

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

DEVELOPING FUELS (DF)

SCORE

/531

PERCENTAGE

%

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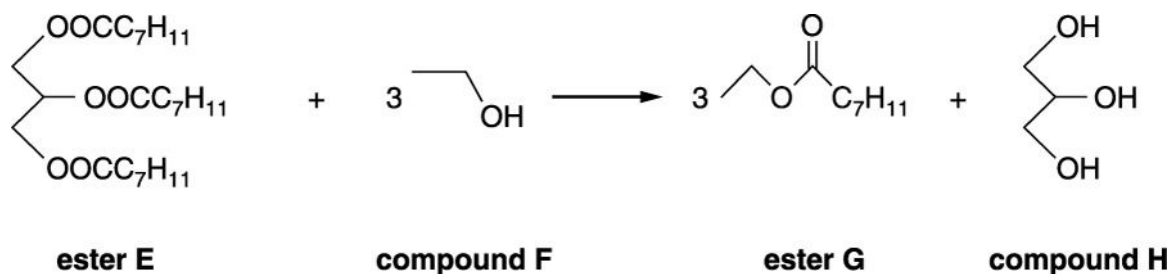
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- 1(a) Trans-esterification reactions are used to make esters from vegetable oils. These esters are suitable for use as biofuels, such as biodiesel.

One trans-esterification reaction is shown below.



- (i) Give the systematic name for compound F.

-----[1]

- (ii) Give the systematic name for compound H.

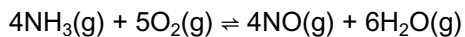
-----[1]

- (b) Ester G is unsaturated.

Give the number of double bonds in the C₇H₁₁ group.

-----[1]

2(a) Ammonia reacts with oxygen to form NO in the presence of a platinum catalyst at 850 °C.



(i) Give the oxidation states of nitrogen in NH₃ and NO.

NH₃ _____ NO _____

[1]

(ii) Give the systematic name of NO.

_____ [1]

(iii) A mixture of 50 cm³ of ammonia and 50 cm³ of oxygen is allowed to reach equilibrium. The total volume is then 105 cm³. All volumes are measured at the same temperature (above 100°C) and pressure.

Calculate the percentage of ammonia that has been converted to NO.

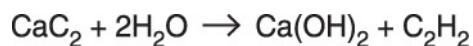
Percentage = _____ % [2]

(iv) At room temperature, a sample of NO immediately turns brown when released into the air.

Explain why this happens.

_____ [2]

- (b) Calcium carbide has been used as a source of ethyne, C_2H_2 , because it reacts with water as shown below.



- (i) Suggest the **full** structural formula for ethyne, showing a bond angle in the molecule with its value.

[2]

- (ii) Ethyne can be polymerised in the presence of a catalyst to give cycloocta-1,3,5,7-tetraene.

Draw a **skeletal** formula for cycloocta-1,3,5,7-tetraene.

[2]

- (iii) A molecule of cycloocta-1,3,5,7-tetraene does **not** have delocalised electrons.

Suggest the **skeletal** formula of the compound formed when cycloocta-1,3,5,7-tetraene reacts with excess bromine.

[1]

(c) The ethyne produced by the method above is often contaminated with phosphane, PH_3 . Phosphane is produced when calcium phosphide (an impurity in the calcium carbide) reacts with water.

(i) Give the formula of calcium phosphide.

-----[1]

(ii) Draw a 'dot-and-cross' diagram for phosphane, PH_3 .

Show outer shell electrons only.

[1]

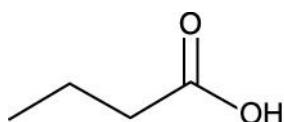
(iii) Unlike ammonia, phosphane, PH_3 , is not very soluble in water.

Explain this difference in solubility.

Answer in terms of intermolecular bonding and the differences between P and N atoms.

-----[4]

- 3 Butanoic acid (often called 'butyric acid') is a foul-smelling liquid that has been used by anti-whaling protesters to throw on board whaling ships.



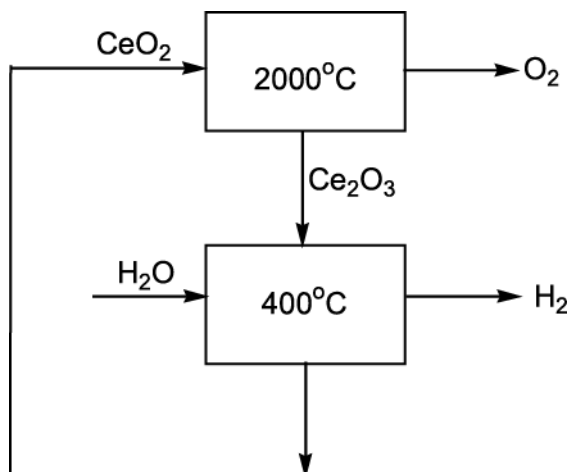
butanoic acid

'Isobutyric acid' is an isomer of butanoic acid.

Give the systematic name of isobutyric acid.

-----[1]

4(a) Ceria, CeO_2 , is used in a thermochemical cycle for splitting water. A simplified diagram of the process is shown below.



(i) Give the systematic name for ceria.

-----[1]

(ii) Give chemical equations for the **two** reactions involved in the cycle.

State symbols are not required.

equation 1: -----

equation 2: -----[2]

(iii) One of the reactions in the cycle is endothermic.

What data for each reactant and product is required to decide which reaction is endothermic?

-----[1]

- (b) Aqueous solutions of $\text{Ce}(\text{SO}_4)_2$ and KMnO_4 can be used as oxidising agents in redox titrations. In both cases reactions are carried out in acidic solutions.

- (i) KMnO_4 should **not** be acidified with hydrochloric acid.

Select and use data from the table below to determine which acid can be used with Ce^{4+} to oxidise Cl^- .

Explain your answer.

Half-reaction	$E^\ominus / \text{V}$
$\text{Ce}^{4+} + \text{e}^- \rightleftharpoons \text{Ce}^{3+}$	+1.28 measured in $1 \text{ mol dm}^{-3} \text{ HCl(aq)}$
$\text{Cl}_2 + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	+1.36
$\text{Ce}^{4+} + \text{e}^- \rightleftharpoons \text{Ce}^{3+}$	+1.44 measured in $1 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4(\text{aq})$
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.51

[3]

- (ii) A student devises an experiment to find out how much cerium is present in an impure sample of ceria

First the student converts 2.5 g of powdered ceria into 100 cm^3 of a solution of $\text{Ce}(\text{SO}_4)_2$ in sulfuric acid. Then 25.0 cm^3 of this $\text{Ce}(\text{SO}_4)_2$ solution is titrated with a standard solution of arsenic(III) in sulfuric acid. In the reaction Ce^{4+} is reduced to Ce^{3+} .

1.00 dm^3 of solution is made up by dissolving 0.250 mol of As_2O_3 in sulfuric acid. The arsenic is present in the solution as AsO_3^{3-} ions. 25.0 cm^3 samples of the $\text{Ce}(\text{SO}_4)_2$ solution required an average titre of 3.00 cm^3 of this AsO_3^{3-} solution.

The half-equation for the oxidation of AsO_3^{3-} ions is given below.



Calculate the percentage purity of the student's ceria sample.

Show **all** your working.

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

percentage purity = _____ % [5]

- (iii) Suggest one improvement to the student's method that will reduce the percentage error in the answer to (ii) without changing the apparatus.

Give a reason for your choice.

----- [1]

- (iv) Calculate the number of oxygen atoms in 2.5 g of **pure** ceria

Show **all** your working.

number of atoms = _____ [2]

- (v) Ceria is also used as a heterogeneous oxidation catalyst for self-cleaning ovens. Ceria is incorporated on the surface of the inside panels of an oven.

Describe how a heterogeneous catalyst works.

----- [4]

5(a) Ethanol is sometimes used as a biofuel to replace petrol in car engines. However it has several disadvantages.

Give **two** disadvantages of ethanol as a replacement fuel for petrol.

[2]

(b) A mixture of 4.0 g of ethanol vapour and 25 dm³ of air is ignited.

Determine whether the ethanol will be completely burned.

All volumes are measured at room temperature and pressure.

Assume air contains 21% oxygen.

[3]

6 Aluminium is produced by the electrolysis of molten aluminium oxide, Al_2O_3 .

(i) Write the equation for the reaction at the cathode when molten aluminium oxide is electrolysed.

[1]

(ii) The oxygen produced at the anode reacts with the carbon electrodes.

Calculate the maximum volume of carbon dioxide (measured at RTP) that would be produced during the electrolysis of 100 kg of Al_2O_3 .

Show **all** your working.

volume = _____ dm^3 [3]

7 Which statement describes an exothermic reaction?

- A More energy is taken in breaking bonds than is released making bonds.
- B More energy is taken in making bonds than breaking bonds.
- C More energy is released making bonds than is taken in breaking bonds.
- D More energy is released making bonds than breaking bonds.

Your answer

[1]

8 How many structural isomers of C_5H_{10} show *E/Z* isomerism?

- A 1
- B 2
- C 3
- D 4

Your answer

[1]

9 Hydrogen is burned as a fuel in a car engine.

Which row shows the possible products?

	Oxides of nitrogen	Sulfur dioxide	Water vapour
A	✓	✓	✓
B			✓
C		✓	✓
D	✓		✓

Your answer

[1]

10 Ethene is reacted with an aqueous solution containing bromine and sodium chloride.

Which row shows possible products of this reaction?

A	$\text{CH}_2\text{BrCH}_2\text{Br}$	$\text{CH}_2\text{C}/\text{CH}_2\text{C}/$	$\text{CH}_2\text{BrCH}_2\text{OH}$
B	$\text{CH}_2\text{OHCH}_2\text{Br}$	$\text{CH}_2\text{C}/\text{CH}_2\text{Br}$	$\text{CH}_2\text{BrCH}_2\text{Br}$
C	$\text{CH}_2\text{BrCH}_2\text{C}/$	$\text{CH}_2\text{BrCH}_2\text{OH}$	$\text{CH}_2\text{C}/\text{CH}_2\text{OH}$
D	$\text{CH}_2\text{C}/\text{CH}_2\text{C}/$	$\text{CH}_2\text{BrCH}_2\text{Br}$	$\text{CH}_2\text{C}/\text{CH}_2\text{OH}$

Your answer

[1]

11 Which one of these reactions represents the standard enthalpy change of combustion of butane?

- A $\text{C}_4\text{H}_{10}(\text{g}) + 4\text{O}_2(\text{g}) \rightarrow 4\text{CO}(\text{g}) + 4\text{H}_2\text{O}(\text{l})$
B $\text{C}_4\text{H}_{10}(\text{g}) + 6\frac{1}{2}\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{l})$
C $2\text{C}_4\text{H}_{10}(\text{g}) + 13\text{O}_2(\text{g}) \rightarrow 8\text{CO}_2(\text{g}) + 10\text{H}_2\text{O}(\text{l})$
D $\text{C}_4\text{H}_{10}(\text{g}) + 6\frac{1}{2}\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{g})$

Your answer

[1]

12 Which of the following is / are correct about the catalytic action of transition metals and their compounds?

- Statement 1:** They can act as homogeneous catalysts using their variable oxidation states.
Statement 2: They provide an alternative route of lower activation enthalpy.
Statement 3: They do not take part in the reaction.

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

Your answer

[1]

13(a) In enclosed spaces, such as submarines, it is necessary to remove carbon dioxide from the air. Solid calcium hydroxide, $\text{Ca}(\text{OH})_2$, can be used to remove the carbon dioxide.

Suggest the equation for the reaction that takes place.

Include state symbols.

[1]

(b) Air is 0.040% CO_2 by volume.

What mass of calcium hydroxide is needed to absorb the carbon dioxide from 5.0 m^3 of air at 23°C and 95 kPa?

mass of calcium hydroxide = _____ g [3]

14(a) Ammonium nitrate (NH_4NO_3) can be used in cold packs to treat sports injuries.

Ammonium nitrate dissolves in water in an endothermic process.

Some students carry out an experiment to measure the enthalpy change of solution of ammonium nitrate. The students have some powdered ammonium nitrate and normal laboratory equipment.

- (i) Describe what the students do and the measurements they make so that they can calculate the enthalpy change of solution.

You do not need to include details of how to carry out the calculation.

[3]

- (ii) The students use a thermometer that can be read to $\pm 0.5^\circ\text{C}$.

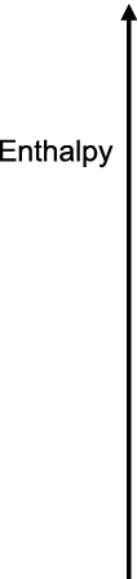
Give the percentage uncertainty in measuring a temperature change of 17°C .

percentage uncertainty = ----- % **[1]**

(b) Draw an enthalpy level diagram for dissolving ammonium nitrate.

Label the enthalpy levels and use the data below to calculate $\Delta_{\text{hydration}}H$ for the NO_3^- ion.

$\Delta_{\text{hydration}}H \text{ NH}_4^+$	-307 kJ mol^{-1}
$\Delta_{\text{LE}}H \text{ NH}_4\text{NO}_3$	-645 kJ mol^{-1}
$\Delta_{\text{solution}}H \text{ NH}_4\text{NO}_3$	$+25.0 \text{ kJ mol}^{-1}$

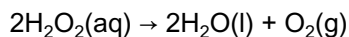


$$\Delta_{\text{hydration}}H \text{ for NO}_3^- = \text{-----} \text{ kJ mol}^{-1} \text{ [4]}$$

(c) State and explain how the lattice enthalpy of ammonium chloride would compare with the lattice enthalpy of ammonium nitrate.

----- [3]

15 Catalase is an enzyme which catalyses the breakdown of toxic hydrogen peroxide in the body.



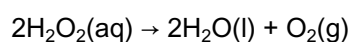
Some students investigate the decomposition of hydrogen peroxide in the presence of catalase. They measure the volume of oxygen produced at known times as the reaction proceeds.

(i) Describe how they could use these results to find the rate of reaction at a certain time.

----- [2]

(ii) The students are given '20 volume' hydrogen peroxide.

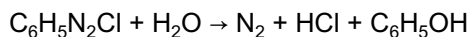
This means 1.0 cm^3 of the solution produces 20 cm^3 oxygen at room temperature and pressure when it breaks down.



Calculate the concentration of '20 volume' hydrogen peroxide (in mol dm^{-3}).

concentration = _____ mol dm^{-3} [2]

16 A compound with the formula $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$ decomposes in dilute aqueous solution.



Some chemists investigate the rate of this decomposition. They collect the nitrogen gas in a graduated syringe at different initial concentrations of the $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$ solution. They time how long it takes for 50 cm^3 of nitrogen to be collected. The volume of solution used in each experiment is 100 cm^3 .

(i) Two of the chemists' results are given in the table below.

Initial concentration / mol dm^{-3}	0.020	0.040
Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$	8.70×10^{-7}	1.74×10^{-6}

Use these data to calculate the rate constant for the reaction. Include units in your answer.

Assume that the reaction is zero order with respect to water.

Show **all** your working.

rate = _____ units _____ [3]

(ii) The chemists could have measured the time to produce a much larger volume of nitrogen.

Suggest why it would have been inappropriate to measure the time to collect larger volumes of gas, particularly in the experiments with lower concentrations of $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$.

----- [2]

(iii) The progress of the reaction can also be followed with a pH meter.

What is the pH of the solution once 50 cm^3 of nitrogen have been collected?

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

- (iv) Besides gas collection and measuring pH, suggest **one** other method with which the chemists could measure the progress of the reaction.

----- [1]

- (v) The chemists carried out the reaction at several temperatures and obtained the results in the left-hand two columns of **Table 1.1**.

Table 1.1

Temperature, T/K	rate constant, k/s^{-1}	$1/T/K^{-1}$	$\ln k$
278	1.5×10^{-6}	3.60×10^{-3}	-13.41
298	4.1×10^{-5}		-10.10
308	2.0×10^{-4}	3.25×10^{-3}	
323	1.4×10^{-3}	3.10×10^{-3}	-6.57

Calculate the missing values in **Table 1.1** and plot a graph of $\ln k$ against $1/T$ on the graph paper below.

Use your graph to calculate a value for the activation enthalpy of the reaction.



activation enthalpy = ... kJ mol^{-1}

17(a) Concrete contains calcium hydroxide, $\text{Ca}(\text{OH})_2$, and is alkaline when damp. The steel reinforcements in concrete do **not** corrode in an alkaline environment. When the calcium hydroxide reacts with carbon dioxide from the air to form calcium carbonate, 'carbonatation' occurs and the pH falls. The increased acidity can cause the steel to corrode.

(i) Write the equation for carbonatation.

[1]

(ii) Calculate the mass of calcium carbonate that is formed when 15 cm^3 of carbon dioxide (measured at room temperature and pressure) react with excess calcium hydroxide.

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

mass = _____ g [2]

(b) Carbonatation produces calcium carbonate. The carbonate ion is alkaline in aqueous solution.

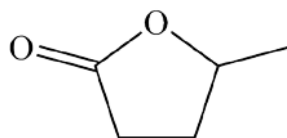
(i) Write an equation for the reaction that occurs between the carbonate ion and water.

[1]

(ii) Explain how the carbonatation reaction in (a)(i) accounts for the fall in pH.

[2]

18 The compound 'GMV' is a potential 'green fuel' as it can be made from glucose and can be blended with petrol.



GMV

- (i) Write an equation, using molecular formulae, for the complete combustion of GMV to carbon dioxide and water.

[2]

- (ii) Calculate the ratio of the masses of carbon dioxide produced by burning equal masses of GMV and hexane.

Show **all** your working.

ratio = _____ [3]

- (iii) A scientist says that the result in (ii) is an indication of the relative effects on the environment when GMV and hexane are used as vehicle fuels.

Discuss this statement.

----- [2]

- (i) Draw, in the space below, the **skeletal formula** of the structure you would expect to obtain when ambrinol (Fig. 2) reacts with bromine.

[1]

- (ii) How many peaks would you expect in the ^{13}C NMR spectrum of ambrinol?

[1]

- (iii) Give the number of chiral centres in ambrinol.

Explain how you arrived at your answer.

[2]

- (iv) Discuss whether or not you would expect the enantiomers of ambrinol to smell the same.

[2]

- (b) Describe chemical tests, resulting in colour changes, by which you could distinguish between vanillin, guaiacol and benzaldehyde (Fig. 3).

Include a positive reaction for each substance.

[4]

- (c) Explain the significance of the graph (shown in Fig. 3) to Turin's theory.

Give the cause of the peak just above 3000 cm^{-1} .

[3]

- (d) This part of the question explores Turin's use of isotopes to support his theory.

- (i) State the meaning of the term *isotopes*, using the terms *atomic number* and *mass number*.

Give the number of neutrons in an atom of deuterium and an atom of ^{13}C .

meaning: -----

number of neutrons: -----

[2]

- (ii) A sample of carbon dioxide contains 98.89% ^{12}C , the rest being ^{13}C .

Calculate the A_r value for the carbon in the carbon dioxide to **two** decimal places.

$A_r =$ _____ [1]

(iii) Draw the **skeletal formula** of 'acetophenone'.

State the difference between this molecule and 'acetophenone-d₈' (**page 5**).

----- [2]

(iv) * Discuss examples from the article that support Turin's theory and **not** the 'lock and key' theory.

----- [6]

20(a) PVC and nylon make two types of film that are used to wrap food.

PVC is used as a cling-wrap. It is made by polymerising 'vinyl chloride', $\text{CH}_2 = \text{CHCl}$.

- (i) Give the systematic name for 'vinyl chloride'.

-----[1]

- (ii) Give the **skeletal** formulae of **two** possible products that vinyl chloride forms when reacted with hydrogen bromide.

Write your formulae in the boxes below.

--	--

[1]

- (iii) A student has a sample of gaseous vinyl chloride.

Describe a chemical test that would indicate the presence of vinyl chloride.

-----[1]

(b)

(i) Draw the **full** structural formula of the repeating unit of PVC.

[1]

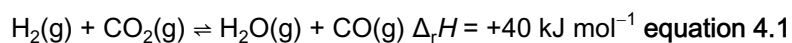
(ii) The use of PVC as a cling-wrap depends on its intermolecular bonds.

Name the strongest type of intermolecular bond between PVC chains.

-----[1]

21 Research is being conducted into chemical reactions that can be used on other planets such as Mars.

One reaction being studied is shown below.



The atmosphere of Mars consists mainly of carbon dioxide.

Hydrogen is initially brought from Earth.

A catalyst of iron and chromium is used.

State why the catalyst is used and give its effect on K_c .

----- [2]

22 Some students investigate the volume the volume of carbon dioxide released when carbonate rocks decompose.

They carry out an experiment in which a known mass of magnesium carbonate is heated and the gas evolved is collected in a 100 cm³ gas syringe. The apparatus is allowed to cool to room temperature and the volume of the gas collected is measured.

(i) What is the maximum mass of magnesium carbonate that could be used in this experiment?

maximum mass = _____ g [1]

(ii) The students repeat the experiment using the same mass of calcium carbonate instead of magnesium carbonate.

Describe and explain how the volume of gas collected will compare to the volume collected when magnesium carbonate was decomposed.

----- [2]

23(a) A student investigates the use of spirit burners as alternative heating sources for laboratories without a gas supply.

A spirit burner containing ethanol is weighed. 100 cm³ of water are measured into a beaker clamped above the spirit burner. The temperature of the water is recorded. The spirit burner wick is lit and allowed to heat the water. The thermometer is used to stir the water. After about 5 minutes the flame of the burner is extinguished, the maximum temperature reached by the water is recorded and the spirit burner is re-weighed.

The student records the following results.

Mass of spirit burner and ethanol before burning / g	20.33
Mass of spirit burner and ethanol after burning / g	18.92
Initial temperature of the water / °C	17.5
Maximum temperature reached by the water / °C	88.0

- (i) The temperatures are measured using a thermometer that has graduation marks at every 1 °C.

Calculate the percentage error associated with the temperature difference in the above results.

Give your answer to **two** significant figures.

percentage error = _____ % [1]

- (ii) Using the student's results, calculate the enthalpy change of combustion of ethanol.

Assume that the density of water is 1.00 g cm⁻³.

Show **all** your working.

enthalpy change of combustion = _____ kJ mol⁻¹ [3]

(b)

- (i) The student repeats the experiment using a spirit burner containing methanol instead of ethanol. The same mass of fuel is burned in both experiments.

Suggest **two** reasons why the total energy transferred from the spirit burner is different in the two experiments.

----- [2]

- (ii) Describe how the student can ensure that the same amount of energy is transferred from the spirit burner in the experiment using methanol as is transferred in the experiment described in (a)(ii).

State the assumption you have made.

----- [2]

- (c) At the end of the experiments the student notices that there is a black deposit on the bottom of the beaker.

Suggest what this might be and why it might have been formed.

----- [2]

24(a) A student carries out an experiment to compare the smells of different esters.

The student follows the procedure given below.

