# RIVER VALLEY HIGH SCHOOL
## YEAR 6 PRELIMINARY EXAMINATION II

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CANDIDATE NAME | | | | | | | | | |
| CLASS | | | | | | | | | |
| CENTRE NUMBER | S | 3 | 0 | 4 | 4 | INDEX NUMBER | 0 | 0 | | |

# H1 CHEMISTRY 8872/02

Paper 2 Structured and Free Response Questions **13 Sep 2017**

**2 hours**

Additional Materials: Ruled paper, Graph Paper, Section B Cover Page, Data Booklet

**READ THESE INSTRUCTIONS FIRST.**

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

Write your name, class and index number in the spaces at the top of this page. Write in dark blue or black pen. You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

**Section A**
Answer **all** questions on the Question Paper.

**Section B**
Answer **all** questions on separate ruled paper. Begin each question on a fresh sheet of ruled paper. At the end of the examination, fasten all ruled paper securely, with the cover page for Section B on top.
Hand in the Question Paper and answers to Section B **separately**.
The number of marks is given in brackets [ ] at the end of each question or part question.

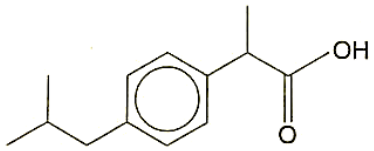
| For Examiner's Use | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Paper 2 | | | | | | | | |
| Section A | 1 | 2 | 3 | 4 | Section B | 5/6/7 | Total (Paper 2) | |
| | 15 | 11 | 7 | 7 | | 40 | 80 | |
| Paper 1 | 30 | | | | Total | 110 | Grade | |

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

## Section A (40 marks)

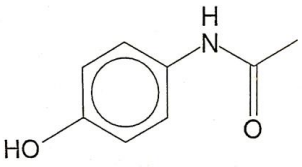
Answer **all** the questions in this section in the spaces provided.

**1** Among the many pharmaceutical drugs manufactured worldwide, one of the most important types is the painkillers. The structures of three such painkillers are shown.



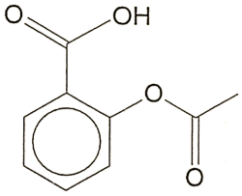

**ibuprofen**

($M_r$ = 206)




**paracetamol**

($M_r$ = 151)

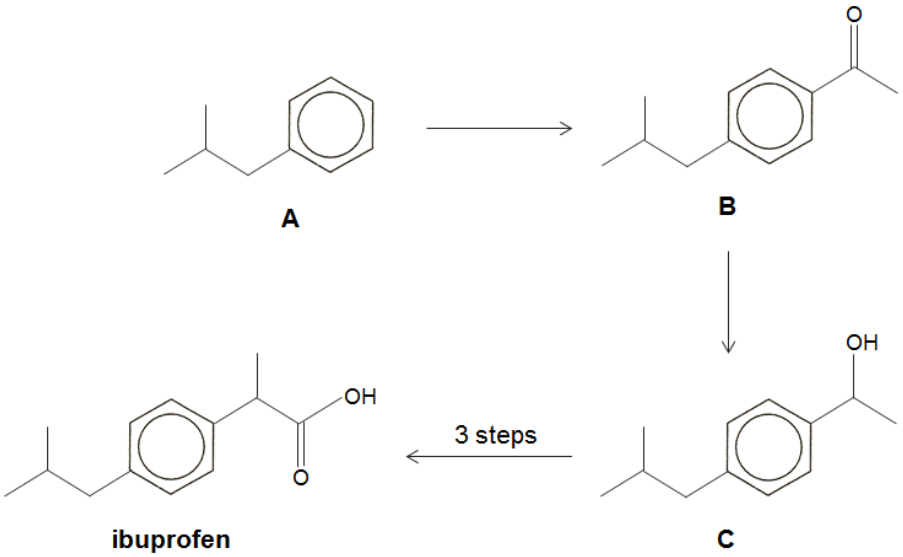



**aspirin**

($M_r$ = 180)

Ibuprofen is used to treat arthritis and relieve pain, fever and swelling. It is available over-the-counter in 200 and 400 mg tablets. The recommended dosage varies with body mass and indication, but 1.20 g is considered the maximum daily adult dosage. Long term use of ibuprofen can lead to stomach ulcers.

