RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE NAME									
CLASS	6								
CENTRE NUMBER	S	3	0	4	4	INDEX NUMBER	0	0		

H1 CHEMISTRY 8872/01

Paper 1 Multiple Choice **21 Sep 2017**

50 mins

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Optical Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the one you consider correct and record your choice in **soft pencil** on the Optical Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **14** printed pages.

Section A

For each question there are four possible answers, **A, B, C** and **D**. Choose the **one** you consider to be correct.

1 *Use of the Data Booklet is relevant to this question.*

At room temperature and pressure, a sample of 2 dm^3 of polluted air was passed through limewater so that all the carbon dioxide present was precipitated as calcium carbonate. The mass of calcium carbonate formed was 0.05 g.

What is the percentage, by volume, of carbon dioxide in the air sample?

A 0.30% **B** 0.57%

C 0.60% **D** 1.20%

2 In an experiment, 20 cm^3 of an organic compound was sparked with 160 cm^3 of oxygen. After cooling to room temperature, 120 cm^3 of gas remained. The residual gas was passed through aqueous KOH and 40 cm^3 of gas remained. All gases were measured at room temperature and pressure.

What is the formula of the organic compound?

A C_3H_8 **B** C_4H_8

C C_4H_{10} **D** C_6H_6

3 When $Tl^+(aq)$ reacts with $VO_3^-(aq)$, $Tl^{3+}(aq)$ and $V^{2+}(aq)$ are formed.

Assuming the reaction goes to completion, how many moles of $Tl^+(aq)$ and $VO_3^-(aq)$ would result in a mixture containing equal number of moles of $VO_3^-(aq)$ and $V^{2+}(aq)$ once the reaction had taken place?

	Moles of $Tl^+(aq)$	Moles of $VO_3^-(aq)$
A	1	2
B	1	3
C	2	3
D	3	4

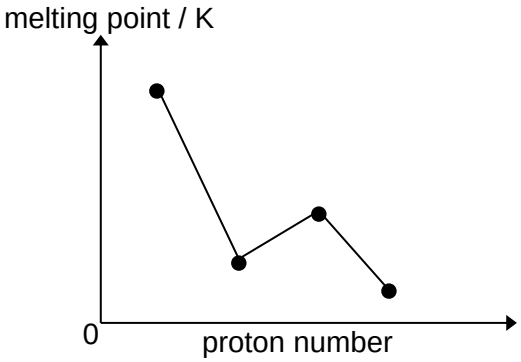
4 **FA 1** contains Fe^{2+} ions. In an experiment, it was found that 25.0 cm^3 of **FA 1** required 18.00 cm^3 of 0.200 mol dm^{-3} acidified $KMnO_4$ (aq) for reaction. What was the volume of 0.150 mol dm^{-3} acidified $K_2Cr_2O_7$(aq) needed to react with 25.0 cm^3 of **FA 1**?

A 18.00 cm^3 **B** 20.00 cm^3

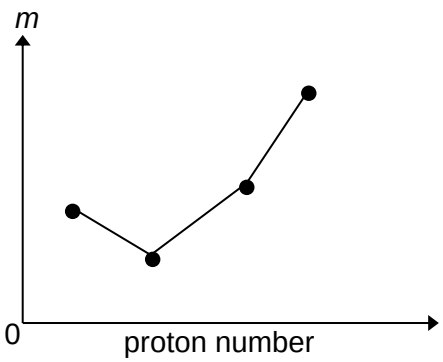
C 24.00 cm^3 **D** 30.00 cm^3

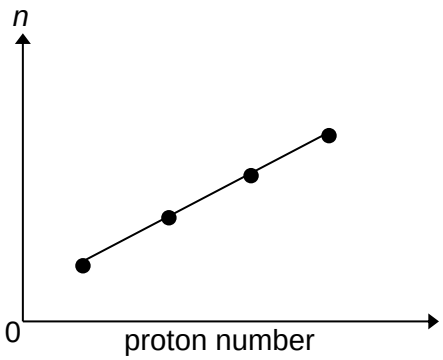
5 The diagram represents the melting points of four consecutive elements in the third period of the Periodic Table.

.



The sketches below represent another two properties, *m* and *n*, of the elements.





What are the properties *m* and *n*?

	Property *m*	Property *n*
A	third ionisation energy	electronegativity
B	number of valence electrons	boiling point
C	ionic radius	effective nuclear charge
D	electrical conductivity	atomic radius

6 Elements **X** and **Y** have the following successive ionisation energies in kJ mol^{-1}.

	1st	2nd	3rd	4th	5th	6th	7th
X	580	1800	2700	11600	14800	18400	23300
Y	1310	3400	5300	7500	11000	13300	20300

What could be the formula of the compound formed by these two elements?

A XY_3 **B** X_2Y_3 **C** X_3Y_2 **D** X_4Y_3

7 Which pair of compounds meets the criteria below?

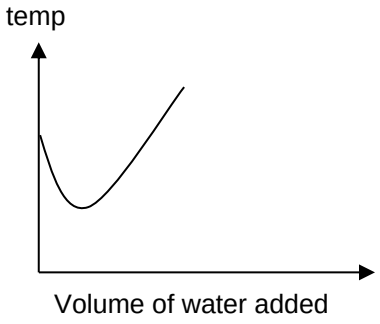
- The first compound has a larger bond angle than the second compound.
- The second compound is more polar than the first compound.

A CO_2, BCl_3 **B** $ICl F_2$, ClO_2 **C** HCN, SO_3 **D** CO_2, NCl_3

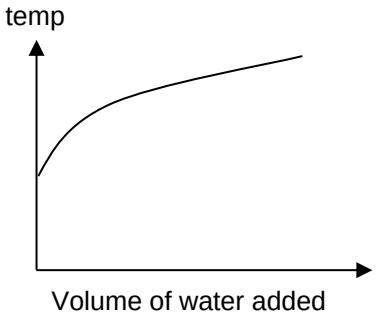
8 When water is stirred with glucose, strong hydrogen bonds are initially formed between glucose molecules and water molecules, but as more water is added, these hydrogen bonds are broken.

Which graph best represents the observed temperature changes?

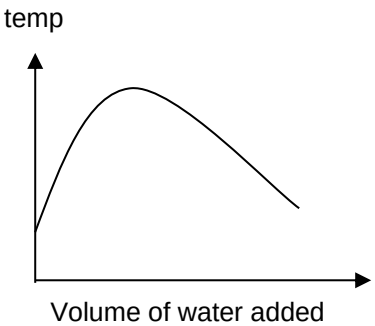
A



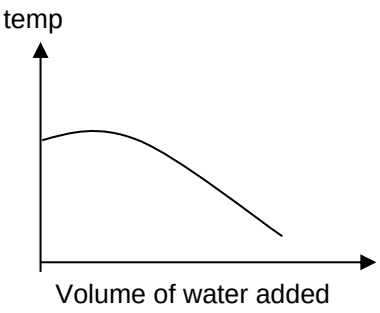
B



C



D



9 *Use of the Data Booklet is relevant to this question.*

A student dissolved 8.4 g of sodium fluoride in 250 g of water.