- Prepare some small test-tubes by adding one drop of concentrated sulfuric acid to each.
- Add 10 drops of a carboxylic acid to the sulfuric acid in one test-tube.
- Add 10 drops of an alcohol to the mixture.
- Carefully lower the tube into a beaker of hot water.
- After 1 minute remove the tube and, when cool, pour the mixture into a boiling tube half-full of sodium carbonate solution.
- Smell the product by gently wafting the odour towards your nose with your hand.
- Repeat this procedure with different combinations of carboxylic acid and alcohol.

(i) What is the purpose of adding concentrated sulfuric acid to each tube?

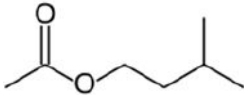
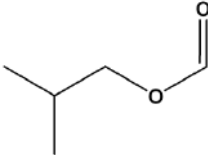
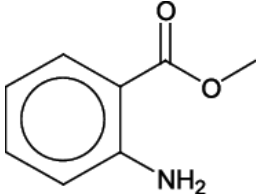
-----[1]

(ii) Why is the mixture poured into the boiling tube of sodium carbonate solution and describe the expected observation.

-----[1]

- (b) The student uses various combinations of alcohol and carboxylic acid. These are shown in the table below with the smell of the ester formed.

Complete the table below by filling in the blanks.

Alcohol	Carboxylic acid	Structure of Ester	Smell
pentan-1-ol	ethanoic acid		pears
3-methylbutan-1-ol			bananas
2-methylpropan-1-ol	Methanoic acid		raspberry
	anthranilic acid		grape

[3]

- (c) The student tries to distil off some pure raspberry ester as its boiling point is lower than either reactant.

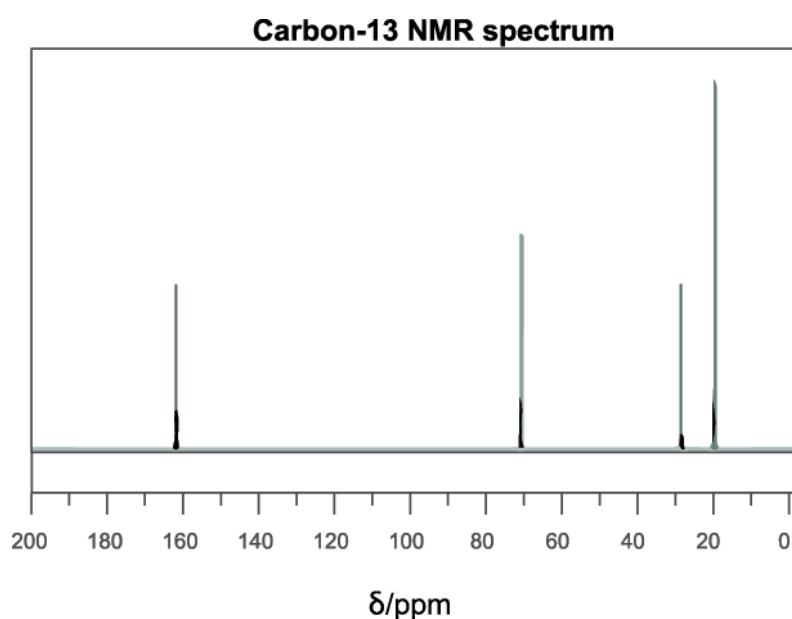
The student repeats the procedure with a larger quantities of reactants. After adding the sodium carbonate the student:

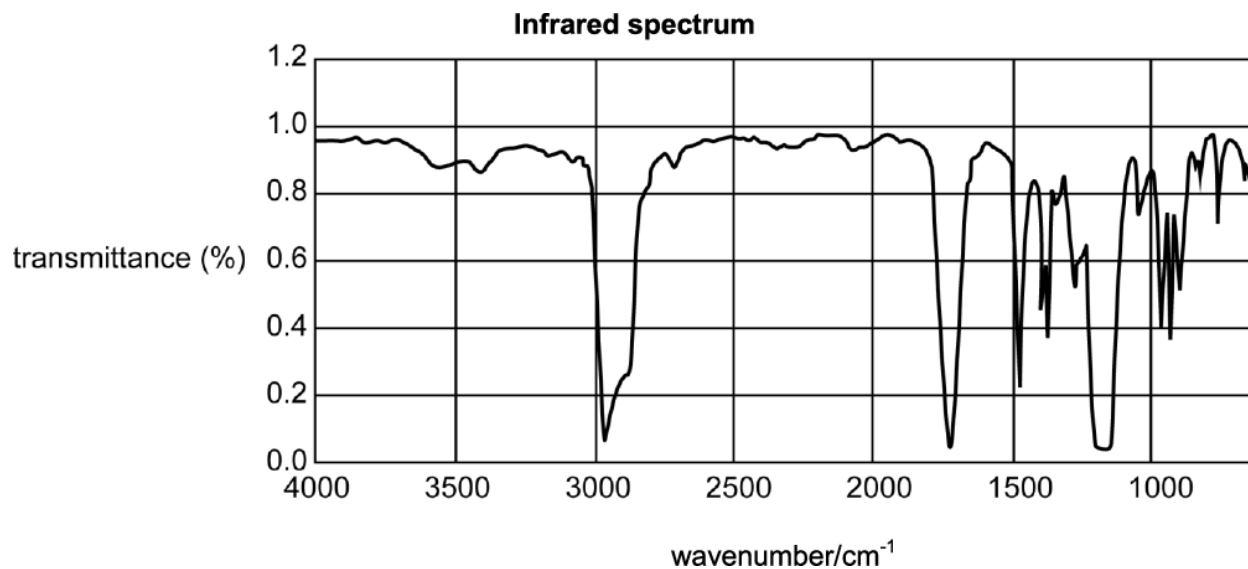
- puts the reaction mixture into a separating funnel and runs off the bottom aqueous layer
- swirls the top ester layer with anhydrous sodium sulfate for 20 minutes
- distils the mixture, collecting the ester.

- (i) State the role of the anhydrous sodium sulfate.

-----[1]

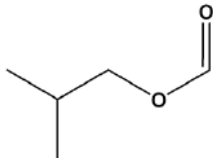
- (ii) * The student gets a local laboratory to run a carbon-13 NMR and an infrared spectrum on the product to confirm whether the preparation had produced the pure raspberry ester.





You may do rough working on this page but it will not be marked.

Some information from the table on page 3 is re-printed here.

Alcohol	Carboxylic Acid	Structure of Ester	Smell
2-methylpropan-1-ol	Methanoic acid		raspberry

Use information from both spectra to explain why they show that the distillation produced the pure raspberry ester.

[6]

25(a) One way of measuring the amount of an alkene in a sample is by titrating it with standard bromine solution. This method enables a value for the bromine number of the sample to be calculated.

The bromine number is the mass (in g) of bromine, Br₂, absorbed by 100 g of a sample.

Calculate the bromine number of a pure sample of hexa-2,4-diene (C₆H₁₀).

Give your answer to the nearest whole number.

bromine number = _____ [2]

(b) A student decides to determine the bromine number of a solution of hexa-2,4-diene in cyclohexane.

The student makes a bromine solution as follows. 100 cm³ of an acidified solution of 0.167 mol dm⁻³ KBr is reacted with 100 cm³ of 0.0500 mol dm⁻³ KBrO₃. The total volume is 200 cm³.

The equation for the reaction is given below.



(i) Show that the KBrO₃ is in excess.

- (ii) 10.0 g of the hexa-2,4-diene solution required 82.0 cm³ of the bromine solution to produce the first permanent yellow tinge to the mixture.

Calculate the bromine number of the hexa-2,4-diene solution.

Give your answer to the nearest whole number.

bromine number = _____ [5]

(c) Hexa-2,4-diene, $\text{CH}_3\text{CH}=\text{CHCH}=\text{CHCH}_3$, can form several *E* / *Z* isomers.

(i) Give **two** reasons why *E*/*Z* isomers exist.

[2]

(ii) Draw structural diagrams to represent all the *E* / *Z* isomers.
Label the appropriate parts of each formula with **E** or **Z**.

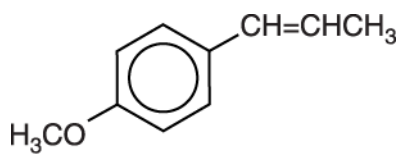
[4]

(d) To ensure that the alkene is fully brominated in the reaction, a mercury catalyst is sometimes used.

Explain how transition metals can act as heterogeneous catalysts.

[3]

26(a) The substance anethole is present in some alcoholic drinks such as 'ouzo'. Alcoholic drinks containing anethole go cloudy when water is added.



anethole

(i) Give the molecular formula of anethole.

-----[1]

(ii) Name the saturated functional group in anethole.

-----[1]

(iii) Naturally occurring anethole is an *E* isomer.

Draw the structure of the *E* isomer.

[1]

(b) The double bond in anethole reacts with bromine.

Draw the **skeletal** formula of the compound produced.

[1]

(c)

(i) Give the mechanism of the reaction of bromine with ethene, showing whole and partial charges, curly arrows, and the final product.

[3]

(ii) Ethene is brominated using **aqueous** bromine.

Suggest why $\text{CH}_2\text{OHCH}_2\text{Br}$ is formed but $\text{CH}_2\text{OHCH}_2\text{OH}$ is **not** formed.

[2]

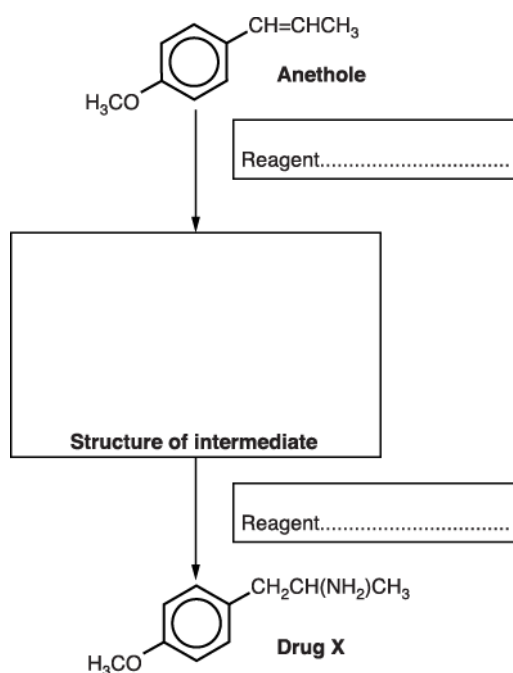
Explain this statement in terms of hydrogen bonding, indicating how these bonds are formed.

[5]

(e) Anethole can be made into drug X.

(i) Complete the flowchart for this synthesis.

Write your answers in the boxes.



[3]

(ii) Drug X is reacted with HCl(aq) .

Draw the structure of the organic product.

[1]

(iii) Drug X has a chiral centre but anethole does not.

Explain this statement.

[3]

(iv) Draw diagrams to show the enantiomers of drug X.

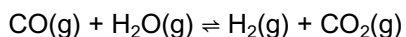


[2]

(v) Explain how infrared spectroscopy could be used to show that all the anethole has been converted into drug X.

[2]

27(a) A reaction that is much used in industry is shown in **Equation 3.1**.



Equation 3.1

The reaction is first carried out at high temperature (around 800 K) using one set of catalysts. Then the gases are cooled to around 500 K and passed over other catalysts.

For the reaction in **equation 3.1**, K_c values are as shown in the table.

Temperature/K	K_c
500	58
800	5

- (i) Is it correct to quote K_c without units for this reaction?

Justify your answer.

----- [1]

- (ii) Use the data to state whether the forward reaction in **equation 3.1** is endothermic or exothermic.

Explain your reasoning.

----- [1]

- (iii) Suggest why the reaction is carried out at high temperature and then at low temperature.

----- [2]

- (b) The conditions are designed to leave only a small concentration of CO in the mixture.

An initial mixture of CO and excess $\text{H}_2\text{O(g)}$ has a CO concentration of $1.5 \times 10^{-3} \text{ mol dm}^{-3}$.

At equilibrium at 500 K, the concentration of CO is $4 \times 10^{-5} \text{ mol dm}^{-3}$.

The equilibrium concentration of hydrogen can be taken to be $1.5 \times 10^{-3} \text{ mol dm}^{-3}$.

- (i) Explain why the equilibrium concentration of hydrogen can be taken to be $1.5 \times 10^{-3} \text{ mol dm}^{-3}$.

----- [2]

- (ii) Calculate the concentration of $\text{H}_2\text{O(g)}$ in the equilibrium mixture at 500 K.

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

$[\text{H}_2\text{O(g)}] = \text{-----} \text{ mol dm}^{-3}$ [3]

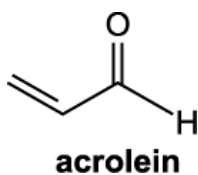
- (iii) Calculate the pressure (in atmospheres) that gives a gas a concentration of $1.5 \times 10^{-3} \text{ mol dm}^{-3}$ at 'room temperature'.

The volume of one mole of a gas at room temperature and 1 atmosphere pressure is 24 dm^3 .

pressure = ... atm [1]

- 28 The smell of burning fat is caused mainly by the presence of 'acrolein'. This is formed by the decomposition of propane-1,2,3-triol from the fat.

Acrolein is a colourless liquid that has many uses in organic chemistry.



Acrolein also occurs in cigarette smoke and is the main carcinogenic agent.

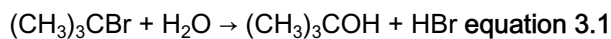
How could a sample of cigarette smoke be tested for the presence of unsaturated compounds? Indicate the positive result of the test.

----- [1]

- 29 't-butyl bromide', $(\text{CH}_3)_3\text{CBr}$, is used in industry to make other organic chemicals such as 't-butyl alcohol', $(\text{CH}_3)_3\text{COH}$.

Some students carry out an experiment to follow the hydrolysis of $(\text{CH}_3)_3\text{CBr}$ with water.

Since the haloalkane is not soluble in water, they use a mixture of propanone and water as a solvent.



Give the systematic names of t-butyl bromide and t-butyl alcohol.

t-butyl bromide _____

t-butyl alcohol _____

[2]

30(a) Sodium chloride is used to melt ice on roads each winter.

(i) Some data for the dissolving of sodium chloride are given below.

	$\Delta H^\circ / \text{kJ mol}^{-1}$
lattice enthalpy of NaCl	-780
enthalpy change of solution of NaCl	+4
enthalpy change of hydration of Na^+	-406

Draw an enthalpy level diagram that connects these values and the enthalpy change of hydration of the chloride ion.

Label the energy levels.

Use the data to calculate the enthalpy change of hydration of the chloride ion.

$$\Delta_{\text{hyd}} H^\circ \text{Cl}^- = \text{-----} \text{ kJ mol}^{-1} \text{ [4]}$$

(ii) Draw a diagram of a hydrated sodium ion in solution.

Show full and partial charges.

(iii) A student says:

- there are ionic bonds in the lattice
- ionic bonds are formed between the water and the ions in solution
- the energy required to break bonds in the lattice is very similar to the energy given out when bonds are made.

Comment on these statements.

[3]

(b) 10.0 g of sodium chloride are dissolved in 200 cm³ of water.

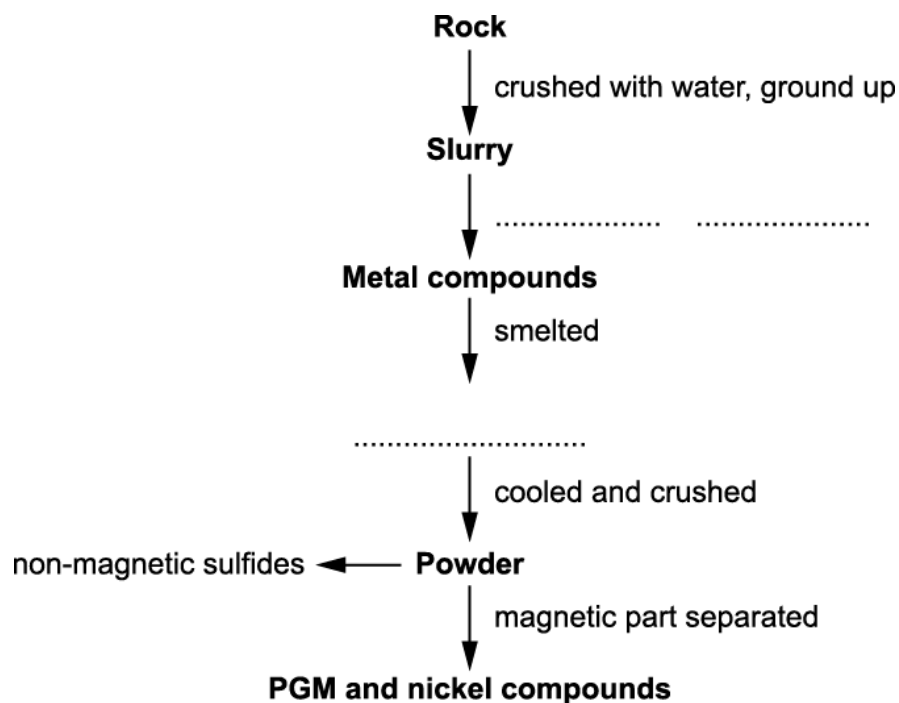
Calculate the temperature change that would occur. Give the sign.

(Take the mass of solution as 210 g and its specific heat capacity to be the same as that of water.)

temperature change = _____ °C [2]

31(a) This question is based on the article *The Platinum Group Metals* which is included as an insert to this paper.

- (i) Write words on the dotted lines to complete the flowchart below to summarise the extraction of PGM from rocks.



[1]

- (ii) Suggest an equation for the reaction of one of the 'non-magnetic sulfides' with sulfuric acid to form a sulfate.

[1]

- (iii) How is the metal obtained from the solution of its sulfate?

[1]

(b)

- (i) Suggest **two** reasons why PGM are used in catalytic converters rather than other equally effective catalysts.

----- [1]

- (ii) Write the equation for a reaction in which both CO and NO are removed from exhaust gases in a catalytic converter.

[1]

- (c) Complete the electron configuration of Rh^{3+} , by comparison with Co^{3+} .

[Kr] ----- [1]

(d)

- (i) $[\text{Ru}_2\text{OCl}_{10}]^{4-}$ has an oxygen atom connecting two Ru atoms.

Draw a three-dimensional diagram to suggest the shape of this ion. Give the co-ordination number of Ru in your structure.

co-ordination number ----- [2]

- (ii) Suggest a **name** for the shape of $[\text{AuCl}_4]^-$.

----- [1]

- (e) Give the formula of a 'bulky organic monocation' from the article and explain why three such species are needed by $[\text{MC}_6]^{3-}$.

----- [2]

(f) Estimate how much faster $[\text{Ag}(\text{H}_2\text{O})_2]^+$ exchanges chloride ions compared with $[\text{Ru}(\text{H}_2\text{O})_6]^{3+}$.

----- [1]

(g) Give the equation for a ligand exchange reaction of copper involving ammonia. Give the starting and finishing colours involved.

[2]

(h) A student says that silver(I) salts are colourless because the d subshells are not split by the ligands.

Discuss this statement. (Ag has the same outer electron configuration as Cu.)

----- [3]

- [6]

They want to see if this is linked to the strength of the intermolecular bonding in the liquids.

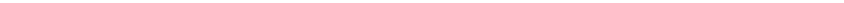
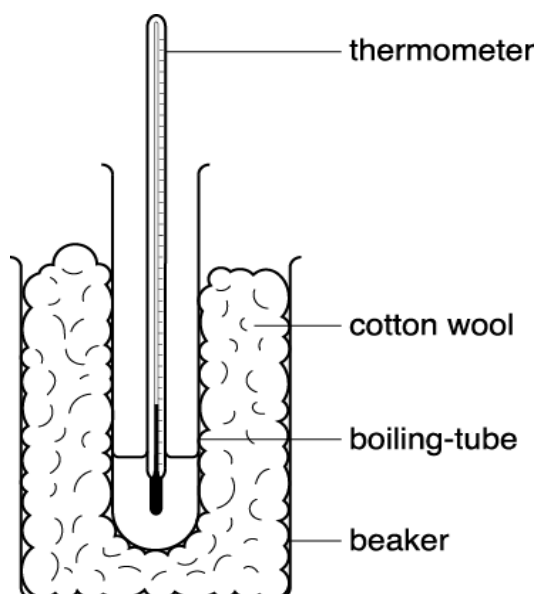
Water	Ethanol	Propanone	Pentane	2-Methylbutane
H ₂ O	C ₂ H ₅ OH	(CH ₃) ₂ CO	C ₅ H ₁₂	CH ₃ CH(CH ₃)CH ₂ CH ₃
Drop in temperature after two minutes				
least  greatest				

Table 3.1

[6]

- (b) The students go on to investigate whether mixing pairs of the liquids results in a temperature change. They used the following apparatus and the results for two pairs of the liquids are shown in **Table 3.2**.



Liquid A	Liquid B	Starting temperature, Liquid A / °C	Starting temperature, Liquid B / °C	Finishing temperature on mixing / °C	Temperature change, ΔT / °C
Ethanol	cyclohexane	23.0	23.0	19.5	3.5
pentane	2-methylbutane	23.0	23.0	23.0	0.0

Table 3.2

- (i) Explain the purpose of the cotton wool.

 ----- [1]

- (ii) When the pairs of liquid A and liquid B are mixed, there are three possible intermolecular bonds between the molecules in the mixture.

These are A-A, B-B and A-B intermolecular bonds.

Explain the temperature change in the ethanol/cyclohexane mixture shown in **Table 3.2**, in terms of the intermolecular bonds A-A, B-B, and A-B.

----- [2]

- (iii) Using ideas of bond breaking and making, suggest why there is no temperature change in the pentane/2-methylbutane mixture.

----- [1]

- (c) A student reads that molecules of trichloromethane, CHCl_3 , and methyl ethanoate, $\text{CH}_3\text{COOCH}_3$, do not form hydrogen bonds with themselves, but when mixed, do so with each other. See Fig 3.1 below.

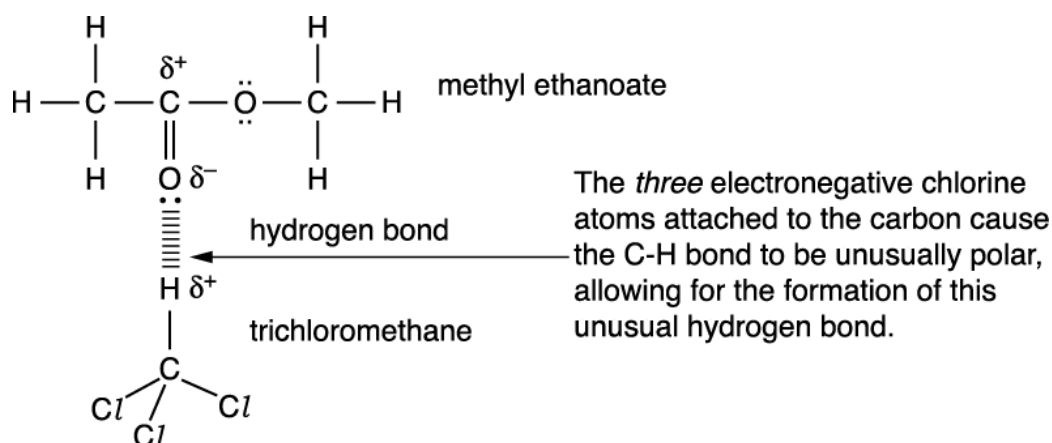


Fig. 3.1

The student tries to measure the strength of the hydrogen bond between molecules of the liquids. They are given the following data.

