

Name:		Index Number:		Class:	
-------	--	---------------	--	--------	--



# DUNMAN HIGH SCHOOL

## Preliminary Examination 2018

### Year 6

H1 CHEMISTRY

8873/01

Paper 1 Multiple Choice

24 September 2018

1 hour

Additional Materials: Data Booklet  
Optical Mark Sheet

### INSTRUCTIONS TO CANDIDATES

- Write your **name**, **index number** and **class** on this question paper and the OTAS Mark Sheet.
- 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 separate Optical Mark Sheet.
- Each correct answer will score one mark. A mark will not be deducted for wrong answer.
- Any rough working should be done in this booklet.
- The use of an approved scientific calculator is expected, where appropriate.
- On the OTAS Mark Sheet, please shade the code as "Class/Index number".

*For illustration only:*

*A student from class 6C38, with index number 02, should shade "3802".*

WRITE		SHADE APPROPRIATE BOXES										
I N D E X	3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	8	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	2	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
N U M B E R		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		A	B	C	D	E	F	G	H	I		

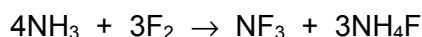
This document consists of 13 printed pages and 1 blank page.

1 Which option contains one mole of the stated particles?

Note that D =  ${}^2_1\text{H}$ .

- A carbonate ions in 60 g of sodium carbonate
- B neutrons in 1.8 g of heavy water,  $\text{D}_2\text{O}$
- C electrons in 0.1 mol of  $\text{OH}^-$
- D oxygen atoms in 11.2 dm<sup>3</sup> of  $\text{O}_3$ , under s.t.p

2  $\text{NF}_3$  can be obtained from the reaction between ammonia and fluorine gas.



Which statement about the reaction is correct?

- A  $\text{NH}_3$  undergoes disproportionation.
- B The oxidation number of nitrogen in  $\text{NF}_3$  is +3.
- C  $\text{NH}_3$  is a stronger oxidising agent than  $\text{F}_2$ .
- D One mole of  $\text{F}_2$  loses two moles of electrons.

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

Which statement regarding  ${}^{26}\text{Mg}^{2+}$  and  ${}^{27}\text{Al}^{3+}$  ions is true?

- 1  ${}^{26}\text{Mg}^{2+}$  has more protons than  ${}^{27}\text{Al}^{3+}$ .
- 2 Both ions have more neutrons than protons in their nuclei.
- 3 Both ions have outer electronic configuration  $2s^22p^6$ .
- 4 Both ions have the same number of neutrons.

- A 1 and 2 only
- B 1 and 3 only
- C 3 and 4 only
- D 2, 3 and 4 only

4 In which substance must covalent bonds break on melting?

- A calcium
- B silicon
- C sodium carbonate
- D ice

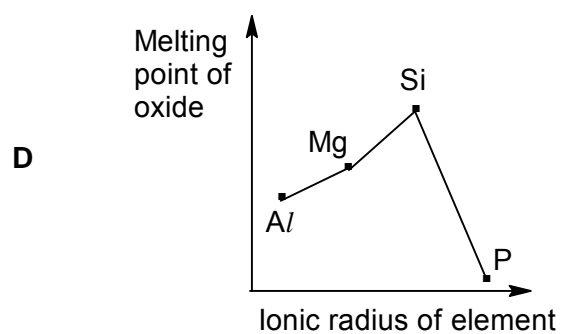
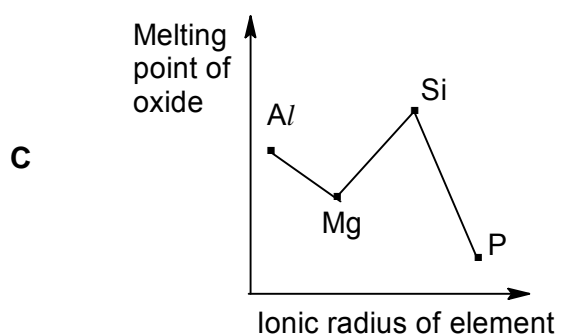
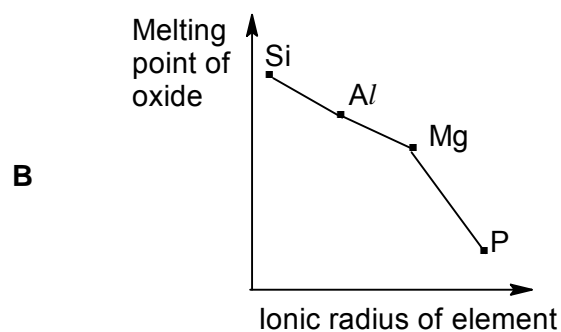
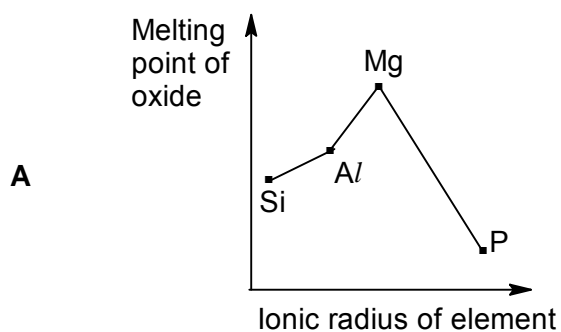
- 5 Valence Shell Electron Pair Repulsion theory can be used to predict the shapes of molecules and ions.

Which of the following are the shapes of  $\text{NO}_2$  and  $\text{NO}_3^-$  respectively?

	$\text{NO}_2$	$\text{NO}_3^-$
<b>A</b>	linear	trigonal planar
<b>B</b>	linear	trigonal pyramidal
<b>C</b>	bent	trigonal planar
<b>D</b>	bent	trigonal pyramidal

- 6 Use of the Data Booklet is relevant to this question.

Which graph shows the correct trend when the melting points of the oxides of elements Mg, Al, Si and P is plotted against its ionic radius?



- 7 Two different Group 1 metals, **K** and **L**, were separately thrown into two beakers of cold water. **K** skipped on the water surface and effervescence was seen. **K** disappeared after sometime. **L** exploded upon contact with water.

Which statement is **false**?

- A **L** could be rubidium if **K** is sodium.  
 B **K** is a stronger reducing agent than **L**.  
 C Hydrogen gas is given off when **L** came into contact with water.  
 D The water in the beaker becomes basic upon reacting with **K**.
- 8 **X<sub>2</sub>**, **Y<sub>2</sub>** and **Z<sub>2</sub>** are **Cl<sub>2</sub>**, **Br<sub>2</sub>** and **I<sub>2</sub>** but are not necessarily in the given order.

The table below recorded observations when these halogens are separately added to aqueous solutions containing the halide ions followed by the addition of an organic solvent, **CCl<sub>4</sub>**.

Experiment	Reactants	Observation after shaking with <b>CCl<sub>4</sub></b>
1	<b>X<sub>2</sub></b> (aq) + <b>Y<sup>-</sup></b> (aq)	Violet organic layer seen.
2	<b>Y<sub>2</sub></b> (aq) + <b>X<sup>-</sup></b> (aq)	<i>(Observations not recorded)</i>
3	<b>Z<sub>2</sub></b> (aq) + <b>X<sup>-</sup></b> (aq)	Orange-red organic layer seen.
4	<b>Z<sub>2</sub></b> (aq) + <b>Y<sup>-</sup></b> (aq)	Violet organic layer seen.

Which statement could be deduced from the above experiments, given **X<sub>2</sub>** (aq) is an orange solution?

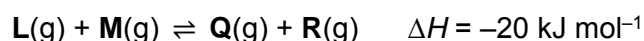
- A The colour of the organic layer in Experiments 2 and 4 is the same.  
 B Identity of **Z<sub>2</sub>** is **Br<sub>2</sub>**.  
 C In Experiment 3, there is no redox reaction occurring.  
 D **X<sub>2</sub>** is a stronger oxidising agent than **Z<sub>2</sub>**.
- 9 For which process is the enthalpy change always negative?
- A Melting of ice.  
 B Reaction between an acid and a base.  
 C Breaking a covalent bond of a diatomic molecule.  
 D Forming a compound from its elements.

- 10 A rock sample was found to contain isotopes **T** and **U** which are radioactive. Initially, the ratio of the number of atoms of **T** to **U** in the rock sample is 1 : 16. The decay of isotopes **T** and **U** was found to follow first order kinetics. The half-life of **T** is 12 days while that of **U** is 3 days.

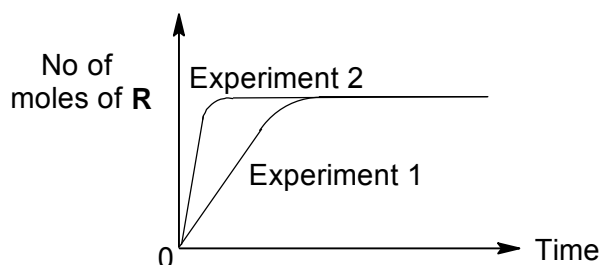
How long, in days, will it take for a rock sample to contain a molar ratio of **T** to **U** of 4 : 1?

- A 6  
B 12  
C 18  
D 24

- 11 The stoichiometry of a reaction is shown by the equation below.



Two experiments were carried out in enclosed vessels which the rate of production of **R** was measured. The results are shown in the diagram below.



Which changes in the conditions might explain the results shown?

- 1 Temperature of the vessel in Experiment 2 is higher.
- 2 A smaller vessel is used in Experiment 2.
- 3 A catalyst is used in Experiment 2.

- A 1, 2 and 3  
B 1 and 2 only  
C 2 and 3 only  
D 1 only

- 12 In which reaction is the first reactant **not** acting as a Bronsted-Lowry base?

- A  $\text{NH}_3 + \text{CH}_3\text{Cl} \rightarrow \text{CH}_3\text{NH}_3^+ + \text{Cl}^-$   
B  $\text{OH}^- + \text{HSO}_4^- \rightarrow \text{H}_2\text{O} + \text{SO}_4^{2-}$   
C  $\text{CH}_3\text{OH} + \text{HClO}_4 \rightarrow \text{CH}_3\text{OH}_2^+ + \text{ClO}_4^-$   
D  $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{NO}_3^+ + \text{HSO}_4^-$

- 13 Nanoparticle zinc oxide is an ingredient found in most sunscreens. The white bulk powder form of zinc oxide is not used even though it can absorb UV rays.

Which statement about zinc oxide as a nanoparticle is true?

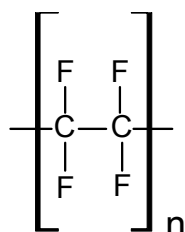
- 1 Zinc oxide is not white owing to the extremely small size of the nanoparticle.
- 2 Nanoparticle zinc oxide is water soluble.
- 3 Zinc oxide can absorb UV rays only when it is in nanoparticle form.
- 4 Since the surface area to volume ratio is very high, nanoparticle zinc oxide can be applied to the skin more evenly.

- A 1, 2 and 4 only                      B 2 and 3 only  
C 1 and 4 only                         D 3 and 4 only

- 14 Which statement explains why graphene is such a strong material?

- A Graphene is a crystalline allotrope of carbon.  
B Graphene exists as a three dimensional structure.  
C The layered structure of graphene allows the layers to slide over each other.  
D The strong network of carbon-carbon covalent bonds that exists in graphene.

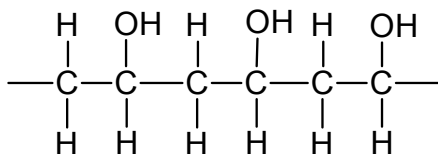
- 15 A polymer is formed as a result of addition polymerisation and it has the following structure.



Which is the monomer?

- A                       B 
- C                       D 

- 16 Poly(vinyl alcohol) is a commonly used eye drop and has the structure shown below.



poly(vinyl alcohol)

Which of the following properties makes poly(vinyl alcohol) suitable for its use?

- 1 The polymer is transparent.
- 2 It is fairly soluble in water.
- 3 It has high heat resistance.
- 4 It attracts water to itself.

