H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

CHEMISTRY

9647/02

Paper 2 Structured Questions

23 September 2013

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in the spaces provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/12**
2	**/22**
3	**/10**
4	**/18**
5	**/10**
Total	**/72**

This document consists of **17** printed pages.

Answer **all** questions in the spaces provided.

1 Planning (P)

Acids can be classified in terms of their basicity depending on the number of protons that can be donated to a base. A student is investigating the basicity of a solution of 0.80 mol dm^{-3} acid, **A**, using just the acid and sodium hydroxide of the same concentration. He conducted two experiments by mixing different volumes of **A** and sodium hydroxide, and taking the temperature rise for each experiment.

(a) Based on the definition of the enthalpy change of neutralisation (ΔH_n) and his results, deduce the basicity of acid **A**.

Experiment	Volume of acid	Volume of NaOH	ΔT /^oC
1	40	20	3.6
2	20	40	7.2

……

……

……

……

……

[2]

(b) (i) The temperature rise of the reaction can be determined graphically by measuring how the *temperature changes with time*.

You are to plan an experiment to determine the ΔH_n between a solid sample of **A** and sodium hydroxide.

You are provided with a solid sample of **A** (M_r = 174) and sodium hydroxide solution of 0.80 mol dm^{-3}.

In your plan, you should give:

- details including calculations to determine the quantities of the reactants to be used;
- choice of apparatus (You may use apparatus normally found in the school laboratory.);
- the essential details for obtaining the graph of temperature against time in order to determine the temperature rise;
- table(s) of readings to taken.

For Examiner's Use

Calculations:

Procedure:

……

……

……

……

……

……

……

……

……

……

……

Table of Results

For Examiner's Use

(ii) Sketch the graph that you would expect, showing clearly how you can determine the temperature rise.

[8]

(c) Explain why temperature rise in the experiment should not be too low.

……

……

[1]

(d) An alternative method to determine the temperature rise is to measure the highest temperature reached. Explain if this is a better method.

……

……

[1]

[Total: 12]

For Examiner's Use

2 One of the most important features of the transition elements is that they exhibit variable oxidation states. This question illustrates the various oxidation states shown by iron in its compounds.

(a) The reaction between iodide ions, I^-, and peroxidisulfate ions, $S_2O_8^{2-}$, is slow. The reaction can be catalysed by adding a small amount of Fe^{2+} ions.

The initial rate of the slow reaction between iodide ions and peroxidisulfate ions can be studied by using thiosulfate ions. The equations for the reactions are as follows.

$$2I^- + S_2O_8^{2-} \longrightarrow I_2 + 2SO_4^{2-} \quad \text{(slow)} \quad \text{reaction } \mathbf{I}$$

$$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-} \quad \text{(fast)} \quad \text{reaction } \mathbf{II}$$

In the presence of a constant amount of thiosulfate ions, the iodine being slowly produced by reaction **I** will immediately react in reaction **II** until all the thiosulfate ions has been used up. At that point, free iodine will be present in the solution, which will cause a sudden appearance of a deep blue colour if starch is present.

A series of experiments was carried out using different volumes of the five reagents. The following results were obtained.

Expt	Volume of $S_2O_8^{2-}$ /cm^3	Volume of I^- /cm^3	Volume of $S_2O_3^{2-}$ /cm^3	Volume of distilled water /cm^3	Volume of Starch /cm^3	Time for the appearance of deep blue colour/s
1	20	20	10	5	5	30
2	20	15	10	10	5	40
3	5	25	10	15	5	t_3
4	10	15	10	20	5	80

(i) If the orders of reaction with respect to peroxidisulfate ions and iodide ions are both one respectively, deduce an expression relating the volume of these two reactants and time taken for the appearance of deep blue colour.
Explain your reasoning.

For Examiner's Use

(ii) Hence, predict the time, t_3, required for the appearance of deep blue colour in experiment 3.

……

……

……

……

[3]

(b) **(i)** In the Haber process, the rate of formation of ammonia is increased by using an iron catalyst. State the type of catalysis occurring here and describe using the Maxwell-Boltzmann Distribution curve, how the iron catalyst increases the rate of reaction.

……

……

……

……

(ii) Ammonia shows significant deviations from the ideal behaviour that is predicted by the kinetic theory of gases. State two assumptions of the kinetic theory of gases.