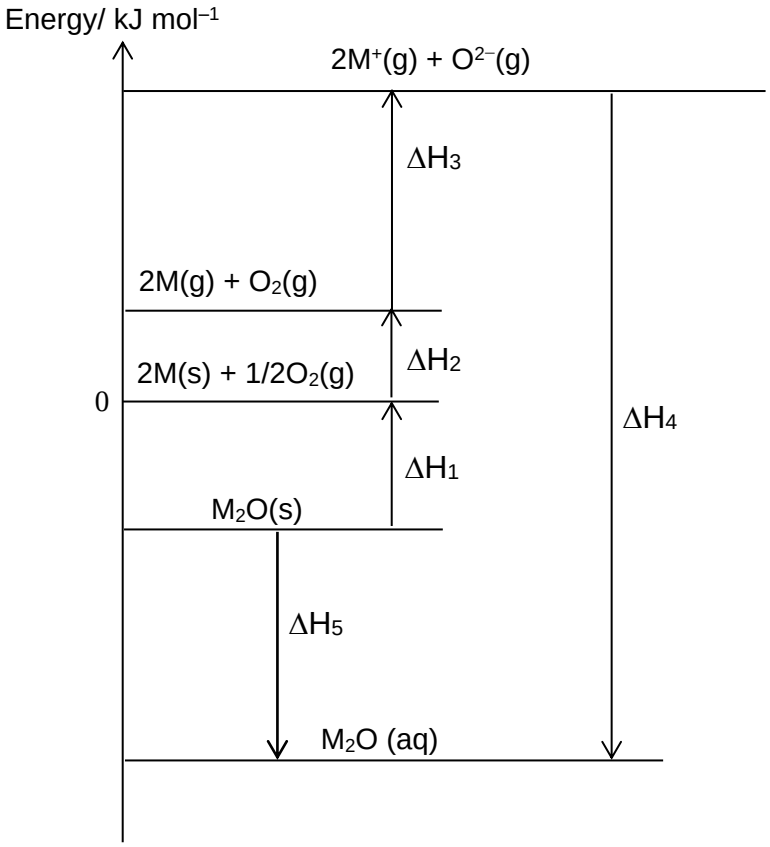
The enthalpy change of reaction is +71 kJ mol^{-1}.

What would be the initial temperature of the water if the final temperature of the solution is 20.00 °C?

Assume that the specific heat capacity of sodium fluoride solution is 4.2 J g^{-1} K^{-1}.

A 6.48 °C **B** 33.08 °C **C** 33.52 °C **D** 47.62 °C

10 An energy cycle involving a metal oxide, M_2O, is shown below.



Which expression represents the enthalpy change of formation of $M_2O(s)$?

A ΔH_1

B $\Delta H_4 - \Delta H_5$

C $\Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4$

D $\Delta H_2 + \Delta H_3 + \Delta H_4 - \Delta H_5$

11 For which of the following reactions does the enthalpy value represent **both** a standard enthalpy change of combustion **and** a standard enthalpy change of formation?

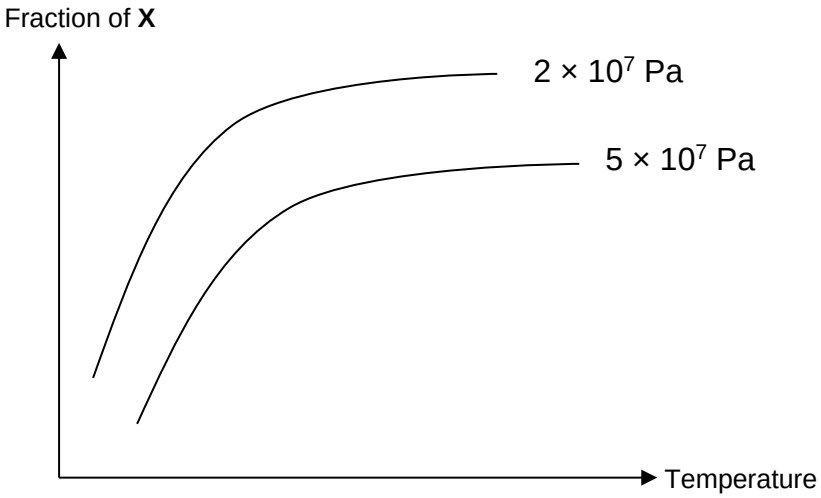
A $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

B $2C(s) + O_2(g) \rightarrow 2CO(g)$

C $C(s) + O_2(g) \rightarrow CO_2(g)$

D $C(s) + 2O(g) \rightarrow CO_2(g)$

12 The graph below shows how the fraction of a substance, **X**, in an equilibrium mixture varies with temperature at pressures of 2×10^7 Pa and 5×10^7 Pa.



Which underlined compound represents **X**?

A $2N_2(g) + 6\underline{H_2O}(g) \rightleftharpoons 4NH_3(g) + 3O_2(g)$ $\Delta H = +1267$ kJ mol^{-1}

B $C(s) + H_2O(g) \rightleftharpoons H_2(g) + \underline{CO}(g)$ $\Delta H = +131$ kJ mol^{-1}

C $2SO_2(g) + O_2(g) \rightleftharpoons 2\underline{SO_3}(g)$ $\Delta H = -197$ kJ mol^{-1}

D $N_2(g) + 3H_2(g) \rightleftharpoons 2\underline{NH_3}(g)$ $\Delta H = -92$ kJ mol^{-1}

13 Nitrogen dioxide decomposes on heating according to the following equation.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 4 moles of nitrogen dioxide was put into a 1 dm^3 container and heated, the equilibrium mixture contained 0.8 moles of oxygen. What is the numerical value of the equilibrium constant, K_c, at the temperature of the experiment?

A $\dfrac{0.8 \times 0.8}{2.4}$

B $\dfrac{0.8^2 \times 0.8}{4^2}$

C $\dfrac{1.6 \times 0.8}{2.4^2}$

D $\dfrac{1.6^2 \times 0.8}{2.4^2}$

14 Which combination of substances would give a buffer solution?

A 2 mol of NaOH and 1 mol of CH_3CO_2H

B 2 mol of CH_3CO_2H and 1 mol of NaOH

C 1 mol of HC*l* and 1 mol of CH_3CO_2Na

D 2 mol of NH_3 and 1 mol of CH_3CO_2Na

15 What is the final pH of the solution formed when two equal volumes of HC*l* solutions, one with pH 1.0 and the other with pH 3.0 are mixed?

A 1.0 **B** 1.3 **C** 2.0 **D** 2.5

16 The kinetics of the reaction between iodide and peroxodisulfate can be investigated by varying the volume of the reactants used. The two reactants are mixed in the presence of a known amount of $Na_2S_2O_3$ and a little starch. The time taken for an intense blue colour to be observed is then determined.

Experiment	Volume used/cm^3			t/s
	1.0 mol dm^{-3} KI	0.040 mol dm^{-3} $Na_2S_2O_8$	H_2O	
1	10.0	5.0	25.0	170
2	15.0	5.0	20.0	113
3	15.0	10.0	15.0	57
4	20.0	20.0	0.0	x

What is the value of x?

A 21 **B** 28 **C** 85 **D** 63

17 Which one of the following is a correct statement about the effect of a catalyst?

A It provides an alternative route with a lower activation energy for a reaction.

B It increases the equilibrium constant for a forward reaction.

C It increases the yield of product in equilibrium.

D It increases the rate of the forward reaction only.

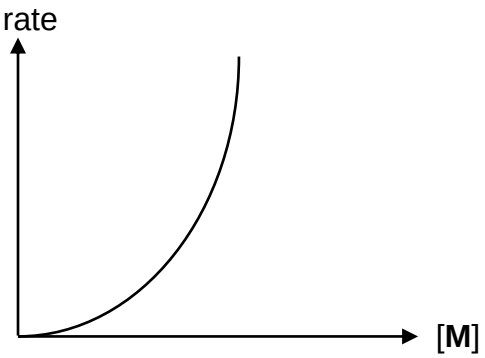
18 **L**, **M** and **N** react to form **P** and **Q** as shown.

$$\mathbf{L} + \mathbf{M} + \mathbf{N} \rightarrow \mathbf{P} + \mathbf{Q}$$

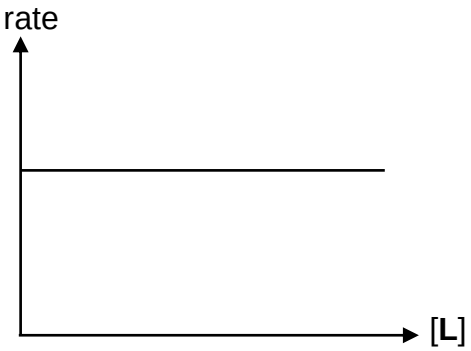
The rate equation for this reaction is rate = k[**M**][**N**].

