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Centre number

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Surname

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Forename(s)

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Candidate signature

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# AS CHEMISTRY

## Paper 2 Organic and Physical Chemistry

Friday 25 May 2018

Morning

Time allowed: 1 hour 30 minutes

### Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

### Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

### Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

### Advice

- You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.

| For Examiner's Use |      |
|--------------------|------|
| Question           | Mark |
| 1                  |      |
| 2                  |      |
| 3                  |      |
| 4                  |      |
| 5                  |      |
| 6                  |      |
| 7                  |      |
| 8                  |      |
| Section B          |      |
| <b>TOTAL</b>       |      |



J U N 1 8 7 4 0 4 2 0 1

IB/M/Jun18/E6

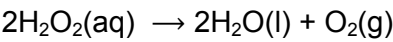
**7404/2**

Section A

Answer **all** questions in this section.

0 1

Hydrogen peroxide solution decomposes slowly to form water and oxygen.  
The reaction is much faster in the presence of a manganese(IV) oxide catalyst.



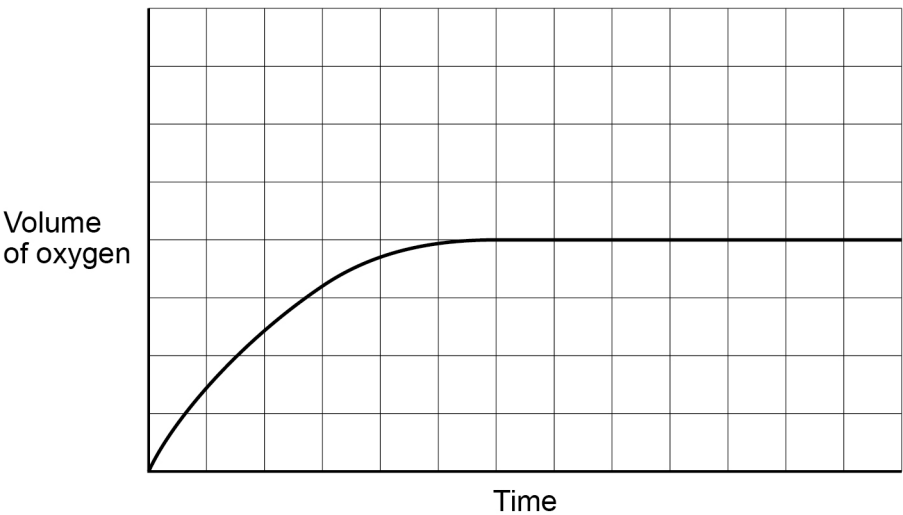
Three experiments, shown in **Table 1**, were carried out to investigate how the volume of oxygen produced varied over time under different conditions. The same mass of catalyst was used in each experiment.

Table 1

| Experiment | Concentration<br>of $\text{H}_2\text{O}_2(\text{aq})$<br>/ $\text{mol dm}^{-3}$ | Volume of<br>$\text{H}_2\text{O}_2(\text{aq})$<br>/ $\text{cm}^3$ | Temperature<br>/ $^{\circ}\text{C}$ | Catalyst |
|------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------------|----------|
| 1          | 1.0                                                                             | 50                                                                | 20                                  | lumps    |
| 2          | 1.0                                                                             | 50                                                                | 20                                  | powder   |
| 3          | 0.5                                                                             | 50                                                                | 20                                  | lumps    |

**Figure 1** shows how the volume of oxygen collected varied with time in Experiment 1.

Figure 1



0 1 . 1

Explain, in general terms, how a catalyst increases the rate of a reaction.

[2 marks]

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0 1 . 2

Draw **two** lines on **Figure 1** to show how the volume of oxygen collected varied with time in Experiments **2** and **3**.  
Label each line with the experiment number.

[2 marks]

0 1 . 3

Explain, in terms of collision theory, the effect of increasing the concentration of hydrogen peroxide on the rate of reaction.

[2 marks]

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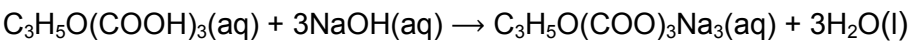


0 2

Citric acid,  $\text{C}_3\text{H}_5\text{O}(\text{COOH})_3$ , occurs naturally in many fruits and can also be synthesised in the laboratory for use as a food flavouring. A student analysed a sample of citric acid to determine its percentage purity.