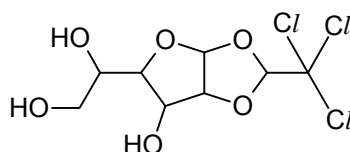
**A** 1, 2 and 4 only

**B** 2 and 3 only

**C** 1 and 4 only

**D** 3 and 4 only

- 17 Chloralose is a drug that is commonly used in neuroscience as an anesthetic.



chloralose

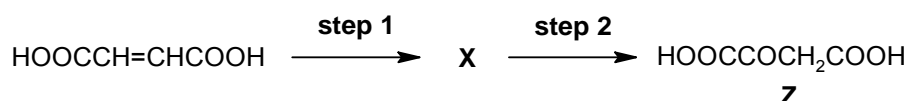
How many  $sp^2$  hybridised carbon atoms and secondary alcohol does chloralose have?

	No. of $sp^2$ hybridised carbon atoms	No. of secondary alcohol
<b>A</b>	0	3
<b>B</b>	0	2
<b>C</b>	3	3
<b>D</b>	3	2

18 Which statement is correct regarding alkanes?

- A They undergo substitution reactions.
- B The carbon atoms in alkanes are  $sp^2$  hybridised.
- C They are generally unreactive due to the polar C–H bond.
- D Propane reacts with chlorine gas to give three different mono-substituted products.

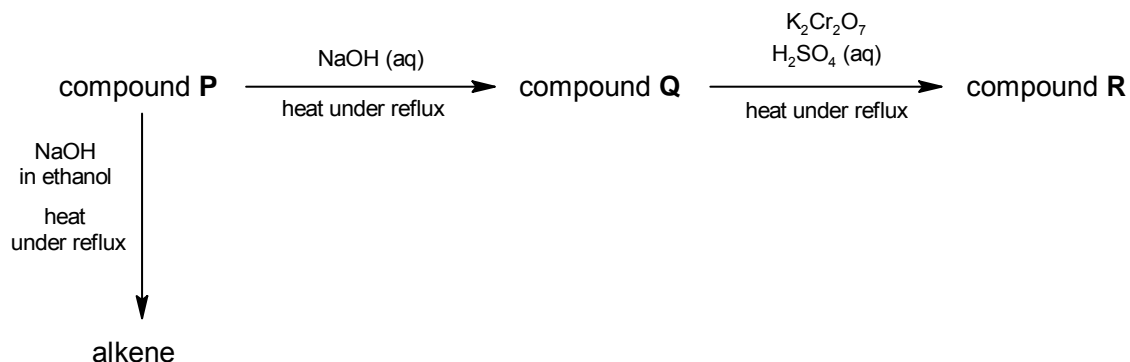
19 Compound **Z** can be obtained by a two-step process involving intermediate **X**.



What is the identity of intermediate **X**?

- A  $\text{HOOCCH}_2\text{CH}_2\text{COOH}$
- B  $\text{HOOCCHBrCH}_2\text{COOH}$
- C  $\text{HOOCCH(OH)CH}_2\text{COOH}$
- D  $\text{HOOCCH(OH)CH}_2\text{OH}$

20 The flow chart shows a series of reactions.

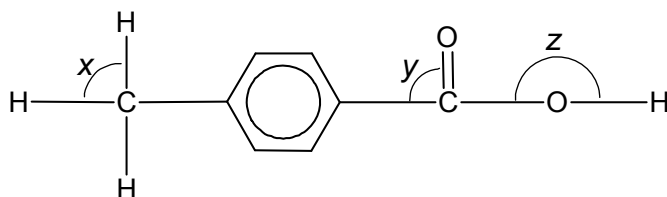


Which class of compound are **P**, **Q** and **R**?

	<b>P</b>	<b>Q</b>	<b>R</b>
<b>A</b>	halogenoalkane	primary alcohol	carboxylic acid
<b>B</b>	halogenoalkane	primary alcohol	aldehyde
<b>C</b>	primary alcohol	aldehyde	carboxylic acid
<b>D</b>	primary alcohol	halogenoalkane	aldehyde



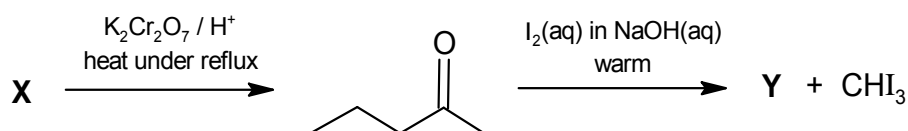
- 21 A compound has the structure shown.



What are the values of the bond angles  $x$ ,  $y$  and  $z$ ?

	$x$	$y$	$z$
<b>A</b>	$90^\circ$	$109.5^\circ$	$104.5^\circ$
<b>B</b>	$90^\circ$	$120^\circ$	$180^\circ$
<b>C</b>	$109.5^\circ$	$109.5^\circ$	$180^\circ$
<b>D</b>	$109.5^\circ$	$120^\circ$	$104.5^\circ$

- 22 The diagram shows reactions involving pentan-2-one.



Which row correctly identifies compounds **X** and **Y**?

	<b>X</b>	<b>Y</b>
<b>A</b>	pentan-1-ol	sodium butanoate
<b>B</b>	pentan-2-ol	sodium butanoate
<b>C</b>	pentan-1-ol	sodium pentanoate
<b>D</b>	pentan-2-ol	sodium pentanoate

- 23 Which reagent is able to distinguish between the following two compounds?

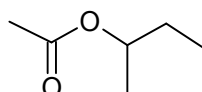



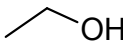
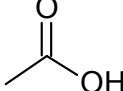
- |          |                            |          |                                      |
|----------|----------------------------|----------|--------------------------------------|
| <b>A</b> | Hot aqueous NaOH           | <b>B</b> | Liquid bromine                       |
| <b>C</b> | 2,4-dinitrophenylhydrazine | <b>D</b> | Concentrated $\text{H}_2\text{SO}_4$ |

24 Which products are formed when butanal reacts with Fehling's solution?

- A  $\text{Cu}_2\text{O}$  and  $\text{CH}_3\text{CH}_2\text{COO}^-$
- B  $\text{Cu}_2\text{O}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
- C  $\text{Cu}_2\text{O}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$
- D  $\text{CuO}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$

25 Which synthetic route will give the following ester as the product?



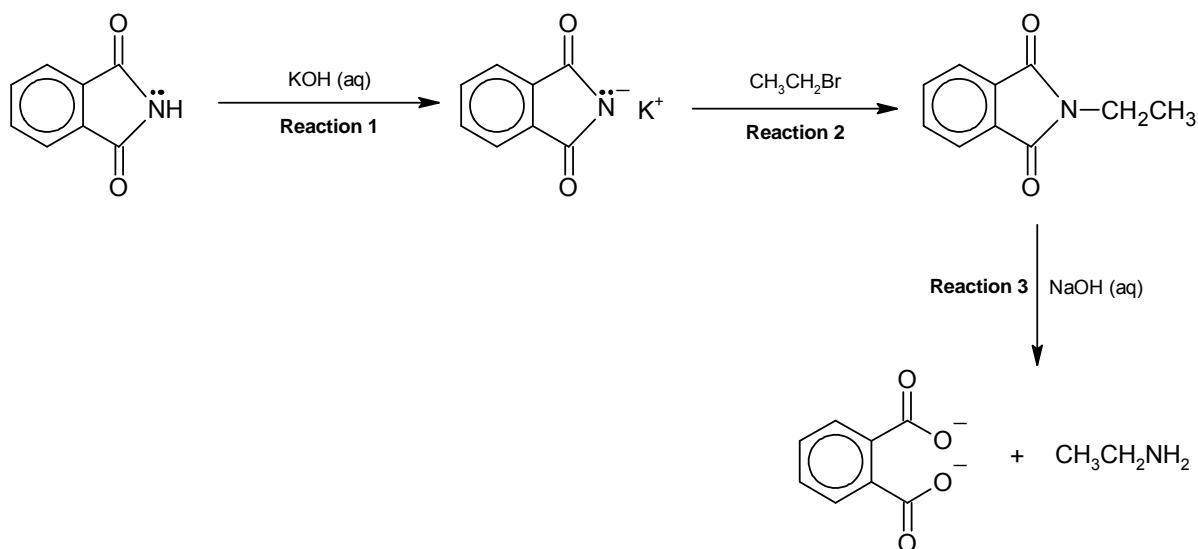
- A   $\xrightarrow{\text{hot acidified KMnO}_4}$   $\xrightarrow{\text{PCl}_5}$   $\xrightarrow{\text{propan-2-ol}}$
- B   $\xrightarrow[\text{heat under reflux}]{\text{KMnO}_4, \text{H}_2\text{SO}_4 (\text{aq})}$   $\xrightarrow{\text{SOCl}_2}$   $\xrightarrow{\text{butan-1-ol}}$
- C   $\xrightarrow[\text{in dry ether}]{\text{LiAlH}_4}$   $\xrightarrow{\text{PCl}_5}$   $\xrightarrow{\text{butan-2-ol}}$
- D  $\text{CH}_3\text{Br}$   $\xrightarrow[\text{heat under reflux}]{\text{KCN in ethanol}}$   $\xrightarrow[\text{heat under reflux}]{\text{H}_2\text{SO}_4 (\text{aq})}$   $\xrightarrow[\text{heat under reflux}]{\text{butan-2-ol, conc H}_2\text{SO}_4}$

26 Hoping to make ethyl propanoate, a student mixed propanoic acid and ethanol, added a little concentrated sodium hydroxide solution as catalyst and left the mixture in a sealed container in a warm water bath for several days. The experiment failed.

What was the only thing the student got wrong?

- A the use of propanoic acid
- B the use of ethanol
- C the addition of a little concentrated sodium hydroxide solution
- D leaving the mixture in a warm water bath for several days.

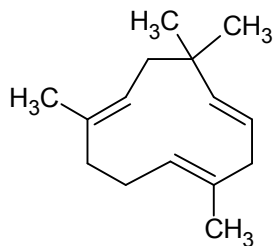
27 The diagram below shows a sequence of reactions.



How can the three reactions be classified?

	Reaction 1	Reaction 2	Reaction 3
<b>A</b>	hydrolysis	substitution	acid–base
<b>B</b>	hydrolysis	addition	acid–base
<b>C</b>	acid–base	substitution	hydrolysis
<b>D</b>	acid–base	addition	hydrolysis

- 28 Humulene can be extracted from carnation flowers.



Humulene is treated with hot, concentrated acidified  $\text{KMnO}_4$ .

Which compound will be found in the mixture of products?

- 1  $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CO}_2\text{H}$
- 2  $\text{CH}_3\text{COCH}_2\text{CO}_2\text{H}$
- 3  $\text{HO}_2\text{CCH}_2\text{C}(\text{CH}_3)_2\text{CO}_2\text{H}$
- 4  $\text{HO}_2\text{CC}(\text{CH}_3)_2\text{CO}_2\text{H}$

- |          |                 |          |                 |
|----------|-----------------|----------|-----------------|
| <b>A</b> | 1 and 4 only    | <b>B</b> | 2 and 3 only    |
| <b>C</b> | 1, 3 and 4 only | <b>D</b> | 1, 2 and 3 only |

- 29 One mole of compound **Q** reacts with an excess of sodium to produce one mole of hydrogen gas.

What could **Q** be?

- 1  $\text{HO}_2\text{CCH}_2\text{CHO}$
- 2  $\text{HOCH}_2\text{CH}_2\text{OH}$
- 3  $\text{CH}_3\text{CO}_2\text{H}$

- |          |              |          |                 |
|----------|--------------|----------|-----------------|
| <b>A</b> | 1 only       | <b>B</b> | 2 only          |
| <b>C</b> | 2 and 3 only | <b>D</b> | 1, 2 and 3 only |

- 30 When one ethene molecule reacts with one bromine molecule by electrophilic addition, how many bonds are broken and formed?

	number of $\sigma$ bonds broken	number of $\pi$ bonds broken	number of $\sigma$ bonds formed	number of $\pi$ bonds formed
<b>A</b>	1	1	2	0
<b>B</b>	0	1	2	0
<b>C</b>	1	0	0	2
<b>D</b>	1	1	0	2



2018 DHS YEAR 6 H1 CHEMISTRY (8873) Preliminary Examination  
Paper 1 MCQ – Answers

1	2	3	4	5	6	7	8	9	10
C	B	D	B	C	A	B	A	B	D

11	12	13	14	15	16	17	18	19	20
C	A	C	D	D	A	B	A	C	A

21	22	23	24	25	26	27	28	29	30
D	B	A	C	D	C	C	D	B	A

<b>Name:</b>		<b>Index Number:</b>		<b>Class:</b>	
--------------	--	----------------------	--	---------------	--



**DUNMAN HIGH SCHOOL**  
**Preliminary Examination 2018**  
**Year 6**

**H1 CHEMISTRY**

8873/02

Paper 2 Structured Questions

**13 September 2018**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Answer Paper  
 Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your 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** the questions.