Which of the following graphs is correct of the above reaction, when **N** is in excess?

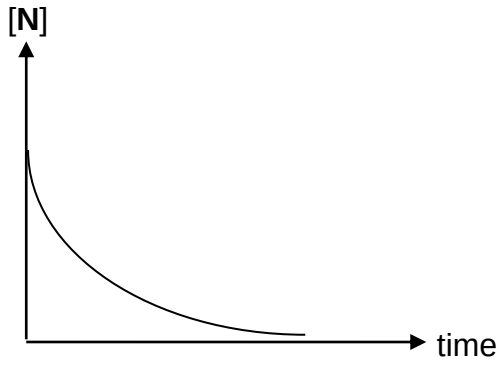
A



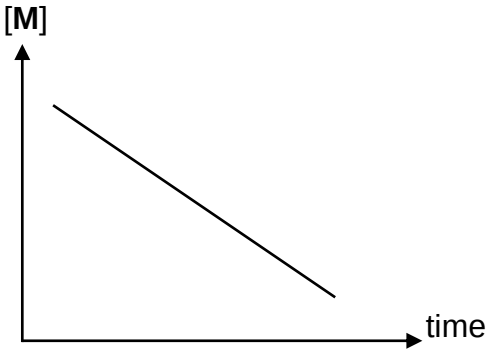
B



C



D



19 Which one of the following best describes the compounds formed by aluminium?

	Oxide	Chloride
A	Basic	basic
B	Amphoteric	neutral
C	Amphoteric	acidic
D	Basic	acidic

20 The chloride of the following elements are dissolved in water. The chloride of element which produces the solution with the greatest pH is

A A*l*

B Na

C Mg

D P

21 Alkynes are a series of non-cyclic hydrocarbons with the general formula, C_nH_{2n-2} containing one carbon-carbon triple bond per molecule.

How many alkynes with 6 carbon atoms satisfies the above formula?

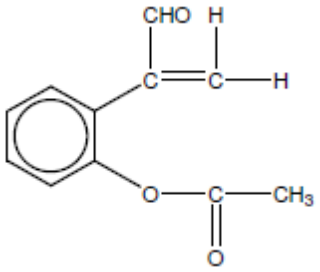
A 5

B 6

C 7

D 8

22



Compound A

Which reagent will not react with compound **A?**

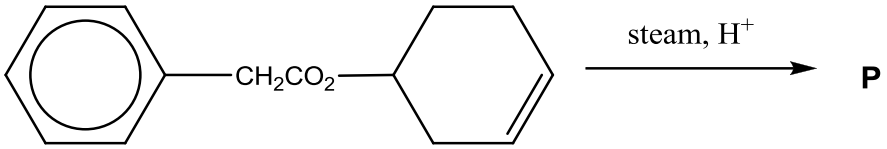
A alkaline I_2 (aq)

B alkaline Cu^{2+} ions

C $LiAlH_4$ in dry ether

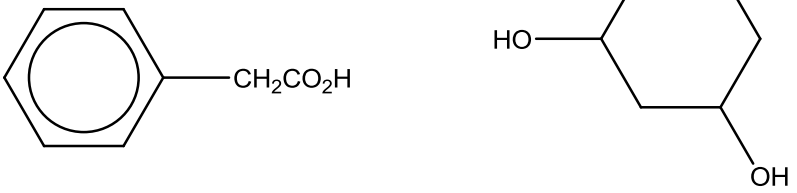
D cold alkaline $KMnO_4$

23 The diagram shows a reaction.

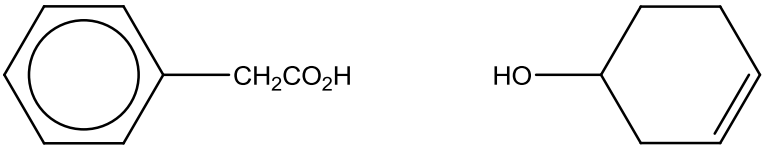


What could be the final products, **P**?

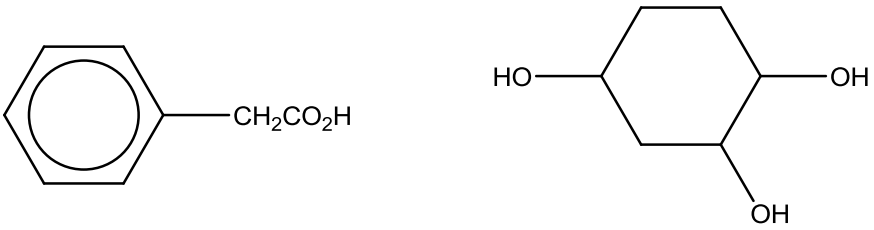
A



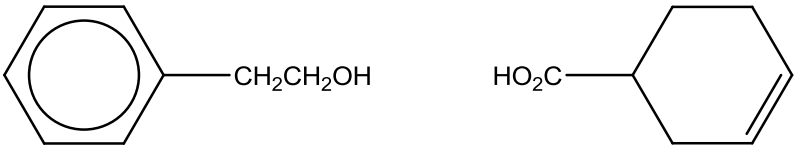
B



C



D



24 Which of the following statements is **false** in the reaction of C_2H_6 with Br_2?

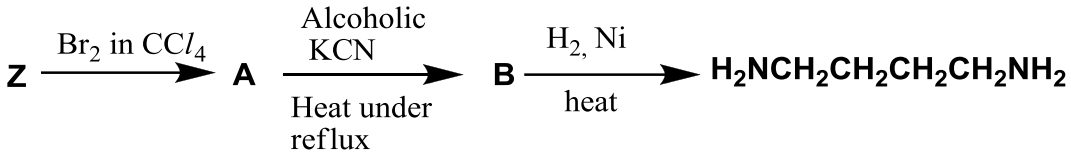
A Steamy fumes are produced in the reaction.

B A mixture of brominated alkanes is formed.

C High temperature can be used in place of UV light.

D The intermediate formed is highly reactive as it has a lone pair of electrons.

25 An organic compound **Z** underwent the following successive reactions.



Which of the following compounds is **Z** likely to be?

A $CH_2=CH_2$

B $ClCH=CHCl$

C $CH_3CH=CHCH_3$

D $CH_2=CHCH=CH_2$

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Which of the following statements about the carbonate ion, CO_3^{2-}, are correct?

1 The carbon atom is the central atom.

2 The carbon in CO_3^- has an octet electronic configuration.

3 It has the same bond angle as the nitrate ion, NO_3^-.

27 *Use of the Data Booklet is relevant to this question.*

Species containing one or more unpaired electrons are said to be paramagnetic as they can be attracted by an external magnetic field.

Which of the following species are paramagnetic?

1 Cr^{3+}

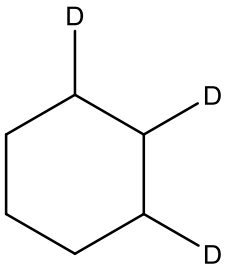
2 Fe^{2+}

3 Cu^{+}

28 Deuterium is an isotope of hydrogen, $^{2}_{1}H$.

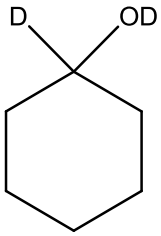
Which compound can be formed by the addition of D_2 to another molecule, in the presence of platinum catalyst?