The student dissolved 784 mg of impure citric acid in water to prepare  $250\text{ cm}^3$  of solution in a volumetric flask.

The student titrated  $25.0\text{ cm}^3$  samples of this solution with  $0.0500\text{ mol dm}^{-3}$  sodium hydroxide solution using phenolphthalein as the indicator.



0 2 . 1

The student rinsed the burette before filling it with the sodium hydroxide solution.

State why the student should use sodium hydroxide solution rather than water for the final rinse of the burette.

[1 mark]

0 2 . 2

The student carried out several titrations. The results are shown in **Table 2**.

Complete **Table 2** to show the titre in each titration.

[1 mark]

Table 2

| Titration                     | Rough | 1     | 2     | 3     |
|-------------------------------|-------|-------|-------|-------|
| Final reading / $\text{cm}^3$ | 25.2  | 23.95 | 47.65 | 24.10 |
| Start reading / $\text{cm}^3$ | 0.0   | 0.05  | 23.95 | 0.10  |
| Titre / $\text{cm}^3$         |       |       |       |       |

0 2 . 3

Calculate the mean titre using the concordant results.  
Give your answer to the appropriate number of significant figures.

[2 marks]

Mean titre \_\_\_\_\_  $\text{cm}^3$



**0 2 . 4**

The total uncertainty when using the burette is  $\pm 0.15 \text{ cm}^3$ . This is the combination of uncertainties in the start reading, final reading and the determination of the end point.

Use your answer to Question **02.3** to calculate the percentage uncertainty for the use of the burette in this experiment.

**[1 mark]**

Percentage uncertainty \_\_\_\_\_ %

**0 2 . 5**

Use your answer to Question **02.3** to find the mass, in mg, of citric acid dissolved in  $250 \text{ cm}^3$  of the solution.

The relative molecular mass ( $M_r$ ) of citric acid is 192.0

**[3 marks]**

Mass \_\_\_\_\_ mg

**0 2 . 6**

Calculate the percentage purity of this sample of citric acid.

**[1 mark]**

Percentage purity \_\_\_\_\_ %

9

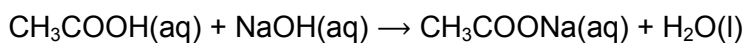
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|   |   |
|---|---|
| 0 | 3 |
|---|---|

This question is about enthalpy changes.

|   |   |   |   |
|---|---|---|---|
| 0 | 3 | . | 1 |
|---|---|---|---|

When ethanoic acid reacts with sodium hydroxide, the enthalpy change,  $\Delta H$ , is  $-56.1 \text{ kJ mol}^{-1}$



Calculate the temperature rise when  $25 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$  aqueous ethanoic acid react with  $25 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$  aqueous sodium hydroxide.

Assume that both solutions have the same initial temperature, have a density of  $1.0 \text{ g cm}^{-3}$  and a specific heat capacity of  $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

**[4 marks]**

Temperature rise \_\_\_\_\_  $^{\circ}\text{C}$



0 3 . 2

A student recorded the temperature of aqueous ethanoic acid in a polystyrene cup for three minutes.

At the fourth minute, the student added sodium hydrogencarbonate.

The student stirred the mixture and carried on recording the temperature every minute for several minutes.