**Section B**

Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use								
P1	P2 Section A				P2 Section B		Total	%
	Q1	Q2	Q3	Q4	Q5	Q6		
30	13	9	20	18	20	20	110	

This document consists of **21** printed pages and **1** blank page.



## Section A

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

- 1 (a) Group 1 elements are strong reducing agents. State and explain the trend of reducing power of Group 1 elements down the Group.

.....

.....

.....

.....

.....[3]

- (b) Group 1 elements and its compounds have many uses. Sodium hydrogencarbonate ( $\text{NaHCO}_3$ ) is often used to treat ant stings which contains methanoic acid ( $\text{HCOOH}$ ), a weak acid.

Write an equation for the dissociation of methanoic acid in water. Indicate which species are the acid, the base and their conjugate pairs in the reaction.

[2]

- (c) When the ant bites, it injects a solution containing 50 % by volume of unionised methanoic acid. A typical ant may inject around  $6.0 \times 10^{-3} \text{ cm}^3$  of this solution.

- (i) Given that the density of methanoic acid is  $1.2 \text{ g cm}^{-3}$ , what is the amount (in moles) of methanoic acid that a typical ant injects?

[1]

As soon as the methanoic acid is injected, it dissolves in water in the body to produce a solution of methanoic acid with pH 2.43.

- (ii) Assuming that it dissolves fully in  $1.0 \text{ cm}^3$  of water in the body, calculate the concentration of the methanoic acid solution that is formed initially. You may ignore the volume of methanoic acid injected in this calculation.

[1]

- (iii) Calculate the percentage of methanoic acid molecules which have dissociated in  $1.0 \text{ cm}^3$  of water.

[2]

- (d) A student was given an unlabelled bottle and was told that it contained pure sample of one of the following three compounds.

- methanol
- methanal
- propanone

- (i) State the reagent used for a chemical test that could show that the sample can be either methanal and propanone but **not** methanol. Describe what would be observed.

Reagent: .....[1]

Observations: .....[1]

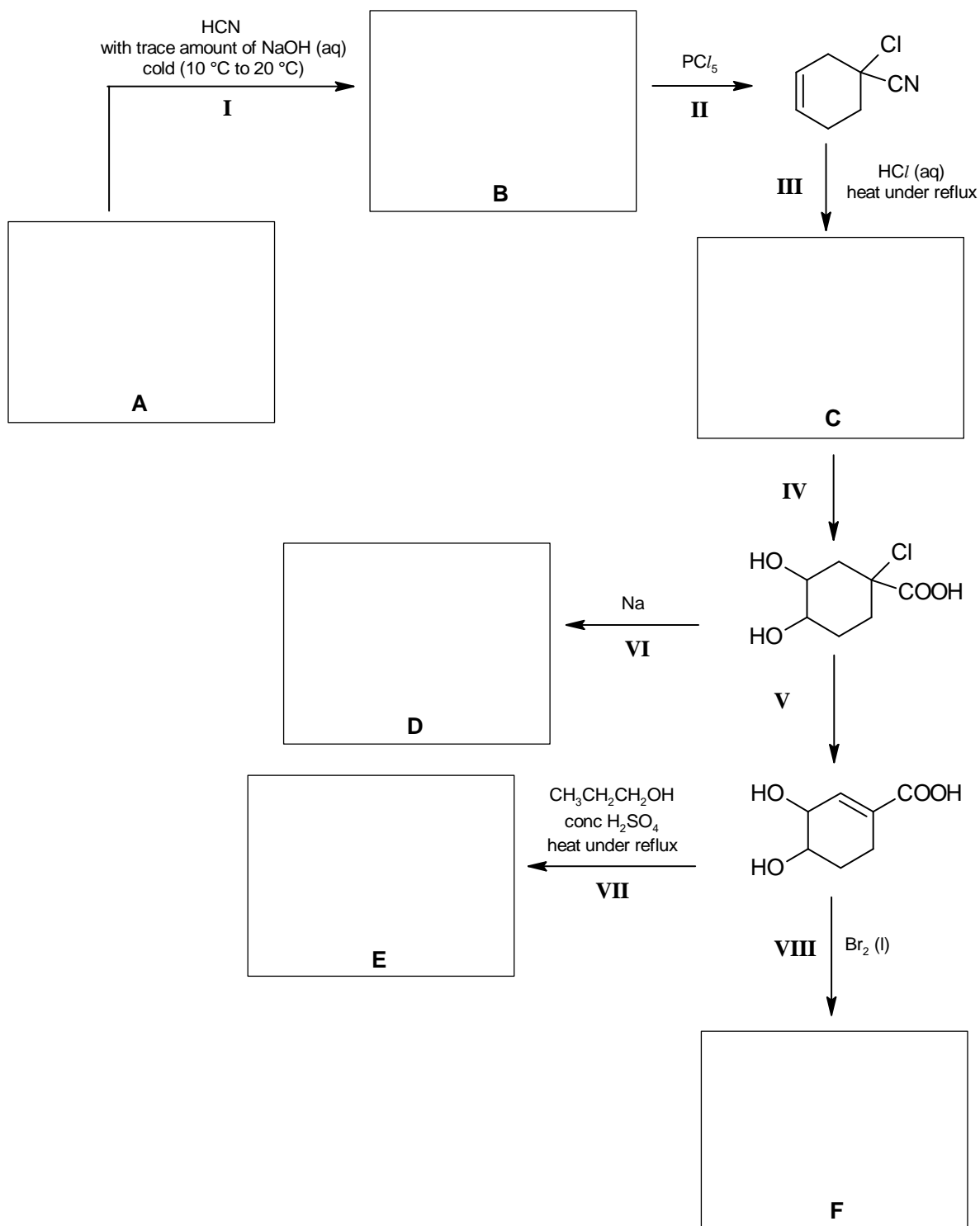
- (ii) Describe one chemical test that could distinguish between methanal and propanone.

.....  
 .....  
 .....  
 .....[2]

[Total: 13]

2 A sequence of reactions starting from compound **A** is shown below.

(a) Draw the structures of compounds **A**, **B**, **C**, **D**, **E** and **F** in the boxes below.



[6]

(b) For the reaction scheme shown above, state

(i) the type of reaction occurring in reaction I.

.....[1]

(ii) the reagents and conditions for reaction V.

.....[1]

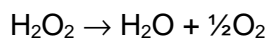
(c) The alcohol  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ , used as the reagent in reaction VII above, can be converted into  $\text{CH}_3\text{CH}=\text{CH}_2$ . How may this conversion be achieved in a laboratory?

.....

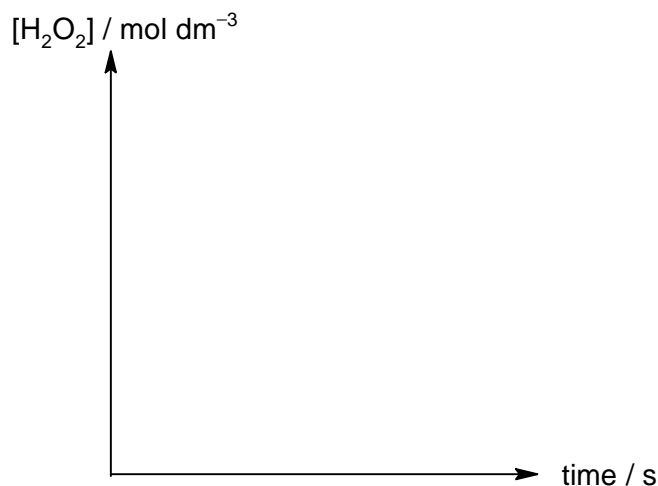
.....[1]

[Total: 9]

- 3 (a) Pure hydrogen peroxide,  $\text{H}_2\text{O}_2$ , was long believed to be unstable. Its decomposition follows a first order reaction.



- (i) Sketch a graph of  $[\text{H}_2\text{O}_2]$  against time to show that the reaction is first order with respect to  $\text{H}_2\text{O}_2$ .



[2]

- (ii) As  $\text{H}_2\text{O}_2$  decomposes slowly at room temperature, catalysts such as platinum metal are often added to lower the activation energy to increase the rate of reaction.

With reference to the information provided below, sketch the energy profile diagram showing the catalysed reaction only.

enthalpy change of the decomposition	$-196 \text{ kJ mol}^{-1}$
activation energy (without catalyst)	$+75 \text{ kJ mol}^{-1}$
activation energy (with catalyst)	$+49 \text{ kJ mol}^{-1}$



[2]

(b) In the presence of UV light,  $\text{H}_2\text{O}_2$  decomposes to form hydroxyl free radicals,  $\bullet\text{OH}$ .

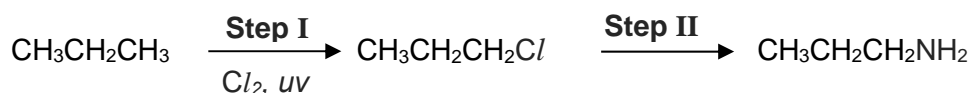
(i) Draw the 'dot-and-cross' diagram for  $\text{H}_2\text{O}_2$ .

[1]

(ii) Using relevant bond energy values from the *Data Booklet*, suggest the relative rate of the formation of  $\bullet\text{Cl}$  from chlorine gas as compared that of  $\bullet\text{OH}$  from hydrogen peroxide.

.....  
 .....  
 .....  
 .....  
 .....[2]

(iii) Propylamine,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$ , may be formed via the following reaction pathway involving free radical substitution in the first step.



Name the type of reaction occurring in **Step II**. State the reagent and conditions required for this step.

Type of reaction: .....

Reagent: .....

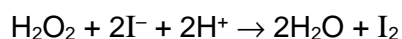
Conditions: .....

[2]

- (iv) As the yield from the reaction in (b)(iii) is low, propose a 3-step synthetic route to produce propylamine from ethene instead. Show clearly the reagents and conditions as well as the intermediates involved.

[3]

- (c) The kinetics of the reaction between hydrogen peroxide and iodide ions in acidic solution was studied.



Four separate experiments were carried out to determine the relative rates by varying the concentrations of the reactants. The results obtained are given in the table below.

Expt	[H <sub>2</sub> O <sub>2</sub> ] / mol dm <sup>-3</sup>	[I <sup>-</sup> ] / mol dm <sup>-3</sup>	[H <sup>+</sup> ] / mol dm <sup>-3</sup>	relative rate
1	0.03	0.03	0.03	1.0
2	0.05	0.03	0.03	1.6
3	0.05	0.01	0.06	0.53
4	0.03	0.01	0.03	0.33

- (i) With reference to the overall equation given above, write the oxidation and reduction half-equations.

Oxidation half-equation: .....[1]

Reduction half-equation: .....[1]

- (ii) Use the data to deduce the orders of reaction with respect to  $\text{H}_2\text{O}_2$ ,  $\text{I}^-$  and  $\text{H}^+$ . Show your working clearly.

[3]

- (iii) Hence, write the rate equation and state the units of the rate constant.

[2]

- (iv) Unreacted iodide ions may be easily separated from the reaction mixture by adding silver nitrate solution, followed by filtration. State the identity and colour of the precipitate formed.

