Oxford Cambridge and RSA

# Friday 27 May 2022 – Afternoon

## AS Level Chemistry B (Salters)

**H033/02** Chemistry in depth

**Time allowed: 1 hour 30 minutes**

**You must have:**
- the Data Sheet for Chemistry B

**You can use:**
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

**INSTRUCTIONS**
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

**INFORMATION**
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

**ADVICE**
- Read each question carefully before you start your answer.

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Answer **all** the questions.

**1** The element magnesium is an important Group 2 metal. Its presence in distant stars has been shown using atomic emission spectra.

**(a)** **(i)** The atomic **emission** spectrum of an element shows a series of coloured lines on a black background.

Describe how the appearance of the **absorption** spectrum of the element is similar to **and** different from its **emission** spectrum.

Similar .....

.....

Different .....

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

**(ii)** What evidence for the structure of atoms is provided by atomic spectra?

.....

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

**(b)** Ionisation enthalpies have also been used to develop theories about atomic structure.

**(i)** Write an equation for the reaction that represents the first ionisation enthalpy of magnesium.

Include state symbols.

**[2]**

**(ii)** The first ionisation enthalpies of the elements of Period 3 show a general increase across the period.

Explain this increase.

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..... **[3]**

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**(c)** The mass spectrum of magnesium shows that it has three stable isotopes as shown below.

| Isotope | Abundance / % |
|---|---|
| $^{24}Mg$ | 78.60 |
| $^{25}Mg$ | 10.11 |
| $^{26}Mg$ | 11.29 |

Calculate a value for the relative atomic mass of magnesium based on these data.

Give your answer to **two** decimal places.

relative atomic mass = ..... **[2]**

**(d)** Magnesium-24 is formed in some stars by nuclear fusion of two identical carbon nuclei.

Complete the nuclear equation for the formation of this isotope.

$$\mathbf{2} \quad \rightarrow \quad {}^{24}_{12}\mathbf{Mg}$$ **[1]**

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**(e)** A student is asked to prepare a sample of hydrated magnesium chloride crystals (containing water of crystallisation) starting from solid magnesium oxide.

The student adds magnesium oxide to hot hydrochloric acid until the oxide is in excess.

The student then evaporates the mixture until just a solid is left.

Explain why this procedure would **not** produce hydrated magnesium chloride crystals and give a correct method.

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

**(f)** Calcium and barium are two other Group 2 elements.

A student places a small piece of calcium into 100 $cm^3$ of cold water in a beaker. A steady fizzing occurs, the calcium disappears and a white, cloudy mixture of pH 11 is left. The temperature increases by 26 °C.

The student then repeats the experiment with an equal amount of barium.

Describe **two** differences that the student would observe when comparing the reaction of barium with that of calcium.

1 .....

.....

2 .....

.....

**[2]**

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**(g)** Another student is provided with samples of magnesium carbonate and strontium carbonate and asked to identify which is which. The student heats equal amounts of each carbonate in separate test tubes using the same Bunsen flame. The student measures the time taken for the gas evolved to turn limewater cloudy.

The student says that the time taken will be shorter when strontium carbonate is heated because strontium is more reactive than magnesium.

Comment on the student's statement, giving the correct chemistry where necessary.

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..... **[3]**

**(h)** Complete the electronic configuration for the magnesium **ion**, $Mg^{2+}$.

**$1s^2$** ..... **[1]**

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**2** Heterogeneous catalysts are used on a large scale for catalytic cracking in industry.