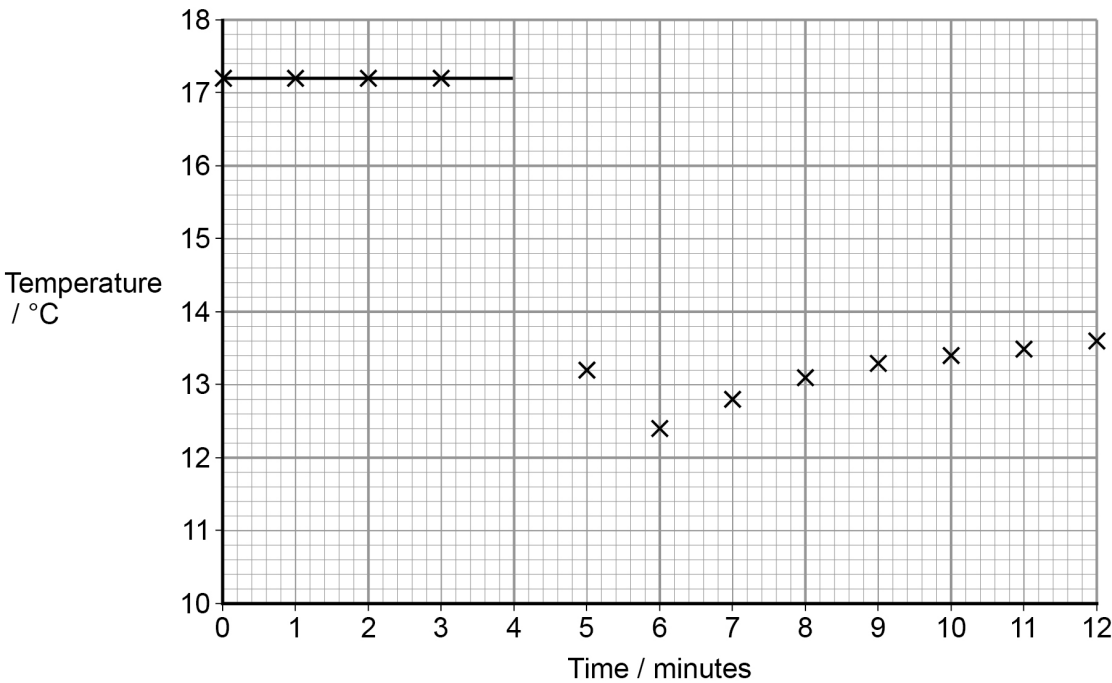
The student's measurements are shown in **Figure 2**.

A best-fit line showing the temperature before mixing has been drawn.

Draw an appropriate best-fit line on **Figure 2** and use it to find the temperature change at the time of mixing.

[2 marks]

Figure 2



Temperature change at time of mixing \_\_\_\_\_ °C

6

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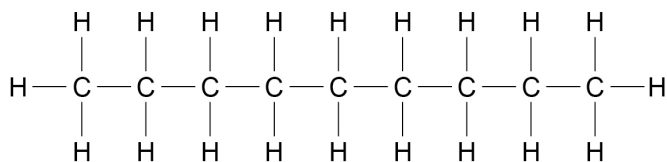
0 4

The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula  $C_9H_{20}$

They are found in crude oil and can be separated by fractional distillation.

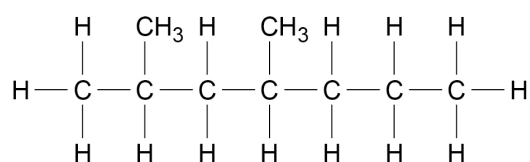
Both can be used in fuels or cracked to form other products.

nonane



boiling point 151 °C

2,4-dimethylheptane



boiling point 134 °C

0 4 . 1

State the general formula of an alkane containing  $n$  carbon atoms.

Deduce an expression for the relative molecular mass ( $M_r$ ) of an alkane in terms of  $n$ .

**[2 marks]**

General formula \_\_\_\_\_

Expression \_\_\_\_\_

0 4 . 2

Explain why nonane has a higher boiling point than 2,4-dimethylheptane.

**[2 marks]**

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0 4 . 3

Give an equation for the complete combustion of nonane.

[1 mark]

0 4 . 4

Nonane is often found in fuel for jet engines. Combustion in jet engines produces pollutants including nitrogen monoxide (NO).

Explain how this nitrogen monoxide is formed.

[2 marks]

0 4 . 5

Nonane can be cracked to form large quantities of propene.

Name the type of cracking used.

[1 mark]

0 4 . 6

The main use of propene, formed from cracking, is to make poly(propene).

Draw the repeating unit of poly(propene).

