Modified Enlarged 24pt

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Friday 27 May 2022 – Afternoon

AS Level Chemistry B (Salters)

H033/02 Chemistry in depth

Time allowed: 1 hour 30 minutes
plus your additional time allowance

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.

Centre number					

Candidate number				

First name(s) ______________________________

Last name ______________________________

READ INSTRUCTIONS OVERLEAF

DC (PQ/SW) 318644

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 (*).

ADVICE

Read each question carefully before you start your answer.

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]

(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. [1]

$$2 \qquad\qquad \longrightarrow \qquad\qquad {}^{24}_{12}Mg$$

(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]**

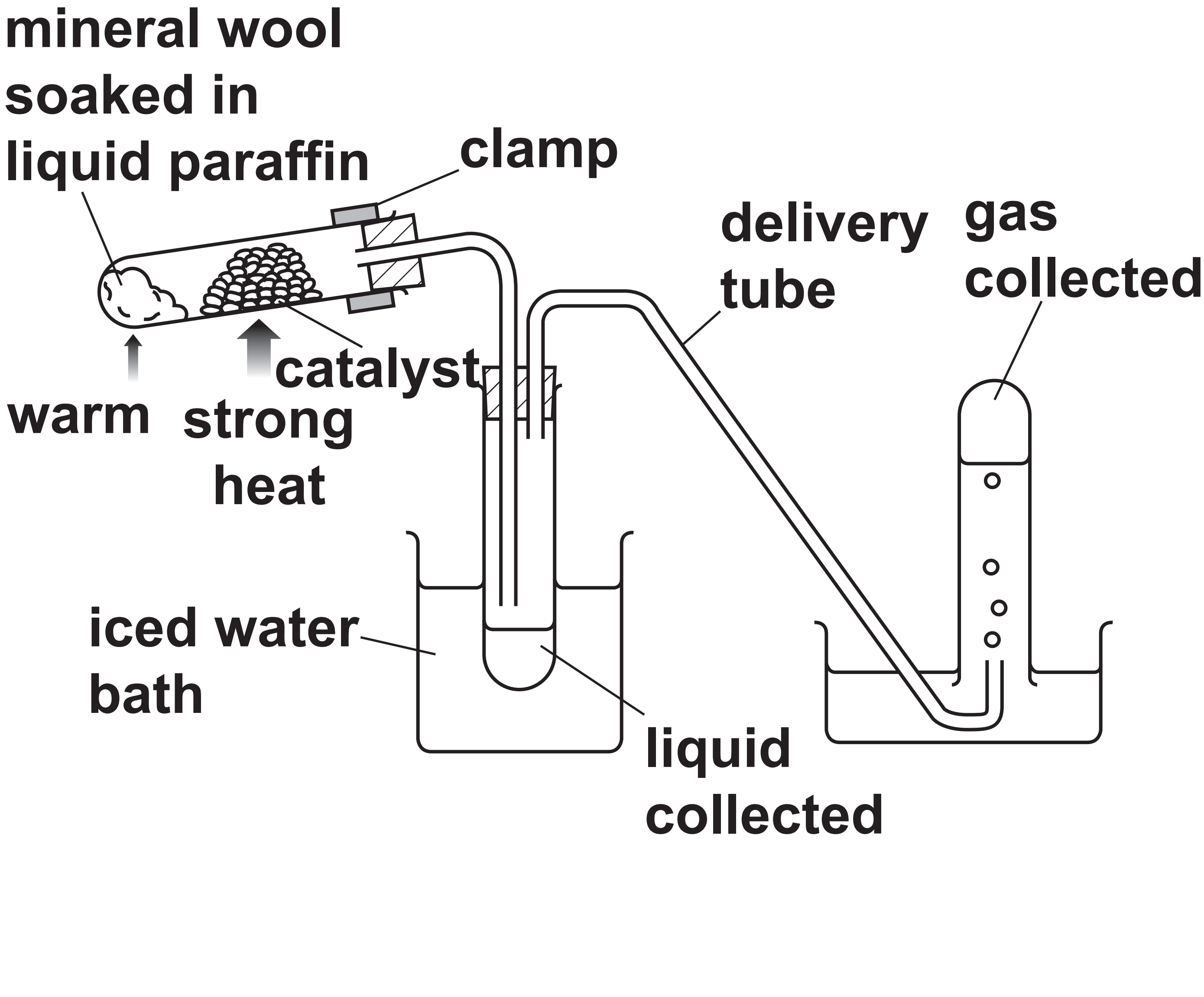
(h) Complete the electronic configuration for the magnesium ION, Mg^{2+}.

$1s^2$ ____________________________ [1]

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: [1]

C_2H_4 C_6H_{14} $C_{12}H_{26}$

Liquid paraffin ________________

Liquid collected ________________

Gas collected ________________

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

What can the student deduce from this?

____

________________________________ [1]

(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.

____

______________________________ [1]

(ii) Complete the missing stages in the mechanism of heterogeneous catalysis given below. [1]

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.