**(a)** A student sets up the apparatus shown in **Fig. 2.1** to investigate the cracking of 'liquid paraffin'.

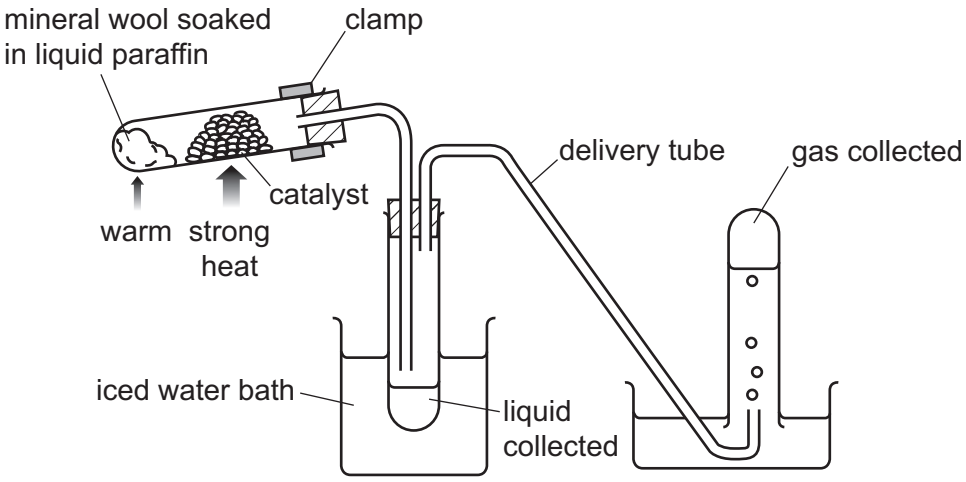


**Fig. 2.1**

**(i)** Explain why the catalyst is described as **heterogeneous**.

.....

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

**(ii)** The catalyst gets coated with carbon over time and becomes less effective.

Give the general name of a substance that reduces the function of a catalyst in this way.

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

**(iii)** The compounds below **might** be found in the apparatus in **Fig. 2.1** when it is in use.

Match the appropriate formula with the places from **Fig. 2.1**:

| | $C_2H_4$ | $C_6H_{14}$ | $C_{12}H_{26}$ |
|---|---|---|---|
| Liquid paraffin | | ..... | |
| Liquid collected | | ..... | |
| Gas collected | | ..... | |

**[1]**

**(iv)** The gas collected is found to turn bromine water from orange/brown to colourless.

What can the student deduce from this?

.....

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

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**(b)** In cordless hair straighteners, butane is passed over a platinum coil that acts as a heterogeneous catalyst.

Butane reacts with oxygen in the air and releases thermal energy.

**(i)** Explain how a catalyst increases the rate of a chemical reaction.

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

**(ii)** Complete the missing stages in the mechanism of heterogeneous catalysis given below.

**Stage 1** Reactants diffuse to and are adsorbed onto the catalyst surface.

**Stage 2** .....

.....

**Stage 3** .....

.....

**Stage 4** Products are desorbed from the catalyst surface and diffuse away.

**[1]**

**(iii)** Butane reacts with oxygen according to the following equation.

$C_4H_{10} + 6½O_2 \rightarrow 4CO_2 + 5H_2O$

Calculate the volume of oxygen, in $m^3$ (measured at RTP), required for the complete reaction of 1.0 g butane with oxygen.

Give your answer to an **appropriate** number of significant figures.

volume of oxygen = ..... $m^3$ **[4]**

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**(c)** Catalytic reactions also occur in the stratosphere where chlorine radicals are formed from the breakdown of chlorofluorocarbons, CFCs.

Chlorine radicals take part in the catalytic cycle shown:

$Cl + O_3 \longrightarrow ClO + O_2$

$ClO + O \longrightarrow Cl + O_2$

**(i)** Give the overall equation for the reaction that occurs in the cycle.

**[1]**

**(ii)** What is acting as a catalyst in this catalytic cycle and what **type** of catalysis is involved?

.....

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

**(d)** A CFC has the following percentage composition by mass:

C, 11.7%; F, 18.8%; C*l*, 69.5%.

The relative molecular mass of this CFC is 204.

Calculate the molecular formula of this CFC.

molecular formula = ..... **[3]**

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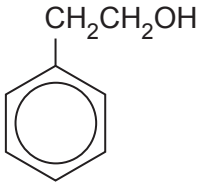
**3** This question concerns some reactions of compound **A**.