Liquid	Density / g cm^{-3}	Specific heat capacity / $\text{J g}^{-1} \text{K}^{-1}$
Trichloromethane	1.48	0.96
methyl ethanoate	0.93	2.10

Table 3.3

- (i) Using the same apparatus as in the previous question part, the student mixes equimolar quantities of the two liquids and measures the temperature change.

Calculate the volumes of the two liquids you need to mix in order to give a solution that contains 0.15 moles of each liquid.

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

volume of trichloromethane = _____ cm^3

volume of methyl ethanoate = _____ cm^3

[3]

- (ii) Suggest a piece of apparatus that would be most suitable for measuring out your calculated volumes.

----- [1]

- (iii) The student measures a temperature rise of $11.0\text{ }^{\circ}\text{C}$ when the calculated volumes are mixed.

Calculate the heat energy transferred to each liquid and hence the strength, in kJ mol^{-1} , of the hydrogen bond between molecules of the liquids.

Liquid	Density / g cm^{-3}	Specific heat capacity / $\text{J g}^{-1} \text{K}^{-1}$
trichloromethane	1.48	0.96
methyl ethanoate	0.93	2.10

strength of hydrogen bond = _____ kJ mol^{-1} [3]

33(a) This question refers to the *Practical Insert* that is provided as an insert to this paper.

- (i) Suggest and explain a mistake in the student's procedure which may have led to the titre values in the first set of results showing an increase.

----- [2]

- (ii) Choose suitable values from the student's second set of titration results to calculate the concentration of the original sulfamic acid solution.

Give your answer to **two** significant figures.

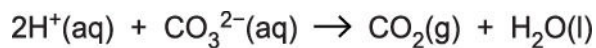
concentration = _____ mol dm⁻³ [4]

- (iii) The concentration of sulfamic acid solution given on the bottle of limescale remover is slightly lower than the student's value.

Suggest how the sodium hydroxide solution may have caused this difference.

----- [2]

(b) In **Part B** of the experiment, sulfamic acid reacts with excess carbonate as in the equation below.



(i) Use the data from the results section in **Part B** of the insert to calculate the M_r of the sulfamic acid.

You may assume that all the acid reacts and that the reaction takes place at room temperature and pressure.

$M_r =$ _____ [4]

(ii) The measuring cylinder used to collect the carbon dioxide has an uncertainty of $\pm 1 \text{ cm}^3$. Calculate the percentage uncertainty in the volume of CO_2 measured.

percentage uncertainty = _____ % [1]

(iii) Suggest one procedural error that could result in the student's value being higher than the accurate value of 97.1.

_____ [1]

34 How many σ and π bonds are there in a molecule of propanone?

	σ bonds	π bonds
A	8	1
B	8	2
C	9	2
D	9	1

Your answer

[1]

35(a) Ozone is a pollutant in the troposphere but beneficial in the stratosphere.

Ozone in the troposphere is formed from gases in vehicle exhaust emissions reacting with hydroxyl radicals.

(i) Oxides of nitrogen are present in vehicle exhausts.

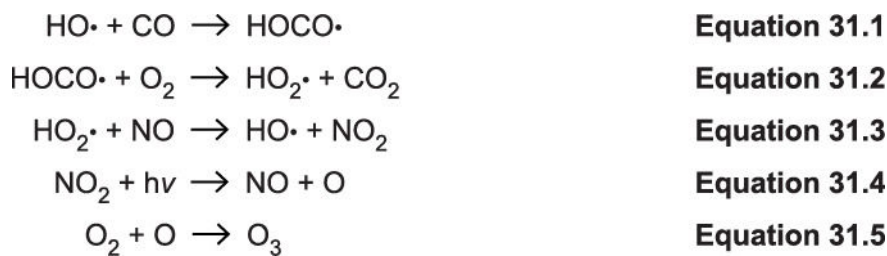
Explain why they are present.

----- [1]

(ii) Draw a 'dot-and-cross' diagram of an OH radical and explain why OH is a radical.

Explanation----- [2]

(b) Ozone is produced in the series of reactions shown below.



(i) Many of these reactions may be classified as propagation reactions.

Explain the meaning of the term propagation reaction.

----- [1]

(ii) **Equations 31.1–31.5** can all be combined to give one overall equation.

Give the overall equation.

[1]

(c) Many of the species in **equations 31.1–31.5** can be described as homogeneous catalysts.

State the meaning of the terms homogeneous and catalyst.

Homogeneous-----

Catalyst-----
----- [2]

36(a) Esters have many uses in organic chemistry, including in polymers.

Some students want to determine the equilibrium constant for the esterification reaction in **equation 33.1** in acidic conditions.



They set up their experiment with known masses of ethanol, ethanoic acid and concentrated sulfuric acid catalyst.

They place the reactants in a stoppered bottle and wait a week for equilibrium to be established.

Suggest how the students could find the amount of ethanoic acid in the bottle at equilibrium.

----- [2]

- (b) By using the method from (a), the students find that the amount of ethanoic acid present at equilibrium is 0.123 mol.

They produce the table below.

Substance	Mass present at the start / g	Amount present at the start / mol	Amount present at equilibrium / mol
ethanol	15.8		
ethanoic acid	21.0		0.123
ethyl ethanoate	0	0	
water	0	0	

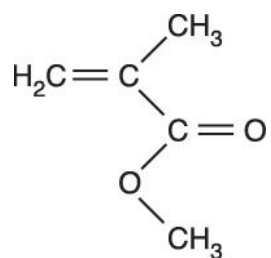
Carry out appropriate calculations to fill in the blanks in the table.

Use figures from the table to work out a value for the equilibrium constant, K_c , of the reaction in equation 33.1.

$K_c =$ _____ [4]

- (c) Another ester is the monomer for the polymer polymethyl methacrylate or PMMA. PMMA is often used to make lightweight transparent materials as a replacement for glass.

The monomer has the structure shown below.



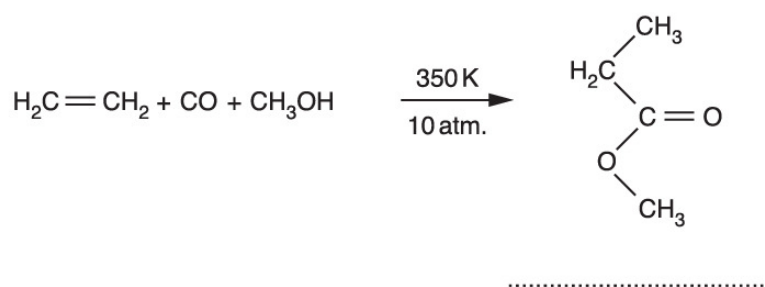
Draw the structural formula for **one** repeating unit of the polymer.

[1]

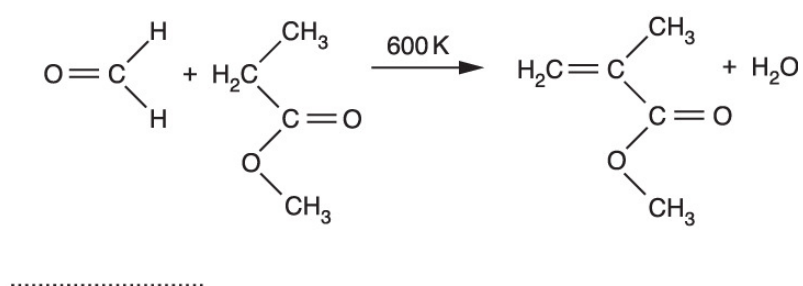
(d) The monomer can be made in the following reaction sequence.

Give the systematic names of two of the compounds on the dotted lines below their structures.

Stage 1:



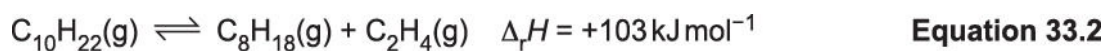
Stage 2:



[1]

- (e) The ethene used in **stage 1** comes from thermal cracking of long chain alkanes from crude oil in the presence of steam.

One such reaction is shown below.



Substance	Entropy / $\text{J mol}^{-1} \text{K}^{-1}$
$\text{C}_{10}\text{H}_{22}$	+425.9
C_8H_{18}	+361.1
C_2H_4	+219.5

Use the entropy values given to find the minimum temperature needed for the forward reaction to be feasible.
Give your answer to an **appropriate** number of significant figures.

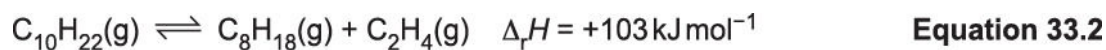
minimum temperature = _____ K [3]

- (f) Give the effects that the following changes have on the value of K_c for the reaction in **equation 33.2**.

Change	Increased temperature	Increased pressure	Use of a catalyst
Effect on K_c			

[2]

(g) The yield of the reaction in **equation 33.2** is typically 50%.



Calculate the volume (in dm^3) of ethene produced when 25.0 kg of decane are cracked at 900 K and a pressure of 150 kPa.

volume of ethene = _____ dm^3 [3]

(h) An alternative method of obtaining ethene is catalytic cracking using zeolite catalysts.

Explain the advantage to the environment of this method over steam cracking.

----- [1]

37 15.0 g of calcium chloride are dissolved in water.

Use the information below to find the temperature rise of the solution.

You may assume the mass of the solution is 100 g and its specific heat capacity is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$.

	Enthalpy change/ kJ mol^{-1}
$\Delta_{\text{LE}} H \text{ CaCl}_2$	-2258
$\Delta_{\text{hyd}} H \text{ Cl}^-$	-364
$\Delta_{\text{hyd}} H \text{ Ca}^{2+}$	-1650

temperature rise = _____ $^{\circ}\text{C}$ [3]

38 Polymer X is $-\text{CH}(\text{OH})-\text{CH}(\text{COOCH}_3)-\text{CH}(\text{OH})-\text{CH}(\text{COOCH}_3)-$

What is the monomer of polymer X?

- A $\text{CH}(\text{OH})-\text{CH}(\text{COOH})$
- B $\text{C}(\text{OH})=\text{C}(\text{COOCH}_3)-\text{C}(\text{OH})=\text{C}(\text{COOCH}_3)$
- C $\text{CH}(\text{OH})=\text{CH}(\text{COOCH}_3)$
- D $\text{CH}_2-\text{CH}(\text{COOH})$

Your answer

[1]

39 An engine runs on ethanol.

What would **not** be found in the exhaust from this engine?

A SO_2

B CO_2

C NO

D CO

Your answer

[1]

40 Why are many bond enthalpies described as *averages*?

A They are averaged out over many molecules with different kinetic energies.

B They are averaged out over different compounds containing the same bond.

C They are the averages of the bond in liquid and gaseous compounds.

D They are average values from different data books.

Your answer

[1]

41 What is the correct name of an isomer of pent-1-ene?

A cyclopentene

B pent-4-ene

C 1-methylbut-2-ene

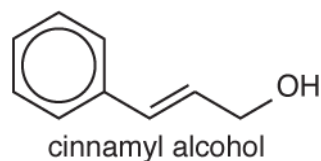
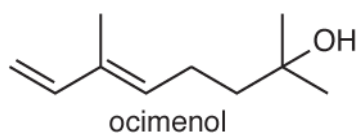
D 3-methylbut-1-ene

Your answer

[1]

42(a) A perfume laboratory is investigating the molecules responsible for the smell of some common flowers.

Their investigations suggest that the following two liquid compounds are important in the characteristic smell of hyacinth flowers.

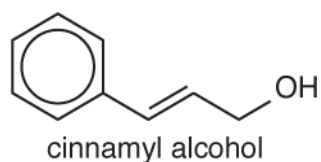
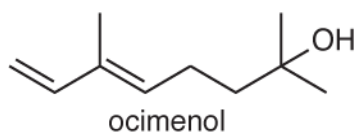


Ocimenol and cinnamyl alcohol are both unsaturated molecules.

Explain how you could use a solution of bromine water to show which of the molecules has the greater degree of unsaturation.

[4]

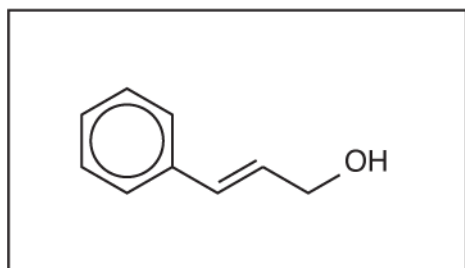
(b) Both ocimenol and cinnamyl alcohol molecules show stereoisomerism.



- Name the **type** of stereoisomerism shown by these molecules.
- Explain how this isomerism arises.
- The structure of one of the stereoisomers of cinnamyl alcohol is shown in the left hand box below; draw the structure of the other isomer in the right hand box.

Type of stereoisomerism -----

Explanation

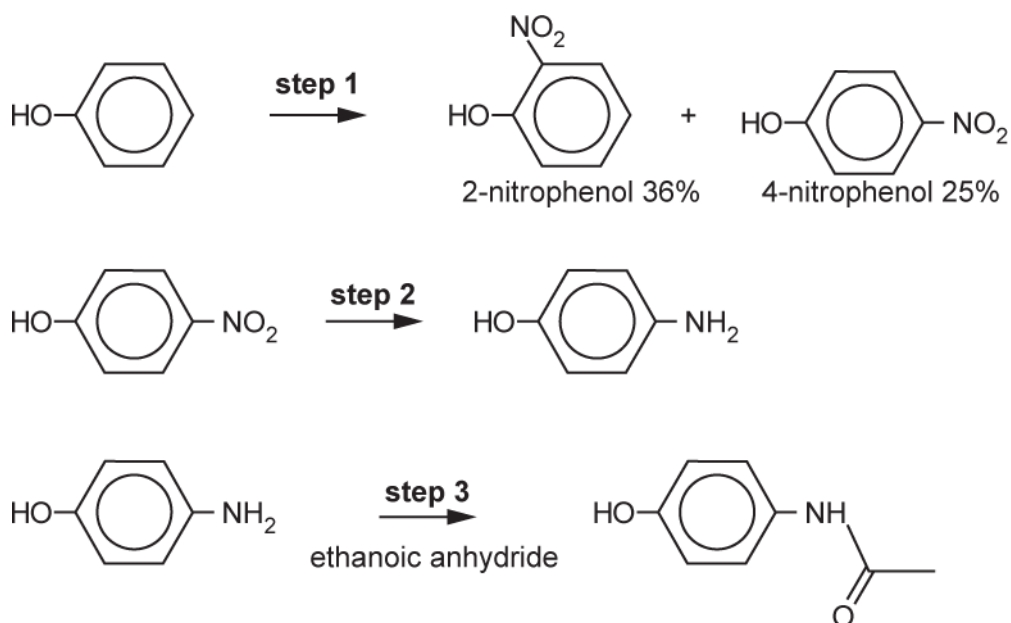


[3]

- 43 Calculate the volume of carbon dioxide (in dm^3) at 298 K and 95.0 kPa that could be captured by reacting it with 1.00 kg of MgO .

volume = ----- dm^3 [3]

44(a) Some students set out to make paracetamol by the method shown below.



- (i) The students want to make 5.0 g of 4-nitrophenol in **step 1**.
Calculate the mass of phenol they should start with.

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

mass of phenol = ----- g [2]

- (ii) The two nitrophenols formed can be separated since they have different boiling points. 2-nitrophenol has a lower boiling point than 4-nitrophenol. This is because internal hydrogen bonding can occur in 2-nitrophenol.

Draw the structure of 2-nitrophenol with the -OH and -NO_2 groups shown as full structural formulae; show where the internal hydrogen bond would form.

[2]

(iii) Name the **type** of reaction that occurs in **step 2** and name the functional group that has been formed.

Type of reaction

Functional group formed

[1]

(iv) Write an equation for the reaction in **step 3**.

Use **skeletal** formulae for the organic compounds.

[2]

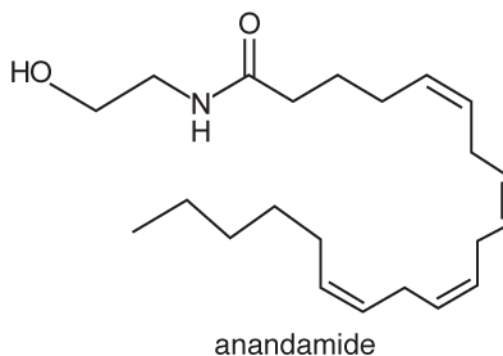
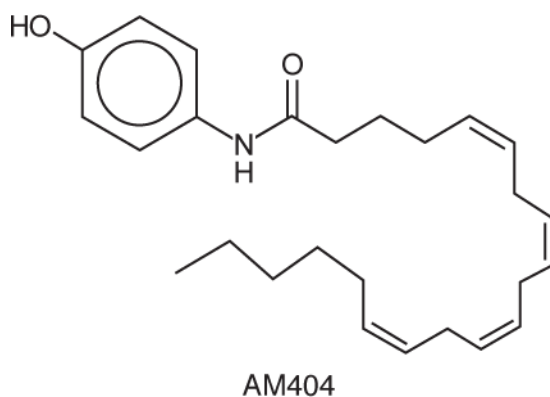
(v) The students purify the product from **step 3** by recrystallisation from water.

Describe the steps in the recrystallisation of a solid product from water. Indicate how insoluble and soluble impurities are removed.

----- [4]

(b) Paracetamol is thought to be converted to AM404 in the body.

AM404 is thought to inhibit the enzyme-catalysed breakdown of anandamide. Anandamide reduces pain responses.



(i) Suggest how AM404 inhibits the breakdown of anandamide.

----- [3]

(ii) Describe the stereochemistry of the double bonds in AM404.

----- [1]

(iii) Explain how the double bonds in AM404 hold the carbon chain in shape.

----- [1]

- 45 A student looks up the enthalpy change of solution for anhydrous magnesium sulfate and finds it is $-84.00 \text{ kJ mol}^{-1}$.

The student measures the enthalpy change of solution of $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ by adding it to water and measuring the temperature change.

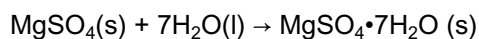
The student's results are shown in the table.

Solute	Mass of solute dissolved / g	Mass of solution / g	Initial temperature of water/ °C	Final temperature of water/ °C
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$	9.7	50.0	18.0	15.0

Calculate $\Delta_{\text{sol}}H$ for $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ in kJ mol^{-1} .

Assume the specific heat capacity of the solution is the same as that of water.

Use your answer, with the $\Delta_{\text{sol}}H$ for the anhydrous salt and draw an appropriate cycle to find a value for Δ_rH for the reaction shown below.



$\Delta_rH = \text{-----} \text{ kJ mol}^{-1}$ [4]

46 Which statement about NO_x pollution is correct?

- A It is only produced in petrol engines.
- B It can cause acid rain.
- C It is not removed at all by catalytic converters.
- D It consists mainly of NO_3 gas.

Your answer

[1]

47 What is the volume of CO_2 (in dm^3) measured at RTP when 20 g CaCO_3 completely decompose?

- A 0.20
- B 2.4
- C 4.8
- D 24

Your answer

[1]

48

A 25.0 g sample of Hg_2Cl_2 is vaporised at 400°C and a pressure of 101 kPa.

A student assumes that the formula of the gaseous mercury chloride molecules is Hg_2Cl_2 .

Calculate the volume of gas, in dm^3 , that would be expected under these conditions.

volume of gas = ----- dm^3 [3]

49(a)

Propene gas, C_3H_6 , is obtained industrially from a variety of sources.

Propene is mainly used as a starting material for making polymers.

The mass spectrum of propene has several peaks including those at m/z 27 and 43.

(i) Give the species responsible for these peaks

27

43

[2]

(ii) Propene has an isomer, cyclopropane.

Explain why high-resolution mass spectrometry would **not** distinguish between propene and cyclopropane.

.....

.....

.....

.....

.....

.....

[2]

(iii) Suggest, with reasons, **two** spectroscopic methods (apart from mass spectroscopy) that would distinguish between cyclopropane and propene.

Method 1

Reason:

.....

.....

Method 2 -----

Reason: -----

[4]

(b)

(i) How many σ and π bonds are there in a propene molecule?

Number of σ bonds ----- Number of π bonds ----- [1]

(ii) Propene has a H–C–H bond where the C atom forms a double bond.

What is the bond angle of this H–C–H bond?

----- [1]

(c) Propene, C_3H_6 , can be made by cracking longer-chain hydrocarbons.

(i) Write the equation for the cracking of nonane to give two molecules of propene and one other molecule.

[1]

(ii) What mass of propene (in kg) would be obtained from 15 kg of nonane in the reaction in (i) if the percentage yield was 85%?

mass of propene = ----- kg [2]

(d) Most of the propene that is manufactured is used to make the polymer poly(propene).

Draw the full structural formula of the repeating unit of poly(propene).

[1]

(e) Cyclohexene is another industrially important alkene.

(i) Explain how the enthalpy change of hydrogenation of cyclohexene is used to give evidence for the bonding in the benzene molecule.

[3]

(ii) *Cyclohexene and benzene both react with bromine but in different ways.

Compare the two reactions and explain why they are different.

[illegible]

[6]

50(a) This question concerns the article The Strange Story of Napoleon's Wallpaper that is supplied as Insert for H433/02, June 2018.

One reason arsenic is poisonous because it reacts with –SH groups in amino acids.

Suggest how the removal of –SH groups might interfere with the way these amino acids form proteins.

----- [1]

(b) Arsenate(V) can replace phosphate(V) in nucleic acids.

Draw the skeletal formula of a DNA nucleotide containing thymine and with As instead of P.

[2]

(c) Write an equation for the reaction of a solution of As^{3+} with hydrogen sulfide. Show state symbols.

[2]

(d) A Marsh test is carried out for arsenic in a sample of As_2O_3 .

(i) Draw a labelled diagram of a suitable apparatus, showing the reactants and products.

[3]

(ii) Write equations for the formation and decomposition of arsine in the apparatus.

[2]

(e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$.

(i) Suggest a '*dot-and-cross*' diagram for the anion in Scheele's green.

[2]

(ii) State which part of Scheele's green is responsible for the green colour.

-----[1]

(f) State and explain the C–As–C bond angle in trimethylarsine.

[4]

(g) Summarise the evidence that Napoleon was killed by his wallpaper.

[3]

51(a) Some students heat a sample of $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$ to try to make MgCO_3 .

Calculate the percentage loss in mass they will obtain if they succeed.

percentage loss in mass = ... % [2]

- (b) 'Morton's salt'TM contains a mixture of sodium chloride with magnesium carbonate. It is advertised using the slogan 'When it rains it pours' indicating that the table salt is free-flowing in humid weather.

Magnesium carbonate is hygroscopic (absorbs water) and forms hydrated salts, eg $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$, but does not dissolve. This stops the sodium chloride absorbing water.

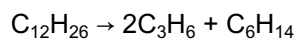
The students continue to heat the MgCO_3 formed and realise that the compound is decomposing, giving off CO_2 gas.