……

……

……

……

(iii) A sample of ammonia can be liquefied at room temperature just by increasing the pressure of the sample. Why does the application of pressure cause the gas to liquefy?

……

……

……

……

[7]

(c) Iron(III) chloride is a dark brown solid which dissolves in water to give an acidic solution. This solution is often used, in the electronics industry, to etch (dissolve) the copper used in printed circuit boards.

(i) Explain, with the aid of a chemical equation, why aqueous iron(III) chloride is acidic.

……

……

……

(ii) By selecting appropriate E^{θ} values from the *Data Booklet*, explain why aqueous iron(III) chloride etches (dissolves) copper. Construct a balanced equation for this reaction.

……

……

……

……

[4]

(d) Iron(III) iodide has been successfully made under non-aqueous conditions by following method.

Iron pentacarbonyl, $Fe(CO)_5$, reacted with iodine in hexane solution to form a solution of compound **B**, whose molecular formula is $FeC_4O_4I_2$.
A further calculated amount of iodine is added, and the solution exposed to uv light. A black precipitate of iron(III) iodide results, and a colourless gas is evolved.

(i) State the co-ordination number of iron in the complex, $Fe(CO)_5$ and hence predict the shape of the complex, $Fe(CO)_5$.

Co-ordination number: ……

Shape: ……

(ii) Describe the bonding between iodine and iron in compound **B** and write a balanced equation for the reaction between compound **B** and iodine.

……

……

……

[4]

(e) When a solution of NaClO is added to a strongly alkaline suspension of Fe_2O_3, a purple solution results. When $BaCl_2(aq)$ is added to the solution, a red solid is precipitated with the composition by mass: Ba, 53.4%; Fe, 21.7%; O,24.9%.

(i) Calculate the empirical formula of the red solid, and hence determine the oxidation number of iron in the red solid.

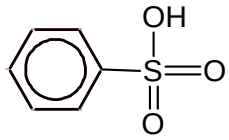
(ii) Construct a balanced ionic equation for the reaction between Fe_2O_3, ClO^- and OH^-.

……

[4]

[Total: 22]

3 Aromatic sulfonic acid is an important precursor to industrial materials and has the following structure:



Aromatic sulfonic acid

(a) Sulfonation of benzene is the reaction mechanism between benzene and sulfuric acid. The first step of the reaction mechanism is given by the following equation.

$$H_2SO_4 \rightleftharpoons H_2O + SO_3$$

Sulfur trioxide is an important intermediate in the reaction mechanism.

(i) Draw a dot-and-cross diagram of sulfur trioxide.

(ii) With reference to the structure of the molecule, state and explain the function of sulphur trioxide in the mechanism.

……

……

……

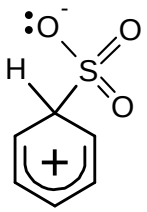
……

……

10

(iii) The final step of the mechanism is different from other benzene reactions because the hydrogen atom is not removed from the ring by a separate negative ion. Instead it is removed by a lone pair of electrons on a negative oxygen atom in the sigma complex.

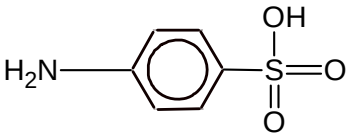
The sigma complex formed has the following structure:



Sigma complex

With the above information, complete the mechanism for the reaction between benzene and sulfuric acid.

(iv) Sulfonation of aniline produces sulfanic acid compounds with an unusually high melting point. With reference to the structure of sulfanic acid, suggest why this is so.



Sulfanic acid

……

……

……

[7]

11

(b) The key reaction during the Contact process is as follows:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g); \qquad \Delta H = -98\ kJ\ mol^{-1}$$

Industrially, the gases are compressed to a pressure of 3 atm before it is passed over a bed of vanadium(V) oxide at 430 °C. Explain the conditions used.