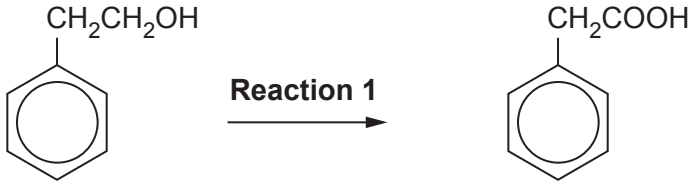



**Compound A**

Compound **A** is found in extract of orange blossom. A group of chemists carry out some reactions with this compound.

**(a) Reaction 1**

Compound **A** can be converted to an acid, compound **B**, as shown.




**Compound A** **Compound B**

**(i)** Explain why the alcohol functional group in compound **A** is classified as **primary**.

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

**(ii)** Give the reagents and conditions required for **reaction 1**.

Reagents .....

Conditions .....

**[1]**

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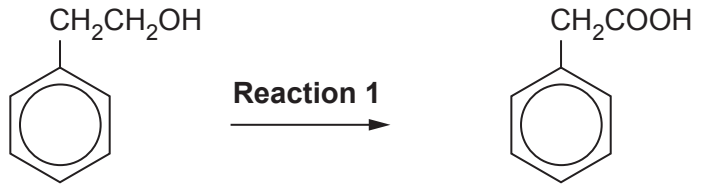
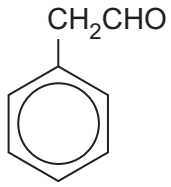
**Reaction 1** (repeated)




**Compound A** **Compound B**

**(iii)** **Reaction 1** occurs via the formation of compound **C**.




**Compound C**

The chemists use infrared spectroscopy to find out whether the conversion of compound **A** into compound **B** (**reaction 1**) is complete after 10 minutes. They set up a reaction mixture and analyse it after 10 minutes.

The infrared spectrum of the mixture shows absorptions at the wavenumbers shown in **Table 3.1**.

| **Type of absorption** | **Wavenumber / $cm^{-1}$** |
|---|---|
| sharp | 1200 |
| several in a range | 1500–1600 |
| sharp | 1710 |
| sharp | 1730 |
| broad | 2900 |
| broad | 3300 |

**Table 3.1**

Use the information from **Table 3.1** to determine whether the conversion is complete after 10 minutes.

Give the relevant bonds for any wavenumbers you refer to.

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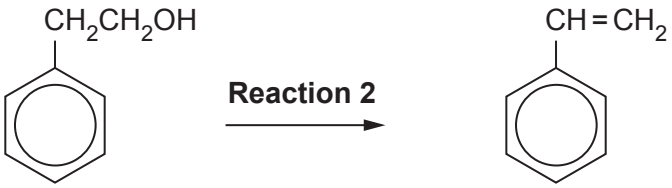
**(b) Reaction 2**

Compound **A** can be dehydrated as shown.




What **type** of reaction is this dehydration?

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

**(c) Reaction 3**

Compound **A** can be reacted with hydrochloric acid.

An incomplete equation is shown below.

Complete the balanced equation for this reaction.

**[1]**

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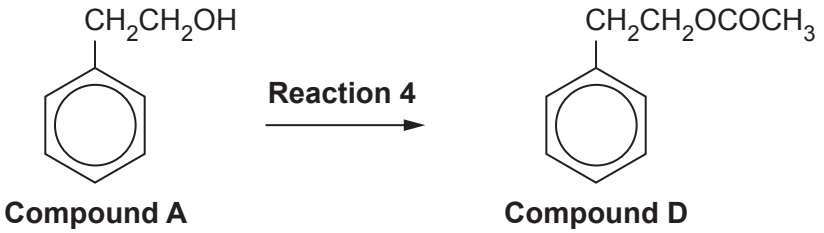
**(d)* Reaction 4**

Compound **A** can be converted to an ester, compound **D**, as shown.




A student attempts to carry out **reaction 4** using two different methods.

In one method the student uses equimolar amounts of compound **A** and ethanoic acid.