Ibuprofen can be synthesised via the following process:




**(a)** A man bought some ibuprofen tablets of dosage 200 mg over the counter and consumed one pill 4 times a day. Explain if this level of consumption safe for the man.

……

…… **[1]**

**(b)** State the type of reaction that converts Compound **A** to **B**.

…… **[1]**

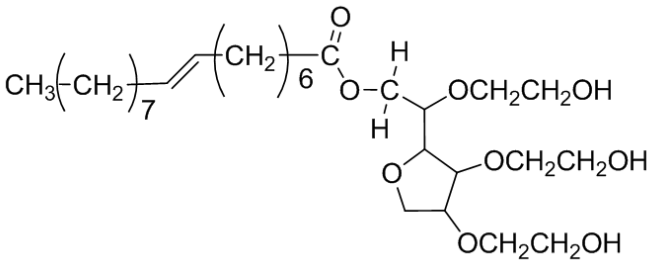
**(c)** In the laboratory, Compound **C** can be converted to ibuprofen using a 3-step synthesis route.

Suggest reagents and conditions for each step, and draw the structures of all intermediates.

**[5]**

**(d)** Young children often find it difficult to swallow tablets. Thus, ibuprofen is supplied as an "infant formula" emulsion.

Given that ibuprofen and water are immiscible, an emulsifier such as polysorbate 80 is used to create a homogeneous mixture.




**polysorbate 80**

Explain why this molecule is able to act as an emulsifier.

……

……

…… **[1]**

**(e)** A certain pharmaceutical brand claims that the ibuprofen tablets it manufactures are 95.0% pure by mass.

To investigate this claim, 5.00 g of a sample was crushed and dissolved in 250 $cm^3$ of 0.450 mol $dm^{-3}$ aqueous KOH. 25.0 $cm^3$ of this solution was withdrawn and titrated against sulfuric acid. The unreacted KOH in this solution required 25.50 $cm^3$ of 0.180 mol $dm^{-3}$ of sulfuric acid for complete neutralisation.

Showing relevant calculations, deduce if the claim is valid.

**[3]**

**(f)** Compare the acidity of ibuprofen and aspirin. Explain your answer.

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…… **[2]**

**(g)** Describe a simple chemical test to distinguish between ibuprofen and aspirin.

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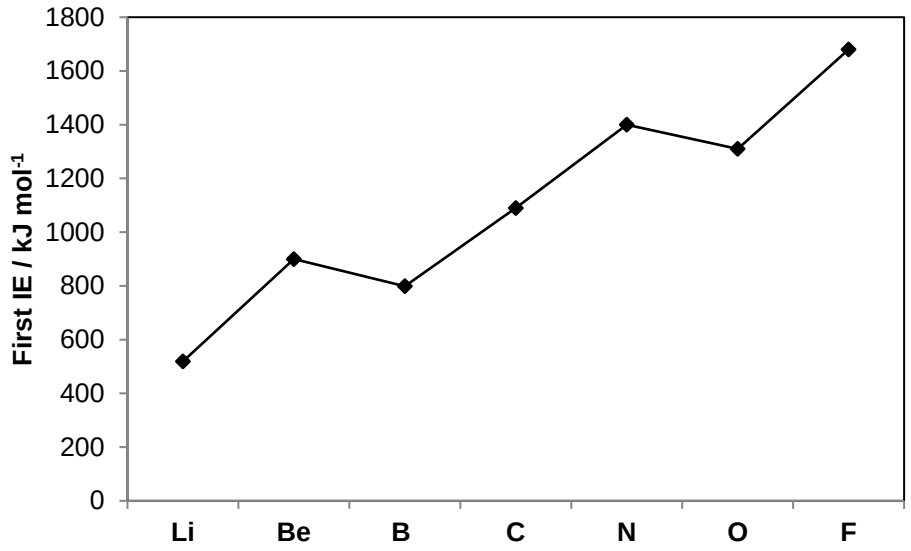
…… **[2]**

**[Total: 15]**

**2** **(a)** The first ionisation energies of the elements lithium to fluorine are shown below.




**(i)** Using an equation, define the first ionisation energy of boron.

…… **[1]**

**(ii)** Describe and explain the general trend in first ionisation energies for the elements lithium to fluorine.

……

……

……

……

……

…… **[2]**

**(iii)** Stating the electronic configurations of oxygen and nitrogen, suggest why the first ionisation energy of oxygen is lower than that of nitrogen.

