UNIVERSITY ENTRANCE EXAMINATION 2019

NUS National University of Singapore

Chemistry

Duration : 2 hours

Please read the following instructions carefully.

1. This paper has THREE (3) sections – A, B and C, and comprises FIVE (5) printed pages

2. Attempt all sections. Do not write on the question paper.

3. Answer all questions in Section A, B and C. Indicate your answers on the answer sheet provided. Write the question number clearly.

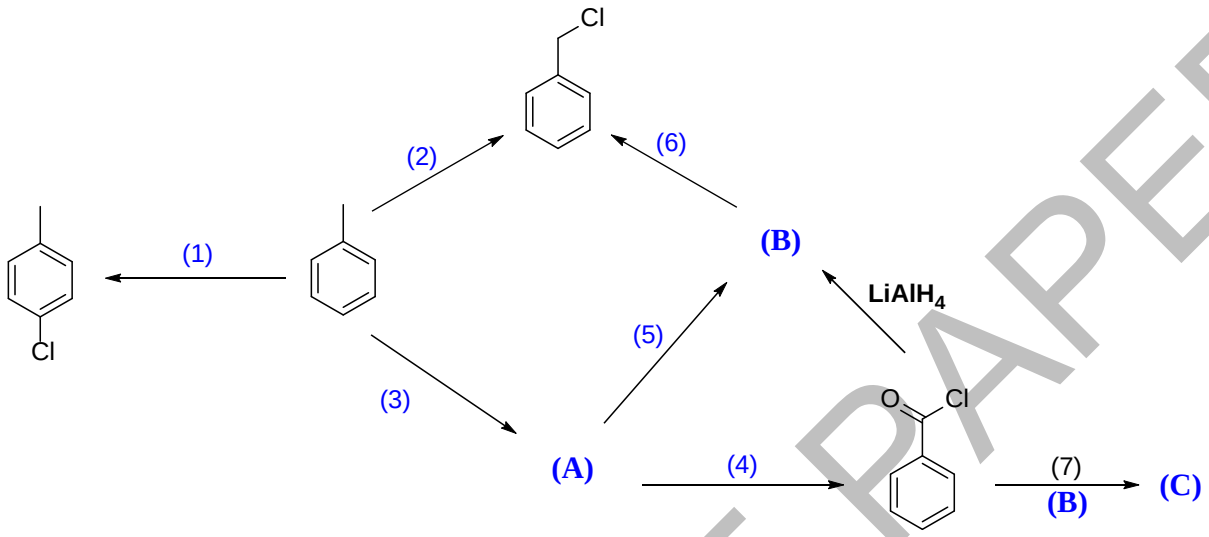
4. At the end of the examination, complete the information required on the cover page. Place the cover page on top of your answer sheets and tie them together using the string provided.

5. Do not take any paper, including the question paper or unused answer sheets, out of the examination hall.

Section A (33 marks)

Answer all questions.

1. Consider the following reaction scheme.



Note: Compound (B) is used as the reagent for reaction (7).

i) Write down the reagents required for reactions (1) to (6).

ii) Name reactions (1) to (7).

iii) Provide the structures of compounds (A) to (C).

(20 marks)

1. Consider the chemical formula $C_4H_{10}O$.

i) Draw the four possible isomers with the alcohol functional group and give their respective IUPAC names. Classify the isomers into primary, secondary and tertiary alcohol groups.

ii) By means of confirmation (i.e. positive results) chemical tests, suggest methods to distinguish the secondary and tertiary alcohols from each other. You may need to perform some preliminary reactions to "break-up" the compounds prior to the subsequent testing of the reaction products. Your answers should include chemical equations or reaction schemes, wherever appropriate.

(13 marks)

Section B (33 marks)

1. Hippuric acid is a monoprotic acid with the molecular formula $HC_9H_8NO_3$. The pK_a of hippuric acid is 3.62.

   i) Calculate the pH of 0.100 M solution of hippuric acid.

   ii) Calculate the concentrations of the species H_3O^+, $C_9H_8NO_3^-$, $HC_9H_8NO_3$ and OH^- in 0.100 M solution of hippuric acid.

   iii) Calculate the percent dissociation in 0.0780 M hippuric acid.