In the other method, equimolar amounts of compound **A** and ethanoic anhydride are used.

At the end of each reaction the mixture is analysed using thin-layer chromatography. The results of this analysis are shown below in **Fig. 3.1**.

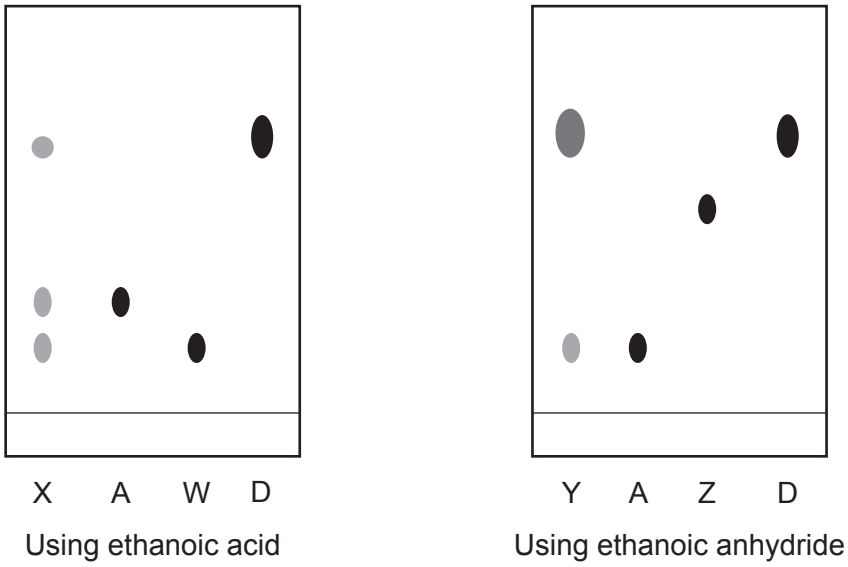



**Fig. 3.1**

**Key to chromatograms in Fig. 3.1**

X = recrystallised product from ethanoic acid

Y = recrystallised product from ethanoic anhydride

A = Compound **A**

W = ethanoic acid

Z = ethanoic anhydride

D = Compound **D**

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Describe how the student would run the chromatograms once the substances have been spotted onto the thin-layer plates.

Use **Fig. 3.1** to explain how well ethanoic acid and ethanoic anhydride work at carrying out **reaction 4**.

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**4** Vehicles using petrol as fuel will still be on the roads for some time to come.

It is important that developments continue to improve fuel efficiency and further reduce harmful emissions.

**(a)** Petrol is a complex mixture of compounds, mainly hydrocarbons.

**(i)** One of the hydrocarbons in petrol is octane, $C_8H_{18}$.

Write an equation for the complete combustion of octane.

**[1]**

**(ii)** Oxides of nitrogen ($NO_x$) which can lead to acid rain are also produced in a petrol engine.

Give the conditions in the engine that cause the usually unreactive nitrogen to react with oxygen.

.....

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

**(b)** 4.3 g of another liquid hydrocarbon present in petrol produce 554 $cm^3$ of vapour at 60 °C and 250 kPa.

Use these data to work out the $M_r$ of the hydrocarbon.

$M_r$ = ..... **[4]**

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**(c)** The alcohol methanol is a liquid oxygenate that is used in petrol to reduce the amount of incomplete combustion that occurs.

**(i)** Methanol burns in oxygen as shown in **equation 4.1**.

$CH_3OH(g) + 1½O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$ $\Delta_c H_{298} = -676\,kJ\,mol^{-1}$ **Equation 4.1**

Some average bond enthalpy data are given in **Table 4.1**.

| **Bond** | **Average bond enthalpy / kJ mol$^{-1}$** |
|---|---|
| C–O | +358 |
| O–H | +464 |
| O=O | +498 |
| C=O | +805 |

**Table 4.1**

Calculate a value for the average bond enthalpy of the C–H bond in methanol.