[1 mark]

Turn over for the next question

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9

Turn over ►



**[6 marks]**

[illegible]

[illegible]

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6

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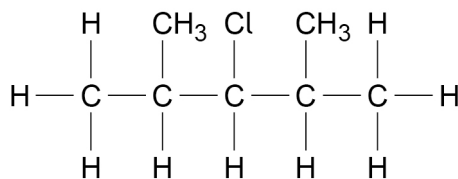


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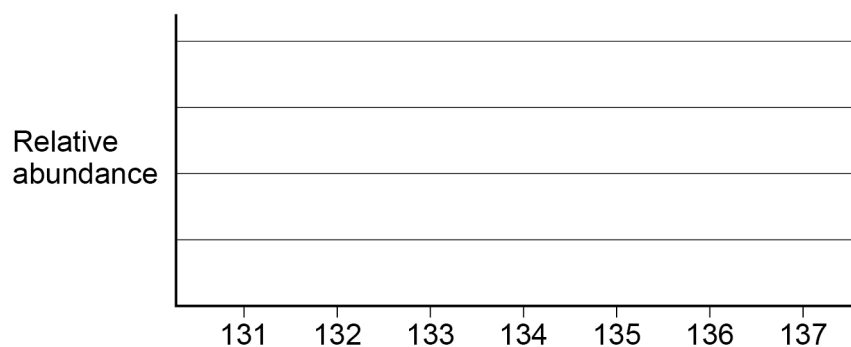
0 6

Compound **A** is a halogenoalkane.**Compound A**

0 6 . 1

Name Compound **A**.**[1 mark]**

0 6 . 2

Compound **A** has a relative molecular mass ( $M_r$ ) of 134.5The main isotope of hydrogen is  $^1\text{H}$ The main isotope of carbon is  $^{12}\text{C}$ Chlorine consists of two common isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ , of which 75% is  $^{35}\text{Cl}$ The mass spectrum of **A** was recorded when **A** was ionised by electron impact to form  $\text{A}^+$  ions.Draw, on **Figure 3**, the peaks for the main molecular ions in the mass spectrum of **A**.**[2 marks]****Figure 3**

Question 6 continues on the next page

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**0 6 . 3** Reaction of **A** with warm, dilute aqueous sodium hydroxide forms alcohol **B**.

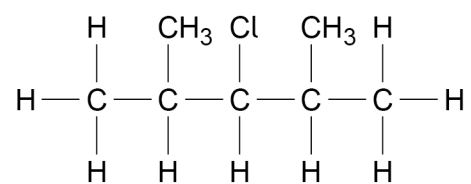
Name the mechanism for this reaction.

Outline the mechanism using the structure of **A** shown.  
Include the structure of the product, alcohol **B**.

**[4 marks]**

Mechanism \_\_\_\_\_

Outline of mechanism



**0 6 . 4** Reaction of **A** with hot, ethanolic potassium hydroxide gives alkene **C**.

Name the mechanism for this reaction.  
State the role of the hydroxide ions.

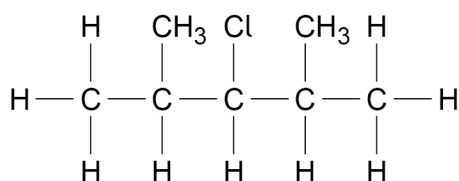
Outline the mechanism using the structure of **A** shown.  
Include the structure of the product, alkene **C**.