The students want to obtain 200 cm^3 CO_2 at 290 K and 99 kPa.

What mass of MgCO_3 should they heat?

mass of MgCO_3 = ... g [3]

52(a) Long chain alkanes can be cracked to provide better fuels and raw materials for the chemical industry. One such cracking reaction is shown in **equation 31.1**.



Equation 31.1

In a cracking reaction 1.50 tonnes of dodecane ($\text{C}_{12}\text{H}_{26}$) produce 478 kg of hexane (C_6H_{14}).

Calculate the percentage yield of the reaction in **equation 31.1**.

percentage yield = ----- % [3]

(b) Some students want to investigate the usefulness of hexane as a fuel.

- (i) Describe an experiment they could use to determine the enthalpy change of combustion of liquid hexane in the laboratory.

----- [1]

- (ii) Show how the result would be calculated from the measurements made when carrying out the experiment in part (i).

----- [1]

- (iii) Describe **two** ways in which the students could make the basic experiment more accurate.

1 -----

2 -----

----- [2]

- (c) The students are given some enthalpy changes of formation and use them to check the accuracy of their answer.

Calculate the standard enthalpy change of combustion of hexane from the data given.

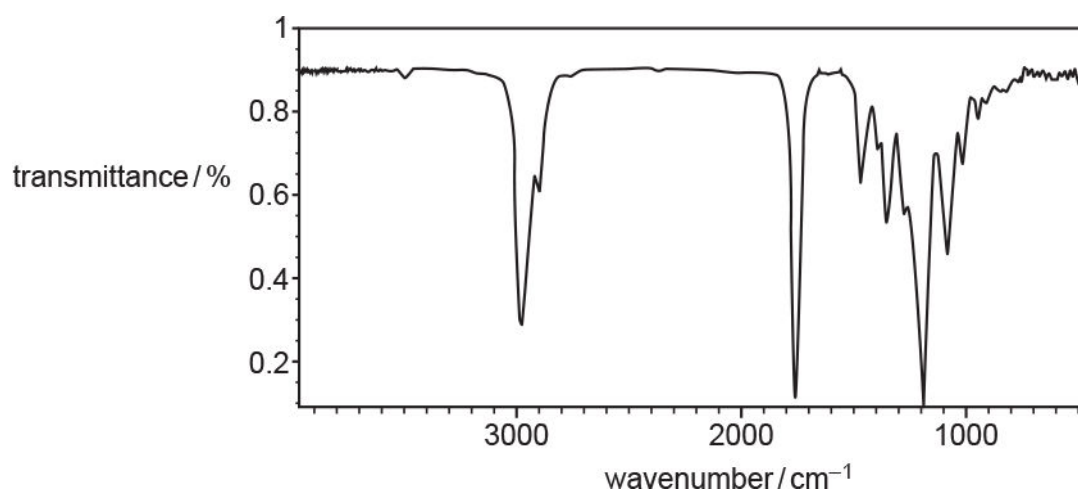
Substance	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{CO}_2(\text{g})$	-393
$\text{H}_2\text{O}(\text{l})$	-286
$\text{C}_6\text{H}_{14}(\text{l})$	-199

$\Delta_c H^\ominus$ hexane = ... kJ mol^{-1} [2]

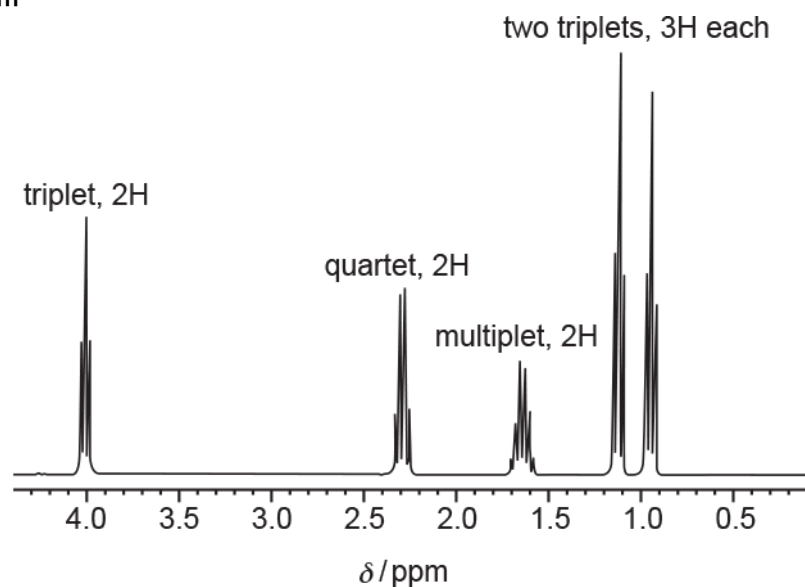
- (d) *Compound A has six carbon atoms and can be made from propene using several steps.

The infrared, proton NMR and mass spectra for compound A are shown.

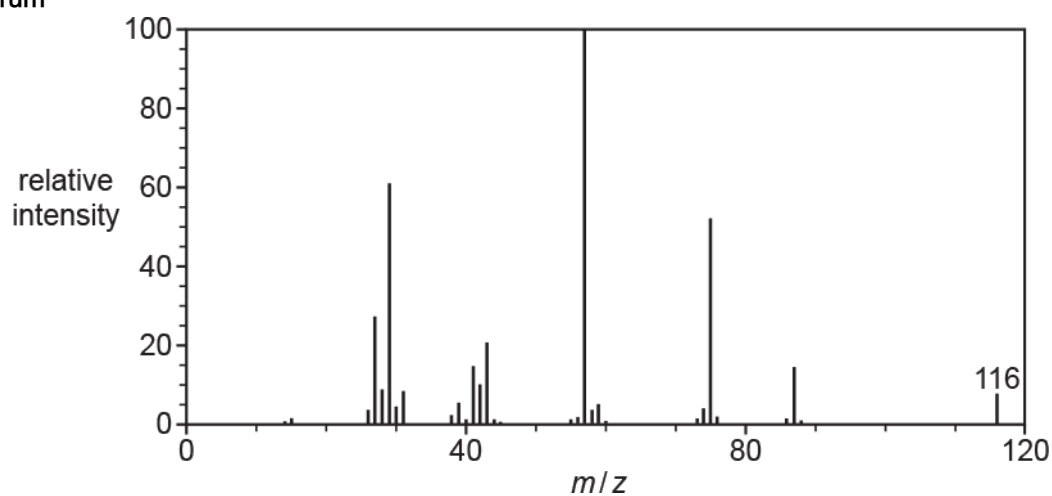
Infrared spectrum



Proton NMR spectrum



Mass spectrum



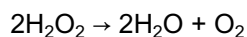
Use the information above to work out the structure of compound A.

Explain your reasoning, using evidence from each spectrum.

Structure of compound A

[6]

53(a) Why does human hair turn grey? Studies have shown that this is caused by lower levels of the enzyme catalase in hair follicles. Catalase catalyses the breakdown of hydrogen peroxide as shown in **equation 3.1**.



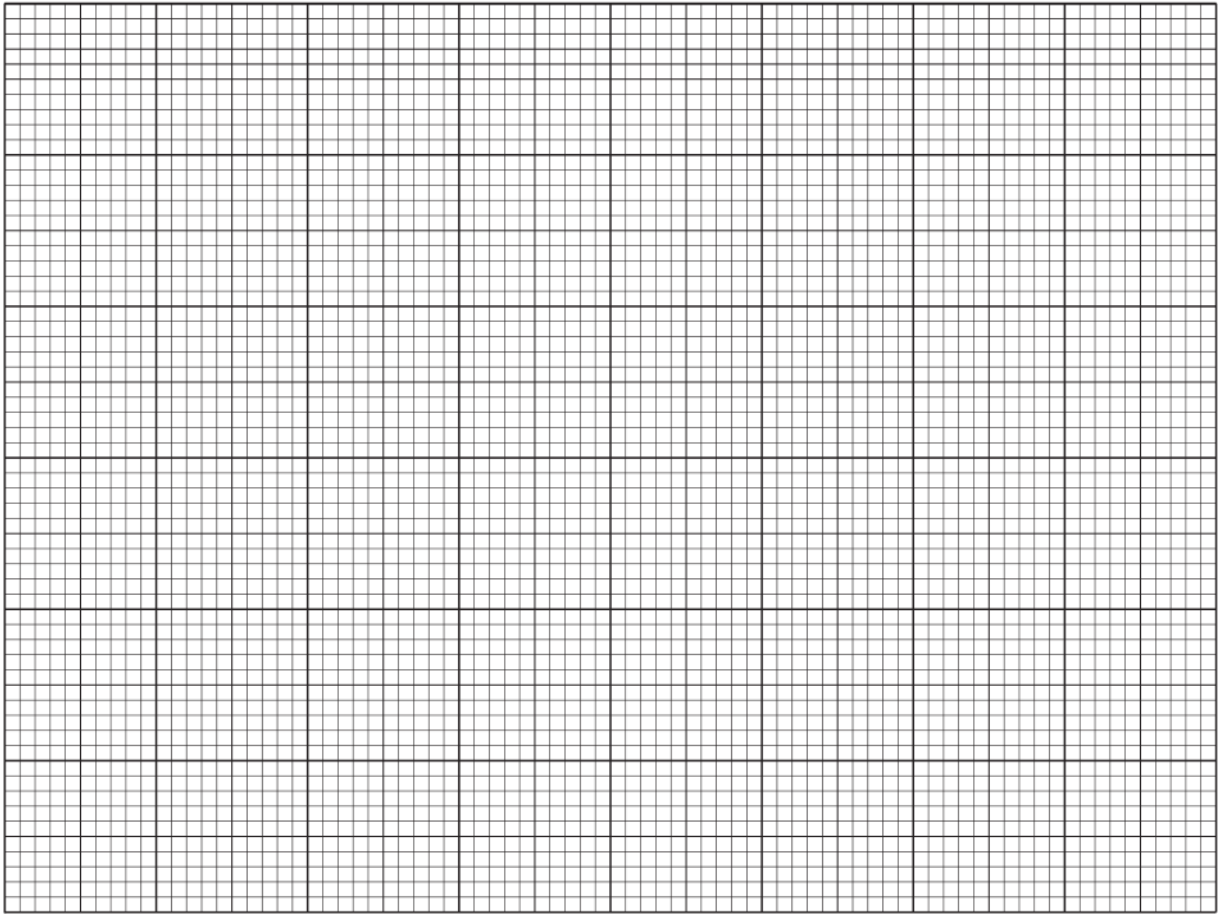
Equation 3.1

When levels of hydrogen peroxide increase, the melanin (dye) in the hair is bleached.

*Some students are given a solution of catalase and solutions of hydrogen peroxide of different concentrations. They study the rate of reaction in **equation 3.1**.

They determine the relative initial rates of reaction at the different hydrogen peroxide concentrations, using the volume of oxygen produced.

Suggest the procedure they follow, including how the students should process their results. You may include a diagram as part of your answer.



[4]

(c) A student says that the graph shows that the decomposition of hydrogen peroxide is first order with respect to both the hydrogen peroxide concentration and the catalase concentration.

- (i) Write the rate equation that would follow from the student's statement.
Give the units of the rate constant.

Rate equation:

Units of rate constant -----

[2]

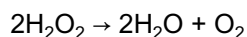
- (ii) Explain why the student is incorrect and give the correct information.

[3]

- (d) Hydrogen peroxide concentration is often measured as 'volume strength'.
1 cm³ of '1 volume' hydrogen peroxide produces 1 cm³ of oxygen at RTP.

Calculate the 'volume strength' of the 0.35 mol dm⁻³ hydrogen peroxide used by the students.

Equation 3.1



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

'volume strength' = _____ volume [3]

- (e) The students have 20.0 cm³ 0.35 mol dm⁻³ H₂O₂ and wish to make a 0.05 mol dm⁻³ solution.

How much water should they add?

volume of water to add = _____ cm³ [2]

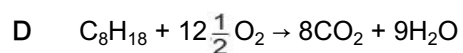
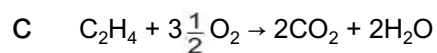
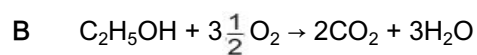
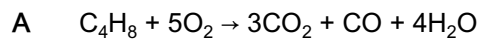
- 54 In which row of the table does the formula match the systematic name and the homologous series?

	Formula	Systematic name	Homologous series
A	C ₆ H ₁₂	cyclohexane	cycloalkane
B	C ₅ H ₁₁ OH	pentan-1-ol	aldehyde
C	C ₃ H ₆	prop-1-ene	alkane
D	C ₇ H ₁₆	septane	alkane

Your answer

[1]

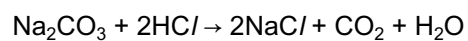
55 Which equation is correct?



Your answer

[1]

56 Sodium carbonate and hydrochloric acid react as follows.



0.010 mol of Na_2CO_3 is mixed with 0.015 mol of HCl .

What volume of CO_2 is formed (in cm^3 at RTP)?

A 180

B 240

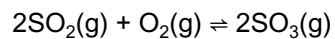
C 360

D 720

Your answer

[1]

57 The reaction for the formation of sulfur trioxide is shown below.



60 cm³ of sulfur dioxide are mixed with 60 cm³ of oxygen and allowed to reach equilibrium.

What is a possible equilibrium mixture from this reaction?

	Volume SO ₂ / cm ³	Volume O ₂ / cm ³	Volume SO ₃ / cm ³
A	0	0	120
B	50	55	10
C	48	54	18
D	20	30	40

Your answer

[1]

58(a) Ozone in the stratosphere is at a pressure of 1100 Pa and a temperature of $-20\text{ }^{\circ}\text{C}$.

- (i) Calculate the amount in moles of ozone in 1.5 dm^3 of ozone from the stratosphere.

amount of ozone = ...mol [2]

- (ii) Calculate the volume (in cm^3) that this number of moles would occupy on the surface of the Earth where the pressure is 97 kPa and the temperature is 298 K.

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

volume of ozone = ... cm^3 [2]

(b) Nitrogen monoxide, NO, is formed in a car engine and it is converted to nitrogen dioxide.

Ozone is formed by the action of sunlight on nitrogen dioxide.

Ozone in the troposphere is a pollutant and can cause photochemical smog.

(i) Explain how nitrogen monoxide forms in a car engine.

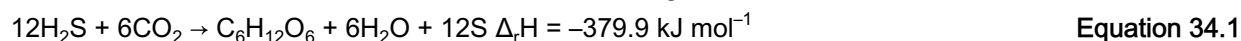
----- [2]

(ii) Describe the appearance of the atmosphere as nitrogen monoxide is converted to nitrogen dioxide.

----- [1]

59(a) It is possible that developed near hot vents deep under the sea. At these hot vents geothermally heated water rich in minerals emerges from the ocean floor.

Bacteria evolve and synthesise carbohydrates using hydrogen sulfide from the hot vent. These bacteria then form the basis of food chains for organisms such as tube worms.



Use the data in the table to find the enthalpy change of formation of glucose, C₆H₁₂O₆.

Substance	$\Delta_f H / \text{kJ mol}^{-1}$
H ₂ S	-20.6
CO ₂	-393.5
H ₂ O	-285.8
S	0

$\Delta_f H \text{ C}_6\text{H}_{12}\text{O}_6 = \dots\dots\dots \text{kJ mol}^{-1}$ [3]

- (b) Analysis of water from a hot vent showed a variety of other minerals dissolved from the Earth's crust, such as copper chloride.

Give the electronic configuration of the chloride ion, using subshells and atomic orbitals.

----- [1]

60(a) Some students have two isomeric compounds **A** and **B** with the molecular formula $C_9H_{10}O$. They are both used in the perfume industry.

The students do some tests to find out which functional groups are present.

They look at the formulae and decide that the molecules are probably unsaturated due to the low proportion of hydrogen.

They test each compound with bromine water.

Both compounds **A** and **B** show a positive result with bromine water.

Describe the colour **change** the students would see in the reaction.

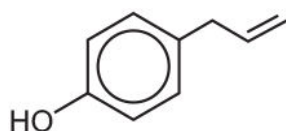
----- [1]

(b) They then decide that the molecules could be aromatic.

What does aromatic mean?

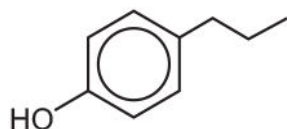
----- [1]

(c) The students are told that the structure of compound **A** is as shown below.



Other organic products can be made from compound **A**.

(i) Give the reagent and conditions to convert compound **A** into the compound shown below.



Reagent -----

Conditions ----- [1]

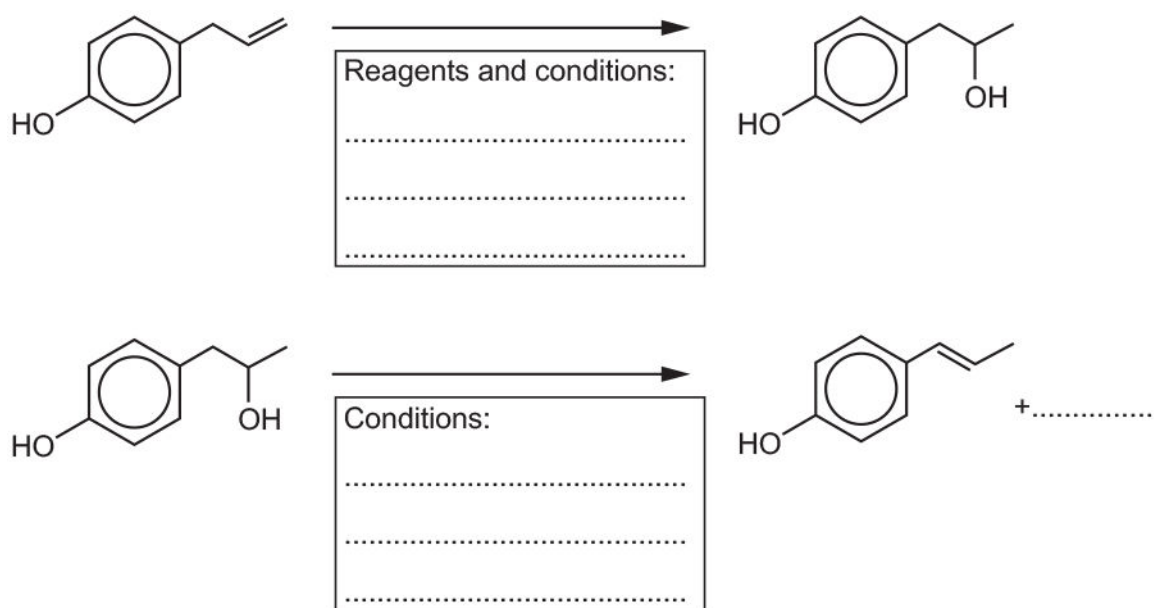
(ii) The students want to make the ethanoate ester of compound **A**.

Give the equation for a reaction to do this.

Use structural formulae for the organic molecules.

[2]

- (d) One of the students suggests the method below to change the position of the double bond on the side chain in two steps.



- (i) Complete the reaction sequence by writing on the dotted lines.

[2]

- (ii) Comment on the student's method of changing the position of the double bond.

.....

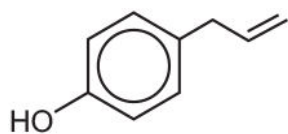
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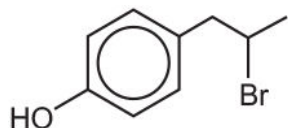
[2]

(e) Compound A is repeated below.



compound A

Hydrogen bromide reacts with compound A to give the compound shown below.



(i) Show the mechanism of the reaction of compound A with hydrogen bromide.

Use curly arrows and partial and full charges where appropriate.

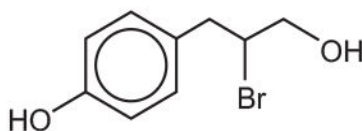
[2]

(ii) Compound A is reacted with aqueous hydrogen bromide containing dissolved sodium chloride.

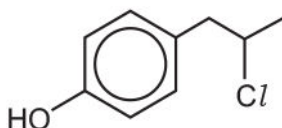
A student suggests that the products shown below are formed in addition to the product in part (i).

Comment on whether the student's suggestions are correct, giving the chemistry involved.

Product 1



Product 2



[3]

61(a) Please refer to the Article 'Clearing the air around smoke formation' in **Insert for H433/02 June 19**.

The enthalpy change of combustion of acetylene, C_2H_2 , can be calculated using enthalpy changes of formation.

Draw the Hess cycle that shows this, giving formulae and state symbols.

Label the enthalpy changes of formation and show how they can be combined to give the enthalpy change of combustion.

You do not need to give ΔH values.

[3]

- (b) The Article refers to a 'back-of-the-envelope' calculation. This shows that the number of acetylene molecules combusting is approximately 1.4 times greater than the number of ethane molecules in the same volume of air/fuel mixture.

Use a similar calculation for **propane**.

Calculate how many more acetylene molecules combust in air in a given volume of air/fuel mixture compared with propane.

(Assume air contains 20% oxygen by volume.)

Number of acetylene molecules combusting is approximately times greater than the number of propane molecules in the same volume.

[4]

(c) *Oxygen is involved in the formation of soot in the flame of a burning hydrocarbon.

Discuss the role of oxygen in controlling the flame temperature, causing small molecule reactions and providing competing routes.

Illustrate your answer with equations where appropriate.

[6]

62(a) The two isomers of propanol, C_3H_7OH , can be used as fuels.

A student measures the enthalpy change of combustion of propan-1-ol, C_3H_7OH . The apparatus used is shown in Fig. 3.1.

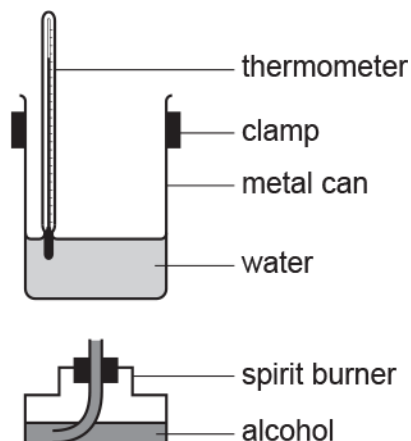


Fig. 3.1

The student's results are shown in Table 3. 1.

Mass of spirit burner + propan-1-ol	43.11 g
Mass of spirit burner + propan-1-ol after burning	42.92 g
Initial temperature of water	19.7 °C
Final temperature of water	31.2 °C
Mass of water in metal can	100 g

Table 3.1

Use the results in Table 3.1 to calculate a value for the enthalpy change of combustion of propan-1-ol, $\Delta_c H$, in kJ mol^{-1} .

Enthalpy change of combustion of propan-1-ol, $\Delta_c H = \dots\dots\dots \text{kJ mol}^{-1}$ [3]

(b) The data book value for the enthalpy change of combustion of propan-1-ol is $-2021 \text{ kJ mol}^{-1}$.

(i) One reason for the difference is heat loss to the surroundings.

Suggest **two** other reasons for the difference between the experimental value and the data book value.

1 _____

2 _____

[2]

(ii) Describe **one** addition to the apparatus in Fig. 3.1 that would improve the accuracy of the experimental value for the enthalpy change of combustion.