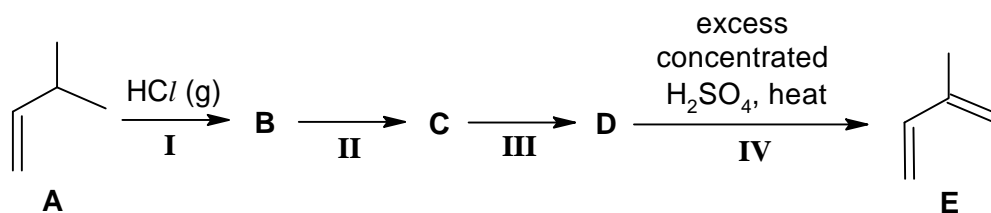
.....[1]

[Total : 20]



4 Isoprene, **E**, is an organic compound that could be used to synthesise limonene, which is commonly used in fragrances.

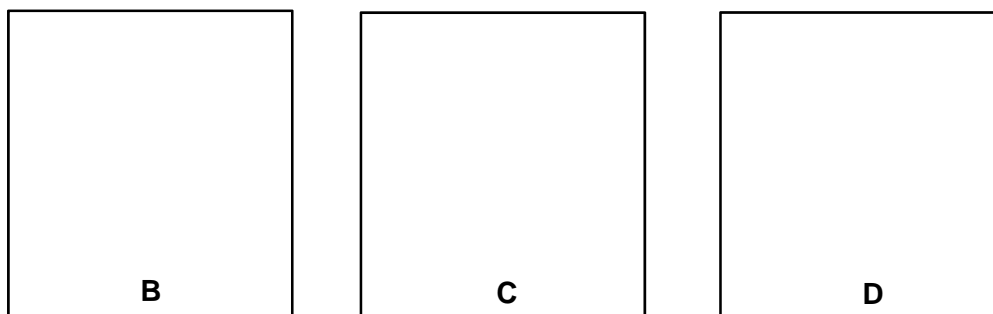
(a) **E** can be synthesised from 3-methylbut-1-ene, **A**, in a 4-step process as follows.



(i) **B** is a major product of step I.

Draw the structures of compounds **B**, **C** and **D**.

[3]



(ii) Hydrogen chloride, the reagent in step I, is commonly used in organic synthesis.

State and explain how the thermal stabilities of hydrogen halides varies down the Group.

.....

.....

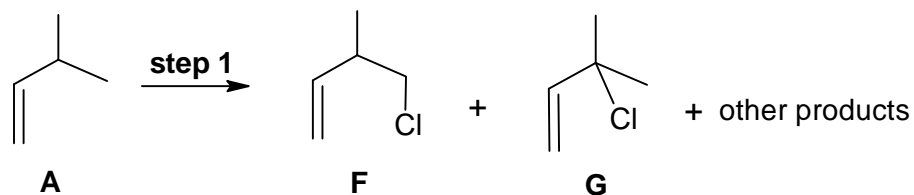
.....

.....

.....

.....[2]

- (b) The following reaction shows an alternative route to form an intermediate for the synthesis of isoprene.



- (i) State the reagent and condition of **step 1** which will result in formation of compounds **F** and **G**.

Reagent: .....

Condition: .....

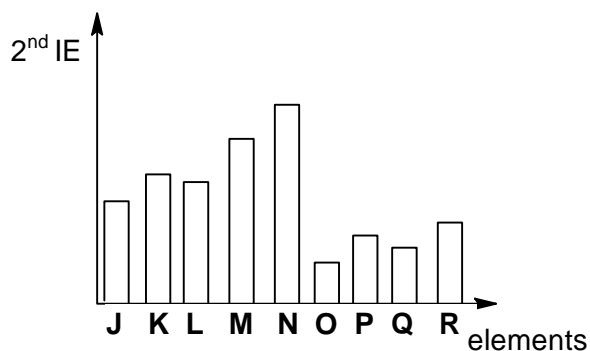
[1]

- (ii) Predict the ratio in which **F** and **G** will be formed.

compound	<b>F</b>	<b>G</b>
ratio		

[1]

- (c) The bar chart below shows the second ionisation energy ( $2^{\text{nd}}$  IE) of nine consecutive elements (**J** to **R**) in Periods 2 and 3 of the Periodic Table.



- (i) Write an equation for the second ionisation energy of element **J**.

.....[1]

- (ii) Identify element **N**.

Element **N** is .....[1]

(iii) Using your answers in (c)(i), (c)(ii) and the electronic configurations of the species involved, explain the significantly higher 2<sup>nd</sup> IE of **N** compared to **O**.

.....  
.....  
.....  
.....  
.....[2]

(d) The Periodic Table shows the element, Helium, placed at the top of Group 18.

(i) Suggest why the element Helium could be placed at the top of Group 2.

.....  
.....[1]

(ii) Suggest why the element Helium is not placed at the top of Group 2, by comparing **one** physical property. Explain your answer.

.....  
.....  
.....  
.....  
.....[2]

(e) Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> and P<sub>4</sub>O<sub>10</sub> are oxides of Period 3 elements.

(i) Explain why both Al<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub> are insoluble in water.

.....  
.....  
.....  
.....  
.....[2]

(ii) Explain, with the aid of an equation, the reaction of P<sub>4</sub>O<sub>10</sub> with water.

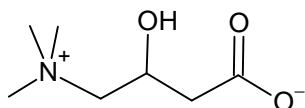
.....  
.....  
.....[2]

[Total: 18]

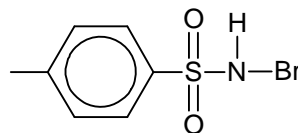
## Section B

Answer **one** question from this section, in the spaces provided.

- 5 Levocarnitine is a quaternary ammonium compound involved in metabolism in most mammals.



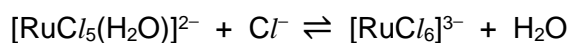
levocarnitine



bromamine-T

- (a) A kinetic study on the  $\text{RuCl}_3$  catalysed reaction between levocarnitine and bromamine-T was carried out in aqueous hydrochloric acid.

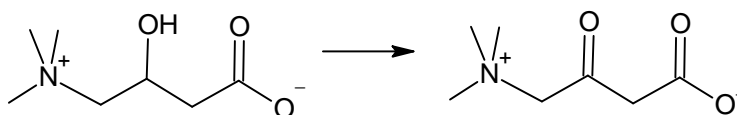
- (i) The following equilibrium exists for  $\text{RuCl}_3$  in aqueous hydrochloric acid.



Explain why  $[\text{RuCl}_6]^{3-}$  is likely to be the reactive species instead of  $[\text{RuCl}_5(\text{H}_2\text{O})]^{2-}$  in this study.

.....  
 .....  
 .....[1]

- (ii) Levocarnitine is converted into the following product by bromamine-T.



levocarnitine

State the type of reaction that levocarnitine had undergone and explain your answer in terms of changes in oxidation number.

.....  
 .....  
 .....  
 .....[2]

- (b) A series of experiments were carried out at different temperatures under first order conditions with respect to bromamine-T.

The value of the observed rate constant,  $k$ , for the catalysed reaction was determined at each temperature and the results are summarised in the table below.

$k$ / $10^4 \text{ s}^{-1}$	temperature, $T$ / K
1.82	293
3.00	303
4.62	313
7.30	323

The activation energy,  $E_a$ , and the pre-exponential factor,  $A$ , which is a constant, for the reaction can be determined from the equation.

$$k = Ae^{\frac{-E_a}{RT}}$$

$R$  is the molar gas constant.

$T$  is the reaction temperature in kelvin.

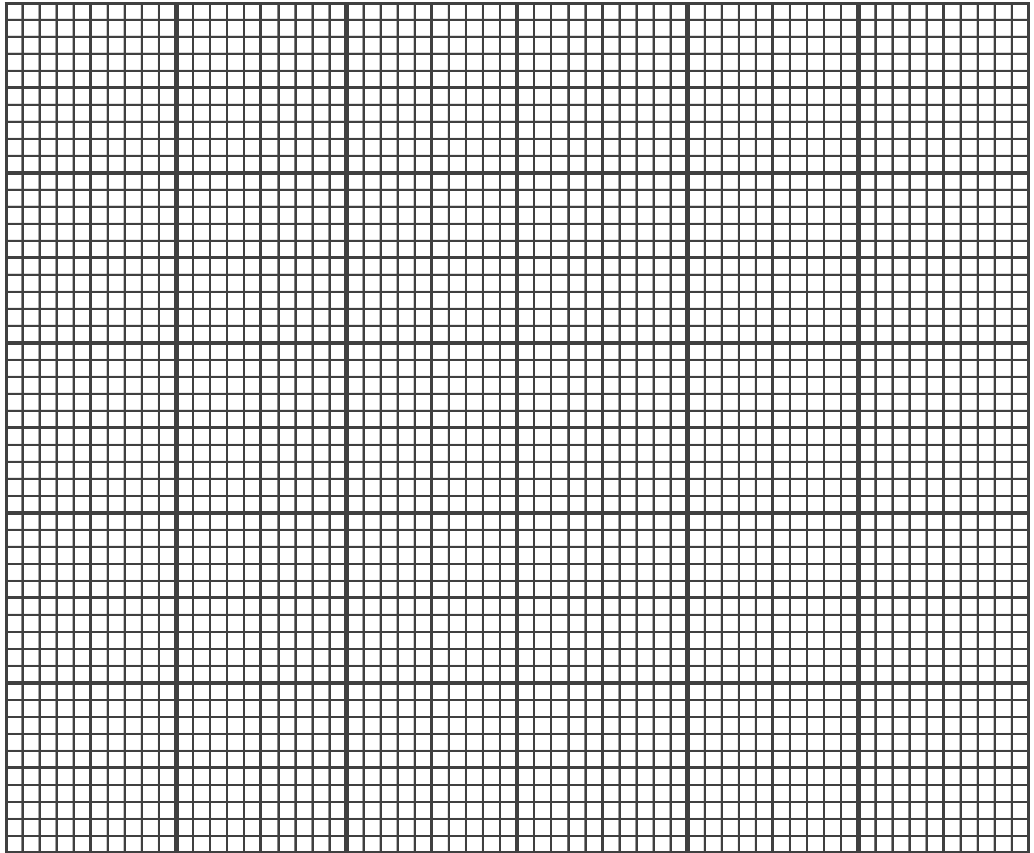
$k$  is the observed rate constant at a chosen temperature.

- (i) Calculate the values of  $\ln k$  and  $\frac{1}{T}$  for each of the experiments above.

$k$ / $10^4 \text{ s}^{-1}$	$\ln k$	temperature, $T$ / K	$\frac{1}{T}$ / $\text{K}^{-1}$
1.82		293	
3.00		303	
4.62		313	
7.30		323	

[2]

- (ii) Hence plot a graph of  $\ln k$  against  $\frac{1}{T}$  and determine  $E_a$  from the gradient of the best-fit line which is  $\frac{-E_a}{R}$ .



Gradient .....

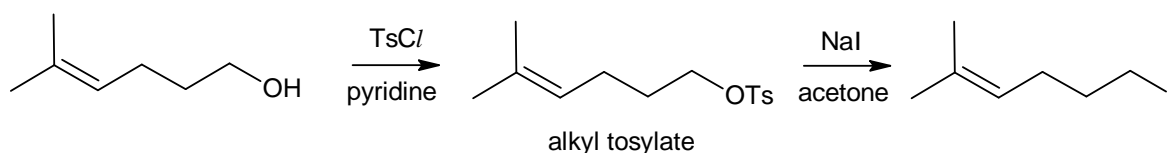
$E_a$  .....

[4]

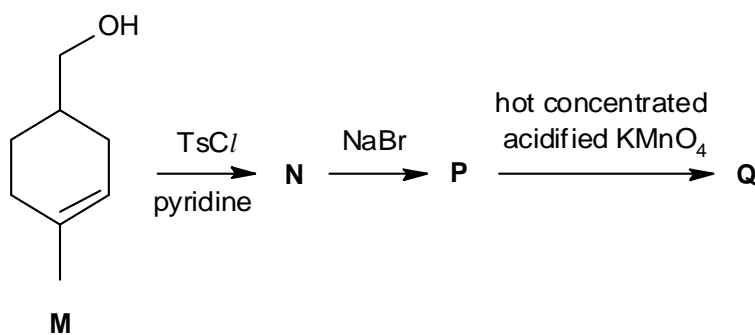
- (iii) State the effect of temperature on the rate of the reaction and explain your answer with the aid of a Boltzmann distribution curve.

