pages before you start this exam.

Answer any FIVE questions.

Only the first five questions answered in the answer book will be marked. Supporting references and data constants needed for the questions are included on the last page.

<u>You must start each question on a new page.</u>

1. (a) Uranium is used as a fuel, primarily in the form of its oxide, in nuclear power plants. A small sample of uranium metal (0.2055 g) is heated to 800 to 900 °C in air to give 0.2400 g of a dark green oxide, U_xO_y.

   (i) How many moles of uranium metal were used?

   (ii) What is the empirical formula of the oxide U_xO_y?

   (iii) If the empirical formula is the same as the formula unit, what is the name of the oxide?

   (iv) How many moles of U_xO_y must have been obtained?

(5 marks)

   (b) The oxide U_xO_y is also obtained if $UO_2(NO_3).nH_2O$ is heated to temperatures greater than 800 °C in air. However, if you heat it below 200 °C, only the water of hydration is lost. If you have 0.865 g $UO_2(NO_3).nH_2O$ and obtain 0.679 g $UO_2(NO_3)$ on heating, how many molecules of water of hydration were there in each formula unit of the original nitrate?

(6 marks)

   (c) A mixture consisting of KCl and $MgCl_2$ weighs 1.2505 g. The mixture was dissolved in water and an excess of $AgNO_3$ was added. The chloride ions were precipitated as AgCl. The mass of AgCl obtained was 2.5788 g. Calculate the percentages of KCl and $MgCl_2$ in the original mixture.

(9 marks)

2. (a) In planet Qzac-α, there are three (3) spin quantum numbers (m_s = 0, or +1/2 or -1/2). All other rules for the electron in an orbital are the same as on Earth.

   (i) How many groups of *p*-elements will there be in the periodic table on Qzac-α?

(2 marks)

   (ii) How many groups of *d*-elements will there be in the periodic table on Qzac-α?

(2 marks)

   (iii) Draw the periodic table (similar in structure to the periodic table on Earth) for the first 30 elements on planet Qzac-α. Use the alphabets $_1$A, $_2$B, $_3$C, ...$_{25}$Y, $_{26}$Z and $_{27}$Ae, $_{28}$Af, $_{29}$Bc and $_{30}$Cq as the symbols and the atomic numbers to help you.

(7 marks)

   (iv) What will be the symbol and atomic number of the first three noble gases on planet Qzac-α?

(3 marks)

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(v) Write the formulae of the compounds between F and Z.

(1 mark)

(b) Explain clearly the terms "orbit" and "orbital".

(5 marks)

3. (a) Suppose an electron in an excited state can return to the ground state in two steps. It first falls to an intermediate state, emitting radiation of wavelength λ_1 and then it falls to the ground state, emitting radiation of wavelength λ_2. The same electron from the original excited state can return to the ground state in one step, with the emission of radiation of wavelength λ. Show that the following relationship is true:

$$\frac{1}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

(4 marks)

(b) The energy needed to ionize an atom of an element X when it is in its most stable state is 500 kJ mol^{-1}. However, if an atom of X is in its lowest excited state, only 120 kJ mol^{-1} is needed to ionize it. What is the wavelength of the radiation emitted when an atom of X undergoes a transition from the lowest excited state to the ground state?

(5 marks)

(c) Plot a graph of first ionization energy versus the atomic number for the elements shown in the table below.

Element	**IE_1 x 10^6 J/mol**
Li	0.52
Be	0.90
B	0.80
C	1.09
N	1.40
O	1.31
F	1.68
Ne	2.08

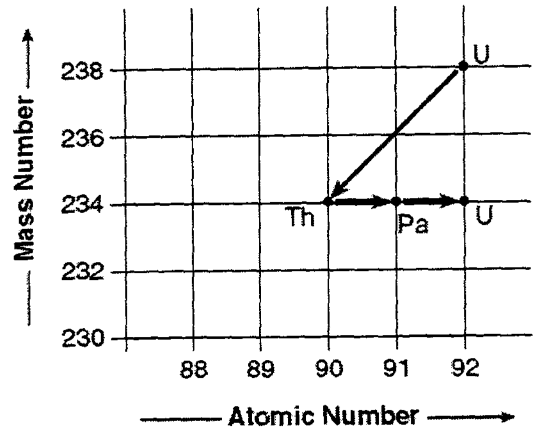
Explain in detail the characteristic shape of the graph that you have drawn.

