TEMASEK JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CANDIDATE NAME | | | | | | | | | |
| CIVICS GROUP | | | / | | | | | | |
| CENTER NUMBER | S | | | | | INDEX NUMBER | | | |

**CHEMISTRY** **8872/02**

Paper 2 **11 September 2017**

**2 hours**

Candidates answer section **A** on the Question Paper.

Additional Materials: Answer Paper

Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your Civics Group, centre number, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

**Section A**
Answer **all** questions.

**Section B**
Answer **two** questions on separate answer paper.

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 | |
|---|---|
| **A1** | / 15 |
| **A2** | / 13 |
| **A3** | / 12 |
| **Section B** | / 40 |
| **Paper 1** | / 30 |
| **Total** | |

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

## Section A

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

**1** This question is on the elements in period 3 of the Periodic Table.

**(a)** Describe what you see when phosphorus and sulfur are separately burned in air or oxygen. [2]

**(b)** The oxides MgO, $Al_2O_3$ and $SiO_2$ are all used as refractory materials due to their high melting points. The last two are major constituents of gemstones, such as rubies, sapphires and amethysts.

If a sample of one of the oxides was provided as a white powder, describe the reactions you could carry out on the powder to determine which of the three oxides it was. Write balanced equations where appropriate. [3]

**(c)** When dry chlorine is passed over heated aluminium foil in a hard glass tube, a vapour is produced which condenses to a yellow-white solid on the cooler parts of the tube. At low temperatures, the vapour has the empirical formula $AlCl_3$ and a $M_r$ of 267.

**(i)** Suggest the molecular formula of the vapour, and draw a dot-and-cross diagram to describe its bonding. [2]

**(ii)** When a large amount of water is added to the yellow-white solid, a clear, weakly acidic solution results.

Write equations to explain the observation. [2]

Chlorine also reacts with phosphorus under suitable condition to give phosphorus pentachloride.

**(iii)** When phosphorus pentachioride is added to water, the resulting solution has a pH of 1. Explain with the aid of an equation. [2]

**(d)** Silver chloride is an important photosensitive inorganic material widely used in photographic applications. It is industrially produced by mixing solutions of silver nitrate and sodium chloride.

$$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s) \qquad \Delta H^\ominus = -65.7 \text{ kJ mol}^{-1}$$

**(i)** Use the data in the table to calculate *x*, the standard enthalpy change of formation of $Ag^+(aq)$.

| Species | $\Delta H_f^\ominus$ |
|---|---|
| $Ag^+(aq)$ | *x* |
| $Cl^-(aq)$ | -167 |
| AgCl(s) | -127 |

[2]

**(ii)** Suggest whether a lower or higher temperature should be used to increase the yield of silver chloride. Explain your answer.

[2]

[Total: 15]

**2** **(a)** In 1887, a Swedish scientist Svante Arrhenius postulated that acids and bases dissociate in water to form hydrogen ions, $H^+$, and hydroxide ions, $OH^-$, respectively.

**(i)** Suggest a limitation of the Arrhenius concept of acids and bases.

[1]

A theory proposed by Danish chemist J.N. Brønsted and British chemist T.M. Lowry overcame the shortcomings of the Arrhenius theory.

**(ii)** Using the Brønsted–Lowry model, explain the roles of nitric acid in the two reactions below.

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$ *Reaction 1*

$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ *Reaction 2*

[2]

**(b)** Propanoic acid inhibits the growth of mold and some bacteria. Most propanoic acid produced is consumed as a preservative for both animal feed and food for human consumption.

The $K_a$ values of propanol, propanoic acid and malonic acid are given below.

| Compound | Formula | $K_{a1}$ | $K_{a2}$ |
|---|---|---|---|
| Propanol | $CH_3CH_2CH_2OH$ | $7.94 \times 10^{-17}$ | — |
| Propanoic acid | $CH_3CH_2CO_2H$ | $1.35 \times 10^{-5}$ | — |
| Malonic acid | $HO_2CCH_2CO_2H$ | $1.41 \times 10^{-3}$ | $2.00 \times 10^{-6}$ |