1



2 $CH_3CD_2ND_2$

3



29 During the preparation of many organic compounds, by-products are formed. This usually occurs because the reagents can react in more than one way, depending on the conditions used, or because the products formed may react with the reactants.

2-bromobutane may be prepared by slowly adding concentrated sulfuric acid to sodium bromide to form hydrogen bromide which reacts with butan-2-ol. The reaction mixture is kept cool to optimise the reaction yield.

$$CH_3CH(OH)CH_2CH_3 + HBr \rightarrow CH_3CH(Br)CH_2CH_3 + H_2O$$

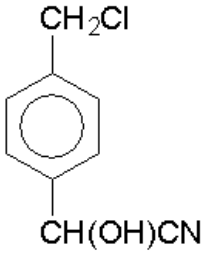
What could be a by-product of this reaction if the temperature is allowed to rise?

1 $CH_2=CHCH_2CH_3$

2 $CH_2BrCH_2CH_2CH_3$

3 $CH_3CBr_2CH_2CH_3$

30 A newly-discovered drug that is claimed to cure AIDS contains an active ingredient of the following structure:



Which of the following statements concerning its properties are **correct**?

1 It gives a white precipitate with silver nitrate after heating with aqueous sodium hydroxide.

2 It gives a white precipitate with aqueous bromine.

3 It gives a pale yellow precipitate with alkaline aqueous iodine.

Answers to Paper 1

1	C	11	C	21	C
2	B	12	B	22	A
3	D	13	D	23	A
4	B	14	B	24	D
5	A	15	B	25	A
6	B	16	A	26	A
7	D	17	A	27	B
8	C	18	B	28	C
9	C	19	C	29	B
10	D	20	C	30	D

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.

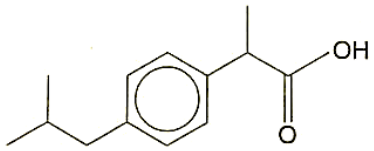
For Examiner's Use								
Paper 2								
Section A	1	2	3	4	Section B	5/6/7	Total (Paper 2)	
	15	11	7	7		40	80	
Paper 1	30				Total	110	Grade	

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

Section A (40 marks)

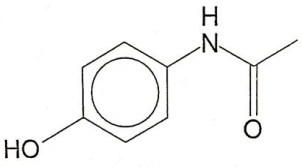
Answer **all** the questions in this section in the spaces provided.

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.



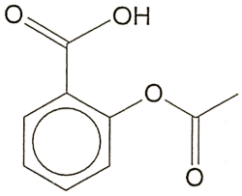
ibuprofen

(M_r = 206)



paracetamol

(M_r = 151)

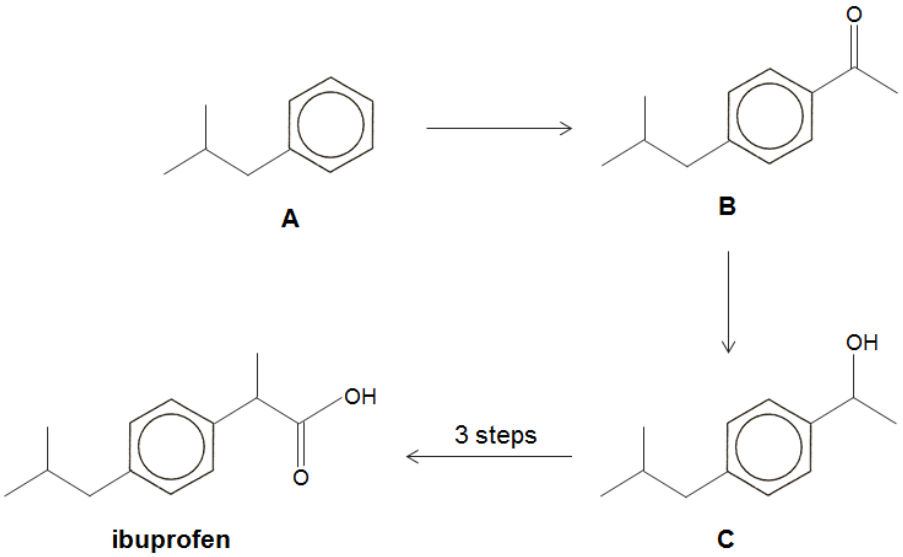


aspirin

(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]**

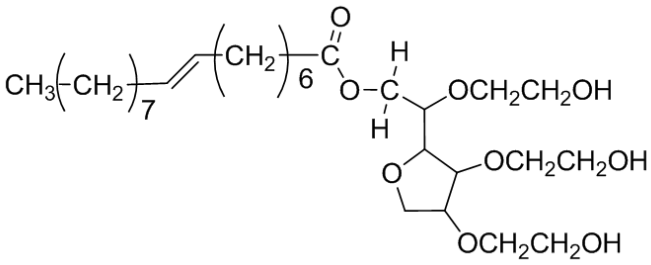
(c) In the laboratory, Compound **C** can be converted to ibuprofen using a 3-step synthesis route.

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.

……

……

……

……

……

…… **[2]**

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

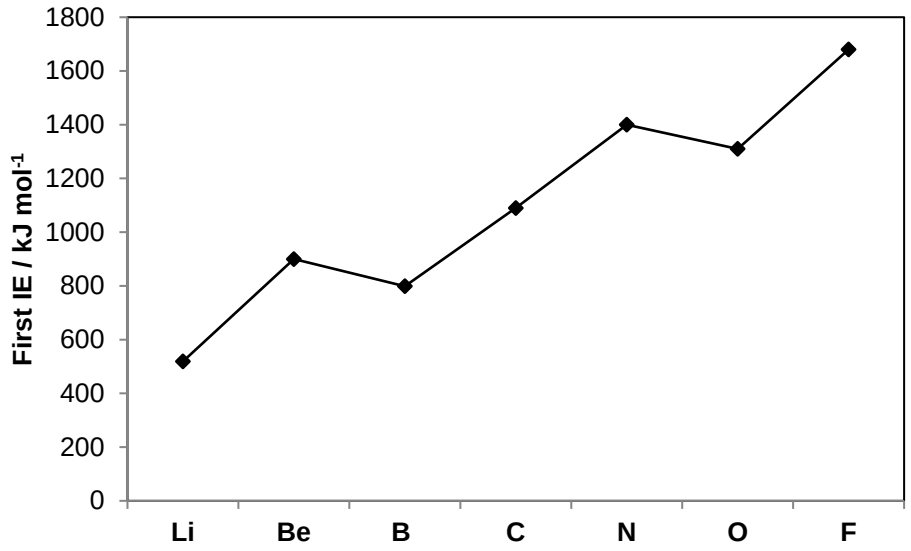
……

……

…… **[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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……

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……

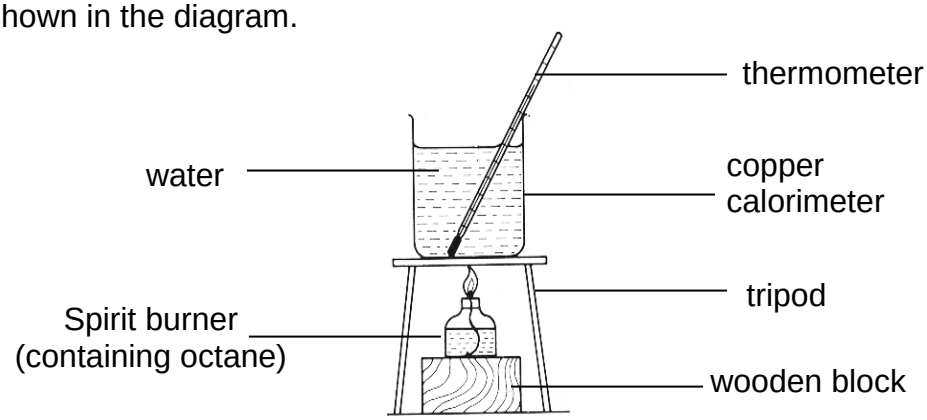
……

[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]

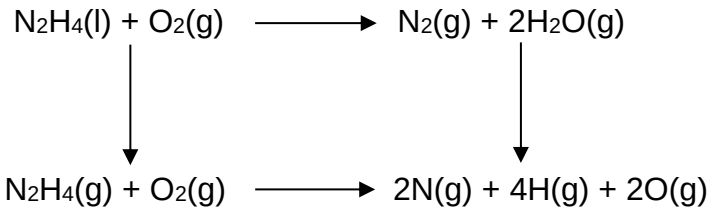
(ii) Define the standard enthalpy change of combustion.