(6 marks)

(d) Give the set of four quantum numbers for each of the electrons in a boron atom.

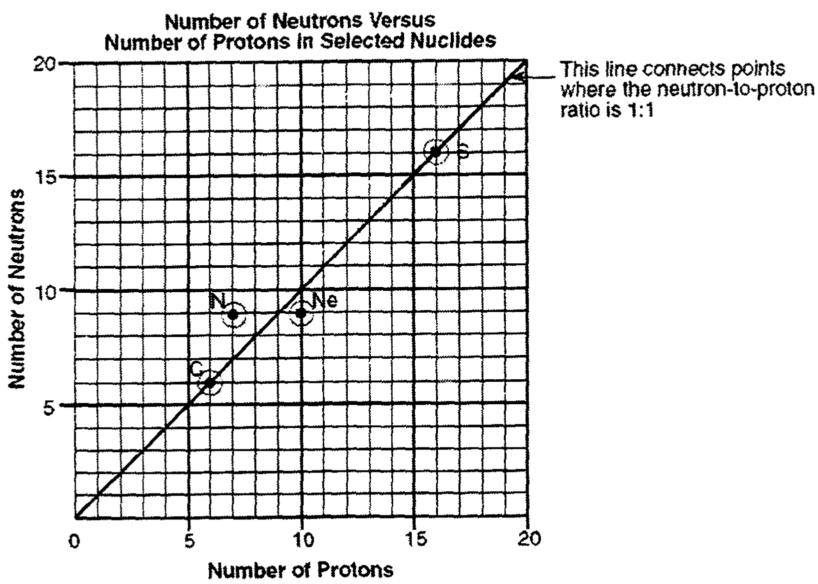
(5 marks)

4. (a) The chart shows the spontaneous decay of U-238 to Pa-234 to U-234. Describe each step of the transformation that has taken place.



(3 marks)

(b) The chart shows part of the belt of stability for the elements C, N, Ne and S.



(i) Draw a table that shows the distribution of neutron and proton for all the elements shown on the graph.

(ii) Explain why S-32 is a stable nuclei.

(iii) What is the neutron: proton ratio for N-16?

(iv) Suggest a possible decay mechanism for the N-16 to become stable.

(6 marks)

(c) The hydrogen bomb that use fusion reactions were developed during World War II. One reaction used in a hydrogen bomb was

$$^{2}_{1}H \; + \; ^{3}_{1}H \; \rightarrow \; ^{4}_{2}He \; + \; ^{1}_{0}n$$

Calculate the energy, in kJ <u>per gram of reactants</u>, for this reaction.
[$^{2}_{1}H$ = 2.01355 g mol^{-1}; $^{3}_{1}H$ = 3.01550 g mol^{-1}; $^{4}_{2}He$ = 4.00150 g mol^{-1}; $^{1}_{0}n$ = 1.00867 g mol^{-1}].

(5 marks)

(d) Iodine-131 is used in the form of sodium iodide to treat cancer of the thyroid. The isotope decays by ejecting a β particle.

(i) Write the balanced equation to show this decay process.

(ii) The isotope has a half-life of 8.05 days. If 25.0 mg of $Na^{131}I$ was used to treat a thyroid cancer patient, what mass of the sodium salt remains in the patient after 30 days?

(6 marks)

5. (a) Define or briefly explain the following:

(i) Dipole moment

(ii) Octet rule

(iii) Ionization potential

(iv) Resonance energy

(v) p- and n-type semiconductors

(5 marks)

(b) What are liquid crystals? How do you differentiate between nemectic liquid crystals and smectic liquid crystals?

(3 marks)

(c) "A covalent bond formed between two hydrogen atoms results in the lowering of potential energy". Explain this statement with reference to a suitable diagram.