……

……

……

…… **[2]**

**(b)** Across Period 3, the nature of elements changes from metallic to non-metallic. The difference in electronegativity between the elements and the oxide decreases correspondingly, giving rise to different types of oxides.

Choose and describe three oxides which are different in terms of structure and bonding. For each type of oxide, write equations for the reactions with water when applicable, and give the approximate pH of resultant solutions.

……

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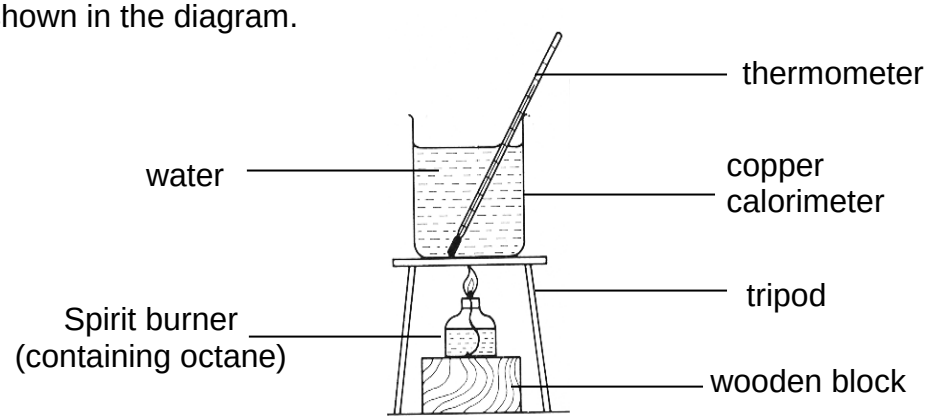
**[6]**

**[Total: 11]**

**3** **(a)** Some important uses of hydrocarbons include fuels, plastics, paints and solvents. In some countries, where crude oil is either scarce or expensive, biofuels such as ethanol are also increasingly being used for fuels instead of hydrocarbons.

**(i)** James carried out an experiment to determine the enthalpy change of combustion of octane, $C_8H_{18}$, using the apparatus shown in the diagram.




These are the results that James obtained:

Volume of water = 1000 $cm^3$

Initial temperature of water = 29.6 °C

Highest temperature of water = 50.0 °C

Initial mass of burner and octane = 59.35 g

Final mass of burner and octane = 53.77 g

Specific heat capacity of water = 4.18 J $g^{-1}$ $K^{-1}$

Heat capacity of calorimeter = 385 J $K^{-1}$

Use these results to determine the experimental enthalpy change of combustion of octane.

**[3]**

**(ii)** Define the standard enthalpy change of combustion.

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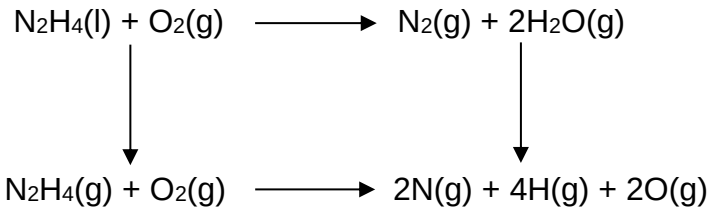
……

…… **[1]**

**(b)** Liquid hydrazine reacts with oxygen to form nitrogen and steam which could involve the following energy cycle shown below.




**(i)** Given that the enthalpy change of vapourisation of hydrazine is +58.0 kJ $mol^{-1}$, use appropriate bond energies from the *Data Booklet* to calculate the enthalpy change of reaction between liquid hydrazine and oxygen.

**[2]**

**(ii)** Suggest a reason to account for the discrepancy between the theoretical enthalpy change of reaction between liquid hydrazine and oxygen and your answer in **(b)(i)**.

……

……

…… **[1]**

**[Total: 7]**

**4** Under suitable conditions, $SCl_2$ reacts with water to produce a yellow precipitate of sulfur and an acidic solution **G**. Solution **G** contains a mixture of $SO_2$(aq) and another compound.

**(a)** State the oxidation number of S in $SCl_2$ .

……. **[1]**

**(b)** Construct an equation for the reaction between $SCl_2$ and water.

……. **[1]**

**(c)** In the Contact Process, one important step is the conversion of $SO_2$ to $SO_3$ as shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

2.00 L flask was filled with 0.0400 mol $SO_2$ and 0.0200 mol $O_2$. At equilibrium, at 900 K, the flask contained 0.0296 mol of $SO_3$. Determine the value of $K_c$.