……

……

……

……

……

……

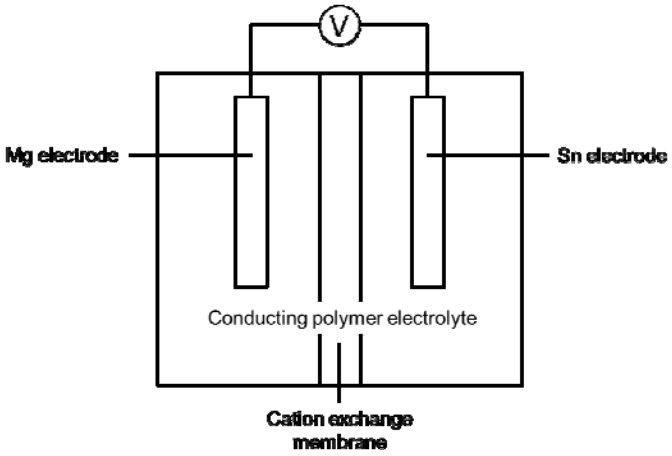
[3]

[Total: 10]

For Examiner's Use

4 Magnesium is the fourth most abundant element in the earth. Scientists are working on developing rechargeable magnesium-ion batteries for use in electric cars, as they offer a cheaper and more energy efficient alternative to lithium-ion batteries.

A simplified representation of a magnesium-ion battery is shown below. When the battery discharges, magnesium ions are formed, which move across the cation exchange membrane to the Sn electrode, forming solid Mg_2Sn.



(a) **(i)** Write half equations for the reactions occurring at the cathode and the anode when the battery discharges.

Cathode: ……

Anode: ……

(ii) The magnesium-ion battery provides a voltage of 3.01 V. With reference to the *Data Booklet*, calculate E^{θ} (Sn/Mg_2Sn), assuming standard conditions.

(iii) The car battery has to be recharged after use. After clocking a mileage of 500 km, 83.8 g of Mg_2Sn was deposited on the electrode of the battery. How many hours will it take for the car battery to be recharged, using a current of 10.0 A? What is the polarity of each electrode during the charging process?

Mg electrode: ……

Sn electrode: ……

(iv) Besides cost, explain another advantage the magnesium-ion battery has over the lithium-ion battery.

……

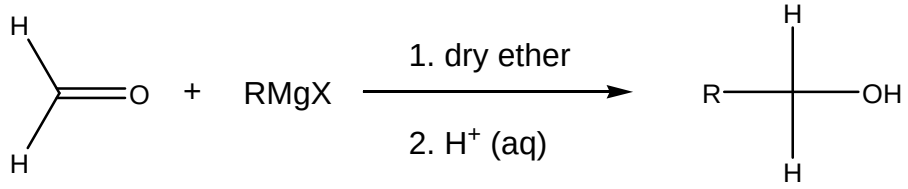
……

[8]

(b) Magnesium is also used in the synthesis of Grignard reagents, RMgX (R = alkyl or aryl groups, X = Cl or Br), from organic halides. The organic halide is added to a suspension of magnesium in dry ether, forming the Grignard reagent

$$RX + Mg \rightarrow RMgX$$

Grignard reagents are examples of organometallic compounds as they contain a carbon-metal bond. They are useful for organic synthesis as they can form new carbon-carbon bonds with unsaturated compounds such as carbonyls. The reaction of methanal and a general Grignard reagent is illustrated below:



(i) Draw the displayed formula of the product of the reaction between butanone and C_6H_5MgCl.

For Examiner's Use

(ii) How would you determine if the reaction in **b(i)** has gone to completion?

……

……

……

(iii) The Grignard reagent can be considered as a good source of a carbanion, "R^-". Using this information, explain whether the product mixture formed will be optically active. Explain your answer with the aid of a diagram.