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

$$C_4H_{10} + 6\tfrac{1}{2}O_2 \longrightarrow 4CO_2 + 5H_2O$$

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]

(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%.

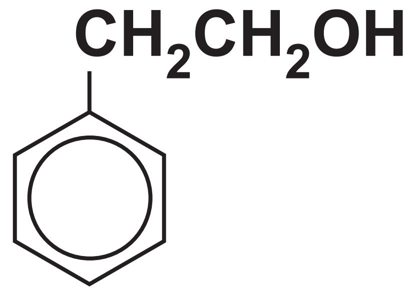
The relative molecular mass of this CFC is 204.

Calculate the molecular formula of this CFC.

molecular formula = ____________________ [3]

3 This question concerns some reactions of compound A.

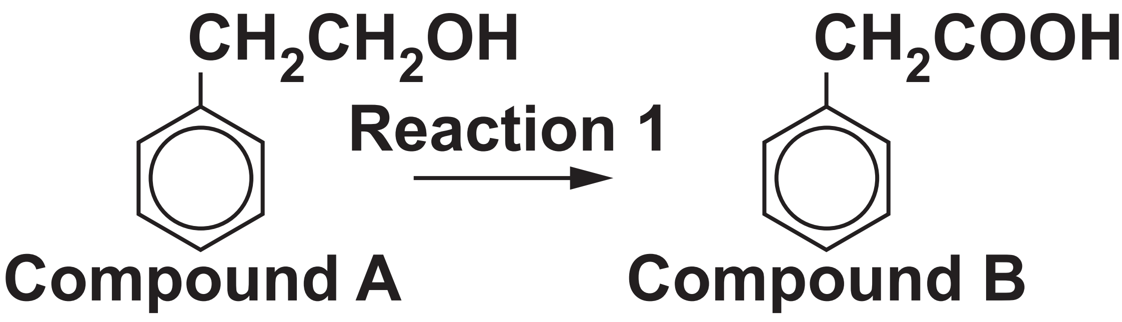
Compound A



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.



(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.

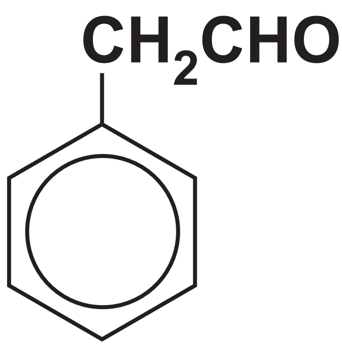
Reagents ______________________

Conditions ______________________ [1]

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.

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

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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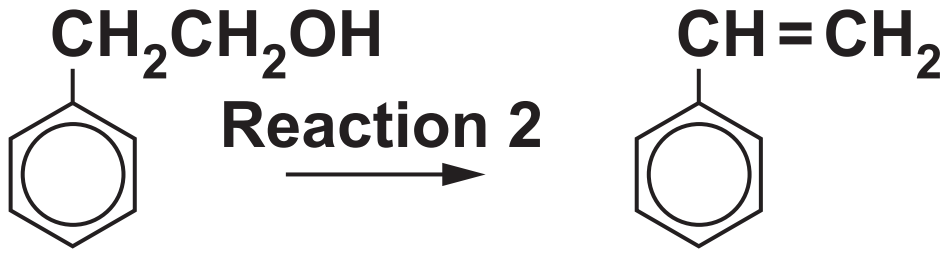
__________________________________ **[3]**

(b) REACTION 2

Compound A can be dehydrated as shown.



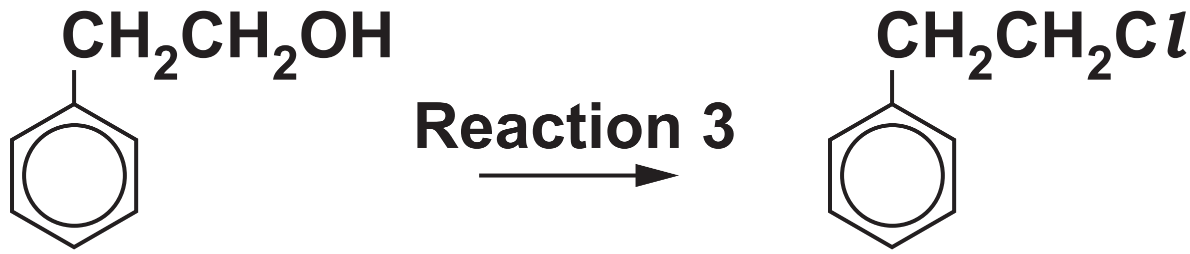
What TYPE of reaction is this dehydration?

______________________________ **[1]**

(c) REACTION 3

Compound A can be reacted with hydrochloric acid.