.....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....[4]

Tosyl chlorides (TsCl) are often used to convert alcohols into alkyl tosylates which undergo substitution reactions. An example of this application is given below.



- (c) Consider the reaction scheme below involving an alkyl tosylate **N**.



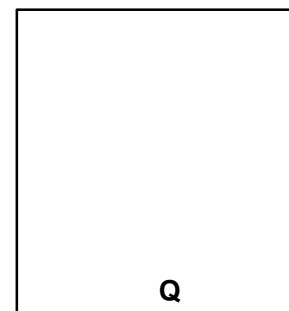
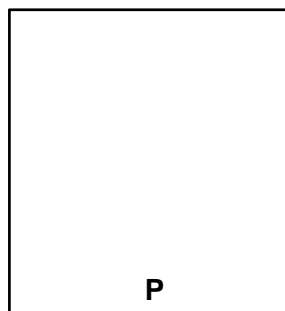
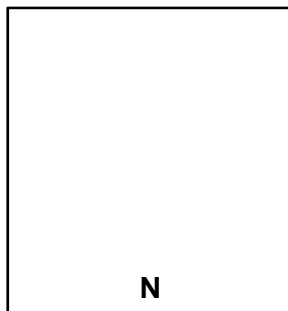
- (i) State the functional group(s) present in the starting material, **M**.

.....[2]

- (ii) Describe what will be observed when **M** is heated with acidified potassium dichromate(VI) and draw the structure of the organic product formed.

.....  
.....  
.....  
.....[2]

- (iii) Draw the structures of the compounds **N**, **P** and **Q**.



[3]

[Total: 20]



6 Methanoic acid is the simplest carboxylic acid and is an important intermediate in chemical synthesis. It occurs naturally and is found notably in ants.

(a) (i) Methanoic acid is a *weak acid*. What do you understand by the term in *italics*?

.....  
 .....  
 .....  
 .....[2]

(ii) The acid dissociation constant,  $K_a$ , for methanoic acid is  $1.6 \times 10^{-4} \text{ mol dm}^{-3}$ . Calculate the pH of a  $0.100 \text{ mol dm}^{-3}$  solution of methanoic acid, given that  $[\text{H}^+] = \sqrt{K_a \times [\text{HCOOH}]}$ .

[2]

(iii) A solution comprising methanoic acid and sodium methanoate can function as a buffer solution. With the aid of a balanced equation, describe how this buffer solution can resist pH changes when a small amount of sulfuric acid is added.

.....  
 .....  
 .....  
 .....[2]

(b) The energy contents of methanoic acid can be determined by means of calorimetric experiments. These experiments are usually carried out using polystyrene cup in a normal school laboratory. The standard enthalpy change of neutralisation can also be determined.

(i) Define what is meant by the *standard enthalpy change of neutralisation*.

.....  
 .....  
 .....  
 .....[1]

- (ii) Write a balanced chemical equation for the neutralisation of methanoic acid with potassium hydroxide.

.....[1]

- (iii) How would you expect the enthalpy change of neutralisation in (b)(ii) to compare with the enthalpy change of neutralisation of nitric acid with potassium hydroxide? Explain your answer.

.....

.....

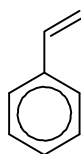
.....

.....[2]

- (iv) Suggest a suitable indicator for the titration between methanoic acid and potassium hydroxide.

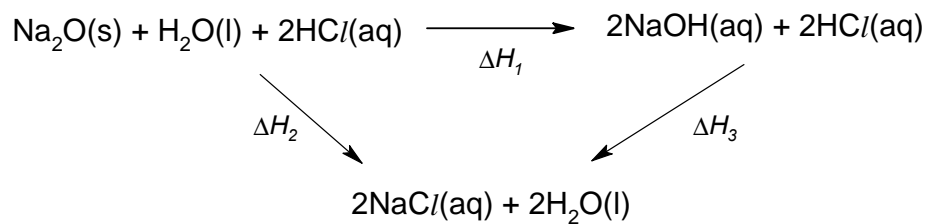
.....[1]

- (v) Draw the structure of polystyrene (with at least three repeating units) given that the monomer styrene has the structure as shown below.



[1]

- (c) Enthalpy change of reaction 1,  $\Delta H_1$ , can be determined using enthalpy change of reaction 2,  $\Delta H_2$ , and enthalpy change of reaction 3,  $\Delta H_3$ , in the energy cycle below.



When 6.2 g of  $\text{Na}_2\text{O(s)}$  is dissolved in 250  $\text{cm}^3$  of 1.0  $\text{mol dm}^{-3}$   $\text{HCl(aq)}$ , the temperature of the solution rose by 17  $^\circ\text{C}$ .

- (i) Using the cycle above, calculate  $\Delta H_2$ .

[3]

- (ii) The enthalpy change of neutralisation between  $\text{NaOH(aq)}$  and  $\text{HCl(aq)}$  is known to be  $-57.3 \text{ kJ mol}^{-1}$ . Calculate  $\Delta H_1$ .

[1]

- (d) The German company BASF is a world leader in the production of methanoic acid. It has an efficient process of producing methanoic acid from methyl methanoate. The process is described below.

Step 1:

Methyl methanoate is mixed with water and allowed to react to produce methanol and methanoic acid.

Step 2:

Methanol is reacted with carbon monoxide and a catalyst to produce methanoic acid.

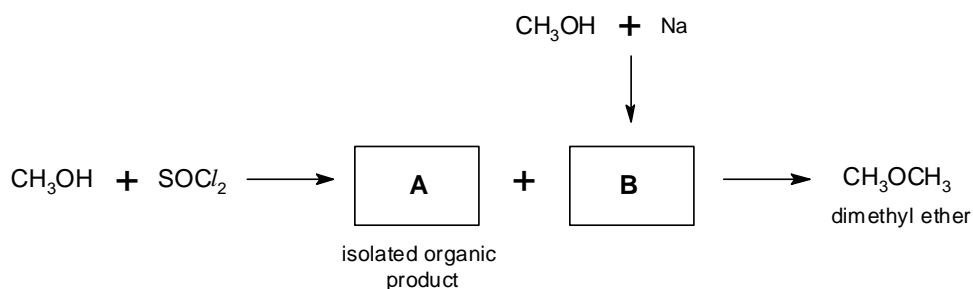
- (i) State the type of reaction occurring in Step 1.

.....[1]

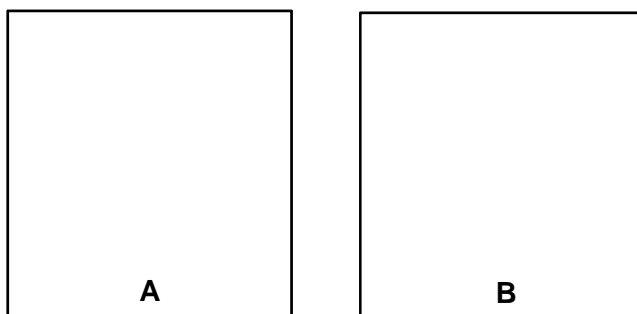
- (ii) Suggest why a catalyst is used in Step 2.

.....  
 .....  
 .....[1]

- (iii) Methanol produced using the process can also be used to produce dimethyl ether which is an alternative fuel to diesel.



Draw the displayed formulae of compounds **A** and **B**.



[2]

[Total: 20]

**BLANK PAGE**

**DUNMAN HIGH SCHOOL**  
**Preliminary Examination 2018**  
**Year 6****H1 CHEMISTRY**

8873/02

Paper 2 Structured Questions

**13 September 2018****2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your 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** the questions.**Section B**Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use								
P1	P2 Section A				P2 Section B		Total	%
	Q1	Q2	Q3	Q4	Q5	Q6		
30	13	9	20	18	20	20	110	

## Section A

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

- 1 (a) Group 1 elements are strong reducing agents. State and explain the trend of reducing power of Group 1 elements down the Group.

[3]

Reducing power of Group 1 elements increases down the group.

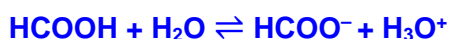
Number of filled principle quantum shell increases and valence electrons are increasingly further away from the nucleus

Valence electrons are less strongly attracted to the nucleus and smaller amount of energy is needed to remove the valence electron so it is more easily oxidised.

- (b) Group 1 elements and its compounds have many uses. Sodium hydrogencarbonate ( $\text{NaHCO}_3$ ) is often used to treat ant stings which contains methanoic acid ( $\text{HCOOH}$ ), a weak acid.

Write an equation for the dissociation of methanoic acid in water. Indicate which species are the acid, the base and their conjugate pairs in the reaction.

[2]



Acid:  $\text{HCOOH}$

Conjugate base:  $\text{HCOO}^-$

Base:  $\text{H}_2\text{O}$

Conjugate acid:  $\text{H}_3\text{O}^+$

- (c) When the ant bites, it injects a solution containing 50 % by volume of unionised methanoic acid. A typical ant may inject around  $6.0 \times 10^{-3} \text{ cm}^3$  of this solution.

- (i) Given that the density of methanoic acid is  $1.2 \text{ g cm}^{-3}$ , what is the amount (in moles) of methanoic acid that a typical ant injects?

[1]

$$\begin{aligned} \text{volume of HCOOH} &= 6.0 \times 10^{-3} \times 0.5 \\ &= 3.0 \times 10^{-3} \text{ cm}^3 \end{aligned}$$

$$\begin{aligned} \text{mass of HCOOH} &= 3.0 \times 10^{-3} \times 1.2 \\ &= 0.00360 \text{ g} \end{aligned}$$

$$\text{no of moles of HCOOH} = \frac{0.00360}{46.0}$$

$$= \underline{7.83 \times 10^{-5} \text{ mol}} \text{ (3 s.f.)}$$

As soon as the methanoic acid is injected, it dissolves in water in the body to produce a solution of methanoic acid with pH 2.43.

- (ii) Assuming that it dissolves fully in  $1.0 \text{ cm}^3$  of water in the body, calculate the concentration of the methanoic acid solution that is formed initially. You may ignore the volume of methanoic acid injected in this calculation.

[1]

$$[\text{HCOOH}] = \frac{7.826 \times 10^{-5}}{0.001}$$

$$= \underline{7.83 \times 10^{-2}} \text{ mol dm}^{-3} \text{ (3 s.f.)}$$

- (iii) Calculate the percentage of methanoic acid molecules which have dissociated in 1.0 cm<sup>3</sup> of water.

[2]

$$[\text{H}^+] = 10^{-2.43}$$

$$= \underline{3.7154 \times 10^{-3}} \text{ mol dm}^{-3} \text{ (5 s.f.)}$$

$$\text{percentage} = \frac{[\text{H}^+]}{[\text{HCOOH}]} \times 100\%$$

$$= \frac{3.72 \times 10^{-3}}{7.826 \times 10^{-2}} \times 100\%$$

$$= \underline{4.75 \%} \text{ (3 s.f.)}$$

- (d) A student was given an unlabelled bottle and was told that it contained pure sample of one of the following three compounds.

- methanol
- methanal
- propanone

- (i) State the reagent used for a chemical test that could show that the sample can be either methanal and propanone but **not** methanol. Describe what would be observed.

[2]

Reagent: 2,4-DNPH

Observations: orange precipitate observed.

- (ii) Describe one chemical test that could distinguish between methanal and propanone.

[2]

Add Tollens' reagent and warm to both samples. Only methanal will form black/ grey solid or silver mirror

OR

Add Fehling's solution and warm to both samples. Only methanal will form reddish- brown precipitate.

OR

Add alkaline aqueous iodine and warm to both samples. Only propanone will form yellow precipitate.