_____ [1]

- (c) The data book value for the enthalpy change of combustion of propan-2-ol is very similar to that of propan-1-ol.

- (i) Write out the **full** structural formulae of the **two** compounds.

propan-1-ol

propan-2-ol

[1]

- (ii) Explain why the enthalpy change of combustion values are exothermic and very similar. Use your answer to (i) and the idea of average bond enthalpies in your answer.

[3]

- 63 Which row shows the correct pollutants produced when burning the fuel in a car engine?

	Fuel	Sulfur dioxide	Carbon monoxide	Particulates	Oxides of nitrogen
A	Biodiesel	x	✓	✓	x
B	Ethanol	✓	x	x	✓
C	Hydrogen	x	x	x	✓
D	Petrol	✓	x	✓	✓

Your answer

11

[1]

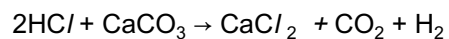
64 How many unsaturated structural isomers are there with the formula C_5H_{10} ?

- A 3
- B 5
- C 6
- D 9

Your answer

[1]

65 100 cm^3 0.75 mol dm^{-3} hydrochloric acid is added to 2.5 g calcium carbonate ($M_r = 100$).



What volume of CO_2 , in cm^3 , is produced at RTP?

- A 600
- B 900
- C 1800
- D 3600

Your answer

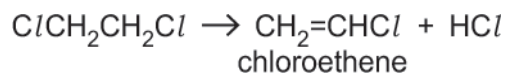
[1]

66(a) Chloroethene is made in an industrial cracking reaction and is the monomer for making poly(chloroethene).

Chloroethene can be made from ethene in two steps:

Step 1 is the formation of $\text{C}/\text{CH}_2\text{CH}_2\text{C}/$ from ethene.

Step 2 is thermal cracking of $\text{C}/\text{CH}_2\text{CH}_2\text{C}/$ to eliminate HCl .



Give the **repeat unit** of poly(chloroethene) and the **type of polymerisation** taking place when it is formed from chloroethene.

Repeat unit	Type of polymerisation
	

[2]

(b) The HCl produced in **step 2** can be used to make more $\text{CH}_2=\text{CHC}/$ by direct reaction with ethyne, $\text{HC}\equiv\text{CH}$.

Suggest the mechanism for the reaction of HCl with ethyne. Show dipoles and curly arrows.

[3]

67(a) 'Fumaric acid' is used as an acidity regulator in food. 'Maleic acid' is a stereoisomer of fumaric acid. The structure of the two acids are shown in Fig. 4.1.

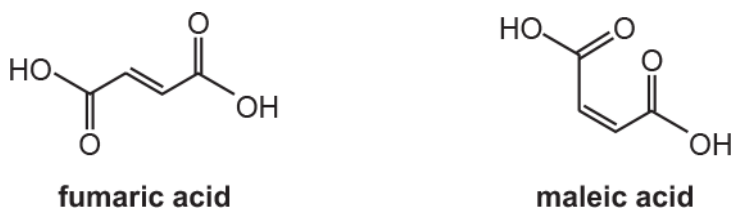


Fig. 4.1

- (i) Describe chemical tests that can be carried out in a laboratory to identify the two functional groups in both acids.

[2]

- (ii) A solution has 2.32 g dm^{-3} of maleic acid.

Calculate the volume (in cm^3) of 2.0 mol dm^{-3} NaOH(aq) that would completely neutralise 250 cm^3 of the solution.

volume = ... cm^3 [3]

(b)

(i) Give the **empirical** formula of both acids.

-----[1]

(ii) Give the systematic name for **maleic acid**.

-----[2]

(c) Explain why maleic acid and fumaric acid are different compounds.

-----[2]

(d) Fumaric acid is made from maleic acid by an acid-catalysed isomerisation reaction.

A student suggests the mechanism shown in Fig. 4.2 for the reaction.

(i) Draw 'curly arrows' on Fig. 4.2 to complete the mechanism.

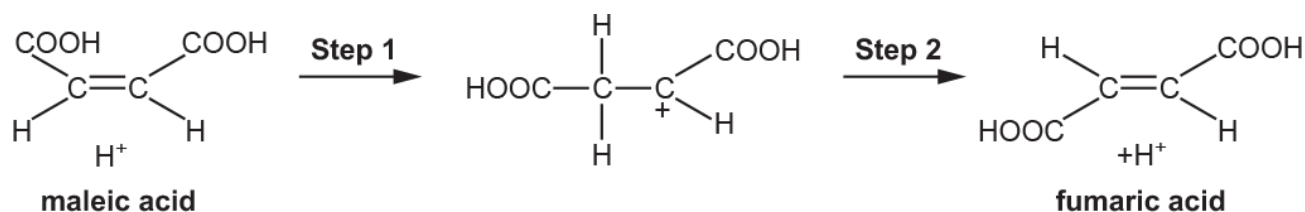


Fig. 4.2

[2]

(ii) Name the **type** of reaction that is occurring in **step 2**.

[1]

(iii) The student then reads that if $^2\text{H}^+$ ions are used for the isomerisation, then there isn't any ^2H found in the fumaric acid formed.

Does this support the student's mechanism in Fig. 4.2?

Explain your answer.

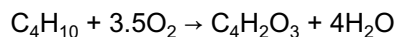
[2]

(e) Maleic acid can be made from 'maleic anhydride', $\text{C}_4\text{H}_2\text{O}_3$.

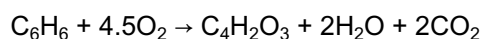
Suggest a skeletal formula for maleic anhydride.

[1]

(f) Maleic anhydride, $C_4H_2O_3$, can be made industrially by oxidising butane or benzene.



Reaction 1



Reaction 2

(i) Use calculated atom economies to suggest, with a reason, which reaction is used more.

----- [2]

(ii) Suggest another reason why the reaction selected in (g)(i) is preferred.

----- [1]

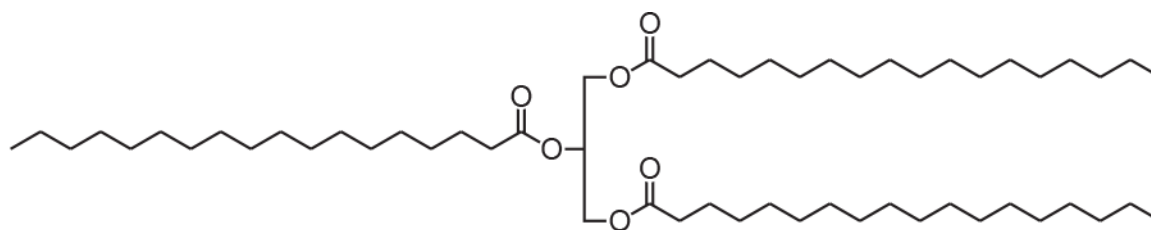
(iii) Calculate the maximum mass of maleic anhydride, $C_4H_2O_3$, (in kg) that could be made from 15 m^3 of butane (measured at RTP).

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

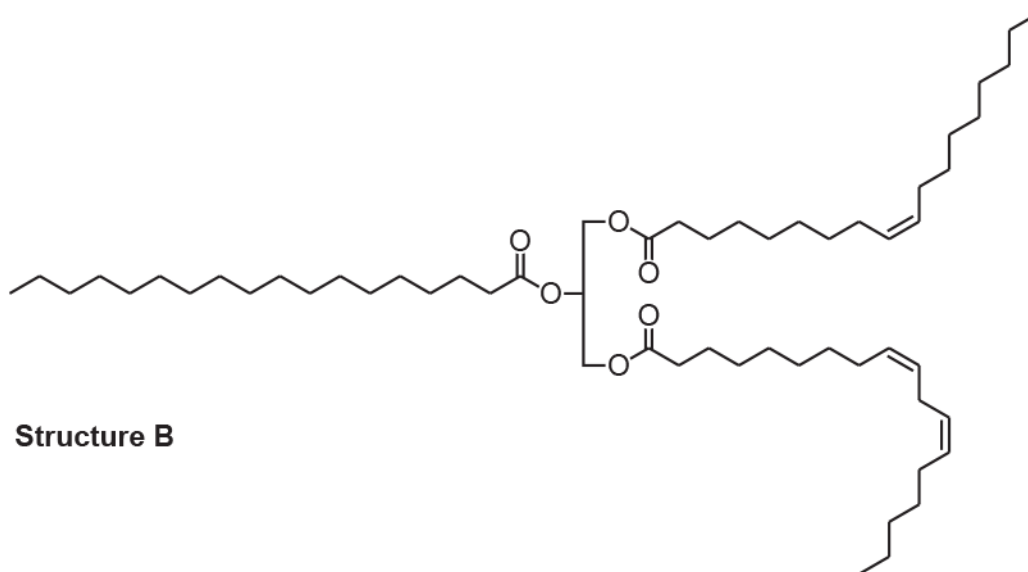
mass of maleic anhydride = ... kg [2]

Most fats and oils are triesters formed from the reaction of propane-1,2,3-triol (glycerol) with long chain carboxylic acids (fatty acids).

Two triesters **A** and **B** are shown below.



Structure A



Structure B

- (i) Structure **B** is described as a 'cis' unsaturated oil.

Explain the meanings of 'cis' and 'unsaturated'.

[2]

- (ii) State the types of intermolecular bonds between molecules of both structures and describe where in the molecules they occur.

[2]

- (iii) Suggest why Structure A is more likely to be a solid at room temperature than Structure B.

[3]

69(a) One of the components of diesel fuel for cars is cetane, $C_{16}H_{34}$.

Write the equation for the complete combustion of cetane.

[1]

- (b) Diesel vehicles are fitted with two-way catalytic convertors containing platinum, palladium and aluminium oxide. These catalyse the oxidation of hydrocarbons and carbon monoxide to carbon dioxide and water.

- (i) State the **type** of catalysis in the catalytic convertor.

Explain your answer.

Type of catalysis

Explanation

[2]

- (ii) How does the catalyst speed up the reaction?

.....

[1]

- (c) There is a high air concentration in the air-fuel mix of diesel engines. This makes the formation of oxides of nitrogen more likely. The catalyst is not effective at removing oxides of nitrogen.

One oxide of nitrogen formed is nitrogen oxide, NO(g) , which oxidises in air to form $\text{NO}_2\text{(g)}$.

- (i) State the appearance of NO and describe what is seen as it comes out of the exhaust pipe of a car.

----- [2]

- (ii) Write an equation for the formation of NO in the engine.

[1]

- 70 The Dead Sea has high concentrations of salts, especially chlorides and bromides.
Chlorine and bromine factories have developed next to the Dead Sea.

Many of the industries using chlorine and bromine as raw materials are located nearby. This avoids transporting these substances over long distances.

Chlorine is obtained by electrolysis. The chlorine is then used to obtain bromine from the bromide ions in the Dead Sea.

- (i) Describe what is seen when chlorine is added to a solution of bromide ions.

[1]

- (ii) Give an ionic equation for the reaction that takes place.

[1]

- (iii) Explain, in terms of electrons, why the reaction takes place.

[1]

- (iv) The density of Dead Sea water is 1.24 kg dm^{-3} .
The concentration of chloride ions is 208 g dm^{-3} .

Calculate the volume of chlorine (in dm^3 at RTP) that is obtained by electrolysis 1.00 tonne of the water.

Give your answer in **standard form**.

volume of chlorine = ... dm³ [4]

END OF QUESTION PAPER

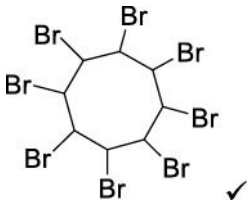
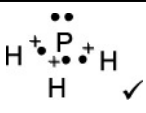
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	ethanol ✓	1	NOT ethan-1-ol Examiner's Comments The name 'ethanol' was given by most candidates, though some described it as 'ethan-1-ol', which was not accepted.
		ii	propane – 1,2,3 – triol ✓	1	ALLOW errors in gaps, commas and dashes ALLOW propan – 1,2,3 – triol IGNORE glycerol / glycerine Examiner's Comments Again, many candidates knew 'propane – 1,2,3 – triol', though many benefited from the lack of insistence on the 'e'.
	b		2 / two ✓	1	Examiner's Comments Most candidates could work out that there were two double bonds in C_7H_{11}.
			Total	3	
2	a	i	–3 +2 ✓	1	signs must precede numbers Examiner's Comments Had two easy parts to start with and few faltered here.
		ii	nitrogen monoxide ✓	1	ALLOW nitrogen(II) oxide (allow gaps), NOT nitrogen(II) monoxide no ecf from (c)(i) Examiner's Comments Had two easy parts to start with and few faltered here.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$(50-4x) + (50-5x) + 4x + 6x = 105$ $x = 5$ $\% \text{ conversion} = (20 \times 100/50) = 40\% \checkmark \checkmark$	2	40% on answer line scores 2 marks without reference to working. ALLOW, for 1 mark, one of: $(50-4x) + (50-5x) + 4x + 6x = 105$ $(50-x) + (50-1.25x) + x + 1.5x = 105$ 20 cm³ of NH₃ reacted OR 30 cm³ of NH₃ left Examiner's Comments Had two easy parts to start with and few faltered here. On the other hand, was only scored by a handful of candidates.
		iv	NO is oxidised by oxygen / reacts with oxygen to form NO₂ • NO₂ is brown •	2	ALLOW 'it' for 'NO' Examiner's Comments Had two easy parts to start with and few faltered here. was high-scoring again, though some failed to say it was oxygen that oxidised the NO to NO₂ and others did not mention that the latter was brown.
	b	i	$\overset{180(^{\circ}) \checkmark}{\text{H}-\text{C}\equiv\text{C}-\text{H} \checkmark}$	2	Structure mark can be awarded if not linear Angle mark depends on: - correct structure being given. - structure being linear - curve indicating the angle starting and finishing on bonds rather than an atom <i>Give benefit of doubt on rubbed out structures where possible (also in following parts)</i> Examiner's Comments There were many correct answers, though some of the curved lines attempting to show the bond angle did not start and finish on bonds. The next two parts were often well done.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	 ring of eight carbons ✓ correct double bonds ✓	2	If a correct non-skeletal structural formula is given, award one mark only. Do not award either mark if there are any extra carbons on ring. Second mark depends on first. Examiner's Comments There were many correct answers.
		iii	 ✓	1	must be skeletal to score Examiner's Comments There were many correct answers.
	c	i	Ca ₃ P ₂ ✓	1	Examiner's Comments Some managed Ca₃P₂ but many attempts involved an H atom as well.
		ii	 ✓	1	Examiner's Comments Some managed Ca₃P₂, had a high rate of scoring.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	1. ammonia / NH_3 (not just N) forms hydrogen bonds with / in water ✓ 2. phosphane / PH_3 (not just P) forms id-id bonds with / in water ✓ 3. P is less electronegative (than N) ora ✓ 4. <i>consideration of relative energies</i> more energy is needed to break the hydrogen bonds in water than is released / made by making the imb / named imb (between phosphane and water) OR hydrogen bonds in water are stronger than imb / named imb (between phosphane and water) OR similar energy is needed to break the hydrogen bonds in water than is released / made by forming the hydrogen bonds (between) ammonia (and water) OR hydrogen bonds in water are of similar strength(AW) to those (between) ammonia (and water).✓	4	ALLOW forms no / weaker hydrogen bonds OR forms permanent dipole-permanent dipole bonds / forms Van der Waals ALLOW abbreviations / spelling errors and 'forces' for 'bonds' IGNORE 'more energy is needed to break the hydrogen bonds in water than is needed to break the imb' etc 'in water' must be stated or implied IGNORE reference to number of bonds broken and made ALLOW statements that suggest that the hydrogen bonding in water is weaker than that between ammonia and water Examiner's Comments Was an area where planning would have paid dividends. Some candidates sailed through the first three marks but others tripped up by saying either that nitrogen (rather than ammonia) formed hydrogen bonds with water or that ammonia was more electronegative than phosphane. For the fourth mark a clear statement about the relative strength of bonds or the amount of energy released in breaking bonds and use in making bonds was needed. Some achieved this but others failed to express themselves clearly, particularly not saying that the hydrogen bonds they were talking about were in water.
			Total	17	
3			methylpropanoic acid / 2-methylpropanoic acid ✓	1	IGNORE gaps and dashes Examiner's Comments Many candidates correctly named the isomer of butanoic acid.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	Cerium(IV) oxide ✓	1	ALLOW without parentheses
		ii	$4\text{CeO}_2 \rightarrow 2\text{Ce}_2\text{O}_3 + \text{O}_2$ OR $2\text{CeO}_2 \rightarrow \text{Ce}_2\text{O}_3 + 0.5\text{O}_2$ ✓ $\text{Ce}_2\text{O}_3 + \text{H}_2\text{O} \rightarrow 2\text{CeO}_2 + \text{H}_2$ ✓	2	
		iii	Enthalpy changes of formation ✓	1	ALLOW bond enthalpies / energies
	b	i	$E^\ominus$ of $\text{Ce}^{4+}/\text{Ce}^{3+}$ in $\text{H}_2\text{SO}_4(\text{aq})$ is more positive than $E^\ominus$ of Cl_2/Cl^- ✓ So will oxidise Cl^- to Cl_2 ✓ In $\text{HCl}(\text{aq})$ $E^\ominus$ of $\text{Ce}^{4+}/\text{Ce}^{3+}$ is less positive so will not oxidise Cl^- to Cl_2 AND so $\text{H}_2\text{SO}_4(\text{aq})$ is used ✓	3	ALLOW less negative ALLOW more negative
		ii	FIRST CHECK ANSWER ON ANSWER LINE answer = 83% to 2 sig figs award 5 marks $n(\text{AsO}_3^{3-})$ used in titration = $3.00/1000 \times 0.500$ OR 0.00150 (mol) (conc. of AsO_3^{3-} is double that of As_2O_3) ✓ $n(\text{Ce}^{4+})$ used in titration = $2 \times (3.00/1000 \times 0.500)$ OR 2×0.00150 OR 0.00300 (mol) ✓ M_r of $\text{CeO}_2 = 172.1$ ✓ mass CeO_2 present in 100 cm^3 of solution = $4 \times 172.1 \times 0.00300 = 2.0652 \text{ g}$ ✓ % purity of CeO_2 sample = $2.0652 \times 100/2.5 = 83\%$ to 2 sig figs ✓	5	ALLOW ECF from first marking point ALLOW ECF from second marking point
		iii	Use a more dilute AsO_3^{3-} solution to increase volume of titre / reduce % error in titre OR Use more ceria sample to increase volume of titre / reduce % error in titre ✓	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	FIRST CHECK ANSWER ON ANSWER LINE answer = 1.7×10^{22} atoms of oxygen award 2 marks $n(\text{CeO}_2) = 2.5/172.1 = 0.01453 \text{ (mol)}$ ✓ $n(\text{O}) = 0.01453 \times 2 = 0.02905 \text{ (mol)}$	2	
		iv	$0.02905 \times 6.02 \times 10^{23} = 1.7 \times 10^{22}$ atoms of oxygen ✓		ALLOW ECF from first marking point ALLOW 2 or more sig figs
		v	Reactants adsorbed onto surface of catalyst and form bonds to surface (AW) ✓ Bonds within reactants weaken and break ✓ New bonds form (AW) ✓ Products formed desorb / leave from catalyst (AW) ✓	4	
			Total	19	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5	a		<i>Two marking points from the following:</i> • Large amounts of arable land are required to produce the crops required to obtain large amounts ethanol • (Environmental problem caused by) disposal of fermentation waste • Current car engines need to be modified to use high concentrations of ethanol ✓✓	2	ALLOW ethanol has a lower enthalpy change of combustion than petrol IGNORE better for the environment
	b		$n(\text{O}_2) = 25 \times 0.21 / 24.0 = 0.219 \text{ mol}$ ✓ M_r of $\text{C}_2\text{H}_5\text{OH} = 46.0$ $n(\text{C}_2\text{H}_5\text{OH}) = 4.0 / 46.0 = 0.087 \text{ mol}$ Recognition of ratio $\text{O}_2 / \text{C}_2\text{H}_5\text{OH}$: $0.219 / 0.087 = 2.5$ ✓ This is smaller than the required ratio of 3 (from $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$), so the ethanol is not completely burned. ✓	3	ALLOW ECF from first marking point.
			Total	5	
6		i	$\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$ ✓	1	ALLOW 'e' without minus IGNORE state symbols
		ii	FIRST CHECK ANSWER ON ANSWER LINE Answer = 35000 OR 35280 award 3 marks $n(\text{Al}_2\text{O}_3) = 100000/102$ OR 980 (mol) ✓ half a mol CO_2 for every mol O ✓ (stated or shown in calc) volume $\text{CO}_2 = 24 \times 980 \times 3/2 = 35000$ OR 35280 ✓	3	ALLOW ECF from first marking point
			Total	4	
7			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8			A	1	
			Total	1	
9			D	1	
			Total	1	
10			B	1	
			Total	1	
11			B	1	
			Total	1	
12			B	1	
			Total	1	
13	a		$\text{Ca(OH)}_2(\text{s}) + \text{CO}_2(\text{g}) \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$	1	State symbols must be included
	b		FIRST CHECK ANSWER ON ANSWER LINE answers rounding to 5.7 (g) award 3 marks Amount $\text{CO}_2 = \text{PV}/\text{RT}$ ✓ $0.0004 \times 5.0 \times 9.5 \times 10^4 / 8.314 \times 296$ OR $0.0772\dots$ (= amount Ca(OH)_2) ✓ Mass $\text{Ca(OH)}_2 (= 0.0772 \times 74.1) = 5.7 \text{ (g)}$ ✓	3	Ecf from second point ALLOW 74 for formula mass of Ca(OH)_2 ALLOW answer to 2 or more sf
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14	a	i	Place known volume / mass of water in a (polystyrene) beaker ✓ Weigh out (a suitable / calculated mass) / add a known mass of ammonium nitrate and add to water with stirring ✓ Measure temperature of water before and after ✓	3	
		ii	$(100/17) = 6(\%)$ ✓	1	ALLOW any sf rounding to 6
	b		$\text{NH}_4^+(\text{g}) + \text{NO}_3^-(\text{g})$ ✓ $\text{NH}_4^+(\text{aq}) + \text{NO}_3^-(\text{aq})/\text{NH}_4\text{NO}_3(\text{aq})$ ✓ $\text{NH}_4\text{NO}_3(\text{s})$ ✓ $\Delta_{\text{hydration}} H \text{NO}_3^- (= 25 - (645 + ^-307) =) - 313$ ✓	4	IGNORE axes and labels line must be above the $\text{NH}_4\text{NO}_3(\text{s})$ line to score this mark must have negative sign to score
	c		More exothermic / more negative ✓ C/ smaller / greater charge density ✓ more strongly attracted to the ammonium ion ✓	3	Not just 'larger'
			Total	11	
15		i	Draw a graph of volume of oxygen against time. ✓ Draw tangent and its gradient gives the rate. ✓	2	
		ii	FIRST CHECK ANSWER ON ANSWER LINE answers rounding to 1.67 (mol dm ⁻³) award 2 marks $20 \text{ cm}^3 \text{O}_2 = 20/24000 \text{ mol}$ ✓ Conc of $\text{H}_2\text{O}_2 (= (1000 \times 2 \times 20)/24000) = 1.67 \text{ (mol dm}^{-3}\text{)}$ ✓	2	ALLOW 2 or more sf
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16		i	FIRST CHECK THE ANSWER ON THE ANSWER LINE rate = 4.35×10^{-5} award 2 marks rate = 4.35×10^{-5} AND units = s^{-1} award 3 marks rate doubles with concentration so reaction 1st order to $\text{C}_6\text{H}_5\text{N}_2\text{C}/$ rate = $k[\text{C}_6\text{H}_5\text{N}_2\text{C}/]$ ✓ $k = \text{rate} / [\text{C}_6\text{H}_5\text{N}_2\text{C}/] = 4.35 \times 10^{-5}$ ✓ s^{-1} ✓	3	Answer can be calculated using either data set.
		ii	only know concentration at start / initial concentration ✓ (therefore) collecting larger volumes would not give initial rate ✓	2	IGNORE references to actual percentages
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE pH = 1.68 (2 d.p.) award 2 marks $n(\text{N}_2) = 0.050 / 24.0 = 0.00208$ mol concentration HC/ = $0.00208 \times 10 = 0.0208$ mol dm^{-3} ✓ pH = 1.68 (2 d.p.) ✓	2	
		iv	<i>One from</i> ✓ (Measure) loss of mass Titrate HC/	1	