(5 marks)

(d) Draw and label a Born-Haber cycle for the formation of $CaBr_2(s)$ from the respective elements at the standard states. Calculate the lattice energy of $CaBr_2(s)$. Comment briefly on the relative stability and ease of formation of $CaBr_2(s)$ and $CaCl_2(s)$ based on their lattice energies.
[Relevant energy data as given in Table 1]

(7 marks)

Table 1

Calcium	
Ionization Energy: 1^{st}	1146 kJ mol^{-1}
2^{nd}	590 kJ mol^{-1}
3^{rd}	4912 kJ mol^{-1}
Heat of Sublimation	192 kJ mol^{-1}
Bromine	
Electron Affinity	331 kJ mol^{-1}
Bond Energy	192 kJ mol^{-1}
Heat of Vaporization	31 kJ mol^{-1}
Heat of Formation	
$CaCl_2$	795 kJ mol^{-1}
$CaBr_2$	683 kJ mol^{-1}
Lattice Energy	
$CaCl_2$	2269 kJmol^{-1}

6. (a) Draw the basic geometrical shapes for the following ions or compounds; $[BF_4]^-$, CCl_3Br, SF_4, SF_6, PCl_5 and $[PF_4]^-$.

(3 marks)

(b) Explain and give examples, how Valence Bond Theory accounts for the shapes and orbital hybridizations of sp^3d and sp^3d^2.

(6 marks)

(c) Explain the application of Band Theory to classify materials into conductor, insulator and semiconductor.

(3 marks)

(d) (i) Construct and label molecular orbital energy diagrams for the following diatomic molecules; He_2, B_2 and O_2.

(4 marks)

(ii) Calculate the net bond order of the above diatomic molecules and give comment on their existence and stability.

(4 marks)

7. (a) Name the types of crystals and describe briefly the nature of their lattice sites.

(4 marks)

(b) A two dimensional (2D) layer of closely-packed identical atoms may form lattices, cubic closest-packed (ccp) or hexagonal closest-packed (hcp), depending on the addition and orientation of the subsequent similar 2D layer of closely-packed atoms above and below it.

(i) With the aid of sketches describe the construction of ccp and hcp lattices.

(7 marks)

(ii) Calculate the number of atoms in each ccp and hcp lattice.

(3 marks)

(iii) Metallic gold crystallizes in a face-centered cubic (fcc) lattice. Calculate the atomic radius of gold if the unit cell length is 4.07 Å.

(2 marks)

(c) A metal alkoxide of general formula $M(OR)_4$ was used to prepare a ceramic material via sol-gel process. What are the reaction steps involved for the ceramic formation from the above alkoxide?

(4 marks)

APPENDIX:

Table of relative atomic mass and physical constants

Symbol	Name	Atomic Wt		Symbol	Name	Atomic Wt
Ac	Actinium	[227]		**Mo**	Molybdenum	95.94(2)
Al	Aluminium	26.981538(2)		**Nd**	Neodymium	144.24(3)
Am	Americium	[243]		**Ne**	Neon	20.1797(6)
Sb	Antimony	121.760(1)		**Np**	Neptunium	[237]
Ar	Argon	39.948(1)		**Ni**	Nickel	58.6934(2)
As	Arsenic	74.92160(2)		**Nb**	Niobium	92.90638(2)
At	Astatine	[210]		**N**	Nitrogen	14.0067(2)
Ba	Barium	137.327(7)		**No**	Nobelium	[259]
Bk	Berkelium	[247]		**Os**	Osmium	190.23(3)
Be	Beryllium	9.012182(3)		**O**	Oxygen	15.9994(3)
Bi	Bismuth	208.98038(2)		**Pd**	Palladium	106.42(1)
Bh	Bohrium	[264]		**P**	Phosphorus	30.973761(2)
B	Boron	10.811(7)		**Pt**	Platinum	195.078(2)
Br	Bromine	79.904(1)		**Pu**	Plutonium	[244]
Cd	Cadmium	112.411(8)		**Po**	Polonium	[209]
Cs	Caesium	132.90545(2)		**K**	Potassium	39.0983(1)
Ca	Calcium	40.078(4)		**Pr**	Praseodymium	140.90765(2)
Cf	Californium	[251]		**Pm**	Promethium	[145]
C	Carbon	12.0107(8)		**Pa**	Protactinium	231.03588(2)
Ce	Cerium	140.116(1)		**Ra**	Radium	[226]
Cl	Chlorine	35.453(2)		**Rn**	Radon	[222]
Cr	Chromium	51.9961(6)		**Re**	Rhenium	186.207(1)
Co	Cobalt	58.933200(9)		**Rh**	Rhodium	102.90550(2)
Cu	Copper	63.546(3)		**Rb**	Rubidium	85.4678(3)
Cm	Curium	[247]		**Ru**	Ruthenium	101.07(2)
Db	Dubnium	[262]		**Rf**	Rutherfordium	[261]
Dy	Dysprosium	162.500(1)		**Sm**	Samarium	150.36(3)
Es	Einsteinium	[252]		**Sc**	Scandium	44.955910(8)
Er	Erbium	167.259(3)		**Sg**	Seaborgium	[266]
Eu	Europium	151.964(1)		**Se**	Selenium	78.96(3)
Fm	Fermium	[257]		**Si**	Silicon	28.0855(3)
F	Fluorine	18.9984032(5)		**Ag**	Silver	107.8682(2)
Fr	Francium	[223]		**Na**	Sodium	22.989770(2)
Gd	Gadolinium	157.25(3)		**Sr**	Strontium	87.62(1)
Ga	Gallium	69.723(1)		**S**	Sulfur	32.065(5)
Ge	Germanium	72.64(1)		**Ta**	Tantalum	180.9479(1)
Au	Gold	196.96655(2)		**Tc**	Technetium	[98]
Hf	Hafnium	178.49(2)		**Te**	Tellurium	127.60(3)
Hs	Hassium	[277]		**Tb**	Terbium	158.92534(2)

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He	Helium	4.002602(2)		**Tl**	Thallium	204.3833(2)
Ho	Holmium	164.93032(2)		**Th**	Thorium	232.0381(1)
H	Hydrogen	1.00794(7)		**Tm**	Thulium	168.93421(2)
In	Indium	114.818(3)		**Sn**	Tin	118.710(7)
I	Iodine	126.90447(3)		**Ti**	Titanium	47.867(1)
Ir	Iridium	192.217(3)		**W**	Tungsten	183.84(1)
Fe	Iron	55.845(2)		**Uub**	Ununbium	[285]
Kr	Krypton	83.798(2)		**Uuh**	Ununhexium	
La	Lanthanum	138.9055(2)		**Uun**	Ununnilium	[281]
Lr	Lawrencium	[262]		**Uuo**	Ununoctium	
Pb	Lead	207.2(1)		**Uuq**	Ununquadium	[289]
Li	Lithium	[6.941(2)]		**Uuu**	Unununium	[272]
Lu	Lutetium	174.967(1)		**U**	Uranium	238.02891(3)
Mg	Magnesium	24.3050(6)		**V**	Vanadium	50.9415(1)
Mn	Manganese	54.938049(9)		**Xe**	Xenon	131.293(6)
Mt	Meitnerium	[268]		**Yb**	Ytterbium	173.04(3)
Md	Mendelevium	[258]		**Y**	Yttrium	88.90585(2)
Hg	Mercury	200.59(2)		**Zn**	Zinc	65.409(4)
				Zr	Zirconium	91.224(2)

Physical constants:

1 amu $= 1.6606 \times 10^{-24}$ g	1 electron volt $= 1.6022 \times 10^{-19}$ J $= 96.485$ kJ mol^{-1}.
$N_A = 6.022 \times 10^{23}$ particles mol^{-1}	$\pi = 3.1416$
R $= 0.08206$ L atm mol^{-1} K^{-1} $= 1.987$ cal mol^{-1} K^{-1} $= 8.3145$ J mol^{-1} K^{-1} $= 8.3145$ kPa dm^3 mol^{-1} K^{-1}	
h $= 6.6262 \times 10^{-34}$ J s. $= 6.6262 \times 10^{-27}$ erg s.	
c $= 2.9979 \times 10^{8}$ m s^{-1}.	
e $= 1.60219 \times 10^{-19}$ coulomb	

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