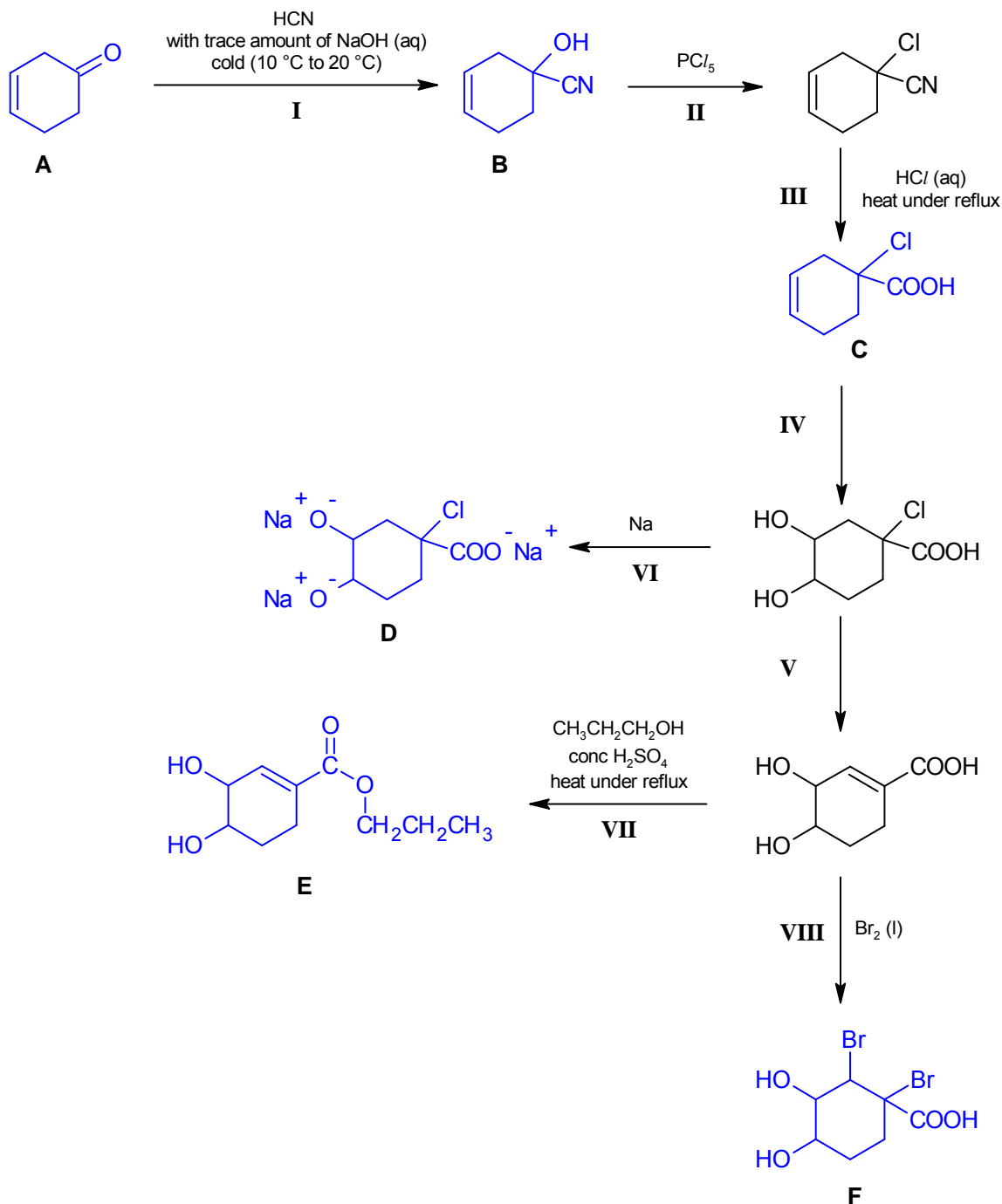
[Total: 13]



2 A sequence of reactions starting from compound A is shown below.

(a) Draw the structures of compounds A, B, C, D, E and F in the boxes below.

[6]



(b) For the reaction scheme shown above, state

(i) the type of reaction occurring in reaction I.

(Nucleophilic) **Addition**

[1]

(ii) the reagents and conditions for reaction V.

**KOH in alcohol, heat under reflux**

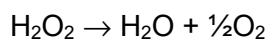
[1]

- (c) The alcohol  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ , used as the reagent in reaction VII above, can be converted into  $\text{CH}_3\text{CH}=\text{CH}_2$ . How may this conversion be achieved in a laboratory? [1]

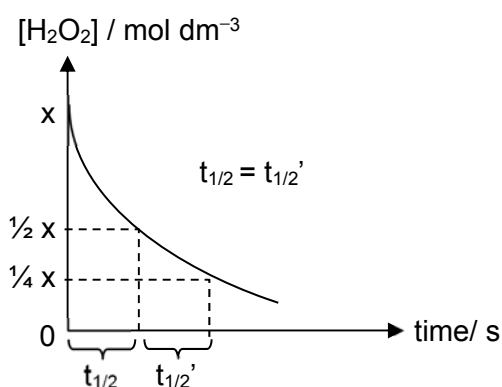
Add excess concentrated  $\text{H}_2\text{SO}_4$  to a sample of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$  and heat.

[Total: 9]

- 3 (a) Pure hydrogen peroxide,  $\text{H}_2\text{O}_2$ , was long believed to be unstable. Its decomposition follows a first order reaction.



- (i) Sketch a graph of  $[\text{H}_2\text{O}_2]$  against time to show that the reaction is first order with respect to  $\text{H}_2\text{O}_2$ . [2]

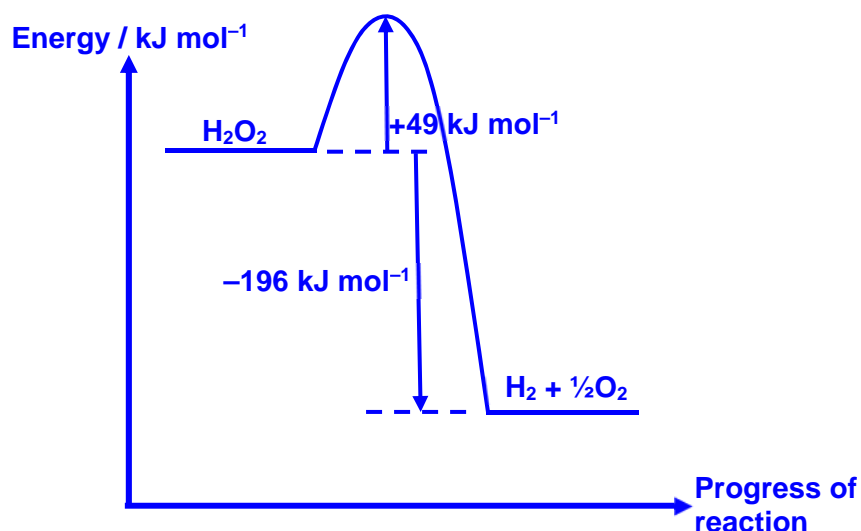


- (ii) As  $\text{H}_2\text{O}_2$  decomposes slowly at room temperature, catalysts such as platinum metal are often added to lower the activation energy to increase the rate of reaction.

With reference to the information provided below, sketch the energy profile diagram showing the catalysed reaction only.

enthalpy change of the decomposition	$-196 \text{ kJ mol}^{-1}$
activation energy (without catalyst)	$+75 \text{ kJ mol}^{-1}$
activation energy (with catalyst)	$+49 \text{ kJ mol}^{-1}$

[2]



(b) In the presence of UV light, H<sub>2</sub>O<sub>2</sub> decomposes to form hydroxyl free radicals, •OH.

(i) Draw the 'dot-and-cross' diagram for H<sub>2</sub>O<sub>2</sub>.

[1]



(ii) Using relevant bond energy values from the *Data Booklet*, suggest the relative rate of the formation of •Cl from chlorine gas as compared that of •OH from hydrogen peroxide.

[2]

From the *Data Booklet*,

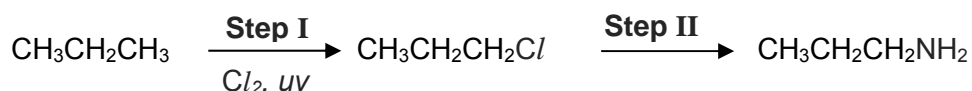
Bond energy of O–O = 150 kJ mol<sup>-1</sup>

Bond energy of Cl–Cl = 244 kJ mol<sup>-1</sup>

Ease of cleavage of bond: O–O > Cl–Cl

Rate of formation of •OH radicals is **faster** than •Cl.

(iii) Propylamine, CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub>, may be formed via the following reaction pathway involving free radical substitution in the first step.



Name the type of reaction occurring in **Step II**. State the reagent and conditions required for this step.

[2]

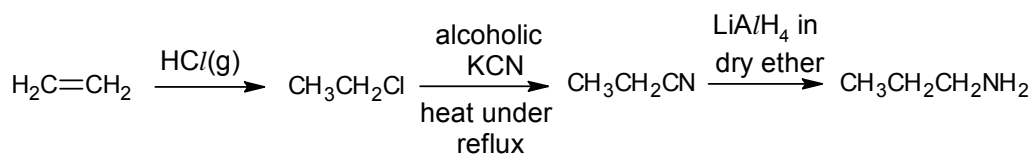
Type of reaction: (Nucleophilic) **Substitution**

Reagent: **NH<sub>3</sub> in excess**

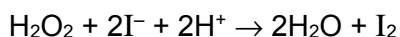
Condition: **in ethanol, heat in sealed tube**

- (iv) As the yield from the reaction in (b)(iii) is low, propose a 3-step synthetic route to produce propylamine from ethene instead. Show clearly the reagents and conditions as well as the intermediates involved.

[3]



- (c) The kinetics of the reaction between hydrogen peroxide and iodide ions in acidic solution was studied.

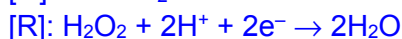


Four separate experiments were carried out to determine the relative rates by varying the concentrations of the reactants. The results obtained are given in the table below.

Expt	[H <sub>2</sub> O <sub>2</sub> ] / mol dm <sup>-3</sup>	[I <sup>-</sup> ] / mol dm <sup>-3</sup>	[H <sup>+</sup> ] / mol dm <sup>-3</sup>	relative rate
1	0.03	0.03	0.03	1.0
2	0.05	0.03	0.03	1.6
3	0.05	0.01	0.06	0.53
4	0.03	0.01	0.03	0.33

- (i) With reference to the overall equation given above, write the oxidation and reduction half-equations.

[2]



- (ii) Use the data to deduce the orders of reaction with respect to H<sub>2</sub>O<sub>2</sub>, I<sup>-</sup> and H<sup>+</sup>. Show your working clearly.

[3]

Comparing Experiments 1 and 2, [H<sub>2</sub>O<sub>2</sub>] increases by 1.6 times as rate also increases by 1.6 times whilst keeping [I<sup>-</sup>] and [H<sup>+</sup>] constant.

⇒ Order of reaction with respect to H<sub>2</sub>O<sub>2</sub> is 1.

Comparing Experiments 1 and 4, [I<sup>-</sup>] increases by 3 times as rate also increases by 3 times whilst keeping [H<sub>2</sub>O<sub>2</sub>] and [H<sup>+</sup>] constant.

⇒ Order of reaction with respect to I<sup>-</sup> is 1.

Comparing Experiments 2 and 3, as [H<sub>2</sub>O<sub>2</sub>] is constant while [I<sup>-</sup>] decreases by 3 times and [H<sup>+</sup>] increases by 2 times, rate decreases by 3 times. Hence, change in [H<sup>+</sup>] does not affect the rate.

⇒ Order of reaction with respect to H<sup>+</sup> is 0.

- (iii) Hence, write the rate equation and state the units of the rate constant.

[2]

$$\text{rate} = k[\text{H}_2\text{O}_2][\text{I}^-]$$

$$\text{Units of rate constant} = \text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

- (iv) Unreacted iodide ions may be easily separated from the reaction mixture by adding silver nitrate solution, followed by filtration. State the identity and colour of the precipitate formed.