**[6 marks]**

Mechanism \_\_\_\_\_

Role of hydroxide ions \_\_\_\_\_

Outline of mechanism



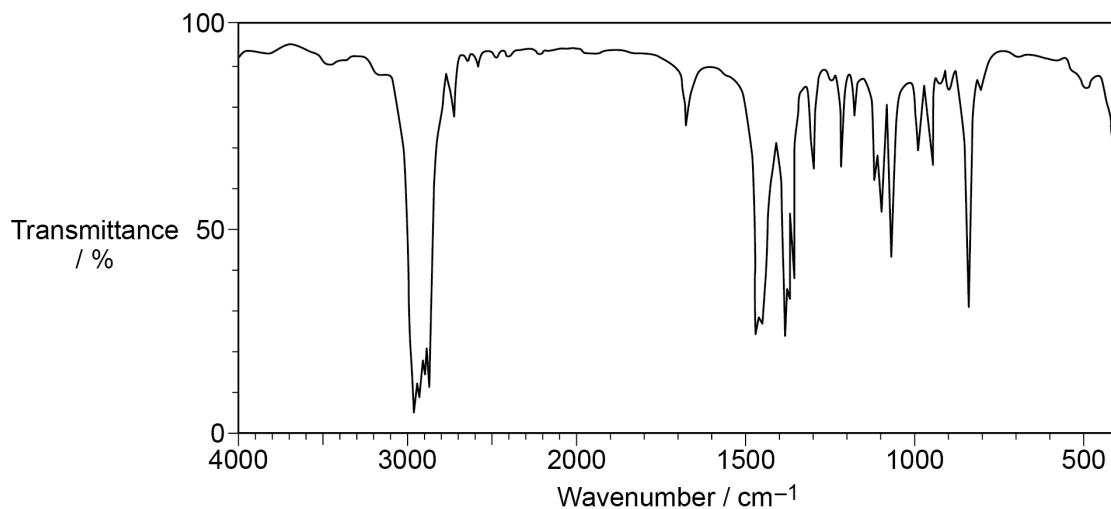
Question 6 continues on the next page

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**0 6 . 5** The infrared spectrum in **Figure 4** is that of either alcohol **B** or alkene **C**.

**Figure 4**



Tick the box that shows the correct compound.

Explain your answer with reference to a bond and the wavenumber of its absorption.

**[1 mark]**

Alcohol **B**

☐

Alkene **C**

☐

Explanation

\_\_\_\_\_

\_\_\_\_\_

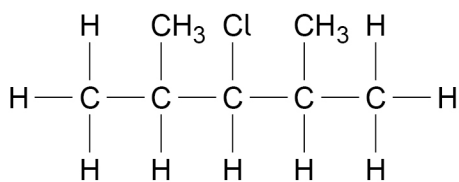
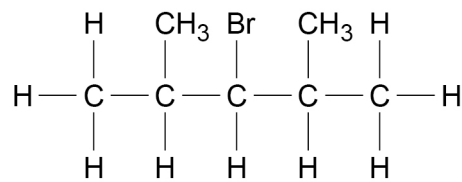
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0 6 . 6

Compound **D** reacts with dilute aqueous sodium hydroxide in a similar way to **A** to form alcohol **B**.

Compound **A**Compound **D**

Explain why **D** reacts more quickly than **A** with dilute aqueous sodium hydroxide at the same temperature.

[1 mark]

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Turn over for the next question

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**[6 marks]**

[illegible]

[illegible]

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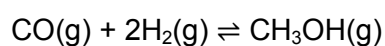
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|   |   |
|---|---|
| 0 | 8 |
|---|---|

Methanol can be manufactured in a reversible reaction as shown by the equation.



|   |   |   |   |
|---|---|---|---|
| 0 | 8 | . | 1 |
|---|---|---|---|

State and explain the effect of using a catalyst on the yield of methanol in this equilibrium.

**[2 marks]**

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|   |   |   |   |
|---|---|---|---|
| 0 | 8 | . | 2 |
|---|---|---|---|

Give an expression for the equilibrium constant ( $K_c$ ) for this reaction.

**[1 mark]**



08.3

A mixture of carbon monoxide and hydrogen was allowed to reach equilibrium in a container of volume  $250 \text{ cm}^3$  at temperature  $T$ .  
At equilibrium, the mixture contained  $0.340 \text{ mol}$  of carbon monoxide,  $0.190 \text{ mol}$  of hydrogen and  $0.0610 \text{ mol}$  of methanol.

Calculate the value of the equilibrium constant ( $K_c$ ) for this reaction at temperature  $T$ .

[3 marks]

$K_c$  \_\_\_\_\_  $\text{mol}^{-2} \text{ dm}^6$

08.4

Methanol decomposes on heating in a reaction that is the reverse of that used in its manufacture.



Use your answer from Question **08.3** to determine the value of  $K_c$  for this equilibrium at temperature  $T$ .

State the units for this value of  $K_c$

(If you were unable to complete the calculation in Question **08.3**, assume a value of  $K_c = 0.825 \text{ mol}^{-2} \text{ dm}^6$ . This is **not** the correct value.)