Use the data in **Table 4.1** and the value of $\Delta_c H_{298}$ in **equation 4.1**.

average bond enthalpy of C–H = ..... kJ mol$^{-1}$ **[3]**

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**(ii)** The **standard** enthalpy change of combustion of methanol ($\Delta_c H^{\ominus}_{298}$) is **not** the same as the value given in **equation 4.1**.

Give a reason for this.

.....

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

**(iii)** There are two carbon-oxygen bonds listed in **Table 4.1**.

Explain why the C=O double bond is shorter than the C–O single bond.

.....

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

**(d)** A student carries out an experiment to measure $\Delta_c H$ for methanol, $CH_3OH$. The student burns the methanol in a spirit burner below a beaker containing 100 $cm^3$ water, as shown in **Fig. 4.1** on page 18.

The following measurements are recorded:

| | |
|---|---|
| mass of spirit burner and methanol before combustion | 12.58 g |
| mass of spirit burner and methanol after combustion | 11.62 g |
| temperature of water before combustion | 17.0 °C |
| temperature of water after combustion | 45.0 °C |

Use these measurements to calculate a value for $\Delta_c H$ of methanol in $kJ\,mol^{-1}$.

$\Delta_c H$ of $CH_3OH$ = ..... $kJ\,mol^{-1}$ **[3]**

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**(e)*** The student uses the following procedure to obtain the measurements in **part (d)**.

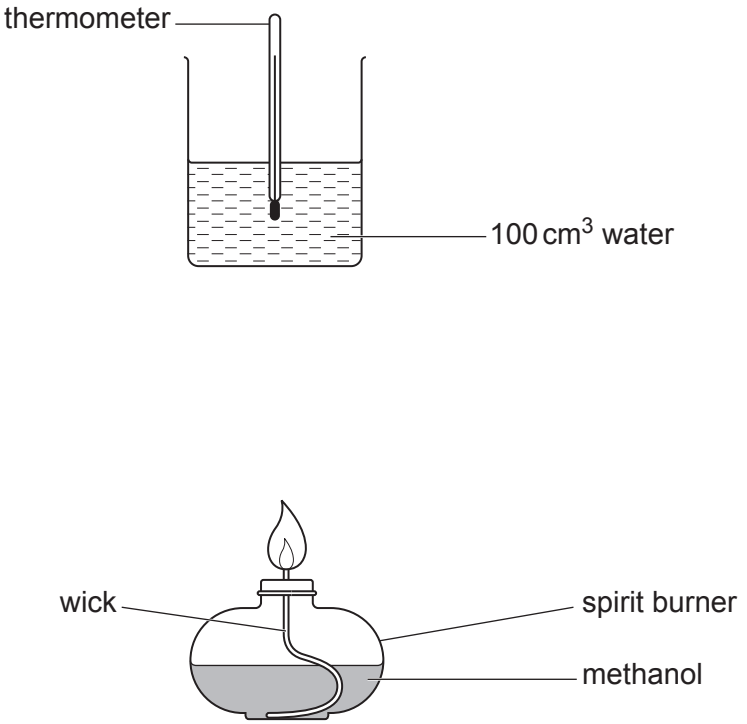


**Fig. 4.1**

**Procedure:**

1 The mass of a spirit burner containing methanol is measured and recorded.

2 100 $cm^3$ of water is measured into a 250 $cm^3$ glass beaker using the graduations on the beaker.

3 The temperature of the water is measured and recorded.

4 The apparatus is set up as shown in **Fig. 4.1**, with the beaker being held in position using a clamp, boss and stand (not shown).

5 The wick of the spirit burner is ignited.

6 When the temperature of the water in the beaker has risen by about 30 °C, the flame on the spirit burner is blown out.

7 After the water is emptied out of the beaker and the apparatus has been put away, the mass of the spirit burner is measured and recorded again.

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The student wants to improve the accuracy of the calculated enthalpy change of combustion by changing the method.

Suggest and explain possible improvements to the procedure on page 18.

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**END OF QUESTION PAPER**

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## ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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