(20 marks)

2. Bromomethane is converted to methanol in an alkaline solution. The reaction is first order in each reactant.

$$CH_3Br_{(aq)} + OH^-_{(aq)} \rightarrow CH_3OH_{(aq)} + Br^-_{(aq)}$$

   (a) Predict the rate law of the above reaction.

   (b) Predict the change in the reaction rate if the

   i) concentration of OH^- is decreased by a factor of 5;

   ii) concentrations of both reactants are doubled.

(5 marks)

3. In the gas phase reaction at 600 K, Isopropyl alcohol decomposes to acetone as given below:

$$(CH_3)_2CHOH_{(g)} \rightleftharpoons (CH_3)_2CO_{(g)} + H_{2(g)} \quad \Delta H° = +57.3kJ$$

   Predict the change in the number of moles of acetone, whether increase, decrease or remain the same, when an equilibrium mixture of reactants and products are subjected to the following changes:

   i) The temperature is increased

   ii) The total volume is increased

   iii) Argon is added

   iv) A catalyst is added

(8 marks)

Section C (34 marks)

1. Answer all the questions.

(a) One property of manganese that characteristic of a transition element is its ability to exhibit variable oxidation states. What features of manganese allow it to do so?

(2 marks)

(b) Manganese(IV) oxide undergoes a 2-step reaction to produce compounds **Y** and **Z**, as summarised in the reaction scheme below.

MnO_2 —(Oxidation in basic medium, **I**)→ MnO_4^{2-} —(Hot water / CO_2 gas, **II**)→ Brown black solid **Y** in purple solution **Z**

i) The brown black solid **Y** contains 63.8% by mass of manganese and 36.2% by mass oxygen. Using these information, deduce the empirical formula of **Y**.

ii) Suggest the identity of **Z** and state the type of reaction that occurs at step **II**. Construct a balance equation for this reaction.

iii) Explain the role of bubbling CO_2 gas into the hot solution of MnO_4^{2-}.

(10 marks)

(c) Potassium manganate(VII) is an oxidation agent used in redox titrations. A 50.0 mL sample of iron(II) oxalate, FeC_2O_4, was dissolved in water and the solution made up to 250 mL. A 25.0 mL portion of this solution was acidified and titrated with 20.80 mL of 0.025 M potassium manganate(VII).

i) Draw the 'dot-and-cross' diagram of $C_2O_4^{2-}$. Deduce the geometry and bond angles with respect to one central carbon atom.

ii) Write the overall balanced equation with state symbols for the reaction between potassium manganate(VII) and iron(II) oxalate.

iii) State the change in oxidation numbers of manganese and carbon in the above reaction.

iv) Deduce the observations made from the start to end point of the titration.

(8 marks)

2. Answer all the questions.

(a) Magnesium nitrate decomposes at 330 ^{o}C.

i) Write a balanced chemical equation with state symbols, for the decomposition of magnesium nitrate.

ii) How would you expect the decomposition temperature of barium nitrate to differ from that of magnesium nitrate? Explain your answer.

(6 marks)

(b) Group 2 oxides and carbonates are materials widely used in industrial furnaces.

i) Magnesium oxide is used as refractory lining in furnaces. Explain in terms of bonding and structure, why magnesium oxide is a suitable material for this purpose.

ii) Calcium carbonate is used in the furnace for the removal of sulphur dioxide in the exhaust, forming solid calcium sulphite, $CaSO_3$, and carbon dioxide gas. Write a balanced chemical equation with state symbols, for this reaction.

iii) With respect to the above reaction in (ii), a stream of furnace exhaust containing sulphur dioxide gas was passed through 100 g of solid calcium carbonate. The mass of solid was found to be 110 g after the experiment. Assuming all the sulphur dioxide was removed from the stream of exhaust and converted to calcium sulphite, calculate the amount of sulphur dioxide present in the exhaust gas.

[A_r of Ca = 40.0; S = 32.0; C = 12.0; O = 16.0]

(8 marks)