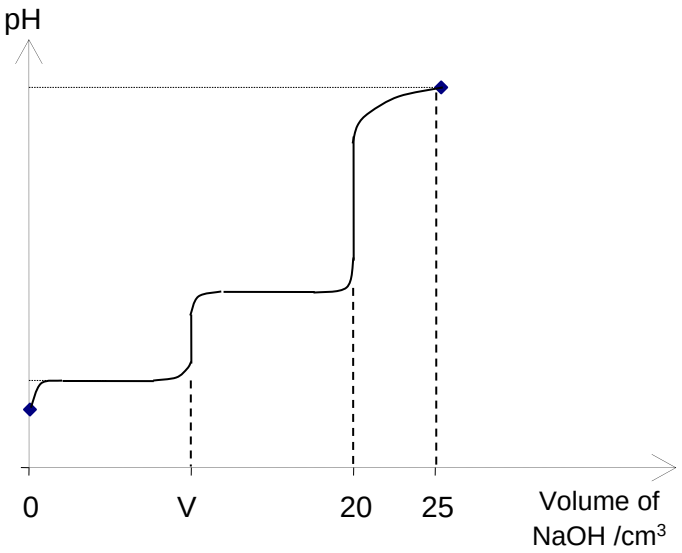
Suggest reason(s) why

**(i)** $K_a$ of propanoic acid is higher than that of propanol. [2]

**(ii)** $K_{a1}$ of malonic acid is higher than $K_a$ of propanoic acid. [1]

**(iii)** $K_{a1}$ of malonic acid is higher than $K_{a2}$ of malonic acid. [1]

**(c)** 25 $cm^3$ of 0.10 mol $dm^{-3}$ of NaOH is gradually added to 10 $cm^3$ of 0.10 mol $dm^{-3}$ malonic acid.




**(i)** State the value for V.

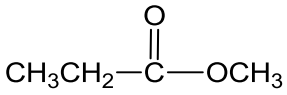
[1]

V = _____

**(ii)** Calculate the pH of the mixture when 25 $cm^3$ of NaOH has been added.

[2]

**(d)** Compound **A** can be directly synthesised from propanoic acid.

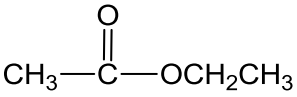


Compound **A**

**(i)** Suggest reagents and conditions to form compound **A** from propanoic acid.

[1]

Compound **B** is an isomer of compound **A**.



Compound **B**

**(ii)** Suggest methods by which compounds **A** and **B** could be distinguished from each other by chemical tests.

[2]

[Total: 13]

**3** **(a)** Glucose is a reducing sugar and can be identified using Benedict's reagent or Fehling's solution as shown by the following equation.

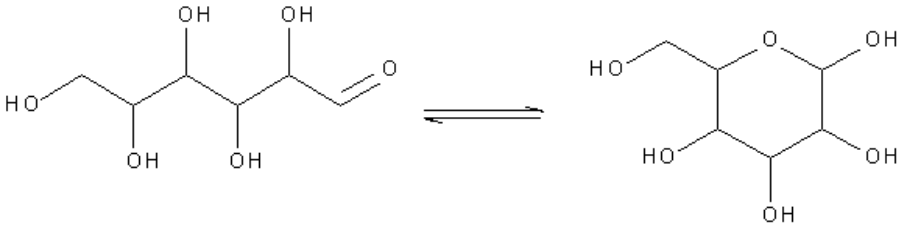
$$C_6H_{12}O_6 + 2Cu^{2+}(aq) \rightarrow Cu_2O(s) + \text{products}$$

A 5.00 g sample of food was treated with an excess copper(II) ions and 0.286 g of copper(I) oxide precipitated was collected.

Calculate the percentage of glucose in the food sample assuming that all the sugar present in the food is in the form of glucose.

[2]

**(b)** Most of the energy our bodies need comes from carbohydrates and fat. Starch is broken down into glucose,$C_6H_{12}O_6$. Glucose exist mainly in cyclic forms with a small percentage in open chains.




open-chain cyclic

Glucose is transported to the cells to react with oxygen via a series of steps to form carbon dioxide, water and energy.

**(i)** Write a balanced equation for the reaction of glucose with oxygen.

[1]

**(ii)** Using data from the *Data Booklet*, calculate the amount of energy released per mole of glucose using the **cyclic** structure.

