NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

INORGANIC CHEMISTRY II

SCH 2201

First Semester Examination Paper

DECEMBER 2017

This examination paper consists of 8 pages

Time Allowed: **3 hours**

Total Marks: 100

Special Requirements: Periodic Table

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 POSSIBLE MARKS	100

SECTION A

1. (a) Ethanoic acid is a common ingredient in cooking. It is also used in industry as a reagent. Ethanoic acid is a weak acid.

(i) Explain, in Bronsted-Lowry terms, what is meant by an acid?
(ii) Explain, with the aid of an equation, the term weak acid.

(3 marks)

(b) Give the **IUPAC names** or the chemical formulas for the complexes below:

(i) $K_3[Co(NO_2)_6]$
(ii) $[Fe(H_2O)_2(en)_2]^{2+}$
(iii) $[Fe(ox)_3]^{3-}$
(iv) sodium tetrachlorocuprate (II)
(v) aminechlorobis(ethylenediamine) chromium (III) sulfate
(vi) potassium tetracyanonickelate (II)

(6 marks)

(c) Explain why the complex $[Cu(H_2O)_6]^{2+}$ is coloured and why the complex $[Zn(H_2O)_6]^{2+}$ has no colour.

(4 marks)

(d) Describe and explain the trend in thermal stability of the nitrates of the Group II elements.

(3 marks)

(e) Nickel exhibits both 4-fold and 6-fold co-ordination in its complexes. Both of the following complexes can exist in two isomeric forms.

Draw structural formulae to show the shapes of these isomers, and describe the type of isomerism shown.

$[Ni(H_2O)_4(NH_3)_2]Cl_2$ $Ni(NH_3)_2Cl_2$

(4 marks)

(f) Explain why most compounds containing transition metals are coloured, whereas compounds of non-transition metals are usually colourless.

(3 marks)

(g) Calcium sulphate is a major by-product of flue gas desulphurisation, which is an important method of decreasing the emission of acid-rain gases from power stations. It is used extensively in plaster and cement. Both magnesium sulphate and barium sulphate find uses in medicine.

Describe and explain the variation in the solubilities of the Group II sulphates in water.

(4 marks)

(h) What is the oxidation state of the metal in the following complexes?

(i) $[Ni(NH_3)_4](ClO_4)_2$ *+2*

(ii) $[Fe(en)_2SO_4]$

(iii) $Na_3[Co(ONO)_6]$

(iv) $[FeCl_6]^{4-}$

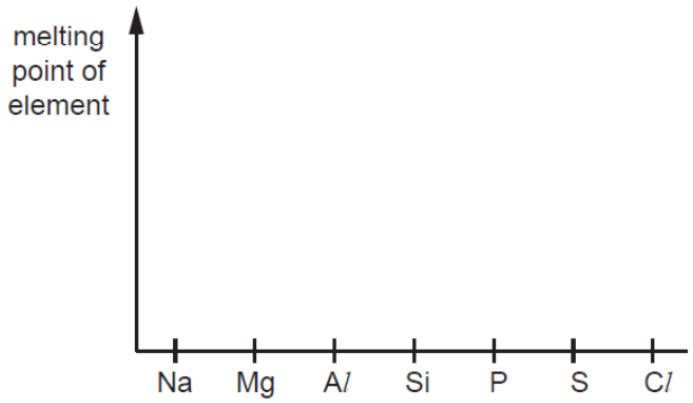
(v) tetracyaniodonickelate (II) ion (5 marks)

(i) Describe three characteristic chemical properties of transition elements that are not shown by Group II elements.

(3 marks)

(j) Elements in the same period of the Periodic Table show different trends in physical and chemical properties.

Draw a clear sketch to show the variation of the **melting point** and briefly explain the variation you have described in your sketch. In your explanation you should refer to the important factors that cause the differences in the property you are describing.



(5 marks)

SECTION B

2. (a) Explain the following observations, writing balanced equations for all reactions.

(i) Warming a pink aqueous solution of cobalt(II) chloride causes its colour to change to blue. On cooling the solution returns to its pink colour.

(ii) When concentrated HCl is added to this pink aqueous solution of cobalt(II) chloride, the solution turns blue. Diluting the solution with water causes its colour to return to pink.

(iii) When NaOH(aq) is added to aqueous solution of cobalt(II) chloride, a pink precipitate is formed. On adding an excess of NaOH(aq), the precipitate dissolves to form a blue solution.

(7 marks)

(b) When $NH_3(aq)$ is added to a green solution containing $Ni^{2+}(aq)$ ions, a grey-green precipitate is formed. This precipitate dissolves in an excess of $NH_3(aq)$ to give a blue-violet solution.
Suggest an explanation for these observations, showing your reasoning and including equations for the reactions you describe.

(4 marks)

(c) The following passage is taken from an Inorganic Chemistry text book.

"In an isolated atom, the five d-orbitals have the same energy. In an octahedral complex ion, however, the presence of the ligands splits the five orbitals into a group of three and a group of two. These two groups have slightly different energies."