**[3]**

**(d)** State and explain how the position of equilibrium and equilibrium constant, $K_c$, will change when the volume of the flask is doubled.

……

……

……

……. **[2]**

**[Total: 7]**

## Section B (40 marks)

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

**5** **(a)** Carbon also forms compounds with other Group 16 elements like sulfur and selenium. The properties of some of these compounds, along with $CO_2$, are given in Table 5.1.

**Table 5.1**

| Compound | Structure | Dipole moment | Boiling point / °C |
|---|---|---|---|
| $CO_2$ | O=C=O | 0 | sublimes |
| $CS_2$ | S=C=S | 0 | 46 |
| COS | S=C=O | 0.71 | –50 |
| COSe | Se=C=O | 0.73 | –22 |

**(i)** Explain, in terms of structure and bonding, the difference in the boiling point of $CS_2$ and COS. **[2]**

**(ii)** Explain why

- $CO_2$ has no overall dipole moment.
- COSe has a greater dipole moment than COS. **[2]**

**(b)** Aside from the common oxides, carbon forms a series of reactive oxocarbons. One such compound is tricarbon monoxide, $C_3O$, a reactive molecule found in space.

**(i)** Suggest a structure of tricarbon monoxide. Indicate clearly any lone pairs present. **[1]**

Tricarbon monoxide is isoelectronic to cyanogen, $(CN)_2$. The molecule of cyanogen contains a C–C single bond.

**(ii)** Draw the dot-and-cross diagram of cyanogen. In your diagram, you should distinguish the electrons originating from the two carbon atoms and those from the two nitrogen atoms. **[1]**

**(iii)** Suggest the shapes of tricarbon monoxide and cyanogen. **[1]**

**(c)** Another oxycarbon is pentacarbon dioxide, $C_5O_2$. It can be obtained by heating compound **X**, $C_6H_6O_3$, at a high temperature.

**X** also gives an orange precipitate with 2,4-DNPH but does not give a silver mirror with Tollens' reagent. **X** reacts with hydrogen in the presence of platinium catalyst under suitable conditions to for **Y**, $C_6H_{12}O_3$. When reacted with limited bromine under ultraviolet light, **X** produced **only one** monobromo compound.

**Y** reacts with ethanolic sodium hydroxide to form **Z**, $C_6H_6$.

Suggest the structures of compounds **X**, **Y** and **Z**. Explain your reasoning. **[8]**

**(d)** **(i)** Define the term *Bronsted acid.* **[1]**

**(ii)** The concentration of a monobasic acid, HY is 0.01 mol $dm^{-3}$, while the pH of the solution is 3.5.

Calculate the concentration of $H^+$ in this solution. State, with reasoning, if HY is a strong or weak acid. **[2]**

**(e)** Values for the ionic product of water, $K_w$, at two different temperatures are given in Table 5.2.

**Table 5.2**

| Temperature / $^oC$ | $K_w$ / $mol^2\ dm^{-6}$ |
|---|---|
| 25 | $1.00 \times 10^{-14}$ |
| 50 | $5.48 \times 10^{-14}$ |

Using Le Chatelier's Principle, explain whether the ionisation of water is an endothermic or exothermic process. **[2]**

**[Total: 20]**

**6** In the late 1940s, Willard Libby developed the radiocarbon dating method for determining the age of an object containing organic material by using the properties of radiocarbon ($^{14}C$), a radioactive isotope of carbon. The principle of carbon dating is as such:

During its life, a plant or animal is exchanging carbon with its surroundings, so the carbon it contains will have the same proportion of $^{14}C$ as the atmosphere. Once it dies, it ceases to acquire $^{14}C$, but the $^{14}C$ within its biological material at that time will continue to decay, and so the ratio of $^{14}C$ to $^{12}C$ in its remains will gradually decrease.

Because $^{14}C$ decays with first order kinetics, the proportion of radiocarbon can be used to determine how long it has been since a given sample stopped exchanging carbon – the older the sample, the less $^{14}C$ will be left.

**(a)** A sample of carbon dioxide gas (that contained both $^{12}CO_2$ and $^{14}CO_2$) was analysed to determine the proportion of $^{14}CO_2$ found within. Analysis results showed that there is one $^{14}CO_2$ molecule for every $10^{12}$ $CO_2$ molecules.