[2]

**(iii)** The literature value for the amount of energy released per mole of glucose is – 2800 kJ.

Apart from bond energies being average values, suggest another reason for the difference between this value and that calculated in **(b)(ii)**.

[1]

Like carbohydrates, fats are metabolised into carbon dioxide and water and when subjected to combustion in a bomb calorimeter. The reaction of tristearin, $C_{57}H_{110}O_6$, a typical fat is as follows:

$$C_{57}H_{110}O_6 + \frac{163}{2} O_2 \rightarrow 57\ CO_2 + 55\ H_2O \quad \Delta H^{\ominus} = -37760\ kJ\ mol^{-1}$$

The fuel value is the energy when one gram of the material undergoes combustion. The table below shows the fuel value of carbohydrates and protein and the food label of a cup noodle:

| | Fuel value / kJ $g^{-1}$ |
|---|---|
| Carbohydrate | 17 |
| Fat (Tristearin) | To be calculated |
| Protein | 17 |


**Nutrition Facts**
Serving Size 1 container (70g)

| Amount Per Serving | |
|---|---|
| **Calories** 310 | Calories from Fat 100 |
| | % Daily Value* |
| **Total Fat** 12g | 18% |
| Saturated Fat | 25% |
| Trans Fat | |
| **Cholesterol** 0mg | 0% |
| **Sodium** 1010mg | 42% |
| **Total Carbohydrate** 44g | 15% |
| Dietary Fiber 4g | 16% |
| Sugars 4g | |
| **Protein** 8g | |

**(iv)** Determine the fuel value of tristearin. ($M_r$ of tristearin = 890)

Hence deduce if tristearin or carbohydrate is a better source of energy. [2]

**(v)** During reading or watching television, the average adult uses about 7 kJ $min^{-1}$.

By considering only the total fat, carbohydrate and protein content, calculate the duration in minutes of such activity that can be sustained by one serving of cup noodle. [1]

**(c)** In the body, glucose is also converted to energy via alcoholic fermentation. This process has been used in making beer and the side products such as esters contribute greatly to the taste and aroma of the beer.

Ethyl acetate can be formed as follows

$$CH_3CO_2H + CH_3CH_2OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

1.51 mol of $CH_3CO_2H$ and 1.66 mol of $CH_3CH_2OH$ was allowed to reach equilibrium in a 100 $cm^3$ solution. 10 $cm^3$ of the equilibrium mixture was extracted and large amounts of cold water was added to quench the reaction. The mixture was then titrated with 22.40 $cm^3$ of 2 mol $dm^{-3}$ NaOH.

Calculate the $K_c$ for the formation of ethyl acetate.

[3]

[Total: 12]

## Section B

Answer **two** questions from this section on separate answer paper.

**4** **(a)** **(i)** Define the term *empirical formula*. [1]

**(ii)** Hydrocarbon **P** with $M_r$ = 70 contains 85.7% by mass of carbon.
Determine the empirical formula and hence the molecular formula of **P**. [2]

**(iii)** Hydrocarbon **P** exhibits stereoisomerism. Draw and label the stereoisomers of **P**. [2]

**(b)** Organic compound **Q,** with molecular formula $C_6H_8O_4$, can be found in most leather products and is used as a mould inhibitor.

**Q** decolourises aqueous bromine. On heating one mole of **Q** with dilute acid, two organic products **R**, $C_4H_4O_4$, and methanol are obtained. Vigorous effervescence was observed when **R** reacted completely with sodium carbonate in equimolar proportions.

Use all of the above information to determine the functional groups present in **Q** and **R**. For each functional group you identify, explain how you came to your decision. Hence determine the identity of **Q** and **R**. [6]

**(c)** Many chemical reactions such as the Contact Process between sulfur dioxide and oxygen occur very slowly at room conditions. One way to speed up the rate of reaction is to use a catalyst.

**(i)** Explain what is meant by *rate of reaction*. [1]

**(ii)** Explain with the aid of a Boltzmann distribution curve, how a catalyst speeds up the rate of the reaction. [3]

**(d)** A kinetics study was conducted on the reaction of $S_2O_8^{2-}$ and $I^-$ to determine the rate equation. Varying volumes of $S_2O_8^{2-}$ and $I^-$ were added to a mixture containing sodium thiosulfate and starch indicator, followed by topping up with suitable volume of water.