……

……

…… **[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	1.00×10^{-14}
50	5.48×10^{-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	4.50×10^{-5}
2	0.015	0.010	6.74×10^{-5}
3	0.020	0.020	1.80×10^{-4}
4	0.030	x	4.05×10^{-4}

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

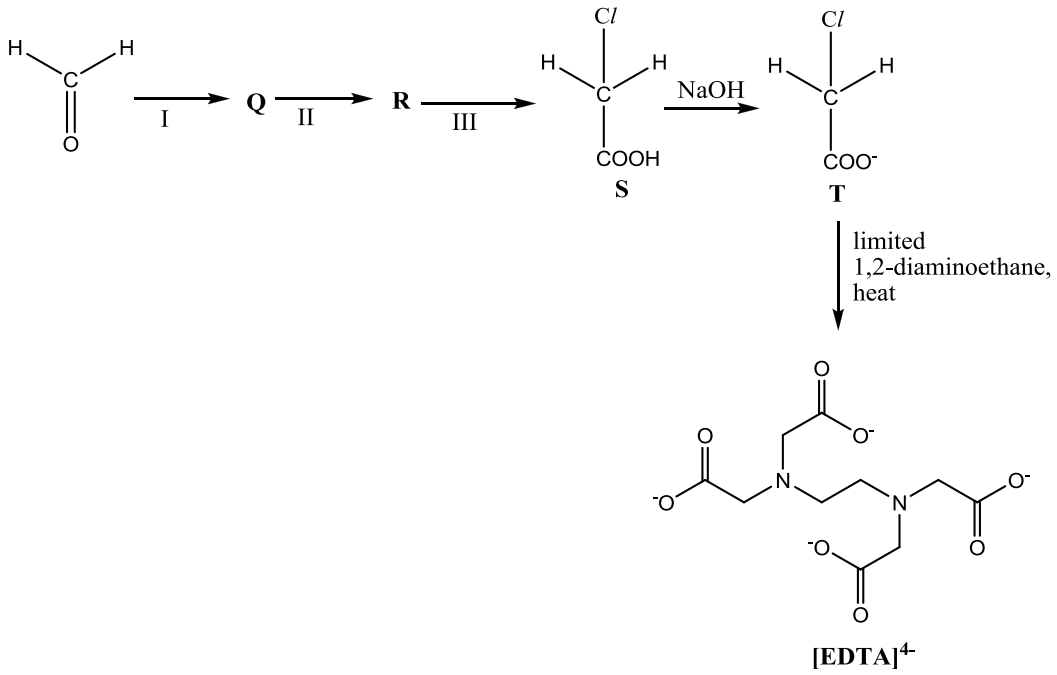
(ii) Determine the order of reaction with respect to nitrobenzene and hydrogen. **[2]**

(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

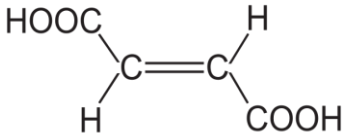
(i) On the same axes, plot graphs of [2-chlorobutane] against time for both Experiments 1 and 2. Label each curve clearly. **[2]**

(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 1.38×10^{-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

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE NAME	**MARK SCHEME**								
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.

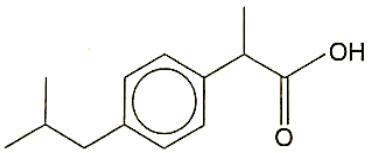
For Examiner's Use								
Paper 2								
Section A	**1**	**2**	**3**	**4**	**Section B**	**5/6/7**	**Total (Paper 2)**	
	/15	/11	/7	/7		/40	/80	
Paper 1	/30				**Total**	/110	**Grade**	

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

Section A (40 marks)

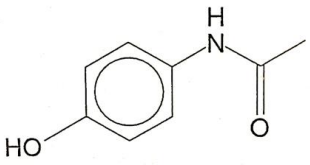
Answer **all** the questions in this section in the spaces provided.

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.



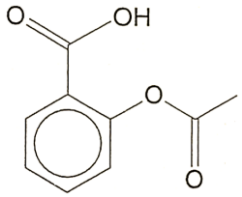
ibuprofen

(M_r = 206)



paracetamol

(M_r = 151)

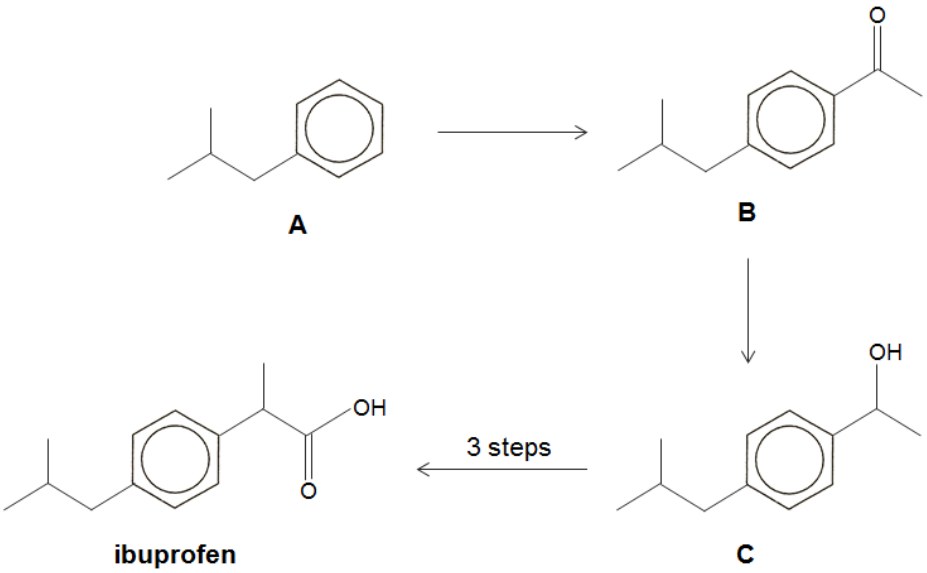


aspirin

(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.