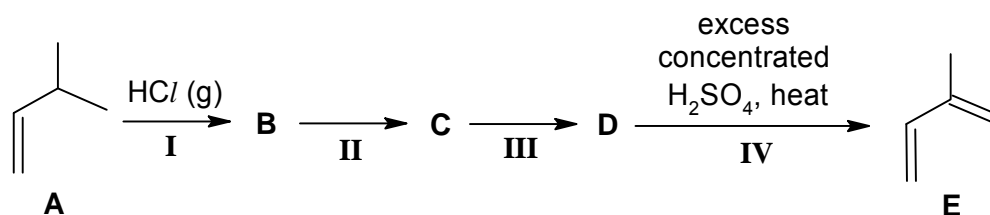
[1]

**AgI** and **yellow** ppt.

[Total : 20]

4 Isoprene, **E**, is an organic compound that could be used to synthesise limonene, which is commonly used in fragrances.

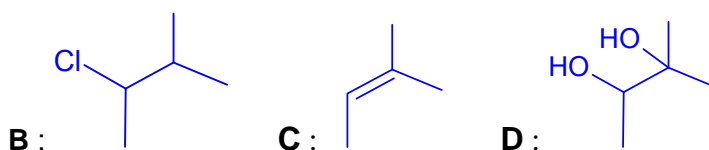
(a) **E** can be synthesised from 3-methylbut-1-ene, **A**, in a 4-step process as follows.



(i) **B** is a major product of step I.

Draw the structures of compounds **B**, **C** and **D**.

[3]



(ii) Hydrogen chloride, the reagent in step I, is commonly used in organic synthesis.

State and explain how the thermal stabilities of hydrogen halides varies down the Group.

[2]

Thermal stability of hydrogen halides decreases down the group

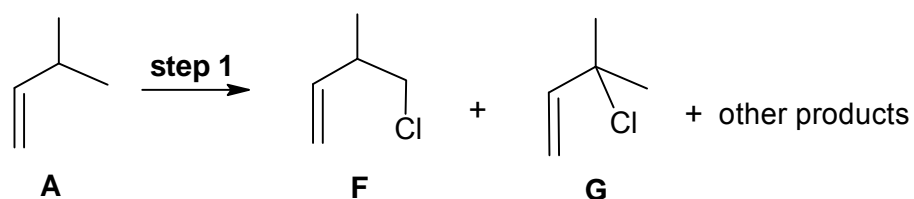
Down the group,

Bond energy decreases [BE (H-F) > BE (H-Cl) > BE (H-Br) > BE (H-I)].

Covalent bond strength also decreases [H-F > H-Cl > H-Br > H-I].

Hence hydrogen halides decompose more readily down the group.

(b) The following reaction shows an alternative route to form an intermediate for the synthesis of isoprene.



(i) State the reagents and conditions of **step 1** which will result in formation of compounds **F** and **G**.

[1]

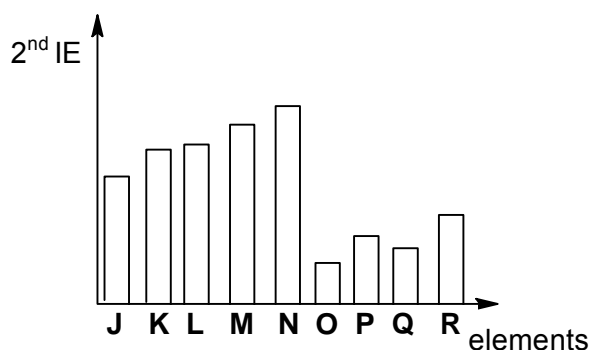
Limited Cl<sub>2</sub>, uv

(ii) Predict the ratio in which **F** and **G** will be formed.

[1]

**F : G**  
**6 : 1**

- (c) The bar chart below shows the second ionisation energy ( $2^{\text{nd}}$  IE) of nine consecutive elements (J to R) in Periods 2 and 3 of the Periodic Table.



- (i) Write an equation for the second ionisation energy of element J. [1]
- $$\text{J}^+(\text{g}) \rightarrow \text{J}^{2+}(\text{g}) + \text{e}^-$$
- (ii) Identify element N. [1]
- Na
- (iii) Using your answers in (c)(i), (c)(ii) and the electronic configurations of the species involved, explain the significantly higher  $2^{\text{nd}}$  IE of N compared to O. [2]
- Electronic configuration:  $\text{N}^{2+} (1\text{s}^2 2\text{s}^2 2\text{p}^6)$ ;  $\text{O}^{2+} ([\text{Ne}] 3\text{s}^1)$

The  $3^{\text{rd}}$  ionisation energy of N involves the removal of a 2p electron

The  $3^{\text{rd}}$  ionisation energy of O involves the removal of a 3s electron

A larger amount of energy is required to remove the 2p electron in  $\text{N}^{2+}$  which is in an inner quantum shell compared to 3s electron in  $\text{O}^{2+}$ .

Hence  $3^{\text{rd}}$  ionisation energy of N is significantly higher than that of O.

- (d) The Periodic Table shows the element, Helium, placed at the top of Group 18.
- (i) Suggest why the element Helium could be placed at the top of Group 2. [1]
- Helium has 2 valence electrons like all other Group 2 elements.
- (ii) Suggest why the element Helium is not placed at the top of Group 2, by comparing **one** physical property. Explain your answer. [2]

Helium atoms are held by weak instantaneous dipole induced dipole interactions while within group 2 elements exist strong electrostatic forces of attraction between cations and a sea of delocalised electrons.

Hence, helium has low melting/boiling point and it exist as a gas while group 2 elements has high melting/boiling point and exist as a solid at room temperature.

OR

Hence, helium is a non-conductor of electricity due to (absence of mobile/delocalised electrons) while group 2 elements are good conductor of electricity due to (presence of delocalised electrons).

(e)  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$  and  $\text{P}_4\text{O}_{10}$  are oxides of Period 3 elements.

(i) Explain why both  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  are insoluble in water.

[2]

$\text{Al}_2\text{O}_3$  is insoluble in water due to a very exothermic lattice energy and hence, it is very difficult to break down the ionic lattice structure.

$\text{SiO}_2$  is insoluble in water due to strong and extensive covalent bonds between Si and O atoms.

(ii) Explain, with the aid of an equation, the reaction of  $\text{P}_4\text{O}_{10}$  with water.

[2]

$\text{P}_4\text{O}_{10}$  is covalent in nature and reacts readily with water to form an acidic solution.



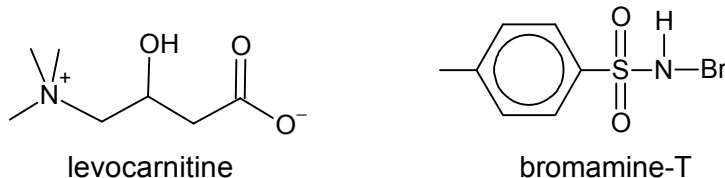
[Total: 18]



## Section B

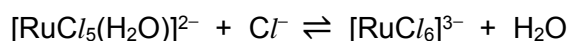
Answer **one** question from this section, in the spaces provided.

- 5 Levocarnitine is a quaternary ammonium compound involved in metabolism in most mammals.



- (a) A kinetic study on the  $\text{RuCl}_3$  catalysed reaction between levocarnitine and bromamine-T was carried out in aqueous hydrochloric acid.

- (i) The following equilibrium exists for  $\text{RuCl}_3$  in aqueous hydrochloric acid.

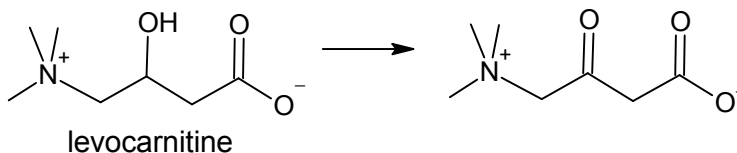


Explain why  $[\text{RuCl}_6]^{3-}$  is likely to be the reactive species instead of  $[\text{RuCl}_5(\text{H}_2\text{O})]^{2-}$  in this study.

[1]

By Le Chatelier's Principle, the presence of **chloride ions from aqueous HCl** will shift the **position of equilibrium to the right**, favouring the formation of  $[\text{RuCl}_6]^{3-}$ .

- (ii) Levocarnitine is converted into the following product by bromamine-T.



State the type of reaction that levocarnitine had undergone and explain your answer in terms of changes in oxidation number.

[2]

### Oxidation

The oxidation number of **carbon** (bonded to -OH group) **increased from 0 in levocarnitine to +2 in the product**.

- (b) A series of experiments were carried out at different temperatures under first order conditions with respect to bromamine-T.

The value of the observed rate constant,  $k$ , for the catalysed reaction was determined at each temperature and the results are summarised in the table below.

$k$ / $10^4 \text{ s}^{-1}$	temperature, $T$ / K
1.82	293
3.00	303
4.62	313
7.30	323

The activation energy,  $E_a$ , and the pre-exponential factor,  $A$ , which is a constant, for the reaction can be determined from the equation.

$$k = Ae^{\frac{-E_a}{RT}}$$

$R$  is the molar gas constant.

$T$  is the reaction temperature in kelvin.

$k$  is the observed rate constant at a chosen temperature.

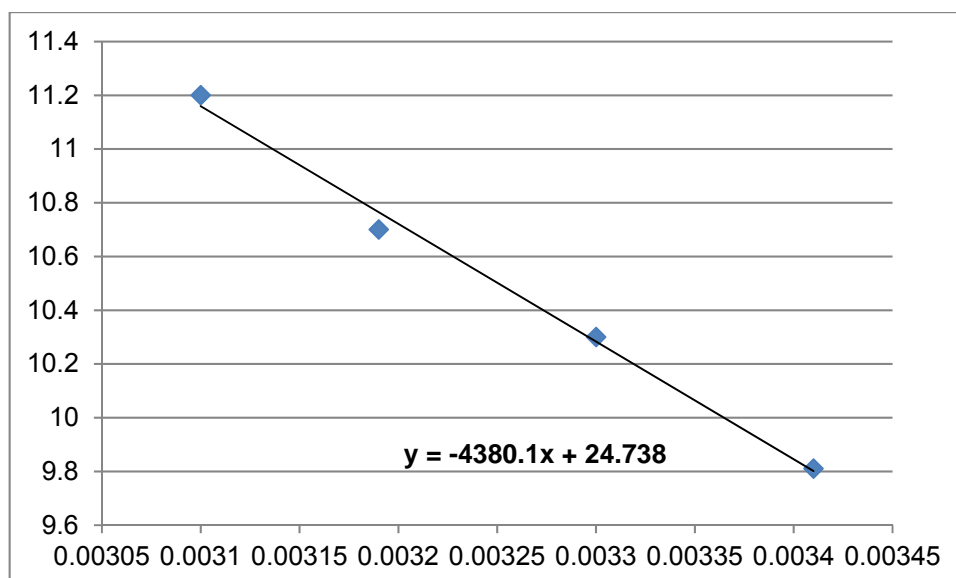
- (i) Calculate the values of  $\ln k$  and  $\frac{1}{T}$  for each of the experiments above.

[2]

$k$ / $10^4 \text{ s}^{-1}$	$\ln k$	temperature, $T$ / K	$\frac{1}{T}$ / $\text{K}^{-1}$
1.82	9.81	293	0.00341
3.00	10.3	303	0.00330
4.62	10.7	313	0.00319
7.30	11.2	323	0.00310

- (ii) Hence plot a graph of  $\ln k$  against  $\frac{1}{T}$  and determine  $E_a$  from the gradient of the best-fit line which is  $\frac{-E_a}{R}$ .