**(i)** Calculate the number of $^{14}CO_2$ molecules in a 10.0 $dm^3$ carbon dioxide gas sample, measured under s.t.p. **[2]**

**(ii)** Calculate the mass of $^{14}CO_2$ in the 10.0 $dm^3$ sample. **[1]**

**(iii)** Hence, explain why it would be difficult to determine the proportion of $^{14}CO_2$ by means of mass measurement. **[1]**

**(b)** To more accurately determine the proportion of $^{14}C$ in a sample of graphite, the graphite is vaporised and ionised to $C^+(g)$ ions. These ions were then passed through two electric plates.

Given that $H^+$ is deflected with an angle of 8.4°, what is the angle of deflection for $^{14}C^+$ ions under the same experimental set-up? **[1]**

**(c)** The half-life of $^{14}C$ is 5730 years. Determine the time that has elapsed for a piece of wood from a dead tree to contain 30.0% of its original $^{14}C$. **[2]**

**(d)** Benzene is obtained from the fractional distillation of crude oil. It can be converted to a series of different useful chemicals such as phenylamine. The formation of phenylamine involves the direct reaction of nitrobenzene and hydrogen gas in the presence of a heterogeneous catalyst.

A series of experiments were carried out at a specific temperature to study the kinetics of this reaction, and the results are shown in Table 6.1.

**Table 6.1**

| Experiment | [nitrobenzene] / mol $dm^{-3}$ | [$H_2$] / mol $dm^{-3}$ | Initial rate / mol $dm^{-3}$ $s^{-1}$ |
|---|---|---|---|
| 1 | 0.010 | 0.010 | $4.50 \times 10^{-5}$ |
| 2 | 0.015 | 0.010 | $6.74 \times 10^{-5}$ |
| 3 | 0.020 | 0.020 | $1.80 \times 10^{-4}$ |
| 4 | 0.030 | $x$ | $4.05 \times 10^{-4}$ |

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

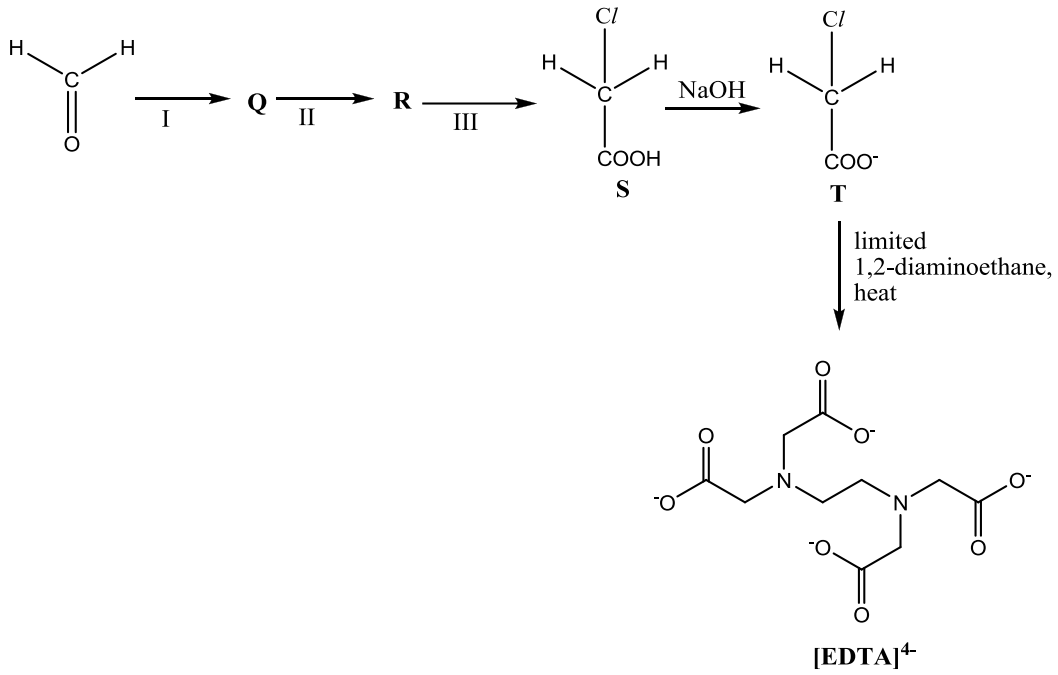
**(ii)** Determine the order of reaction with respect to nitrobenzene and hydrogen. **[2]**

**(iii)** Calculate the rate constant, stating its units. **[2]**

**(iv)** Hence, determine the value of $x$. **[1]**

**(e)** Ethylenediamine tetraacetate, $[EDTA]^{4-}$, is a ligand that acts as a chelating agent. It is widely used to remove transition metal ions such as those of chromium from aqueous solutions.