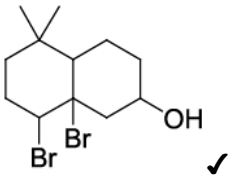
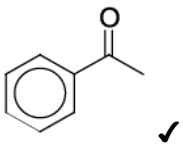
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		v	two missing values: 3.36×10^{-3} and -8.52 ✓ axes drawn, labels correct x-axis: $1/T / K^{-1}$ y-axis: $\ln k$ scales that use over half of each axis ✓ all points plotted correctly with best straight line drawn through points ✓ measurement of slope ($1.33 \pm 0.05 \times 10^4$) ✓ multiplication by 8.314, division by 10^3 and change of sign to give E_a in kJ units [$+111$ (kJ mol^{-1})] ✓	5	units of $1/T$ can be missing ALLOW no sign but not minus sign for last mark ALLOW 2 or more sig figs ALLOW any answer rounding to 106–115 (calculated correctly from slope)
			Total	13	
17	a	i	$\text{CO}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$ ✓	1	IGNORE state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE mass = 0.0625 award 1 mark mass = 0.063 g to 2 sig figs award 2 marks moles $\text{CO}_2 = 15/24000$ OR 6.25×10^{-4} ✓ mass $\text{CaCO}_3 = (6.25 \times 10^{-4} \times 100) = 0.063$ g to 2 sig figs ✓	2	ALLOW ECF from first marking point
	b	i	$\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$ OR $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + 2\text{OH}^-$ ✓	1	ALLOW equilibrium signs IGNORE state symbols
		ii	CaCO_3 is less soluble / weaker base than $\text{Ca}(\text{OH})_2$ ✓ so fewer OH^- (aq) ions are present (as $\text{Ca}(\text{OH})_2$ reacts / CaCO_3 forms) ✓	2	
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18		i	$\text{C}_5\text{H}_8\text{O}_2 + 6\text{O}_2 \rightarrow 5\text{CO}_2 + 4\text{H}_2\text{O}$ Correct molecular formula of GMV ✓ Balanced equation (with ECF) ✓	2	IGNORE state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE ratio = 1 : 1.4 or more sig figs (1.395....) award 3 marks mass CO_2 per mole GMV = $5 \times 44 = 220$ g mass CO_2 per mole hexane = $6 \times 44 = 264$ g ✓ M_r values GMV 100; hexane 86 ✓ ratio $(220/100) : (264/86) = 1 : 1.40$ ✓	3	OR moles CO_2 per mole fuel ALLOW ECF from first marking point
		iii	Comparison of CO_2 is important as it is a greenhouse gas / contributes to global warming ✓ Should be CO_2 per kJ released on burning (AW) ✓	2	
			Total	7	

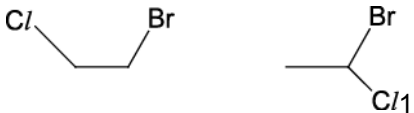
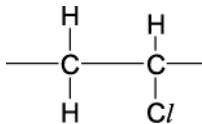
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a	i		1	ALLOW any unambiguous formula clearly displaying the structure of the compound.
		ii	11 ✓	1	
		iii	two ✓ (because ambrinol has two) asymmetric carbon atoms / carbon atoms surrounded by 4 different groups ✓	2	
		iv	yes, because same bonds ✓ hence same vibrations ✓	2	ALLOW: no, based on analogy with named compound ✓ (e.g. carvone) for which enantiomers smell different ✓
	b		vanillin and guaiacol are phenols ✓ purple colour with FeCl_3 ✓ benzaldehyde and vanillin are aldehydes ✓ acid dichromate goes green OR Tollens' reagent OR AgNO_3 and NH_3 ... give silver (mirror) OR Fehlings solution gives red precipitate ✓	4	
	c		IR spectrum that shows how bonds vibrate ✓ Shows similarity between spectra of vanillin and combination of guaiacol and benzaldehyde (AW) ✓ C-H in arenes ✓	3	
	d	i	(atoms with) same atomic number AND different mass number ✓ 1 and 7 ✓	2	must mention both terms
		ii	12.01 ✓	1	
		iii	 all hydrogen atoms replaced with deuterium atoms ✓	2	Correct skeletal formula required. ALLOW 'H'/'proton' for 'hydrogen atom' and 'D' for deuterium atom To score, answer must state that all the atoms are replaced.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	<i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Supporting evidence for Turin's theory AND evidence to discredit the lock and key theory have been correctly identified. There is a clear discussion related to both theories. <i>The evidence selected is relevant and substantiated. The discussion shows a well-developed line of reasoning for the choices of evidence, which is clear and logically structured.</i> <i>Candidate demonstrates a clear and confident knowledge of relevant technical language (names of compounds, 'deuterated', 'vibrate').</i> Level 2 (3–4 marks) Supporting evidence for Turin's theory AND evidence to discredit lock and key theory have been correctly identified although there is a limited attempt to discuss them. <i>The evidence selected is in the most-part relevant.</i> <i>The discussion has some structure but is limited in scope.</i> <i>Candidate demonstrates a sound grasp of technical language (one spelling error).</i> Level 1 (1–2 marks) Evidence for Turin's theory has been identified OR Evidence against lock and key theory <i>The information is supported by limited evidence and the relationship to the evidence may not be clear. The discussion is basic and communicated in an unstructured way.</i> <i>Candidate demonstrates a basic grasp of</i>	6	Indicative scientific points may include: Statements to support Turin's theory - deuterated acetophenone smells different (from non-deuterated form) - deuterated benzaldehyde smells different (from non-deuterated form) - because H and D have different masses and hence C–D and C–H vibrate differently - C¹² and C¹³ exchange does not affect smell, since masses only differ slightly - structures of deuterated acetophenone and benzaldehyde given. Statements to discredit Lock and Key - since structures are similar, lock and key theory would not predict difference (AW). - structurally related molecules can smell utterly different.

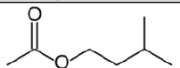
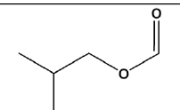
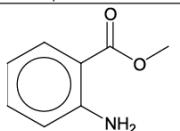
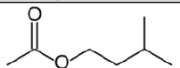
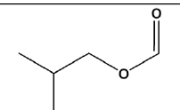
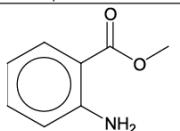
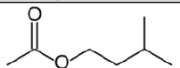
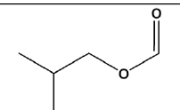
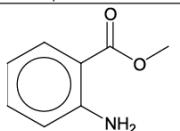
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>relevant technical language (several spelling errors).</i> 0 marks No response or no response worthy of credit.		
			Total	24	
20	a	i	chloroethene	1	
		ii		1	Must be skeletal formulae BOTH structures required for the mark
		iii	(bubble through) bromine water – decolorised	1	ALLOW 'brown / orange to colourless'
	b	i		1	Must be full structural, showing all bonds and atoms IGNORE brackets and 'n'
		ii	permanent (dipole) - permanent dipole	1	no abbreviation ALLOW missing hyphen
			Total	5	
21			speeds up achievement of equilibrium OR speeds up both (forward and back) reactions ✓ no effect on K_c (AW) ✓	2	Can score this alternative for the first marking point while explaining effect on K_c
			Total	2	
22		i	$(\frac{100}{24000} \times 84.3 =) 0.351 \text{ g}$ ✓	1	
		ii	The volume of gas collected will be smaller ✓ (because) the molar mass / M_r of calcium carbonate is bigger than that of magnesium carbonate so a smaller number of moles of calcium carbonate is contained (in the same mass) ✓	2	
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23	a	i	$\% \text{ error} = \frac{2 \times 0.5}{88.0 - 17.5} \times 100 = \frac{1.0}{70.5} \times 100$ $= 1.4 \% \checkmark$	1	Mark is for the answer, not the working out.
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE enthalpy change of combustion = -960 OR -961 (kJ mol⁻¹) award 3 marks <i>ΔH calculation from experiment</i> From results table (or from (i)) $\Delta T = 88.0 - 17.5$ = 70.5 °C $q = 100 \times 4.18 \times 70.5 = 29469 \text{ J OR } 29.469 \text{ kJ } \checkmark$ From results table mass of ethanol = 20.33 - 18.92 = 1.41 g M_r of ethanol = 46.0 Amount of ethanol = $\frac{1.41}{46.0} = 0.0307 \text{ mol}$ $\checkmark$ $\Delta H = 29.469 / 0.0307$ = -960 OR -961 (kJ mol⁻¹) $\checkmark$	3	ALLOW 0.0306521 as this depends on rounding ECF from first marking point and second marking point
	b	i	A different number of moles of alcohol are burnt $\checkmark$ The alcohols have different enthalpy changes of combustion $\checkmark$	2	
		ii	Use the same start and end temperatures of water $\checkmark$ (Assume) the same proportion of energy transferred to the surroundings is transferred to the water (AW) $\checkmark$	2	ALLOW use same temperature change of water
	c		Black solid is carbon $\checkmark$ Due to incomplete combustion (of the fuel) $\checkmark$	2	
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance															
24	a	i	speeds up reaction / catalyst ✓	1	IGNORE references to sulfuric acid removing water produced															
		ii	neutralises excess acid (so easier to smell ester) AND fizzing / effervescence / bubbling ✓	1																
	b		<table><tr><th>Alcohol</th><th>Carboxylic acid</th><th>Structure of Ester</th></tr><tr><td>pentan-1-ol</td><td>ethanoic acid</td><td></td></tr><tr><td>3-methylbutan-1-ol</td><td>ethanoic acid</td><td></td></tr><tr><td>2-methylpropan-1-ol</td><td>methanoic acid</td><td></td></tr><tr><td>methanol</td><td>anthranilic acid</td><td></td></tr></table> ✓ ✓ ✓	Alcohol	Carboxylic acid	Structure of Ester	pentan-1-ol	ethanoic acid		3-methylbutan-1-ol	ethanoic acid		2-methylpropan-1-ol	methanoic acid		methanol	anthranilic acid		3	one mark for each ALLOW any unambiguous representations of structures
Alcohol	Carboxylic acid	Structure of Ester																		
pentan-1-ol	ethanoic acid																			
3-methylbutan-1-ol	ethanoic acid																			
2-methylpropan-1-ol	methanoic acid																			
methanol	anthranilic acid																			
	c	i	removes water / drying agent ✓	1																

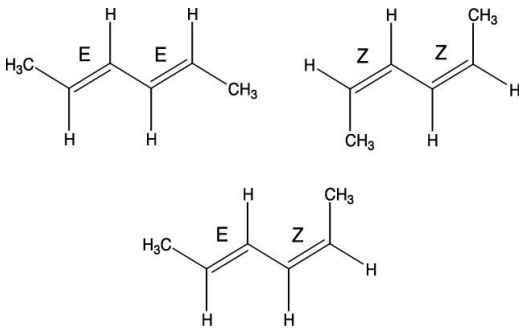
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question. Level 3: 5–6 marks Identifies key absorptions unique to ester, justifying by C13 NMR AND IR spectra. States both wavenumber and relevant absorption for IR Recognises any difference in C13 NMR AND IR spectra for BOTH alcohol and acid spectra <i>The ideas are logical and well-structured providing significant clarity in the communication of the science</i> Level 2: 3–4 marks Identifies key absorptions unique to ester, justifying by C13 NMR AND IR spectrum OR absence of features from acid and alcohol. <i>There is partial structuring of the ideas with the communication of the science generally clear.</i> Level 1: 1–2 marks Identifies key absorptions unique to ester, justifying by C13 NMR OR IR spectrum. Recognises any difference in EITHER spectra for EITHER acid or alcohol <i>The ideas expressed are logical but limit the communication of the science.</i> Level 0: (no marks) <i>No response or no response worthy of credit.</i>	6	Expected chemical points: Ester <i>C-13 spectrum_ (at least 2 from:)</i> • 4C environments suggest ester present; • ca 160 shift suggests C=O • 70 shift suggests C-O <i>IR spectrum_ (at least 2 from:)</i> • no OH absorption • C=O at around 1750 • C-O at around 1250 Alcohol <i>C-13 spectrum</i> • 3C environments • one at δ 50–70 (C-O) <i>IR spectrum</i> • OH absorption in region 3200–3600 • no C=O stretch at 1750 Carboxylic Acid <i>C-13 spectrum</i> • only 1C environment • at δ 160–200 (C=O) <i>IR spectrum</i> • OH absorption in region 2500–3300 All three molecules • C-H at 2900 stretch in IR spectra NB
			Total	12	

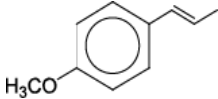
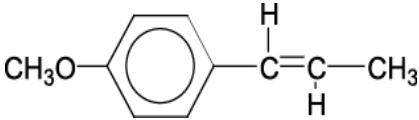
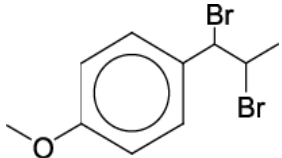
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25	a		moles of C_6H_{10} in 100 g = $100/82.0 = 1.22$ ✓ bromine number = $100/82.0 \times 2 \times 159.8 = 390$ ✓	2	ECF ALLOW M_r for bromine = 160 IGNORE g units with answer Examiner's Comments Most candidates correctly calculated the moles of C_6H_{10} but many of these were unable to convert this into the bromine number. (390)
	b	i	Method 1 MOLES moles of $BrO_3^- = 0.005$ AND moles of $Br^- = 0.0167$ ✓ to be in excess moles of BrO_3^- has to be > $(0.0167/5 =) 0.00334 \text{ mol dm}^{-3}$ ✓ Method 2 CONCENTRATIONS $[BrO_3^-] = 0.0250$ AND $[Br^-] = 0.0835$ ✓ to be in excess $[BrO_3^-]$ has to be > $(0.0835/5 =) 0.0167 \text{ mol dm}^{-3}$ ✓	2	must have words as well as numbers for 2nd mark Examiner's Comments Generally well attempted by a variety of methods but many not using words to explain their calculation and subsequent understanding.
		ii	moles of Br^- (forming Br_2) = $0.167 \times 100 / 1000$ or (0.0167) ✓ moles of Br_2 reacted with 10 g sample = $0.0167 \times 3/5$ ✓ $\times 82/200$ ✓ = (0.00411) mass of Br_2 reacted with 10 g sample = $0.0167 \times 3/5 \times 82/200 \times 159.8 = (0.656 \text{ g})$ ✓ bromine number = $0.0167 \times 3/5 \times 82/200 \times 159.8 \times 10 = 6.56 = 7$ ✓	5	Alternative method: moles of Br_2 formed in reaction in $200 \text{ cm}^3 = 0.0167 \times 3/5 = (0.01002)$ ✓ $[Br_2] = 0.0167 \times 3/5 \times 5 = (0.501)$ ✓ moles of Br_2 used in adding to sample = $0.501 \times 82/1000 = 0.0411$ ✓ mass of Br_2 added to 10.0 g sample = $0.0411 \times 159.8 = (6.56 \text{ g})$ ✓ bromine number = 7 ✓ ECF throughout calculation IGNORE g units with answer ✓ Examiner's Comments Only the most able scored full marks with their working often clearly presented. The majority usually got off on the wrong foot, calculating moles of the C_6H_{10} and thereafter losing their way Some ignored the request for a whole number. (7).

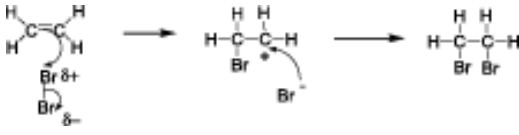
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	restrictive rotation about C=C bonds ✓ two different atoms / groups attached to both carbon atoms of the C=C bond ✓	2	ALLOW C=C bonds cannot rotate ALLOW 'lack of free rotation' NOT just 'double bonds' IGNORE functional Examiner's Comments Well understood, although some asymmetric carbons were still in evidence.
		ii	1 mark for each correct isomer provided no more than 3 ✓✓✓ 1 mark for labels drawn correctly on the 3 correct structures ✓ 	4	extra structures are each CON to one isomer mark already scored (watch out for E-Z and Z-E which is a CON) ALLOW skeletal structures Examiner's Comments Some very good attempts but only the best gained full marks. Frequently E / Z and Z / E isomers were both included. Labelling was often good though some just focused on drawing structural formulae for molecules with one C=C bond and hence only one label.
	d		atoms / transition metals (on surface) can use d (and s) electrons / subshell / orbital(s) ✓ to form (weak) bonds to / interactions with reactants ✓ providing a route of lower E_a ✓	3	IGNORE orbital numbers ALLOW chemisorption BUT NOT adsorption Examiner's Comments Many began by unnecessarily filling up the answer space by explaining the phrase 'heterogeneous catalyst'. Further discussion either involved a catalytic theory based on an intermediate or variable oxidation states. Candidates often managed the final mark for lowering the activation enthalpy.
			Total	18	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
26	a	i	$C_{10}H_{12}O$	1	ALLOW elements in any order Examiner's Comments Most candidates wrote the correct $C_{10}H_{12}O$ but there were some errors.
		ii	ether	1	ALLOW methoxy Examiner's Comments Many candidates wrote 'ether' but some gave 'alcohol' and others did not read the need to name a saturated group and said 'alkene'.
		iii		1	ALLOW any appropriate structural formula or mixture of types of formula. ALLOW  IGNORE small errors in structure if trans is clear Examiner's Comments Most represented the <i>E</i> isomer correctly using a structural, rather than a skeletal formula.
	b			1	must be skeletal (including ether) ALLOW both bromines on same side Examiner's Comments This was usually correct, including the ether group.

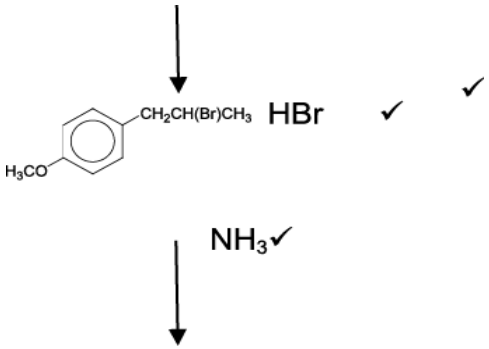
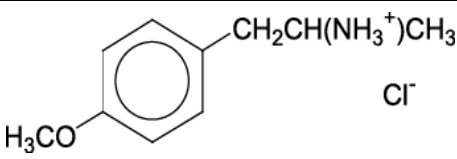
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	 bromine attacking C=C including curly arrow and curly arrow and dipole on bromine✓ intermediate formula (could be cyclic)✓ Br⁻ attacking and formula of product✓	3	curly arrows must start (when projected back) on bond (or – [or lone pair if drawn] on Br⁻) and finish pointing at atoms shown or at the new bond to be formed. IGNORE half arrows. IGNORE partial charges on atoms (or bond) of C=C ALLOW last mark if there is no charge on carbocation Examiner's Comments Some candidates produced very polished mechanisms. Others were not careful enough as to where their curly arrows started. They must start either from a bond or a lone pair (the negative charge on the bromide ion was accepted). The first mark was the hardest to score with some drawing arrows to the alkene from the bromine.
		ii	(First) attack/attraction (AW) is by an electrophile (Br₂) OR by Br⁺/Br^{δ+}✓ (Then) H₂O/water can attack (AW) (carbocation)/ can act as nucleophile AW OR water is not an electrophile✓	2	ALLOW 'OH' for 'water' but not OH⁻ Examiner's Comments A few candidates got the idea that the bromine electrophile had to attack first followed by the water nucleophile. However, many failed to gain the second mark by referring to hydroxide ions rather than water molecules or hydroxyl groups.