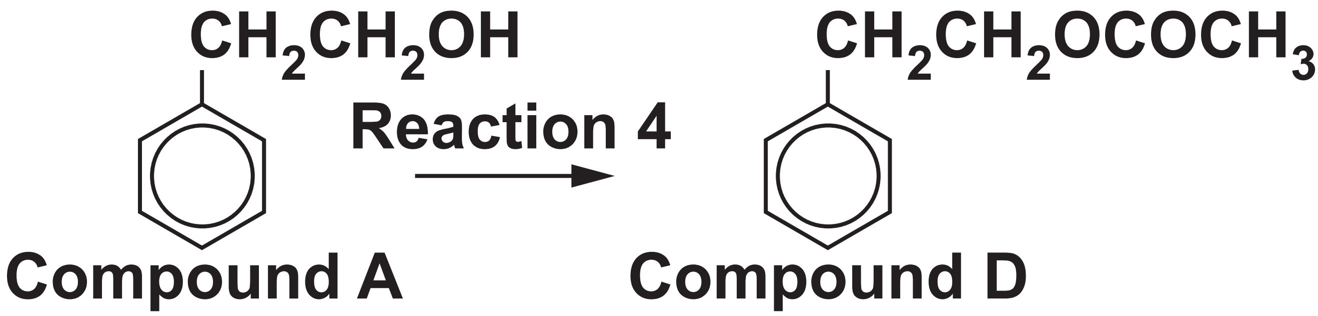
An incomplete equation is shown below.



Complete the balanced equation for this reaction. [1]

(d)* REACTION 4

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



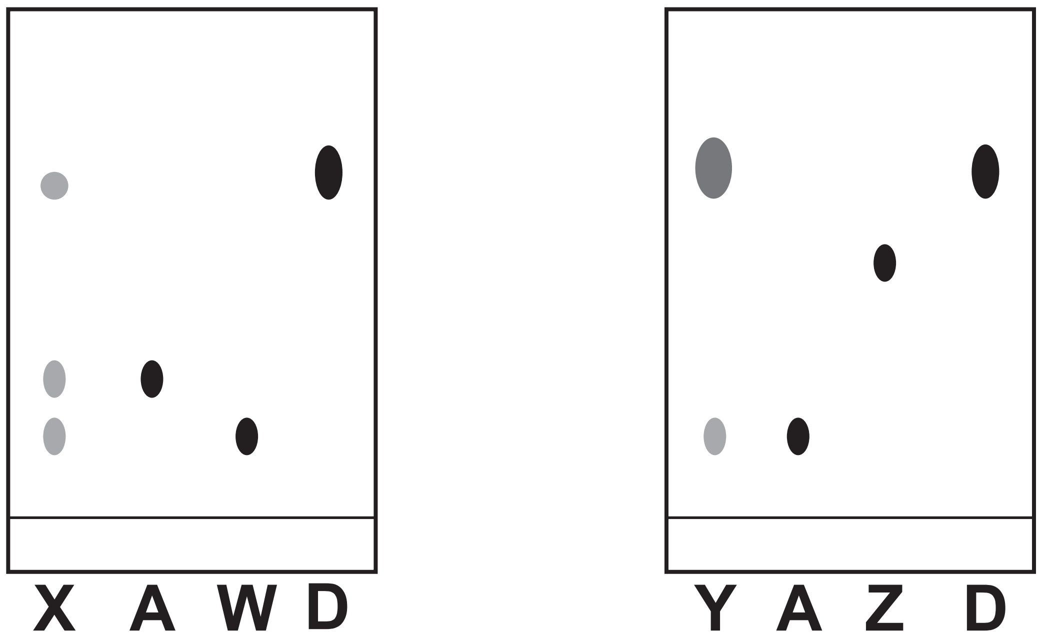
A student attempts to carry out REACTION 4 using two different methods.

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



Using ethanoic acid | Using ethanoic anhydride

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

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.

[6]

Additional answer space if required.

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]

(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.

EQUATION 4.1

$$CH_3OH(g) + 1\tfrac{1}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$

$$\Delta_c H_{298} = -676\,\text{kJ mol}^{-1}$$

Some average bond enthalpy data are given in Table 4.1.

Table 4.1

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

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]

(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 40.

The following measurements are recorded:

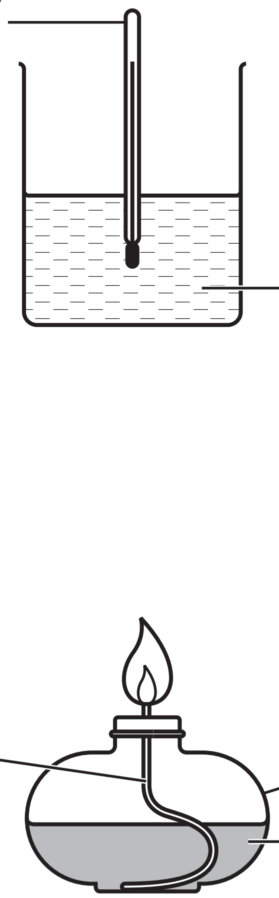
mass of spirit burner and methanol before combustion	12.58 g
mass of spirit burner and methanol after combustion	11.62 g
temperature of water before combustion	17.0 °C
temperature of water after combustion	45.0 °C

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]

(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.

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 pages 40–41.

[6]

Additional answer space if required.

END OF QUESTION PAPER

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).