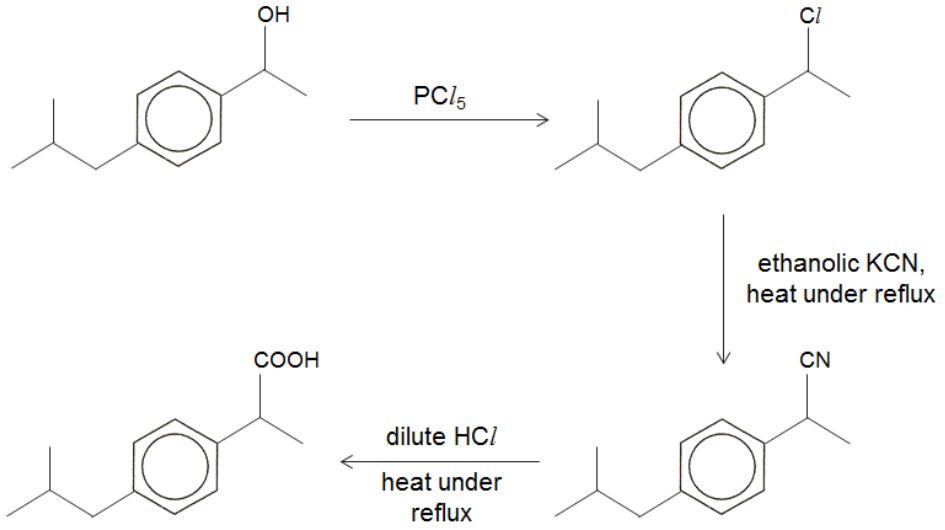
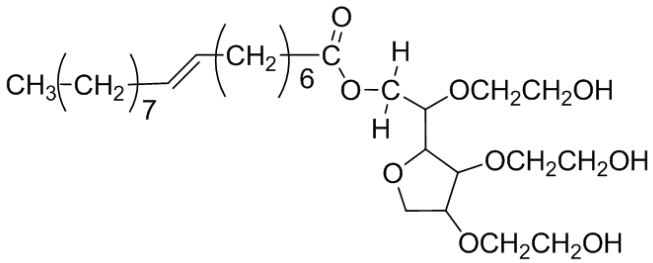
Ibuprofen can be synthesised via the following process:

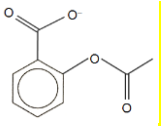
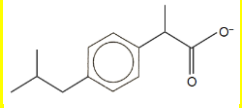


(a) A man bought some ibuprofen tablets of dosage 200 mg over the counter and consumed one pill 4 times a day. Explain if this level of consumption safe for the man.

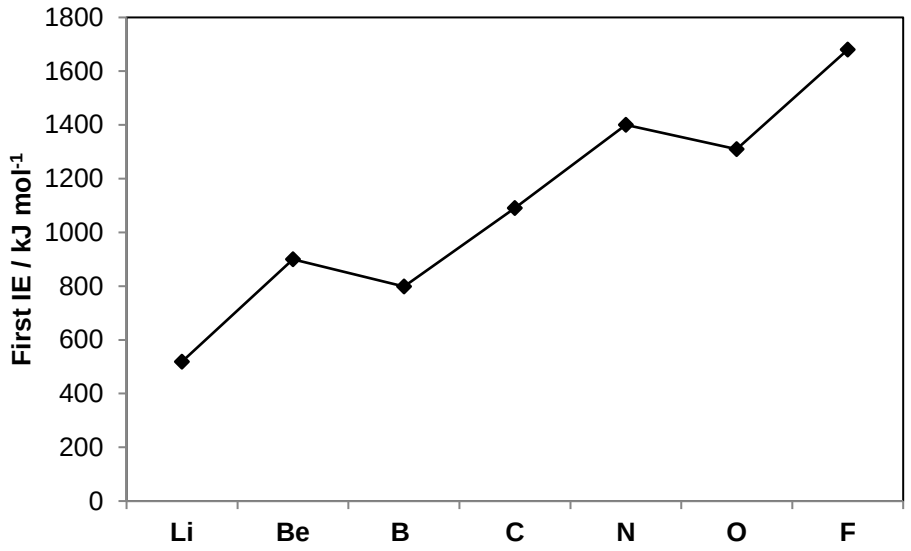
Since 4 x 200 = 800 mg is lower than the maximum dosage of 1200 mg, the level of consumption is safe for the man. **[1]**

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

		(Electrophilic) substitution	**[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.	
		The -OH polar groups allow the molecule to be soluble in water, while the non-polar hydrocarbon groups allow the molecule to be soluble in oil / non-polar liquids. **Accept hydrogen bonding and id-id interactions, in addition to identification of groups.**	**[1]**
	(e)	A certain pharmaceutical brand claims that the ibuprofen tablets it manufactures are 95.0% pure by mass.	

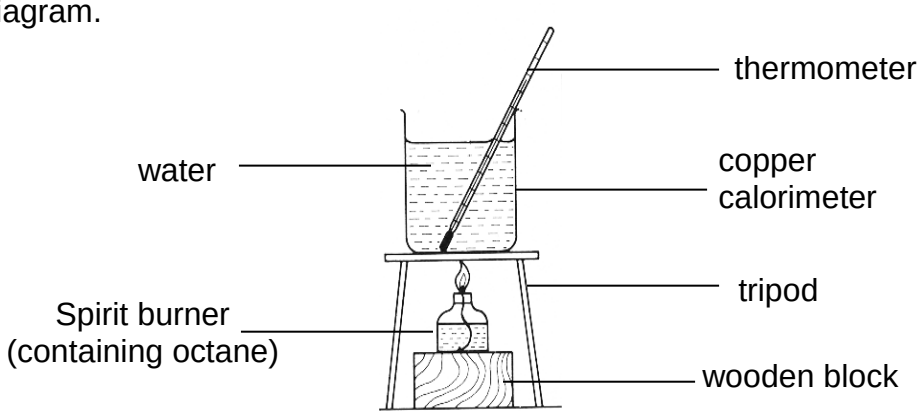
		To investigate this claim, 5.00 g of a sample was crushed and dissolved in 250 cm^3 of 0.450 mol dm^{-3} aqueous KOH. 25.0 cm^3 of this solution was withdrawn and titrated against sulfuric acid. The unreacted KOH in this solution required 25.50 cm^3 of 0.180 mol dm^{-3} of sulfuric acid for complete neutralisation. Showing relevant calculations, deduce if the claim is valid.	
		Amount of H_2SO_4 = $\frac{25.50}{1000} \times 0.180$ = 0.00459 mol Amount of unreacted KOH = 0.00459 x 2 = 0.00918 mol Amount of unreacted KOH (in 250 cm^3) = 0.0918 mol Amount of KOH reacted with ibuprofen sample = $\frac{250}{1000} \times 0.450 - 0.0918$ = 0.0207 mol Since ibuprofen ≡ KOH, Amount of ibuprofen = 0.0207 mol Mass of ibuprofen = 0.0207 x [13(12.0) + 18(1.0) + 2(16.0)] = 4.26 g Percentage purity = $\frac{4.26}{5.00} \times 100\%$ = 85.2% Hence, the claim is invalid.	**[3]**
	(f)	Compare the acidity of ibuprofen and aspirin. Explain your answer.	
		Aspirin is a stronger acid than ibuprofen. The anion of aspirin,  , is <u>more stable</u> than the anion of ibuprofen,  , as the <u>negative charge is delocalised over the COO^- group and into the benzene ring</u>.	**[2]**

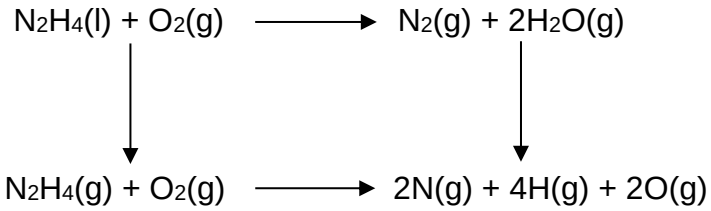
	(g)	Describe a simple chemical test to distinguish between ibuprofen and aspirin.	
		Test: Heat with acidified $KMnO_4(aq)$ Observations: Purple $KMnO_4$ turns colourless for ibuprofen. $KMnO_4$ remains purple for paracetamol and aspirin.	**[2]**
			[Total: 15]