As the reaction of $S_2O_8^{2-}$ and $I^-$ proceeds, the iodine produced will be consumed by the $Na_2S_2O_3$. When all $Na_2S_2O_3$ has reacted, the remaining iodine will react with the starch indicator, forming a blue-black complex. The rate of reaction is determined by the time taken for the blue-black colouration to appear.

| Experiment | Volume of KI / $cm^3$ | Volume of $Na_2S_2O_8$ / $cm^3$ | Volume of $Na_2S_2O_3$ / $cm^3$ | Volume of water / $cm^3$ | Time for blue-black colour / s |
|---|---|---|---|---|---|
| 1 | 10 | 20 | 10 | 10 | 50 |
| 2 | 5 | 20 | 10 | 15 | 100 |
| 3 | 30 | 10 | 10 | 0 | 33 |
| 4 | 20 | 40 | 20 | 20 | ***x*** |

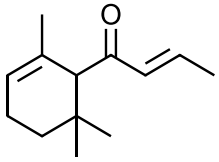
**(i)** Determine the order of reaction with respect to iodide and peroxodisulfate. [2]

**(ii)** Hence, construct a rate equation for the above reaction, and determine the units of the rate constant. [2]

**(iii)** Deduce the time taken, x, for the blue-black colouration to appear for experiment 4. [1]

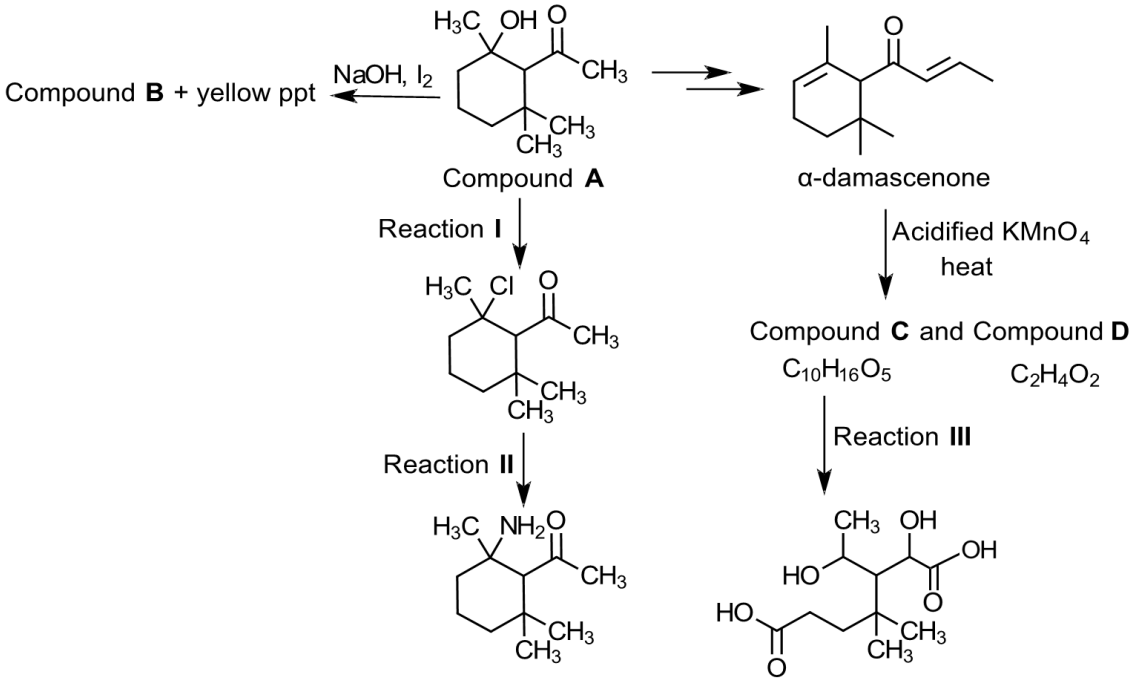
[Total: 20]

**5** In the synthesis of damascenones, which are active ingredients in the characteristic smell of Bulgarian rose oil, it was found that compound **B** is a possible pre-cursor.