[2 marks]

Value of  $K_c$  \_\_\_\_\_

Units of  $K_c$  \_\_\_\_\_

|   |
|---|
| 8 |
|---|

Turn over ►



## Section B

Answer **all** questions in this section.Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.  
Do **not** use additional sheets for this working.**0 9**

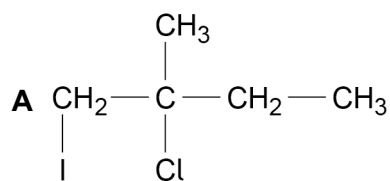
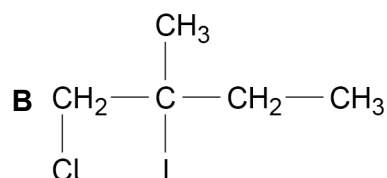
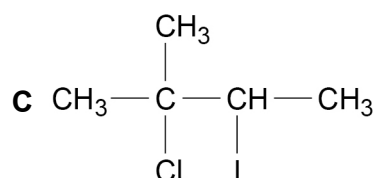
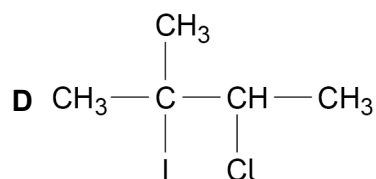
A student has a  $10 \text{ cm}^3$  sample of  $1.00 \times 10^{-2} \text{ mol dm}^{-3}$  methanoic acid solution. The student is asked to dilute the methanoic acid solution to a concentration of  $2.00 \times 10^{-4} \text{ mol dm}^{-3}$  by adding distilled water.

Which volume of water should be added?

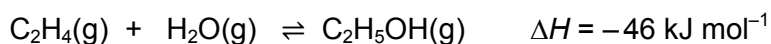
**[1 mark]****A**  $200 \text{ cm}^3$ ☐**B**  $490 \text{ cm}^3$ ☐**C**  $500 \text{ cm}^3$ ☐**D**  $510 \text{ cm}^3$ ☐**1 0**Which molecule does **not** have a permanent dipole?**[1 mark]****A**  $\text{CH}_3\text{Br}$ ☐**B**  $\text{CH}_2\text{Br}_2$ ☐**C**  $\text{CHBr}_3$ ☐**D**  $\text{CBr}_4$ ☐

**1 1**

Which is the major product of the reaction between 2-methylbut-2-ene and iodine monochloride (ICl)?

**[1 mark]**☐☐☐☐**1 2**

Which statement is **not** correct about the industrial preparation of ethanol by the hydration of ethene at 300 °C?

**[1 mark]**

**A** The reaction is catalysed by an acid.

☐

**B** The higher the pressure, the higher the equilibrium yield of ethanol.

☐

**C** The higher the temperature, the higher the equilibrium yield of ethanol.

☐

**D** A low equilibrium yield of ethanol is acceptable because unreacted ethene is recycled.

☐**Turn over ►**

**1 3** Which compound has the highest boiling point?

[1 mark]

**A** butanal

☐

**B** butan-2-ol

☐

**C** but-2-ene

☐

**D** 1-fluorobutane

☐

**1 4** Which statement is correct about the fractional distillation of crude oil?

[1 mark]

**A** A zeolite catalyst is used.

☐

**B** Each fraction contains a mixture of hydrocarbons.

☐

**C** Gaseous fractions are formed by breaking covalent bonds.

☐

**D** The fractionating column is hottest at the top.

☐

**1 5** How many structural isomers with an unbranched carbon chain have the molecular formula  $C_4H_8Br_2$ ?

[1 mark]

**A** 4

☐

**B** 5

☐

**C** 6

☐

**D** 7

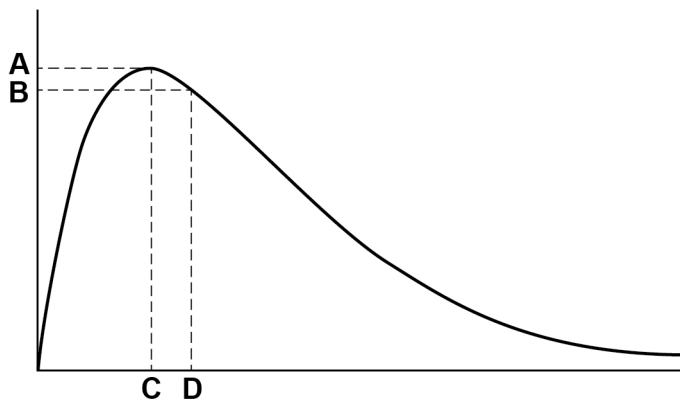
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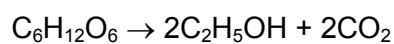
**1 6**

The Maxwell–Boltzmann distribution of molecular energies in a sample of gas at a fixed temperature is shown.