A possible reaction scheme used to synthesise $[EDTA]^{4-}$ from methanal is given below.




**(i)** Suggest the reagents and conditions in steps I, II and III. **[3]**

**(ii)** Draw the displayed formulae of intermediates **Q** and **R**. **[2]**

**(iii)** State the type of reaction when **T** is converted to $[EDTA]^{4-}$.

Give a reason why a limited amount of 1,2-diaminoethane is used. **[2]**

**[Total: 20]**

**7** **(a)** 2-chlorobutane undergoes a substitution reaction with hot aqueous sodium hydroxide. Two separate experiments with different concentrations of 2-chlorobutane were carried out to investigate the kinetics of the reaction.

The obtained results are presented in Table 7.1.

**Table 7.1**

| | **Experiment 1** [2-chlorobutane] = 0.05 mol $dm^{-3}$ | **Experiment 2** [2-chlorobutane] = 0.10 mol $dm^{-3}$ |
|---|---|---|
| **Time / min** | [NaOH] / mol $dm^{-3}$ | [NaOH] / mol $dm^{-3}$ |
| 0 | 0.0050 | 0.0050 |
| 15 | 0.0045 | 0.0040 |
| 30 | 0.0040 | 0.0032 |
| 45 | 0.0036 | 0.0026 |
| 60 | 0.0032 | 0.0021 |
| 75 | 0.0029 | 0.0017 |
| 90 | 0.0026 | 0.0014 |

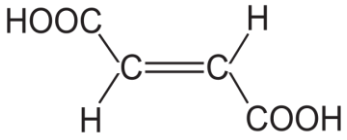
**(i)** On the same axes, plot graphs of [2-chlorobutane] against time for both Experiments 1 and 2. Label each curve clearly. **[2]**

**(ii)** Use your graphs to determine the order of reaction with respect to 2-chlorobutane and NaOH. Justify your answer in each case. **[4]**

**(iii)** Hence, write a rate equation for the reaction. **[1]**

**(iv)** With the aid of a Maxwell-Boltzmann distribution curve, explain how an increase in temperature affects the rate of reaction in Experiment 2. **[3]**

**(b)** Fumaric acid is a dibasic acid. When fumaric acid and its potassium salt are added to foods, they act as an acidity regulator and flavouring agent.




**fumaric acid**

**(i)** Identify the type of isomerism fumaric acid exhibits, and explain how it arises. **[2]**

**(ii)** When 25 $cm^3$ of fumaric acid was titrated against 0.15 mol $dm^{-3}$ potassium hydroxide, the volume of potassium hydroxide required for complete neutralisation was 27 $cm^3$. The pH at this end point was approximately 8.2.

Calculate the concentration of fumaric acid used in the titration. **[2]**

**(iii)** Suggest an indicator that is suitable for the titration of fumaric acid with potassium hydroxide. **[2]**

**(c)** The buffer system of lactic acid, $CH_3CH(OH)COOH$, and sodium lactate, $CH_3CH(OH)COO^-Na^+$, can also be used as acidity regulators in food.

The following equilibrium is established in the buffer system:

$$CH_3CH(OH)COOH(aq) \rightleftharpoons CH_3CH(OH)COO^-(aq) + H^+(aq)$$

The numerical value of the equilibrium constant, $K_a$, is $1.38 \times 10^{-4}$.

**(i)** Write the $K_a$ expression for the equilibrium shown above. **[1]**

**(ii)** The pH of a buffer solution is deduced using the formula:

$$pH = -\lg K_a + \lg \frac{[salt]}{[acid]}$$

Given that the equilibrium concentrations of lactic acid and sodium lactate are 0.35 mol $dm^{-3}$ and 0.20 mol $dm^{-3}$ respectively, calculate the pH of this buffer solution. **[1]**

**(iii)** Write two equations to show how this buffer solution controls pH when a small amount of acid or base is added. **[2]**

**[Total: 20]**

**END OF PAPER**