α-damascenone

Compound **A** and α-damascenone can undergo a series of chemical reactions as shown in the flow chart below:




**(a)** **(i)** State the reagents and conditions for Reaction **I**, **II** and **III**. [3]

**(ii)** Draw the structural formulae of Compound **B**, **C** and **D**. [3]

**(b)** Methanol reacts with acidified potassium dichromate(VI) to form methanoic acid.

Relevant half-equation for this equation is given below:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

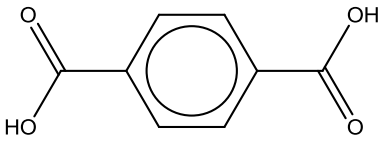
**(i)** Explain, in terms of the change in oxidation number**,** the role of potassium dichromate(VI) in the reaction with methanol. [2]

**(ii)** Write the half-equation for the oxidation reaction of methanol to methanoic acid. Hence using the half-equation given above, construct an ionic equation for the reaction between $Cr_2O_7^{2-}$ and $CH_3OH$ in acid solution. [2]

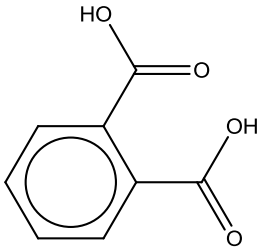
**(c)** **(i)** Define second ionisation energy of aluminium. [1]

**(ii)** Explain why the second ionisation energy of aluminium is greater than that of silicon. [1]

**(d)** Terephthalic acid (TPA) and phthalic acid (PA) both have the molecular formula $C_6H_4(COOH)_2$. While TPA is used principally to make clothing and plastic bottles, PA has limited commercial application. The structures of TPA and PA are shown below.




TPA




PA

**(i)** TPA and PA melts at 300 °C and 207 °C, respectively.
With reference to intermolecular interactions, explain why TPA has a higher melting point than PA. [2]

**(ii)** TPA can be reduced to a diol for the synthesis of a renewable polymer.
Draw the structure of this diol. Illustrate with a diagram, the interaction of this diol with water. [3]

**(iii)** Hence, explain why the diol in **(d)(ii)** is soluble in water. [1]

**(e)** In selecting a suitable material for the manufacture of bulletproof armour, it is necessary to ensure that the material does not shatter upon high impact force from a bullet.

With reference to the structures of gold and fluorite, $CaF_2$, explain why gold is more suitable for the lining of bulletproof armour. [2]

[Total: 20]

**6** High octane fuels that are free from lead additives often contain aromatic hydrocarbons such as benzene, which can be obtained from hexane by the process of "reforming".

$$C_6H_{14} \longrightarrow C_6H_6 + 4H_2$$

**(a)** **(i)** Suggest reasons for the following statements

- Alkane is generally unreactive.
- Benzene undergoes substitution reaction rather than addition reaction. [3]

**(ii)** State the reagents and conditions required for the formation of benzoic acid from benzene. [2]

**(b)** Chlorine-37 is an isotope of chlorine.
Benzene can react with the electrophile $^{37}Cl^+$ to form dichlorobenzene

**(i)** Define the term *isotope*. [1]

**(ii)** Write the electronic configuration for $^{37}Cl^+$. [1]

**(iii)** State the number, charge and location of the sub-atomic particles in $^{37}Cl^+$. [3]

**(iv)** Draw the non-polar isomer of dichlorobenzene. [1]

**(c)** Hexane and benzene undergoes combustion to form carbon dioxide.

**(i)** For each of the three compounds, hexane, benzene and carbon dioxide, state the

- hybridisation
- shape and
- bond angle about carbon. [3]

**(ii)** Describe the bonding that occurs in hexane and carbon dioxide in terms of the overlap of the orbitals. Draw diagrams to illustrate your answer. [3]

**(d)** In the stratosphere, chloroflurocarbons (CFC) such as $CCl_3F$ can form radicals such as $\bullet CCl_2F$, which deplete the ozone layer.

**(i)** Explain what is meant by the term *radical.* [1]

**(ii)** Draw the dot-and-cross diagram of the $\bullet CCl_2F$ free radical. [1]

**(iii)** Hydrofluorocarbons (HFC) such as $CH_2FCF_3$, does not deplete the ozone layer compared to CFCs. Suggest why this is so. [1]

[Total: 20]