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.	
			$B(g) \rightarrow B^+(g) + e^-$	**[1]**
		(ii)	Describe and explain the general trend in first ionisation energies for the elements lithium to fluorine.	
			There is a general increase in the first ionisation energies for elements lithium to fluorine. Across a period, nuclear charge increases while shielding effect remains approximately constant. Effective nuclear charge increases and valence electrons are increasingly attracted to the nucleus. Thus, more energy is required to remove the valence electrons.	**[2]**
		(iii)	Stating the electronic configurations of oxygen and nitrogen, suggest why the first ionisation energy of oxygen is lower than that of nitrogen.	
			O: $1s^2 2s^2 2p^4$ N: $1s^2 2s^2 2p^3$	**[2]**

			Due to coulombic repulsion between the paired 2p electrons in oxygen, less energy is required to remove the 2p electron.	
	(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.		
		Na_2O/MgO/Al_2O_3 has giant ionic lattice structure with strong electrostatic forces of attraction between its oppositely-charged ions. $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ pH = 12 $MgO(s) + H_2O(l) \rightleftharpoons Mg(OH)_2(aq)$ pH = 8 Al_2O_3 is insoluble in water and hence gives a resultant solution of pH 7. SiO_2 has giant covalent structure with strong covalent bonds between the Si and O atoms. SiO_2 is insoluble in water and hence gives a resultant solution of pH 7. P_4O_6/P_4O_{10}/SO_2/SO_3 has simple covalent structure with weak van der Waals forces between molecules. $P_4O_6(s) + 6H_2O(l) \rightarrow 4H_3PO_3(aq)$ pH =2 $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ pH = 2 $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ pH = 2 $SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$ pH = 2	**[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.	
			Heat evolved = 1000 × 4.18 × 20.4 + 385 × 20.4 = 93100 J Amount of octane reacted = $\frac{59.35-53.77}{8\times12.0+18\times1.0}$ = 4.89×10^{-2} mol Enthalpy change of combustion of octane = $-\frac{93100}{4.89\times10^{-2}}$ = −1900 kJ mol^{-1}	**[3]**
		(ii)	Define the standard enthalpy change of combustion.	
			Standard enthalpy change of combustion is the energy evolved when one mole of the substance is burnt in excess oxygen under standard conditions.	**[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.	
			$\Delta H_r = \Delta H_{vap}(N_2H_4) + [BE(N–N) + 4BE(N–H) + BE(O=O)]$ $– [BE(N≡N) + 4BE(O–H)]$ $= +58 + [(+160) + 4(+390) + (+496)] – [(+944) + 4(+460)]$ $= –510$ kJ mol^{-1}	**[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)**.	
			The bond energy values obtained from the *Data Booklet* are average values and would not be representative of the specified reaction.	**[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 .	
		+2	**[1]**
	(b)	Construct an equation for the reaction between SCl_2 and water.	

$2SCl_2 + 2H_2O \rightarrow S + SO_2 + 4HCl$ **[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.

	$2SO_2$	+	O_2	$\rightleftharpoons$	$2SO_3$
I / mol	0.0400		0.0200		0
C / mol	−0.0296		–0.0148		+0.0296
E / mol	0.0104		0.00520		0.0296

K_c (where V = 2)

$= \frac{[^{0.0296}/_V]^2}{[^{0.0104}/_V]^2[^{0.0052}/_V]}$

= 3116

= 3120 mol^{-1} dm^3 **[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.

When the volume of flask is doubled, concentration of all gases will be halved. Since there are more concentration terms on the left hand side of the equation, equilibrium position will shift left.

There will be no change to K_c as temperature remains unchanged. **[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]**

Both CS_2 and COS have simple covalent structures. CS_2 has a larger number of electrons (or larger electron cloud) than COS. More energy is required to overcome the stronger instantaneous dipole-induced dipole interactions between CS_2 molecules than the weaker permanent dipole-induced dipole interactions between COS molecules. Hence, CS_2 has a higher boiling point.

(ii) Explain why

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

CO_2 is linear and hence the dipoles cancel out.

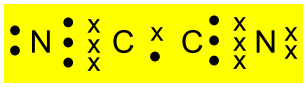
C=S bond is more polar than C=O. There is smaller difference between the dipole moment of C=O and C=S than that between C=O and C=Se.

(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]**

They are both linear.

(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.

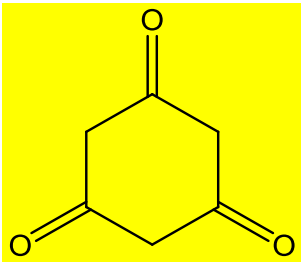
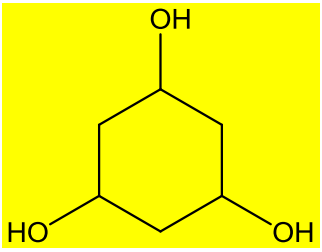
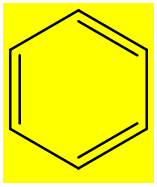
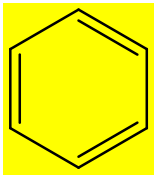
X also gives an orange precipitate with 2,4-DNPH but does not give a silver mirror with Tollens' reagent. **X** reacts with hydrogen in the presence of platinium catalyst under suitable conditions to for **Y**, $C_6H_{12}O_3$. When reacted with limited bromine under ultraviolet light, **X** produced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

Information/Reaction	**Deduction**
X/Y has C:H ratio of 1:1	**X/Y** might contain a benzene ring.
X undergoes condensation with 2,4-DNPH but does not undergo oxidation with Tollens' reagent.	**X** is a ketone.
X undergoes reduction with H_2 **[✓]**	**Y** has 3 OH group. **Y** is a 2^0 alcohol.
X undergoes free-radical substitution with Br_2 to give only one monobromo compound.	**X** is highly symmetrical.
Y undergoes elimination with NaOH(alc) to form **Z**.	**Z** has 3 C=C bond.

Structures:

		 or 
X	**Y**	**Z**

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

A Bronsted acid is a proton donor.

(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]**

pH = 3.5

$[H^+] = 10^{-3.5} = 3.16 \times 10^{-4}$ mol dm^{-3}

Given that the concentration of HY is 0.01 mol dm^{-3} which is much larger than the concentration of H^+, it is a weak acid as it ionises partially.

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

Table 5.2

Temperature / °C	K_w / mol^2 dm^{-6}
25	1.00×10^{-14}
50	5.48×10^{-14}

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

When temperature increases, the value of K_w increases. This implies that equilibrium position of $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$ lies more to the right to remove some of the added heat. Hence, the ionisation of water is an endothermic process.

			[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]**
			Number of moles of $CO_2 = \frac{10}{22.7}$ $= 0.441$ mol Number of $^{14}CO_2$ molecules $= 0.441 \times \frac{6.02\times10^{23}}{10^{12}}$ $= 2.65 \times 10^{11}$ molecules	
		(ii)	Calculate the mass of $^{14}CO_2$ in the 10.0 dm^3 sample.	**[1]**
			Mass of $^{14}CO_2 = \frac{2.65\times10^{11}}{6.02\times10^{23}} \times (14.0 + 16.0 \times 2)$ $= 2.03 \times 10^{-11}$ g	
		(iii)	Hence, explain why it would be difficult to determine the proportion of $^{14}CO_2$ by means of mass measurement.	**[1]**
			The amount/mass of $^{14}CO_2$ is too small to be accurately measured.	
	(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]**

Angle of deflection of $^{14}C^{+}$ = $\left(\frac{1}{14}\right)(8.4)$

= 0.60°

(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]**

Let the number of half-life be n.

$$\frac{30.0}{100} = \left(\frac{1}{2}\right)^{n}$$

$$n = \frac{lg\left(\frac{30.0}{100}\right)}{lg\left(\frac{1}{2}\right)}$$

$n = 1.74$

Time taken = 5730 × 1.74 = 9970 years

(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.