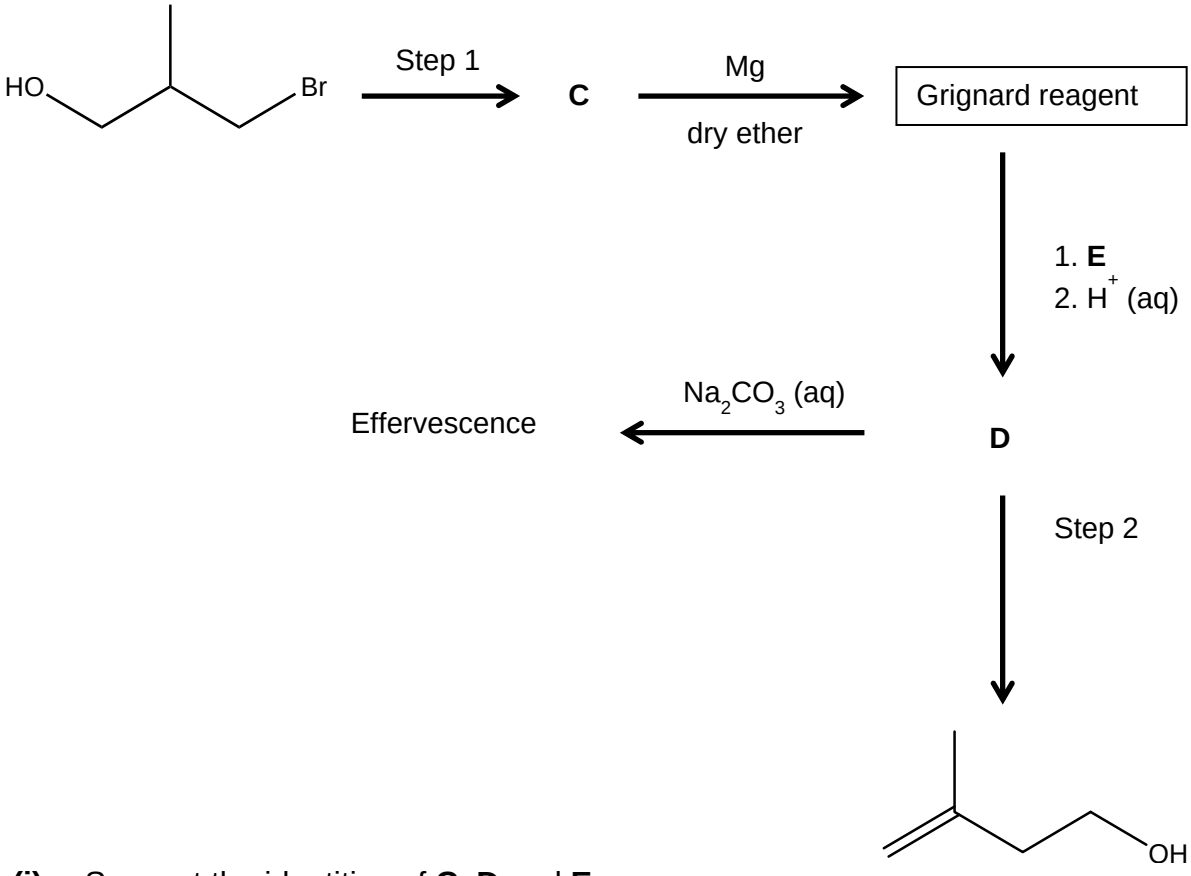
……

……

……

[5]

(c) Refer to the reaction scheme involving a Grignard reagent below.



(i) Suggest the identities of **C**, **D** and **E**.

(ii) Suggest reagents and conditions for Step 1 and 2.

Step 1: ……

Step 2: ……

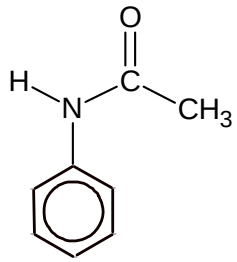
[5]

[Total: 18]

For Examiner's Use

5 Some chemistry students were doing an organic chemistry practical.

(a) Student X heated compound **F** with hydrochloric acid to form two organic products. In order to isolate both products, the reaction mixture was placed in a separating funnel and shaken with water.



Compound **F**

(i) Draw the products of the above reaction.

(ii) Explain why the separation will not be successful.

……

……

……

……

(iii) Describe the correct procedure to separate the hydrolysis products.

……

……

……

……

For Examiner's Use

(b) Under acidic conditions, Student Y treated ethylamine with excess iodomethane in an attempt to form a quarternary amine salt. Explain why this synthesis will not be successful.

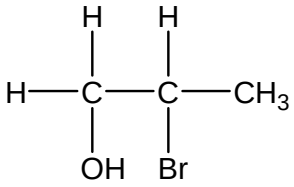
……

……

……

[2]

(c) Student Z predicted that compound **G** was formed from the reaction of propene and aqueous bromine in the presence of concentrated sodium chloride.



Compound **G**

(i) Explain why his prediction is wrong.

……

……

……

……

(ii) Hence, suggest the structure of the major product formed.

[3]

[Total: 10]