(i) draw the shape of one d-orbital in each of the two groups mentioned above.

(2 marks)

(ii) Explain how the presence of the six ligands, L, in $[FeL_6]^{3+}$ splits the 3d orbitals into two groups of different energy, and explain whether the two-orbital group or the three-orbital group has the higher energy.

(4 marks)

(d) The complex ions $[Fe(H_2O)_6]^{3+}$ and $[Fe(H_2O)_6]^{2+}$ differ in their paramagnetism. Explain the origin of paramagnetism in these complexes, and predict which ion will be the more paramagnetic.

(3 marks)

3. (a) (i) With the aid of a diagram of an electrolysis cell, outline the manufacture of chlorine from brine (aqueous sodium chloride).

(3 marks)

(ii) Write the electrode equations for the anode and cathode, including state symbols.

(2 marks)

(iii) Name the two by-products of this electrolysis, and give one commercial use of each.

(2 marks)

(iv) Explain, with the aid of an equation, why the chlorine generated from the cell has to be kept away from the liquid in the cathode compartment.

(2 marks)

(b) Many millions of tonnes of limestone, $CaCO_3$, are quarried each year for use in the steel industries of the world, and in agriculture. For use in agriculture, the limestone is often decomposed by heating it in limekilns, and then adding water.

Write balanced equations representing the following two processes.

(i) heating limestone

(ii) then adding water

(2 marks)

(c) Describe the agricultural use of the product of this process.

(1 mark)

(d) Describe and explain the trend observed in the thermal stabilities of the carbonates of group II.

(3 marks)

(e) (i) Explain what is meant by the term "transition element".

(ii) Explain what is meant by the term "complex ion".

(2 marks)

(f) (i) How do the atomic radii of the transition elements vary from chromium to copper?

(iii) Predict, with a reason, the variation in the densities of the transition elements from chromium to copper.

(3 marks)

4. (a) The melting points of some oxides of Group IV elements are given below.

oxide	**Melting point / ℃**
CO_2	−78
SiO_2	1610
SnO_2	1630

Describe the bonding in each oxide, and how it relates to its melting point.

(i) CO_2

(ii) SiO_2

(iii) SnO_2

(3 marks)

(b) Writing balanced equations where appropriate, describe how the above three oxides differ in their reactions with

(i) NaOH(aq)

(ii) HCl(aq)

(4 marks)

(c) Methanoic acid, HCO_2H, is a weak acid, with $K_a = 1.77 \times 10^{-4}$ mol dm^{-3}.

(i) Write an expression for the K_a of methanoic acid.

(ii) Use your expression to calculate the $[H^+]$ in a 0.0500 mol dm^{-3} solution of methanoic acid.

(iii) Calculate the percentage of HCO_2H molecules that are ionised in this solution.

(iv) Calculate the pH of this solution.

(7 marks)

(d) Using crystal field theory, draw energy level diagrams, write electronic configuration of the central atom/ion, and determine the magnetic moment value in the following:

(i) $[CoF_6]^{3-}$
(ii) $(Fe(CN_6]^{4-}$

(6 marks)

5. The most typical oxides of tin and lead are SnO, SnO_2, PbO and PbO_2.
The following two generalisations can be made about the oxides of the elements in Group IV.

- As the metallic character of the elements increases down the Group, the oxides become more basic.
- The oxides of the elements in their higher oxidation states are more acidic than the oxides of the elements in their lower oxidation states.

(a) Use these generalisations to suggest which of the above oxides of tin or lead is most likely to react with each of the following reagents. In each case write a balanced equation for the reaction.

(i) with NaOH(aq)
formula of oxide:
equation:

(ii) with HCl(aq)
formula of oxide:
equation:

(4 marks)

(b) Provide a short explanation of the following properties of the halogens.

(i) The ability to oxidize other substances decreases with increasing atomic number.

(ii) The boiling points of the hydrogen halides increase in the order HCl < HBr < HI < HF.

(4 marks)

(c) Describe the observations you would make when concentrated sulfuric acid is added to separate portions of NaCl (s) and NaBr (s). Write an equation for each reaction that occurs.

(4 marks)

(d) Ammonia, NH_3, is a colourless, pungent-smelling gas which has been known to man from the beginning of recorded time. It is given off from urine such as that on a wet nappy from a baby. The nitrogen-containing substance in urine is urea, $CO(NH_2)_2$, and this decomposes by hydrolysis into ammonia and another colourless gas.

Construct an equation for the hydrolysis of aqueous urea.

(2 marks)

(e) Now ammonia is synthesised from its elements in the Haber Process.

(i) Write an equation for this process.

(ii) State the three usual operating conditions of the Haber Process.

(iii) State two modern commercial uses of ammonia.

(4 marks)

(f) Ammonia does not burn in air but will burn in pure oxygen.

(i) Balance the equation for this reaction:

…… $NH_3(g)$ + …… $O_2(g)$ → …… $N_2(g)$ + …… $H_2O(g)$

(ii) Use oxidation numbers to explain why this is a redox reaction.

(2 marks)

END OF QUESTION PAPER