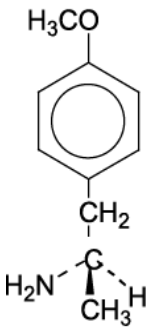
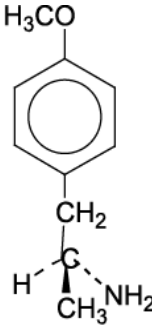
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		1. Hydrogen bonds are formed between lone pair on O✓ 2. and $H^{\delta+}$ / H polarised by O-H/ partially(AW) positive hydrogen/H✓ 3. Anethole hydrogen bonds (with water)✓ 4. hydrogen bonds in water are broken 5. hydrogen bonds in water are greater/stronger than imb between anethole and water OR more hydrogen bonds broken than made OR more energy is needed to break bonds than is released in making them OR anethole only forms one/two/few hydrogen bonds OR rest of anethole can't hydrogen bond (ORA)/ forms id-id✓	5	ALLOW 1., 2. and 3. from diagram reference to hydrogens in anethole forming H-bonds CONs 2. (1. and 2. can be scored separately) 3. and 4. can be scored with some of the alternatives for 5. 5. ALLOW – for dissolving to occur strength/energy of bonds broken must (roughly) equal strength/energy of bonds made IGNORE other attempts at this point if one is correct Examiner's Comments Scoring was high here which is encouraging. Some glossed over the idea of a lone pair on oxygen attracting a partially positive hydrogen. Most realised that anethole would hydrogen bond with water as it had an ether oxygen. Many scored for saying 'few hydrogen bonds' or addressing the partial solubility in a myriad other acceptable ways. The mark least scored was for saying that hydrogen bonds in water were broken.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e	i	 Reaction scheme showing the conversion of anethole to a primary amine via a bromide intermediate.	3	ALLOW any unambiguous formula for intermediate ALLOW 'NaBr/H⁺' for 'HBr' Can be names of reagents IGNORE state symbols on reagents ALLOW substitution of HCl/hydrochloric acid with chlorine on intermediate Mark all points separately. BUT For 1 mark, allow Br₂ or H₂O for first reagent followed by corresponding product in intermediate box. Examiner's Comments Some candidates realised that the bromo derivative was the intermediate and used HBr to form it and ammonia to react with it. Many candidates benefitted from the decision to mark the three points separately, particularly the ammonia mark.
		ii		1	ALLOW 'NH₃Cl' instead of ions but not 'NH₃-Cl' ALLOW N⁺H₃ and (NH₃)⁺ ALLOW without the chloride Examiner's Comments Many candidates correctly protonated the amine group but some added chlorine atoms to the chain or to the ring.
		iii	Drug X has C/chiral centre with four different groups/ asymmetric C✓ indication of which C and which four groups✓ no equivalent C in anethole (AW)✓	3	second marking point can be scored from e(iv) if not scored here ALLOW 'nonsuperimposable mirror image' as alternative to first mpt Examiner's Comments There was high scoring here, the commonest error being to omit 'anethole <i>doesn't</i> have a carbon attached to four different groups'. Diagrams from 1eiv were allowed in awarding the 'which C and which four groups' mark which allowed a lot more candidates to gain marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	  one correct 3d structure✓ mirror image✓	2	ALLOW  instead of ____. ALLOW any unambiguous representation of the 3d structures, but straight lines must not be at 180°. (allow mirror image by ecf) IGNORE incorrect groups when marking mirror image IGNORE non-reflection of NH₂ etc IGNORE bonds to hydrogens rather than C/N ALLOW correct enantiomers even if not shown as mirror images ALLOW any indication of organic group even if slightly erroneous and ambiguous attachments Examiner's Comments Most were able to draw the correct diagrams, though some used the wrong structure for X. Candidates must realise that two 'lines' opposite each other do not represent a three-dimensional structure.
		v	peak/trough at 3300 - 3500 (cm⁻¹)/ one value in the range caused by N-H/NH₂/amine✓ no peak at 1620 – 1680/ one value in the range caused by C=C/ alkene✓	2	Both range and bond/group needed in each case. Award one mark for both ranges without bonds/groups or vice versa Examiner's Comments Many either quoted the absence of a C=C bond or the presence of an N-H bond; some gave both, as required.
			Total	25	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a	i	Yes, and equal moles on each side OR units cancel	1	ALLOW 'particles' or 'molecules' or 'species' for 'moles' Examiner's Comments Most agreed that there should be no units because the units cancelled.
		ii	exothermic AND K_c is lower/ eqm moves to the left/ conc of reactants is higher at higher temperatures ✓	1	
		iii	High temp to increase reaction rate ✓ Low temp to increase yield/ more products/ equilibrium(position) moves to right ✓	2	ALLOW on its own mark separately Examiner's Comments Most noted that the K_c was lower at higher temperature and stated that this pointed to an exothermic forward reaction. The main error was to forecast an endothermic reaction in spite of this.
	b	i	Ratio of CO (reacted) to H_2 (formed) is 1:1 OR H_2 formed is $1.5 \times 10^{-3} - 4 \times 10^{-5}$ ✓ Small amount of CO left/ 4×10^{-5} can be ignored OR 1.46×10^{-3} is 1.5×10^{-3} to 2 sf ✓	2	ALLOW same number of molecules/moles/amounts IGNORE CO and H_2O are 1:1 ALLOW 'virtually all CO converted/reacted' Examiner's Comments This was a question where candidates' powers of expression were tested. Some correctly explained the given value for $[H_+]$ by saying that only a small amount of CO was left and that the ratio of CO initially to hydrogen was 1:1. Other answers, especially using numbers, were more elegant. Sometimes it was not clear what the ratio referred to, or water was mentioned instead of hydrogen.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$[H_2] = [CO_2] \checkmark$ $[H_2O] = (1.5 \times 10^{-3})^2 / 4 \times 10^{-5} \times 58 = 9.70 \times 10^{-4}$ (one or more sf) $\checkmark$ Answer to 1 sf = $1 \times 10^{-3} \checkmark$	3	scores if $(1.5 \times 10^{-3})^2$ seen in working. Correct answer to any sf scores 2 and correct answer to 1sf scores 3 without reference to working. ALLOW 10×10^{-4} Any answer to 1sf scores last mark separately Examiner's Comments Here most candidates spotted that $[H_2] = [CO_2]$ at equilibrium. Many went on to do the calculation correctly. Very few realised that, since one piece of data was to one significant figure, this was the 'appropriate' value for the answer. This significant figure mark was one of the least likely to be scored on the whole paper.
		iii	concentration at 1 atm = $1/24 = 0.042 \text{ mol dm}^{-3}$. $1.5 \times 10^{-3} / 0.042$ = $0.0357 / 0.04 \text{ atm} \checkmark$	1	Answer alone scores mark ALLOW 1 or more sf Examiner's Comments Many recognised that the pressure would need to be smaller than 1 atmosphere to get this concentration and obtained the correct answer. Quite a number got the reciprocal of the correct answer.
			Total	10	
28			Aqueous bromine (AW) goes colourless $\checkmark$	1	
			Total	1	
29			2-bromo-2-methylpropane $\checkmark$ 2-methylpropan-2-ol $\checkmark$	2	IGNORE dashes, commas and gaps
			Total	2	

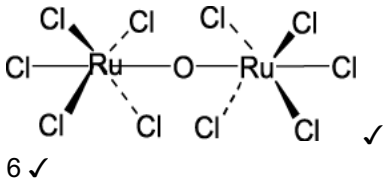
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30	a	i	$\text{Na}^+(\text{g}) + \text{Cl}^-(\text{g}) \checkmark$ $\text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})/\text{NaCl}(\text{aq}) \checkmark$ $\text{NaCl}(\text{s}) \checkmark$ -370 $\checkmark$	4	IGNORE ΔH labels ALLOW two steps to this level Level must be above NaCl(s) line to score. Minus sign required for last marking point
		ii	(one of these needed for second mark) (three of either of these acceptable for first mark) Na^+ surrounded by at least three water molecules (minimum as shown) $\checkmark$ at least one water molecule shown with atoms and dipole $\checkmark$	2	
		iii	(yes) ionic bonds in lattice $\checkmark$ (no) bonds (between water and ions) are ion-dipole $\checkmark$ (yes) bonds broken and made are very similar OR because sum of enthalpies of hydration of ions similar to LE $\checkmark$ OR ion dipole bonds have similar strength to ionic bonding OR enthalpy change of solution is small	3	must clearly state or imply error to score second mark.
	b		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = -0.7789 ($^{\circ}\text{C}$), to any sf, award 2 marks $\Delta T = 4000 \times 10 / (210 \times 4.18 \times 58.5) = -0.8$ ($^{\circ}\text{C}$) $\checkmark\checkmark$	2	ALLOW any sf (1 is most correct) Answers scoring 1 mark: • acceptable number with plus (or no) sign • -4.56 (no moles) • -0.000779 (no unit conversion) correct expression with wrong evaluation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31	a	i	froth/detergent flotation AND matte ✓	1	
		ii	$\text{NiS} + \text{H}_2\text{SO}_4 \rightarrow \text{NiSO}_4 + \text{H}_2\text{S}$ OR $\text{CuS} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{S}$	1	IGNORE state symbols
		iii	electrolysis	1	
	b	i	high melting AND unreactive	1	
		ii	$2\text{CO} + 2\text{NO} \rightarrow \text{N}_2 + 2\text{CO}_2$	1	ALLOW halves or multiples IGNORE state symbols
	c		4d^6	1	
	d	i		2	ALLOW bridging oxygen bonding in axial or equatorial positions IGNORE brackets and charges.
		ii	square planar OR tetrahedral	1	
	e		R_2NH_2^+ ✓ 3 + balances 3– (AW) ✓	2	
	f		$10^7 - 10^{10}$ or any value in that range ✓	1	
	g		$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ ✓ (light)blue dark blue/violet/purple/mauve ✓	2	ALLOW $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ IGNORE state symbols
	h		Wrong: d subshells still split ✓ Ag^+ is d^{10} OR Ag has full d subshell ✓ so no movement possible (AW) ✓	3	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	i	<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes in detail the methods of extraction and gives chemical details from the article of all three compounds. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes in detail the methods of extraction of all three compounds AND Gives the chemical details from the article for either Pd, Pt or Os <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Outlines the methods of extractions for of all three compounds AND Gives the chemicals details from the article for either Pd, Pt or Os. OR Describes in detail the method of extraction for one of the compounds and gives chemical details from the article concerning this compound. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	6	Indicative Scientific points include: Description of extraction of Pd: - extracted by ligand exchange - followed by dissolving in organic solvent Chemical details from article concerning Pd: - equation, eg $[\text{Pd}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 4\text{Cl}^-(\text{aq}) \rightarrow [\text{PdCl}_4]^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$ - this reaction is much slower for other PGMs Description of extraction of Pt: - anion exchange - reacted with $\text{R}_2\text{NH}_2^+ \text{Cl}^-$. Chemical details from article concerning Pt: $2[\text{R}_2\text{NH}_2^+ \text{Cl}^-] + [\text{PtCl}_6]^{2-}(\text{aq}) \rightleftharpoons (\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-} + 2\text{Cl}^-$ $(\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-}$ is soluble in organic solvents whereas the equivalent salts of other PGMs have lower solubility. Description of extraction of Os: - oxidation - oxide volatile and can be removed by heating Chemical details from article concerning Os: - oxidised to OsO_4 - may be mixed with RuO_4
		Total	23	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32	a		<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Description and a detailed explanation linking the rate of evaporation and the type and strength of imb in the liquids. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Description and an attempt at an explanation linking the rate of evaporation and the type and strength of imb in the liquids. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) A basic description of link between rate of evaporation, absorption of energy and cooling effect OR An explanation linking the rate of evaporation and the type and strength of imb in the liquids. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	6	Indicative scientific points may include: Description • liquid drops evaporate at different rates • evaporation endothermic process/enthalpy change of evaporation positive • greater rate of evaporation, greater temp.drop • liquids evaporate faster from left to right Explanation • the stronger the imbs the slower the rate of evaporation • water and ethanol can both H-bond • water forms two H-bonds per molecule, ethanol one • propanone has pd:pd as strongest imb • alkanes have id:id strongest imb • order of strength is H-bonds>pd:pd>id:id • branched isomer(2-methybutane) molecules can't get as close to each other as straight isomer (pentane), therefore id:id weaker
	b	i	Reduce heat exchange/AW with surroundings	1	DO NOT ALLOW reduce heat loss/gain on own IGNORE insulation

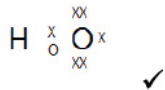
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	More energy used in breaking A-A (and B-B) bonds than 'given back' when A-B bonds form ✓ This suggests A-B bonds are weaker than A-A (and B-B) bonds ✓	2	
		iii	Intermolecular bonds broken and made all of similar strength/A-A,B-B,A-B imbs have similar strength✓	1	
	c	i	FIRST CHECK THE ANSWER ON ANSWER LINE If both answers = 12 (cm ³) award three marks Mass of each liquid = 0.15 × M _r (trichloromethane = 17.9(25); methyl ethanoate = 11.1) ✓ Vol = mass ÷ density (17.925 ÷ 1.48 = 12.11; 11.1 ÷ 0.93 = 11.9) ✓ Appropriate sig figs(2) ... = 12 (cm ³) and 12 (cm ³)✓	3	
		ii	Burette	1	ALLOW graduated pipette
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.9(...) or 3 (kJmol ⁻¹) award three marks E = m × c × ΔT for each (trichloromethane 17.925 × 0.96 × 11.0 = 189.2(88)J) (methyl ethanoate 11.1 × 2.10 × 11.0 = 256.4(1)J) ✓ Total energy transfer (189.2(88) + 256.4(1) = 445.6(98)J ✓ per mole (of H-bond) = 445.6(98) ÷ 0.15 = 2971.3(2)Jmol ⁻¹ = 2.9/3(kJmol ⁻¹) ✓	3	
			Total	17	

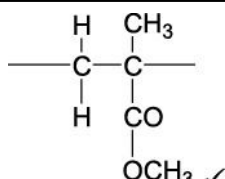
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a	i	did not mix/invert sulfamic acid solution ✓ solution more concentrated at bottom ✓	2	
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 0.087 (mol dm ⁻³) award four marks takes average of two concordant results (= 21.825)✓ calculates moles of hydroxide (= 2.183 × 10 ⁻³)✓ uses eqn to determine moles of acid (= 2.183 × 10 ⁻²) ✓ calculates concn. (i.e. mol per dm ³) to 2sig figs = 0.087 (mol dm ⁻³)✓	4	
		iii	solid absorbs water so mass/ concentration of sodium hydroxide actually dissolved is less✓ titre value therefore greater giving high result ✓	2	
	b	i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 98.6/99 award four marks moles of CO ₂ produced 146/24000 = 6.083 × 10 ⁻³ ✓ uses eqn. to determine moles of acid (above ans. × 2) = 1.217 × 10 ⁻² ✓ 1.217 × 10 ⁻² moles = 1.20g ✓ scales mass up to give mass of 1 mole of acid i.e. 1.20/1.217 × 10 ⁻² = 98.6(03)g✓	4	
		ii	1/146 × 100 = 0.68(...)/0.7 (%)✓	1	DO NOT ALLOW ecf's
		iii	some of gas lost when putting on bung OR some of gas dissolves	1	
			Total	14	
34			D	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35	a	i	Nitrogen and oxygen <u>from the air/atmosphere</u> combine due to high temperature. ✓	1	ALLOW formulae for gases
		ii	 Unpaired electron (on oxygen) ✓	2	IGNORE 'lone', 'single'
	b	i	A radical reacts to produce a new radical (to continue the reaction) (AW) ✓	1	
		ii	$\text{CO} + 2\text{O}_2 \rightarrow \text{CO}_2 + \text{O}_3$ ✓	1	
	c		reactants in the same phase/ physical state ✓ Speeds up a reaction but is not used up OR provides a different reaction pathway with lower E_A ✓	2	DO NOT ALLOW lowers activation enthalpy
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
36	a		Titrate the equilibrium mixture with alkali/NaOH of known concentration (to find total moles of acid) ✓ Subtract moles of (H ₂ SO ₄) catalyst ✓	2																					
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 3.61 award 4 marks <table><tr><th>Sub-stance</th><th>Mass at start</th><th>Amount present at the start</th><th>Amount present at equilibrium</th></tr><tr><td>ethanol</td><td>15.8</td><td>15.8/46 (= 0.343)</td><td>(0.343 – [0.35 – 0.123]) = 0.116</td></tr><tr><td>ethanoic acid</td><td>21.0</td><td>21.0/60 (= 0.35(0))</td><td>0.123</td></tr><tr><td>ethyl ethan- oate</td><td>0</td><td>0</td><td>[0.35–0.123 =] 0.227</td></tr><tr><td>Water</td><td>0</td><td>0</td><td>0.227</td></tr></table> One mark for both amounts at start ✓ One mark for amount of ethanol at equilibrium ✓ One mark for amounts of ester and water at equilibrium ✓ $K_c = 0.227^2 / (0.123 \times 0.116) = 3.61$ ✓	Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium	ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116	ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123	ethyl ethan- oate	0	0	[0.35–0.123 =] 0.227	Water	0	0	0.227	4	ALLOW ecf throughout ALLOW other answers (to 2 or more sf) by using various rounding during calculation.
Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium																						
ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116																						
ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123																						
ethyl ethan- oate	0	0	[0.35–0.123 =] 0.227																						
Water	0	0	0.227																						
	c			1	ALLOW any unambiguous structure IGNORE brackets or 'n'																				
	d		Methyl propanoate AND methanal ✓	1																					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
	e		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = (+)666(K) award 3 marks $\Delta S_{\text{sys}} = (+) 154.7 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$ $T = \Delta H/\Delta S_{\text{sys}}$ OR $T = 103000/154.7 \checkmark$ $T = (+)666 \text{ (K)} \checkmark$	3									
	f		<table border="1"><tr><td>Change</td><td>Increase d temper ature</td><td>Increase d pressure</td><td>Use of a catalyst</td></tr><tr><td>Effect on K_c</td><td>Increase</td><td>No change</td><td>No change</td></tr></table> $\checkmark \checkmark$	Change	Increase d temper ature	Increase d pressure	Use of a catalyst	Effect on K_c	Increase	No change	No change	2	All 3 correct 2 2 correct 1
Change	Increase d temper ature	Increase d pressure	Use of a catalyst										
Effect on K_c	Increase	No change	No change										
	g		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 4390(dm3) award 3 marks Unit conversion, $n = 25000/142$, $p = 150000$, $\checkmark$ Use of $pV = nRT$ and 50% yield, $V = 0.5 \times 25000 \times 8.314 \times 900/142 \times 150000 \checkmark$ Evaluation and conversion to dm3 4390 $\checkmark$	3	ALLOW 2 or more sf								
	h		Allows reaction to occur at lower temp AND less energy used $\checkmark$	1									
			Total	17									
37			FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = (+)38.8 (°C) award 3 marks $\Delta_{\text{sol}}H \text{ CaCl}_2 = 2258 - 1650 - (2 \times -364) = -120 \text{ kJ mol}^{-1} \checkmark$ Energy given out by 15.00 g = $15 \times 120000/111.1 = 16202 \text{ J} \checkmark$ Temp rise $16202/(100 \times 4.18) = (+)38.8(^\circ\text{C}) \checkmark$	3	ALLOW 2 or more sf								
			Total	3									
38			C	1									
			Total	1									

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
39			A	1	
			Total	1	
40			B	1	
			Total	1	
41			D	1	
			Total	1	

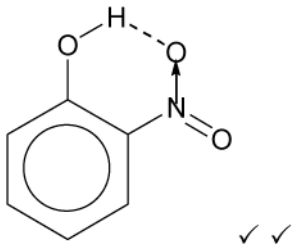
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
42	a		use equal vols / same amount of ocimenol and cinnamyl alcohol ✓ add bromine dropwise / from a burette ✓ bromine decolourised ✓ more drops / volume/greatest titre decolorised for ocimenol / more unsaturated molecule ✓	4	ORA on first two marks ALLOW answer can be in terms of colorimetry and absorption of final solution ALLOW answers in terms of add bromine solution until first permanent brown / yellow IGNORE references to time / rate of decolourisation Examiner's Comments This question was variably answered. Examiners were looking for the simple idea that equal volumes / amounts of the two alcohols could have bromine solution added (either dropwise or by titration) until an orange colour persisted. A significant number of candidates wrongly thought time was a factor and many candidates tried to use a colorimetric method. This is fine, but required a more sophisticated answer to score all four marks.
	b		E / Z ✓ ✓ Because of restricted / no rotation <u>around double bond</u> AND two <u>different</u> groups on each C in the C=C, two forms are different / isomers	3	ALLOW cis / trans ALLOW geometric IGNORE extra C's in chain between double bond and OH Examiner's Comments The type of isomerism and the structure of the other isomer commonly scored. However, the explanation required not only the idea of limited rotation around the double bond, but also the idea of two different atoms or groups on <u>each</u> carbon of the double bond.

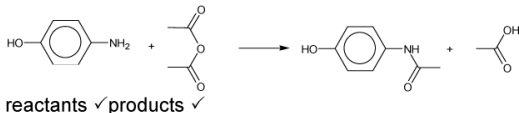
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	7	
43			FIRST CHECK ANSWER ON ANSWER LINE If answer = 647 (2 or more sf) award 3 marks Moles CO₂ absorbed = 1000/40.3 (= 24.81) ✓ Volume CO₂ absorbed = ans to 1st point x 8.31 x 298/95000 (= 0.647) ✓ Evaluation and conversion to dm³ (x1000) = 647 dm³ ✓	3	ALLOW ecf throughout ALLOW 2 or more sf 1 Moles of MgO calculated = moles CO₂ absorbed 2 Correct substitution into $V = nRT/p$ 3 Evaluation and unit conversion Examiner Comments This question was well done, many perfect answers and many that just didn't get the final unit conversion into dm³ at the end.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
44	a	i	FIRST CHECK ANSWER LINE If answer = 13.5 / 14(g) award 2 marks amount 4- nitrophenol = 5.0/139 OR 0.03597 (mol) AND mass phenol to give 100% = 5.0 × 94/139 OR 3.381 (g) ✓ scaling by 100/25 to get 13.5 / 14 (g) ✓	2	ALLOW ecf Any number scaled by 100/25 and to 2 or 3 sf scores second mark (if first mark not scored) Examiner's Comment: Where candidates failed to score here was in not correctly scaling up their calculated mass of phenol from 3.38g to 13.5g or 14g(2sf).
		ii		2	ALLOW on NO₂ group: - double bond to either oxygen with a single or dative bond to the other - one and a half' bonds to each oxygen One mark for correct bonding within NO₂ group One mark for hydrogen bond between correct H and O (even if bonding wrong) Examiner's Comment: Many candidates struggled with this question, suggesting that they are unfamiliar with the bonding within the NO₂ group, but, in many cases they did correctly identify where the internal hydrogen bond would form and so scored 1 mark.
		iii	reduction AND amine	1	Examiner's Comment: This question was not very well answered, very few candidates recognised that the conversion from a NO₂ functional group into a NH₂ functional group is an example of a reduction reaction and so failed to score this mark.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	 reactants ✓ products ✓	2	IGNORE non-skeletal formulae / ambiguous attachments Allow correct use of Ethanoyl chloride for 1 mark Examiner's Comment: This question was generally well answered. Most candidates drew appropriate skeletal structures for the reactants, and it was pleasing to see so many correct representations for the anhydride, and subsequently identifying the products of the reaction.
		v	dissolve in minimum volume of <u>hot</u> water / solvent ✓ filter (hot solution) removing insoluble impurities ✓ allow to crystallise / AW ✓ filter, soluble impurities removed / remain in solution ✓	4	ALLOW wash (and dry) crystals - soluble impurities are washed away ✓ Examiner's Comment: There were very few blank responses to this question. Candidates often identified the steps involved in the process and could communicate this effectively. Weaker candidates often lost marks for not correctly identifying where insoluble impurities were removed, or for failing to identify the removal of soluble impurities at the end of the process. The quality of response may be linked to the use of this task within the set of expected practical's that candidates are expected to undertake as they move through the course.
	b	i	(AM404) has a similar shape to andanamide AW ✓ (AM404) fits / binds / bonds to active site ✓ (AM404 in active site) not broken down / stays on (active site)/ blocks site to / competes with andanamide AW ✓	3	Examiner's Comment: This question was generally well answered by the majority of candidates, most recognised that the shape of AM404 was similar to andanamide and that this resulted in the active site of the enzyme becoming occupied and therefore prevented the enzyme from breaking down andanamide.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(all) cis / Z ✓	1	Examiner's Comment: Generally well answered, the only common error was candidates who gave a response of E / Z isomerism.
		iii	lack of rotation / twisting ✓	1	Examiner's Comment: Most candidates recognised that the reason for the chain being held in its shape was due to the lack of rotation around the carbon - carbon double bond(s).
			Total	16	
45			FIRST CHECK ANSWER ON ANSWER LINE If answer = -99.9 or -100 award 4 marks (+) 99.9 or -68.1 scores 3 (1 of the last 2) 1 Use of $Q=mc\Delta T$: $50 \times 3.0 \times 4.18 = 627 \text{ J or } 0.627 \text{ kJ} \checkmark$ 2 moles $\text{MgSO}_4 \cdot 7\text{H}_2\text{O} = 9.7 / 246.4 = 0.0394$ AND Scale up for 1 mole: $\Delta H = 0.627 / 0.0394 = (+)15.9 \text{ kJ mol}^{-1} \checkmark$ 3 $\Delta H = (-84.0 - (+15.9)) \checkmark$ OR Cycle (or enthalpy level diagram) labelled with species ✓ 4 Evaluated with sign = $-99.9 \text{ kJ mol}^{-1} \checkmark$	2	ALLOW ecf throughout. IGNORE sign for first point. A common mistake is to take the mass as 59.7. NOT -15.9 as temp of water falls. IGNORE (7)H_2O in bottom box. Examiner Comments There were a number of perfectly correct answers but there were many opportunities for making errors. These were the mass of the solution being 9.7 instead of 50, or 50 + or - 9.7. Candidates did not always realise the need to scale up for 1 mole of solute, or if they did, they used an incorrect molecular mass and had a negative enthalpy change despite the temperature falling.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
46			B	1	
			Total	1	
47			C	1	<u>Examiner's Comments</u> It was good to see such a high proportion of correct answers here.
			Total	1	
48			FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 2.93 or 2.94 (dm³) award 3 marks Moles (n) assuming Hg₂Cl₂ = 25.0/472.2 = 0.0529/0.053 ✓ Volume = $\frac{nRT}{P}$ and substitution of correct values i.e. n (0.0529/0.053), R(8.314), T(673), p(101000), ✓ evaluation including conversion to dm³ = 2.93/2.94 (dm³)✓	3	N.B. 0.0529 gives 2.93, 0.053 gives 2.94 ALLOW ecf's from marking points one and two (the latter likely to be wrong units) Any appearance, stated or not, of 25/472.2 OR 0.0529/0.053 Look for any ecf on marking points 1 and 2 <u>Examiner's Comments</u> A pleasing number of candidates were successful in this calculation. The careful laying out of the steps in the calculation also allowed examiners to be able to award error carried forwards marks on a wrong final answer. Typical errors in the calculation included calculating the wrong value for the formula mass of Hg₂Cl₂ and a failure to convert from m³ to dm³.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
49	a	i	$C_2H_3^+$ ✓ $C^{13}C_2H_6^+$ ✓	2	ALLOW structure, eg $CH_2=CH^+$ or CH_2CH^+ or CH_3C^+ ALLOW other unambiguous representations Award one mark for both correct species without plus sign ALLOW formula with comment that ONE of the C atoms is a ^{13}C isotope for MP2 <u>Examiner's Comments</u> Many candidates lost marks here for failing to include the charge on the species identified. However, if they had correctly identified the species and this was their only error then 1 mark was credited. The other common error was failing to recognise that the peak at 43 was a result of the presence of one atom of the Carbon-13 isotope in the fragment. Many candidates gave a formula of $C_3H_7^+$ even though they are told the molecular formula for propene in the stem of the question.
		ii	Both have same type and number of atoms / same molecular formula ✓ Sum of accurate atomic masses would be the same (AW) / same M_r ✓	2	<u>Examiner's Comments</u> This question ought to have been straightforward. However many candidates gave incomplete responses. They either correctly stated that the structural isomers had the same formula mass, or that they had the same molecular formula. However, many candidates, having identified one of these two key statements, then left that as their final answer. With two marks being available candidates should have realised that they needed to make two statements.
		iii	Any two from: IR : propene would have alkene $C=C$ ✓ at 1620-1680 ✓ OR alkene $C-H$ ✓ at 3000 – 3100 ✓ CNMR: propene would have 3 peaks ✓	4	IF only one method chosen, a maximum of two marks can be awarded. No marks available for identification of methods that can be used, all marks are for the reasons provided. ALLOW environments for peaks for both types of NMR