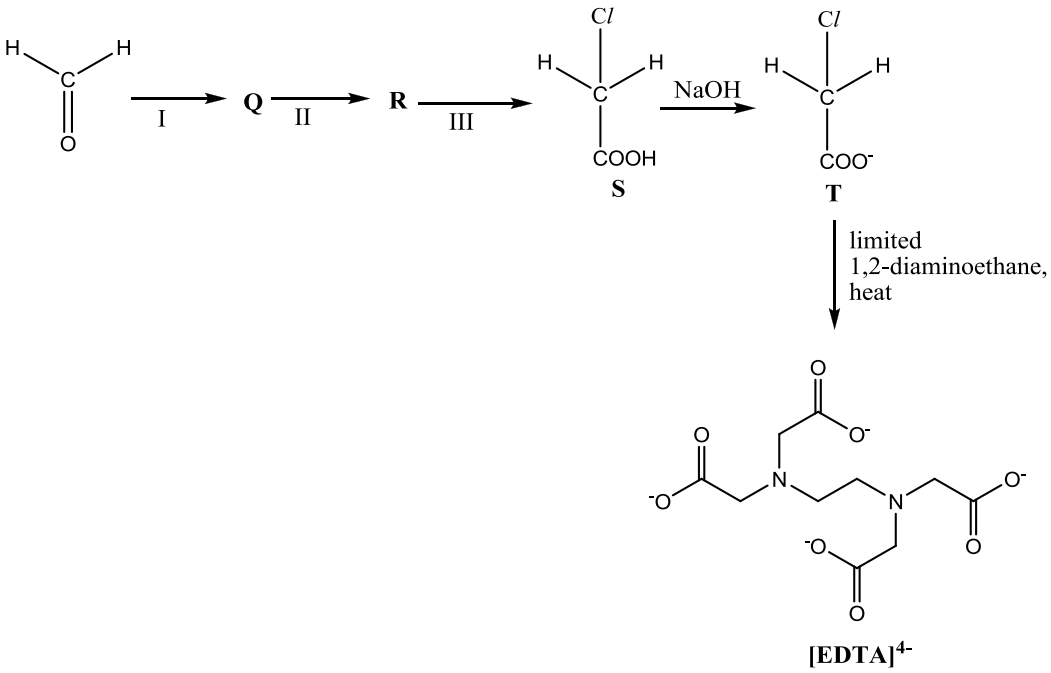
Table 6.1

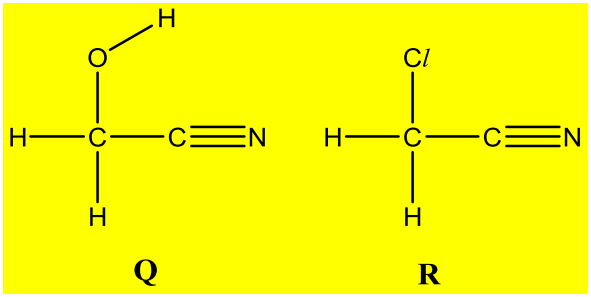
Experiment	[nitrobenzene] / mol dm^{-3}	[H_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.010	0.010	4.50×10^{-5}
2	0.015	0.010	6.74×10^{-5}
3	0.020	0.020	1.80×10^{-4}
4	0.030	x	4.05×10^{-4}

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

A catalyst is a substance that increases the rate of reaction by providing an alternative reaction pathway of lowered activation energy, and is regenerated at the end of the reaction.

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

			Comparing Experiment 1 and 2, when [nitrobenzene] is increased to 1.5 times, rate is increased to 1.5 times. Hence, the reaction is first order with respect to nitrobenzene. Let the rate equation be Rate = k[nitrobenzene][H_2]^a Comparing Experiment 2 and 3: $\frac{6.74\times10^{-5}}{1.80\times10^{-4}} = \frac{k(0.015)(0.01)^a}{k(0.02)(0.02)^a}$ $\left(\frac{6.74\times10^{-5}}{1.80\times10^{-4}}\right)\left(\frac{0.02}{0.015}\right) = \left(\frac{0.01}{0.02}\right)^a$ $a = 1$	
		(iii)	Calculate the rate constant, stating its units.	**[2]**
			Using Experiment 1, $4.50 \times 10^{-5} = k(0.01)(0.01)$ k = 0.450 mol^{-1} dm^3 s^{-1}	
		(iv)	Hence, determine the value of x.	**[1]**
			$4.05 \times 10^{-4} = (0.45)(0.03)x$ $x = 0.0300$ (mol dm^{-3})	
	(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]**
			Step I: HCN with small amount of NaCN Step II: PCl_5/PCl_3/$SOCl_2$ Step III: H_2SO_4(aq), heat under reflux	
		(ii)	Draw the displayed formulae of intermediates **Q** and **R**.	**[2]**
			 **Q** **R**	
		(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]**
			(Nucleophilic) substitution To enable multiple substitution on the amine group.	
				[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]**

See graph

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

Using graph of Experiment 2, $t_{1/2}$ is constant at 48 min.

Hence, order of reaction with respect to NaOH is 1.

For Experiment 1, initial rate = −gradient

$= 3.64 \times 10^{-5}$ mol dm^{-3} min^{-1}

For Experiment 2, initial rate = −gradient

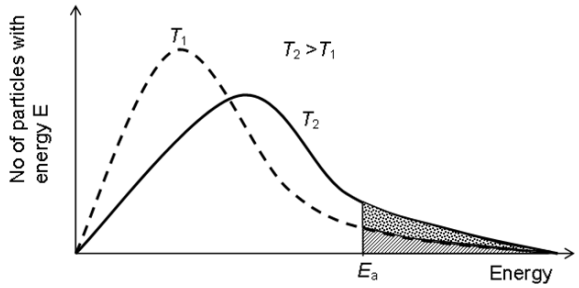
$= 6.67 \times 10^{-5}$ mol dm^{-3} min^{-1}

When [2-chlorobutane] is doubled, rate is doubled. Hence, order of reaction with respect to 2-chlorobutane is 1.

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

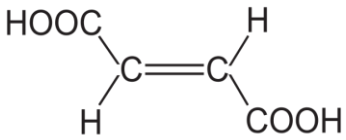
Rate = k[2-chlorobutane][NaOH]

(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]**



When temperature increases, the average kinetic energy of the reactant particles increases. More reactant particles possess energy greater than or equal to the activation energy. As a result, the frequency of effective collisions increases and the rate of reaction increases.

(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]**

Geometrical isomerism, because the presence of π bond in C=C prevents free rotation about the double bond.

(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]**

Amount of KOH = $\frac{27}{1000} \times 0.15$

= 0.00405 mol

Amount of fumaric acid = $\frac{0.00405}{2}$

= 0.00203 mol

Concentration of fumaric acid = $\frac{0.00203}{0.025}$

= 0.0812 mol dm^{-3}

		(iii)	Suggest an indicator that is suitable for the titration of fumaric acid with potassium hydroxide.	**[2]**
			Phenolphthalein, because its working pH range (8-10) lies within the sharp pH change near the equivalence point of the titration.	
	(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 1.38×10^{-4}.		
		(i)	Write the K_a expression for the equilibrium shown above.	**[1]**
			$K_a = \frac{[CH_3CH(OH)COO^-]\,[H^+]}{[CH_3CH(OH)COOH]}$	
		(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]**
			$pH = -\lg(1.38 \times 10^{-4}) + \lg(\frac{0.20}{0.35})$ $= 3.62$	
		(iii)	Write two equations to show how this buffer solution controls pH when a small amount of acid or base is added.	**[2]**
			$CH_3CH(OH)COO^- + H^+ \rightarrow CH_3CH(OH)COOH$ $CH_3CH(OH)COOH + OH^- \rightarrow CH_3CH(OH)COO^- + H_2O$	
				[Total: 20]

END OF PAPER