Which letter represents the mean energy of the molecules?

**[1 mark]****A**☐**B**☐**C**☐**D**☐**1 7**

Ethanol can be made from glucose by fermentation.



In an experiment, 268 g of ethanol ( $M_r = 46.0$ ) were made from 1.44 kg of glucose ( $M_r = 180.0$ ).

What is the percentage yield?

**[1 mark]****A** 18.6%☐**B** 36.4%☐**C** 51.1%☐**D** 72.8%☐**Turn over ►**

**1 8** Which species could act as a nucleophile?

[1 mark]

**A**  $\text{BH}_3$

☐

**B**  $\text{NH}_4^+$

☐

**C**  $\text{PH}_3$

☐

**D**  $\text{SiH}_4$

☐

**1 9** Which statement is correct about poly(chloroethene)?

[1 mark]

**A** It has the empirical formula  $\text{CHCl}$

☐

**B** It decolourises bromine water.

☐

**C** Its brittleness is reduced by plasticisers.

☐

**D** Its polymer chain contains alternate single and double bonds.

☐

**2 0** What is the enthalpy of formation of buta-1,3-diene,  $\text{C}_4\text{H}_6(\text{g})$ ?

| Substance                        | Enthalpy of combustion / $\text{kJ mol}^{-1}$ |
|----------------------------------|-----------------------------------------------|
| $\text{C}_4\text{H}_6(\text{g})$ | -2546                                         |
| $\text{C}(\text{s})$             | -394                                          |
| $\text{H}_2(\text{g})$           | -286                                          |

[1 mark]

**A**  $+112 \text{ kJ mol}^{-1}$

☐

**B**  $-112 \text{ kJ mol}^{-1}$

☐

**C**  $+746 \text{ kJ mol}^{-1}$

☐

**D**  $-746 \text{ kJ mol}^{-1}$

☐

**2 1** A gas cylinder contains 5.0 kg of propane.

How many propane molecules are in the cylinder?

The Avogadro constant,  $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

[1 mark]

**A**  $6.8 \times 10^{22}$

☐

**B**  $7.2 \times 10^{22}$

☐

**C**  $6.8 \times 10^{25}$

☐

**D**  $7.2 \times 10^{25}$

☐

**2 2** Which sample of liquid has the greatest volume?

[1 mark]

**A** 500 mg of pentane (density =  $0.63 \text{ g cm}^{-3}$ )

☐

**B** 650 mg of propan-1-ol (density =  $0.80 \text{ g cm}^{-3}$ )

☐

**C** 1.20 g of dichloromethane (density =  $1.33 \text{ g cm}^{-3}$ )

☐

**D** 1.30 g of trichloromethane (density =  $1.48 \text{ g cm}^{-3}$ )

☐

**2 3** Which equation represents an initiation step?

[1 mark]

**A**  $\text{CH}_3\text{CH}_2\dot{\text{C}}\text{HBr} + \text{Br}_2 \longrightarrow \text{CH}_3\text{CH}_2\text{CHBr}_2 + \dot{\text{Br}}$

☐

**B**  $\text{O}_3 + \dot{\text{Cl}} \longrightarrow \text{O}_2 + \dot{\text{ClO}}$

☐

**C**  $\text{RCH}_2\dot{\text{C}}\text{H}_2 + \text{H}_2\text{C}=\text{CH}_2 \longrightarrow \text{RCH}_2\text{CH}_2\text{CH}_2\dot{\text{C}}\text{H}_2$

☐

**D**  $\text{CH}_3\text{CFCl}_2 \longrightarrow \text{CH}_3\dot{\text{C}}\text{FCl} + \dot{\text{Cl}}$

☐

**END OF QUESTIONS**



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