NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

INORGANIC CHEMISTRY I

SCH 1211

Second Semester Examination Paper

MAY 2017

This examination paper consists of 5 pages

Time Allowed: **3 hours**
Total Marks: **100**
Special Requirements: Periodic Table

$c = 3.00 \times 10^{8}$ m s^{-1}, $h = 6.63 \times 10^{-34}$ J s
$m_e = 9.11 \times 10^{-31}$ kg, $R_H = 1.10 \times 10^{7}$ m^{-1} / 3.29×10^{15} Hz
L (Avogadro's number) = 6.022×10^{23} mol^{-1}

Examiner's Name: DR B. N. Yalala

INSTRUCTIONS

1. Answer all questions from Section A and **ANY THREE** questions from Section B.
2. Section A carries 40 marks and each question in Section B carries 20 marks.
3. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
1.	40
2.	20
3.	20
4.	20
5	20
TOTAL	100

SECTION A

1. (a) Using the periodic table only, rank the elements in each of the following sets in order of decreasing IE1:

    (i) Kr, He, Ar
    (ii) Sb, Te, Sn
    (iii) K, Ca, Rb
    (iv) I, Xe, Cs (4 marks)

(b) Give the ground-state electron configuration of
    (i) As^{3+}
    (ii) Be
    (iii) Fe^{3+}
    (iv) S^{2-}
    (v) Mg (5 marks)

(c) Using Slater's rules, calculate the effective nuclear charge on a 3p electron in
    (i) aluminum, and
    (ii) chlorine.

Explain how your results relate to the relative atomic radii and the relative first ionization energies of the two atoms. (6 marks)

(d) "A covalent bond formed between two hydrogen atoms results in the lowering of potential energy". Explain this statement with reference to a suitable diagram. (6 marks)

(e) A bottle of 12.0 M hydrochloric acid has only 35.7 mL left in it. What will the HCl concentration be if the solution is diluted to 250.0 mL? (2 marks)

(f) Given below are the atomic numbers, electronic configurations, and number of unpaired electrons for three atoms or ions. Indicate the charge and whether the energy state is ground state or excited state for each atom or ion. Assume that all unpaired electrons have their spins parallel. Note: If there is no charge, place 0 in the charge column.

Z	Configuration	Number of unpaired elecrons	Charge	Energy state
16	[Ar]			
19	[Ar] $3d^1$			
28	[Ar] $4s^2$ $3d^6$			

(6 marks)

(g) Generate a table containing the values for n, l, ml and ms for all the electrons with the principal quantum number n = 4. From your table, state the number of electrons that has s = -½.

(4 marks)

(h) (i) Oxygen atoms are smaller than nitrogen atoms, yet oxygen has a lower first ionisation energy than nitrogen. Explain.

(ii) Beryllium atoms are larger than boron atoms, yet boron has a lower first ionisation energy than beryllium. Explain.

(2×2 marks)

(i) Calculate the average atomic mass of chromium, given the following percent abundances and isotope masses: 4.350 % 49.946 amu; 83.790% 51.941 amu; 9.500% 52.941 amu and 2.360% 53.939 amu. (3 marks)

SECTION B

2. (a) Write the Lewis dot structure showing the formal charges of the compounds listed below. Predict the geometry including an estimate of all bond angles, and indicate the likely hybrid orbital on the central atoms of the compounds.

(i) PF_3; (ii) SiF_6^{2-}; (iii) ClO_2^-; iv) SO_2.

(16 marks)

(b) Draw all possible Lewis structures of the carbonate, CO_3^{2-} ion. Using the Valence Bond (VB) theory, explain the resonance in the CO_3^{2-} ion. (4 marks)

3. (a) By using the Molecular Orbital (MO) approach for B_2^- and N_2^+, evaluate or calculate,

(i) The number of bonds,
(ii) The number of unpaired electrons, and
(iii) The bond order. (10 marks)

(b) (i) Using the Rydberg equation, calculate the **ionisation energy** of hydrogen.

(4 marks)

(ii) Emissions are observed at wavelengths of 383.65 nm for transitions from excited states of the hydrogen atom to the n = 2 state. Determine the quantum numbers n_h for these emissions. (2 marks)

(c) (i) The two ions K^+ and Ca^{2+} each have 18 electrons surrounding the nucleus. Which would you expect to have a smaller radius? Why? (**hint:** think about electron-proton attractive forces).

(ii) The Ca^{2+} and Cl^- ions are isoelectronic (i.e. have the same number of electrons), but their radii are not the same. Which ion has the larger radius? Explain.

(2 × 2 marks)

4. (a) In 1957, the French physician Jean Sterne published the first clinical trial of metformin as a treatment for diabetes. It was introduced to the United Kingdom in 1958, Canada in 1972, and the United States in 1995. Metformin is now believed to be the most widely prescribed antidiabetic drug in the world. In the United States alone, more than 48 million prescriptions were filed in 2010. A qualitative chemical analysis showed metformin to consist of carbon, hydrogen and nitrogen only. A sample of metformin of mass 0.5256 g was used in a combustion analysis. The complete combustion yielded 0.7161 g of CO_2, 0.4026 g of H_2O and 0.9357 g of NO_2. In a separate analysis using a mass spectrometer, the molecular ion was detected at m/e 129.1.

(i) What is the empirical formula of metformin?

(ii) What is its molecular formula?

(6 marks)

(b) Metals are made up of positive ions held together by a sea of electrons. These ions are packed in one of the following arrangements;

(i) cubic close-packed (ccp) or face-centred cubic (fcc)

(ii) hexagonal close-packed (hcp)

(iii) body-centered cubic (bcc)

Draw the above packing arrangements and state the nearest neighbour of the ion. For the close-packed arrangements, show by way of sketch, how these ions are arranged to give the respective packing.

(14 marks)

5. (a) Draw a Born-Haber diagram and label the enthalpies involved for the formation of CaF_2 from their respective elements at standard states.

Use the data given in the Table below. The heat of formation of CaF_2 and CaI_2 is -1219.6 and -536 kJ mol^{-1}, respectively. Calculate the lattice energy of CaF_2. If the lattice energy of CaI_2 is -1905 kJ mol^{-1}, find the value of heat of sublimation ($\Delta H_{sublimation}$) of iodine.

Table

Calcium	
Ionisation Energy: 1st	590 KJ mol^{-1}
2nd	1146 KJ mol^{-1}
3rd	4912 KJ mol^{-1}
Heat of Atomisation	192 KJ mol^{-1}
Fluorine	
Electron Affinity	328 KJ mol^{-1}
Bond Energy	159 KJ mol^{-1}
Iodine	
Electron Affinity	295 KJ mol^{-1}
Bond Energy	151 KJ mol^{-1}

(10 marks)

(b) Estimate the lattice energy for fluorite (CaF_2) using the Born-Lande equation given:

$N_A = 6.022 \times 10^{23}$ ion pairs/mol; Madelung constant, M = 2.519; $Z^+ = 2$; $Z^- = -1$; e = 1.602×10^{-19} C; $4\pi\varepsilon = 1.113 \times 10^{-10}$ $C^2J^{-1}m^{-1}$; Born exponent, n = 8.5; cationic radius, $r_+ = 1.12$Å; anionic radius, $r_- = 1.31$Å.

(6 marks)

(c) A hypothetical alloy has a FCC crystal structure, an atomic radius of 0.133 nm, and an atomic weight of 107.60 g/mol. Compute and compare its theoretical density with the experimental value found to be 13.87 g cm^{-3}.

(4 marks)

END OF QUESTION PAPER