[4]

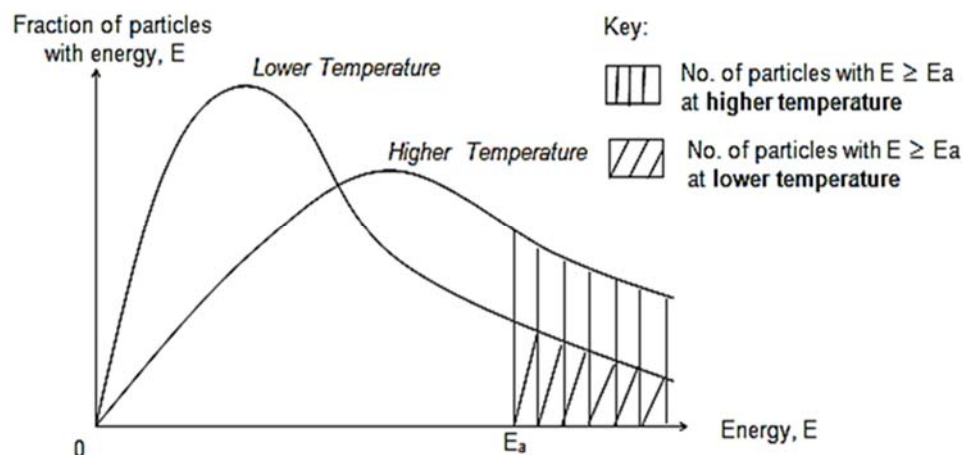


$$\text{Gradient} = \frac{-E_a}{R} = -4380.1 \text{ K}$$

$$\text{Hence } E_a = 36399 \text{ J mol}^{-1} = \underline{\underline{36.4 \text{ kJ mol}^{-1}}}$$

- (iii) State the effect of temperature on the rate of the reaction and explain your answer with the aid of a Boltzmann distribution curve.

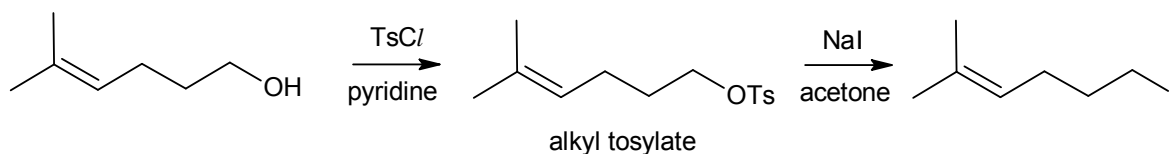
[4]



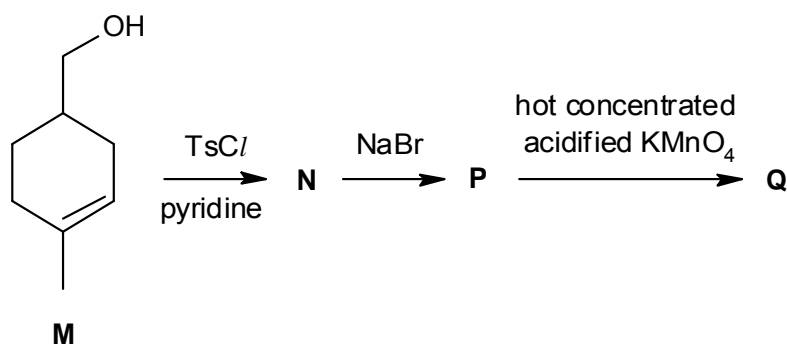
When temperature of the reaction increases,

- ♦ average kinetic energy of reactant particles increases
- ♦ there are more reactant particles with energy  $\geq E_a$
- ♦ number of effective collisions per unit time / frequency of effective collisions increases
- ♦ rate of reaction increases, since the rate of reaction is proportional to the frequency of effective collisions

Tosyl chlorides (TsCl) are often used to convert alcohols into alkyl tosylates which undergo substitution reactions. An example of this application is given below.



- (c) Consider the reaction scheme below involving an alkyl tosylate **N**.

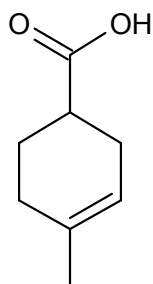


- (i) State the functional group(s) present in the starting material, **M**. [2]

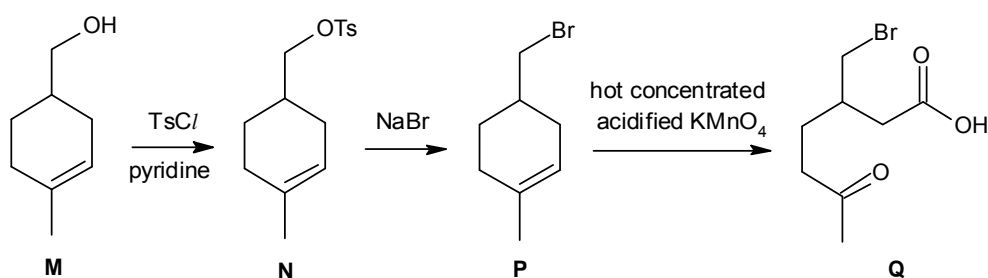
Primary alcohol and alkene

- (ii) Describe what will be observed when **M** is heated with acidified potassium dichromate(VI) and draw the structure of the organic product formed. [2]

Orange acidified potassium dichromate(VI) turns green.



- (iii) Draw the structures of the compounds **N**, **P** and **Q**. [3]



[Total: 20]

6 Methanoic acid is the simplest carboxylic acid and is an important intermediate in chemical synthesis. It occurs naturally and is found notably in ants.

- (a) (i) Methanoic acid is a *weak acid*. What do you understand by the term in *italics*? [2]

An acid is a compound which is a **proton donor**. A weak acid is an acid which only **partially dissociates** in water to release proton.

- (ii) The acid dissociation constant,  $K_a$ , for methanoic acid is  $1.6 \times 10^{-4} \text{ mol dm}^{-3}$ . Calculate the pH of a  $0.100 \text{ mol dm}^{-3}$  solution of methanoic acid, given that  $[\text{H}^+] = \sqrt{K_a \times [\text{HCOOH}]}$ . [2]

$$\begin{aligned}
 [\text{H}^+] &= \sqrt{1.6 \times 10^{-4} \times 0.100} \\
 &= 4.00 \times 10^{-3} \text{ mol dm}^{-3} \\
 \text{pH} &= -\log(4.00 \times 10^{-3}) \\
 &= 2.40 \text{ (3 sf)}
 \end{aligned}$$

- (iii) A solution comprising methanoic acid and sodium methanoate can function as a buffer solution. With the aid of a balanced equation, describe how this buffer solution can resist pH changes when a small amount of sulfuric acid is added. [2]



When a small amount of sulfuric acid is added, methanoate will react with and remove the acid to form methanoic acid. This ensures that the pH of the solution is maintained fairly constant.

- (b) The energy contents of methanoic acid can be determined by means of calorimetric experiments. These experiments are usually carried out using polystyrene cup in a normal school laboratory. The standard enthalpy change of neutralisation can also be determined.

- (i) Define what is meant by the *standard enthalpy change of neutralisation*. [1]

Standard enthalpy change of neutralisation is the energy evolved when one mole of water is formed when an acid is completely neutralised by a base under standard conditions.

- (ii) Write a balanced chemical equation for the neutralisation of methanoic acid with potassium hydroxide. [1]



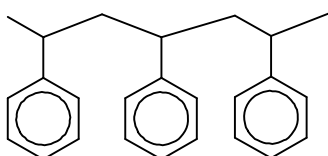
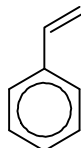
- (iii) How would you expect the enthalpy change of neutralisation in (b)(ii) to compare with the enthalpy change of neutralisation of nitric acid with potassium hydroxide? Explain your answer. [2]

The enthalpy change of neutralisation in (b)(ii) will be **less exothermic**. Some of the heat evolved as a result of the neutralisation is **absorbed by the dissociation of methanoic acid, a weak acid**. Hence, less heat should be evolved.

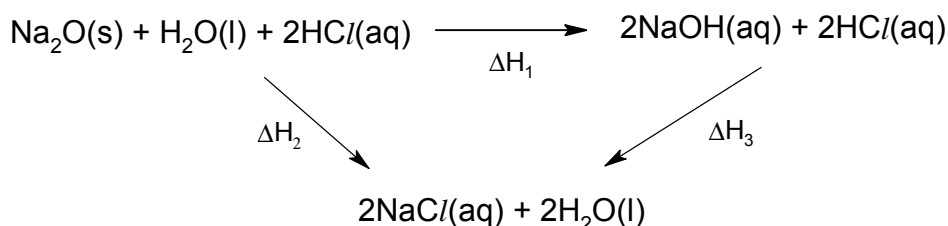
- (iv) Suggest a suitable indicator for the titration between methanoic acid and potassium hydroxide. [1]

Phenolphthalein or any other suitable indicator (e.g. thymol blue)

- (v) Draw the structure of polystyrene (with at least three repeating units) given that the monomer styrene has the structure as shown below. [1]



- (c) Enthalpy change of reaction 1,  $\Delta H_1$ , can be determined using enthalpy change of reaction 2,  $\Delta H_2$ , and enthalpy change of reaction 3,  $\Delta H_3$ , in the energy cycle below.



When 6.2 g of  $\text{Na}_2\text{O}(\text{s})$  is dissolved in 250  $\text{cm}^3$  of 1.0  $\text{mol dm}^{-3}$   $\text{HCl}(\text{aq})$ , the temperature of the solution rose by 17  $^\circ\text{C}$ .

- (i) Using the cycle above, calculate  $\Delta H_2$ .

[3]

$$\text{No. of mol of Na}_2\text{O} = \frac{6.2}{(23 \times 2 + 16)} = 0.100 \text{ mol (exact)}$$

$$\text{No. of mol of HCl} = 0.25 \times 1.0 = 0.250 \text{ mol}$$

Since  $n_{\text{Na}_2\text{O}} : n_{\text{HCl}} = 1:2$ ,  $\text{HCl}$  is in excess.  
This means that 0.200 mol of  $\text{H}_2\text{O}$  was formed.

$$q = mc\Delta T = 250 \times 4.18 \times 17 = 17765 \text{ J}$$

$$\Delta H_2 = \frac{17765}{0.200} \times 2 = -177650 \text{ J mol}^{-1} = -178 \text{ kJ mol}^{-1} \text{ (3 sf)}$$

- (ii) The enthalpy change of neutralisation between  $\text{NaOH}(\text{aq})$  and  $\text{HCl}(\text{aq})$  is known to be  $-57.3 \text{ kJ mol}^{-1}$ . Calculate  $\Delta H_1$ .

[1]

$$\begin{aligned}
 &\text{By Hess' Law,} \\
 \Delta H_1 &= -177.65 - (2)(-57.3) \\
 &= -63.1 \text{ kJ mol}^{-1} \text{ (3 sf)}
 \end{aligned}$$

- (d) The German company BASF is a world leader in the production of methanoic acid. It has an efficient process of producing methanoic acid from methyl methanoate. The process is described below.

Step 1:

Methyl methanoate is mixed with water and allowed to react to produce methanol and methanoic acid.

Step 2:

Methanol is reacted with carbon monoxide and a catalyst to produce methanoic acid.

- (i) State the type of reaction occurring in Step 1.

[1]

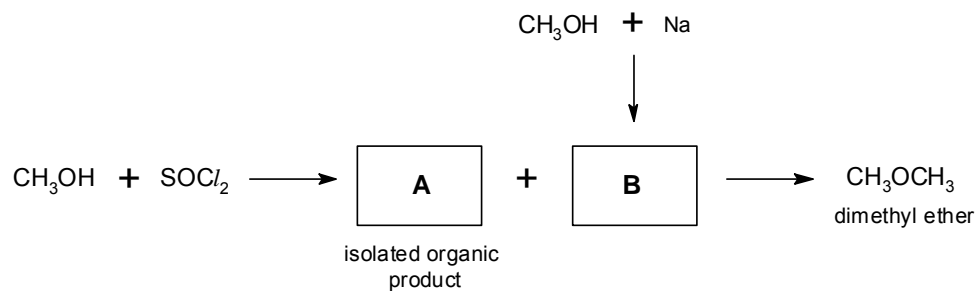
Step 1: Hydrolysis

- (ii) Suggest why a catalyst is used in Step 2.

[1]

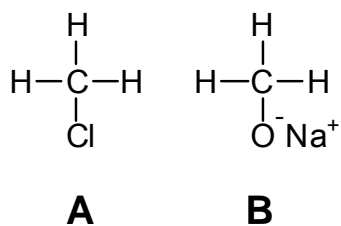
A catalyst is required to speed up the reaction because carbon monoxide has a very strong triple bond which must be weakened / broken in order for the reaction to occur.

- (iii) Methanol produced using the process can also be used to produce dimethyl ether which is an alternative fuel to diesel.



Draw the displayed formulae of compounds **A** and **B**.

[2]



[Total: 20]