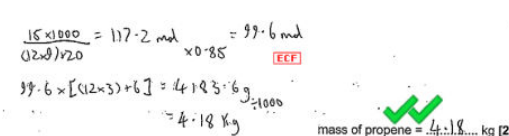
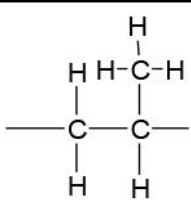
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			cyclopropane would have 1✓ OR propene would have (two) peak(s) at 110-160 ✓ C=C ✓ HNMR: propene would have 3 peaks ✓, cyclopropane would have 1 ✓ OR propene would have (two) peak(s) at 4.5 – 6 ✓ H-C=C ✓		ALLOW propene has multiplet ✓ from central CH ✓ <u>Examiner's Comments</u> There were a few issues raised in this question, which teachers may wish to consider when teaching this topic. This question was characterised by incomplete responses, or responses that lacked precision. To score well on this question, candidates needed to demonstrate their understanding of spectroscopic techniques precisely. This question was of high demand and this was reflected in the marks credited. Very few candidates scored full marks, and many candidates struggled to score more than two marks. Many chose appropriate methods to use, but then struggled to explain how the method chosen would distinguish between the two isomers. Many responses identified that one of the isomers contained a double bond, which was absent in the other isomer, but did not say how the method chosen would identify which isomer contained the double bond. Alternatively, if they did identify that propene had a double bond present, it was not linked to the specific data values quoted for IR spectroscopy, CNMR or HNMR spectroscopy. Also candidates knew that the splitting patterns in CNMR and HNMR were dependant on the environments of the carbon (or hydrogen) atoms and that the pattern could be used to identify the isomer, but again did not show precision in their responses.
	b	i	σ bonds: 8 and π bonds 1	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	120(°)	1	<u>Examiner's Comments</u> These two questions showed no overall pattern in terms of candidates' knowledge and understanding and their overall performance on the paper. There were many candidates who scored both marks at all levels of ability, and equally there were many candidates who scored no marks at all levels of ability. In b(i) there were many examples of structures being drawn where candidates seemed to be trying to count up the number of each type of bond (with varying degrees of success), and similarly a full range of bond angles were suggested with 180°, 109.5° and 90° being the most common incorrect responses.
	c	i	$\text{C}_9\text{H}_{20} \rightarrow 2\text{C}_3\text{H}_6 + \text{C}_3\text{H}_8$	1	IGNORE state symbols

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK ANSWER ON ANSWER LINE If answer = 8.4 (kg) award 2 marks (amount nonane) = $15000/128$ OR $117(\dots\dots)$ (mol) ✓ mass propene (= $2 \times 117 \times 0.85 \times 42/1000$) = 8.4 (kg) ✓	2	ALLOW ecf from incorrect equation in c(i) eg if one propene molecule as a product, then 4.2 on the answer line scores 2 marks. ALLOW $15/128 = 0.117$ for MP1 Examiner's Comments These two questions were generally well attempted. Many candidates correctly constructed the equation in part (i), and used this to arrive at the correct mass of propene in part (ii). Candidates who were less successful generally gave the formula of hexane as a product in part (i) and subsequently arrived at a value of 4.2 kg in part (ii). This was allowed for both marks as an example of the use of error carried forward from an incorrect equation in (i). Exemplar 2  This candidate has used the incorrect equation in (i) but use of error carried forward (ecf) in (ii) resulted in 2 marks being credited.
	d			1	IGNORE brackets and 'n' must be full structural with 'spare' bonds. Examiner's Comments Generally a straightforward question and many candidates scored this mark. A common error evident here was where candidates did not read the stem of the question fully and had not picked up on the instruction in bold requiring them to draw a full structural formula – i.e. a formula showing all the bonds and elements present. These candidates often included a $-\text{CH}_3$ group attached to a carbon atom within the repeating unit, which was not allowed as it was not a full structure.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e	i	Any three from: enthalpy change of hydrogenation of benzene is less (exothermic) than $3 \times$ enthalpy change of hydrogenation of cyclohexene ✓ (therefore) bonding in benzene is not 3 (C=C) double bonds (and 3 C—C bonds) / benzene does not have alternating single and double bonds between the carbon atoms ✓ benzene is more stable ✓ benzene has delocalised electrons / structure ✓	3	ALLOW points made on a diagram ALLOW any appropriate comment relating to delocalisation in benzene <u>Examiner's Comments</u> This question showed a full range of marks, with most candidates making an attempt to answer it as fully as possible. Many candidates scored two marks for correctly stating that the structure of benzene was more stable than expected (if it were the Kekulé structure) due to the presence of the delocalised ring. However, a number of candidates lost marks for claiming that cyclohexene contained three double bonds and then tried to justify their answers from this premise. A significant number of candidates had recalled the value for the hydrogenation enthalpy of cyclohexene (-120kJ/mol) and then tried to use this in the context of their answers. Although they calculated that benzene should be three times the value quoted, (-360kJ/mol), they did not make it clear that the reaction for benzene was less exothermic, and often stated that it was more exothermic which negated marking point 1 on the mark scheme.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	<i>Refer to marking instructions on page 6 of mark scheme for guidance on marking this question.</i> Level 3 (5–6 marks) A detailed comparison that identifies products and reaction conditions for both reactions. AND Correctly identifies both reaction types. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Partial comparison of both reactions. AND Correctly identifies both reaction types. OR Detailed explanation of the one reaction. AND Correctly identifies ONE reaction type. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence</i> Level 1 (1–2 marks) Partial comparison of both reactions. AND Attempts to identify the reaction types. OR Discusses both reaction types. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 <i>No response or no response worthy of credit.</i>	6	Indicative scientific points include: AO2.1 application of knowledge and understanding of cyclohexene reaction • product 1,2 dibromohexane • formula; • Br₂ decolourises • at room temp AO2.1 application of knowledge and understanding of benzene reaction • product bromobenzene • formula; • HBr as a product • needs reflux • halogen carrier • Fe/FeBr₃ catalyst May be given by use of appropriate equation(s) AO3.2 Conclusions about reaction types cyclohexene: • Electrophilic • addition <i>benzene:</i> • electrophilic • substitution; • maintains delocalisation <u>Examiner's Comments</u> This was the first of the two Level of Response questions on this paper. Many candidates struggled to score more than 4 marks on this question, with lower ability candidates often achieving Level 1 and a maximum of 2 marks. The most common issues in this question were the fact that candidates did not identify that the focus of the question was on the nature of the reactions rather than on the mechanism of the reactions. Consequently there were a lot of responses that gave detailed accounts on the general mechanisms of

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			electrophilic addition in alkenes, or electrophilic substitution in arenes without giving reference to the specific reaction conditions or products. Where candidates did address the reactions in the question they often did not state the type of reaction correctly, or identified the reaction incorrectly (e.g. as being nucleophilic rather than electrophilic). The only other common omission in candidates' responses was failing to name the products of the reactions either within the text, or by use of appropriate equations/formulae which would have been perfectly acceptable methods. Exemplar 3 *Benzene contains delocalised electrons which make it a very stable molecule. This means it undergoes only electrophilic substitution reactions so that delocalised electrons & structure aren't disrupted. Benzene if heated under reflux with a catalyst (FeBr₃) undergoes a substitution reaction in which bromobenzene & HBr are formed. In this way delocalised electrons do not react. Cyclohexene has it has only one C=C reacts with Br₂ with an electrophilic addition (at room temperature) in which the C=C breaks down so that 1,2-dibromocyclohexane can be formed. This happens because cyclohexene does not have delocalised electrons & Br₂ reacts only where the C=C bond is present. A clear succinct response, which addresses the Level 3 descriptor fully, scoring 6 marks.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 4 Cyclohexene reacts with bromine by an addition reaction. Both bromine reacts with bromine in a substitution reaction. This is because addition would break the delocalised electron system resulting in the products being less stable than bromine. Cyclohexene reacts with bromine by electrophilic addition. A δ^+ Bromine acts as an electrophile in an π bond dipole forms. The δ^+ approaches the double bond. This is because bonds to the δ^+ breaking the double bond and forming a carbocation. The Br^- then bonds to the C^+ by donating a pair of electrons to it. This forms bromocyclohexane. To preserve the delocalisation, bromine reacts with bromine by electrophilic substitution. The Br^+ bonds to the benzene ring by accepting a pair of electrons from the reaction. The delocalisation then breaks the delocalisation and results in an overall charge. To reform the delocalised π system. π Extra paper [6] 2.2 ii ring of electrons the H atom attached to the C the Bromine is also attached to donate as electrons and so the C-H bond breaks. ~~substitution reaction - bromine cyclohexane~~ 1.2 only 1. Br$^+$ reacts in the reaction with bromine. Both 2 are in the reaction with cyclohexene. Also an additional product HBr is formed in the reaction with benzene.

L2 response scoring 4 marks, as both reaction types have been identified and products given via equations. To progress to L3 the candidate would have needed to include the reactants and reaction conditions for both reactions

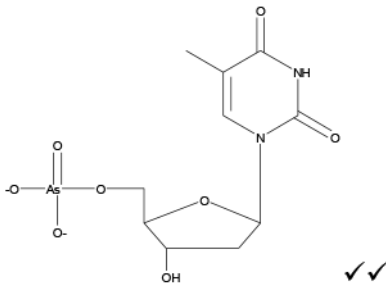
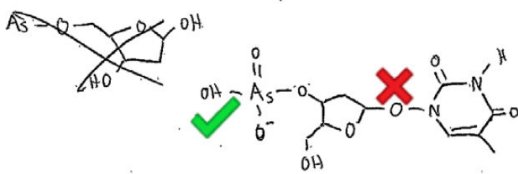
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 5 Cyclohexene undergoes electrophilic addition, whereas benzene undergoes electrophilic substitution. With cyclohexene, bromine molecules gain ~~an~~ a dipole as electrons in the bond repel from those in the C=C double bond. The slightly positive bromine then accepts electrons from the C=C bond, leaving a negative bromine to donate electrons forming another bond. In benzene, a bromine nucleophile is produced instead, as a positive bromine ion. This accepts electrons from the delocalised ring in benzene, replacing a hydrogen which donates electrons to the ring and leaves as an H⁺ ion. The reason for different reactions is that the delocalised electron rings of benzene give it high stability, whereas the single double bond of cyclohexene means it's not as stable. Therefore, more energy is required to break the delocalised ring of benzene in order to add groups, therefore it's less likely to occur so substitution happens instead. L1 response scoring 2 marks. The candidate identifies both reaction types but gives an explanation only in terms of mechanism involved. Does not address any of the criteria in AO2.1 for either reaction so cannot progress beyond Level1
			Total	23	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
50	a		will not allow formation of S-S bonds	1	ALLOW idea that As interferes with sulfur bridges / S-S bonds in the protein Examiner's Comments Question 5 required that centres had given candidates time and opportunity to study the pre-release article "The Strange Story of Napoleon's Wallpaper". It was anticipated that teachers would have spent some time discussing some of the chemistry within the article. The focus of the article should have prompted teachers to guide candidates towards looking at the properties and reactivity of Group V elements, nitrogen and phosphorous. These could be used to predict some of the reactions and properties of arsenic by extending the group trend(s). In part (a) most candidates recognised that the removal of the –SH groups would interfere with the ability of the protein to form the correct tertiary structure. However, to score the mark here they had to make it clear that the arsenic was preventing the formation of S—S bonds (disulfide bridges). It was pleasing to see that in the vast majority of responses that this was the answer given.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b		2	ALLOW arsenate group partially, or fully protonated bonded to either OH group on the ribose ring for 2 marks Correct structure with one error scores 1 mark <u>Examiner's Comments</u> In part (b) candidates needed to make use of the relevant section from the Data Sheet provided. They needed to select the appropriate sugar structure (deoxyribose) and derive the structure of thymine. Finally they needed to substitute As for P in the phosphate group and then join the fragments together in order to produce the correct structure. Many candidates succeeded in this and scored both of the marks available. The two most commonly seen errors were the inclusion of a bridging O atom between the thymine molecule and the deoxyribose ring, or the omission of the C=C within the thymine structure. Exemplar 11  Exemplar response showing the incorrect depiction of a bridging O between thymine and the deoxyribose ring

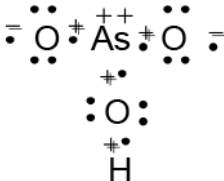
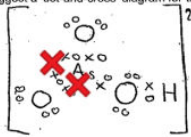
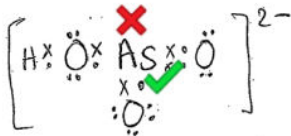
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		$2\text{As}^{3+}(\text{aq}) + 3\text{H}_2\text{S}(\text{g})/(\text{aq}) \rightarrow \text{As}_2\text{S}_3(\text{s}) + 6\text{H}^+(\text{aq})$ balanced equation ✓ Correct state symbol for As_2S_3 ✓	2	<u>Examiner's Comments</u> This was found difficult by candidates, with. Most candidates did not realise the need to balance the charges within the equation and so gave $3\text{H}_2(\text{g})$ as a product rather than $6\text{H}^+(\text{aq})$, losing 1 mark. Many gave the formula of $\text{As}_2\text{S}_3(\text{s})$ in an unbalanced equation, and this was allowed for 1 mark.
	d	i	generating flask containing zinc, sulfuric acid and As_2O_3 ✓ heated tube leaving flask ✓ silvery-black film / Arsenic (metal) labelled ✓	3	ALLOW 'sample' for As_2O_3 IGNORE closed tube <u>Examiner's Comments</u> This was a well answered question and most candidates scored full marks. There were some examples of apparatus that, whilst being impractical or potentially dangerous, did match to the description given in the pre-release material. The marks were not for designing something that would meet today's Health and Safety requirements, but for recognising candidates' ability to extrapolate a description into a suitable diagram of a set up that might work. Therefore sealed tubes, or open tubes with hydrogen escaping near a naked flame, did not result in the loss of any marks. The only common error evident was in failing to label the apparatus appropriately (e.g. failing to label where the arsenic metal would be deposited, or failing to label the heating of the glass tube leaving the reaction flask) Marks were lost through carelessness rather than an inability to produce a suitable diagram..

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\text{As}_2\text{O}_3 + 6\text{H}_2 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} \checkmark$ $2\text{AsH}_3 \rightarrow 2\text{As} + 3\text{H}_2 \checkmark$	2	ALLOW $\text{As}_2\text{O}_3 + 6\text{Zn} + 6\text{H}_2\text{SO}_4 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} + 6\text{ZnSO}_4$ for equation 1 IGNORE state symbols <u>Examiner's Comments</u> Many candidates did not write a balanced equation for the formation of arsine in the reaction vessel, but were able to write a balanced equation for the decomposition of arsine to form arsenic and hydrogen as the products and so scored 1 mark here. In the first equation a common error that was observed was the inclusion of oxygen gas, O_2, as one of the products of an otherwise balanced equation, which resulted in the mark not being credited.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
e i	 8 electrons around As atom ✓ completely correct including lone pair on As ✓	2	ALLOW 'spare' electrons on oxygen as different symbol or the same as others on that oxygen IGNORE overall charge of 2- Examiner's Comments A number of candidates identified the anion present in <i>Scheele's Green</i>, but were unable to then draw the appropriate dot and cross diagram. The most common errors were to produce diagrams containing double bonds to one or more oxygen atom giving ten or more electrons around the central As atom, failing to include a lone pair of electrons on the As atom, and failing to check that each oxygen atom satisfied the octet rule. Exemplar 12 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  Commonly seen incorrect dot and cross diagram for bonding of Scheele's Green anion. Exemplar 13 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  No lone pair on central As atom, but each atom has its full complement of electrons around its outer shell arrived at by drawing a double bond to one of the oxygen atoms.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Cu^{2+} (ion) ✓	1	ALLOW Copper(II) / copper ion <u>Examiner's Comments</u> Most candidates scored this mark as they recognised that coloured substances usually contain a transition metal ion, and so gave Cu^{2+} or copper(II) as their answer. The only common errors were the omission of the charge on the ion, or the omission of the oxidation state after the name of the element.
	f		107.5 (°) ✓ Four pairs of electrons (around As) ✓ Repel and get as far away as possible / move apart to minimise repulsion ✓ Lone pair : bond pair repulsion > bond pair : bond pair repulsion / lone pair repels more (than bond pair) / lone pair takes up more room (AW) ✓	4	ALLOW 107 – 108 ALLOW 'areas of electron density'/'groups of electrons' for 'pairs of electrons' / 3 bonding pairs AND 1 lone pair must be clear that it is electrons repelling to score third mark <u>Examiner's Comments</u> Most candidates scored at least three marks here, and many went on to score all four marks. The only common omission was in failing to make it clear that the lone pair of electrons present on the central arsenic atom had a stronger repulsion on the bonding pairs of electrons and that this produced the bond angle of 107.5°.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	g		Any three from: arsenic found in Napoleon's hair ✓ wallpaper (might have) contained arsenic /contained Scheele's Green ✓ Dampness / mould on the wallpaper released toxic arsenic vapours ✓ wallpaper poisoned others ✓	3	ALLOW (wallpaper) linked to Gosio's Disease <u>Examiner's Comments</u> Most of the candidates were able to provide a response here that scored two if not all three marks. They had clearly studied the pre-release material appropriately and were able to summarise the three key pieces of evidence accurately. Where candidates only scored two marks was often a result of omitting marking point 1 – that traces of arsenic were found in the sample of Napoleon's hair. Most candidates made the link between the Scheele's Green pigment found in the wall paper sample, and that the island environment would have caused the paper to become mouldy. This would then result in releasing toxic arsenic compounds as a vapour that Napoleon would have been exposed to over a period of time.
			Total	20	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
51	a		FIRST CHECK ANSWER ON ANSWER LINE If answer = 39(%) award 2 marks M_r values $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$ 138.3 and $3\text{H}_2\text{O}$ 54 ✓ % loss = $5400/138.3 = 39(\%)$ ✓	2	If answer rounds to 39(%) award 2 marks ALLOW ecf from incorrect calculation of M_r values ALLOW calculation of $\text{MgCO}_3/$ $\text{MgCO}_3 \cdot 3\text{H}_2\text{O} = 61\%$ (% retained) for 1 mark <u>Examiner's Comments</u> This question required candidates to use the information from the stem of the question to identify that when the salt was heated, the loss in mass was due to water being evaporated. Using the information provided they should have calculated the M_r for the hydrated salt, and then the M_r for the moles of water lost. Using these two values they should then have derived the percentage loss in mass. Many candidates calculated the M_r of the hydrated salt correctly, but then calculated the mass of 3 moles of water and subtracted this from the mass of the hydrated salt. This gave them a figure of 84.3 which they then used in their calculation, arriving at the incorrect figure of 61% for the loss in mass. These responses did score 1 mark for the error carried forward (ecf) from the incorrect calculation of M_r values.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	FIRST CHECK ANSWER ON ANSWER LINE If answer = 0.69 (g) award 3 marks (rearranges ideal gas equation) $n = PV/RT$ ✓ (substitution of values into rearranged equation) $n = 99000 \times 200 \times 10^{-6} / 8.314 \times 290 (= 8.212 \times 10^{-3} \text{ mol})$ ✓ (Uses $m = n \times M_r$ to calculate mass of Magnesium Carbonate) mass = $(84.3 \times 8.212 \times 10^{-3}) = 0.69(2\dots)$ (g) ✓	3	ALLOW ecf (If gas equation is inverted and values substituted correctly and evaluated the answer arrived at is 10265, award 2 marks) (If final answer rounds to 690(g) award 2 marks as candidate has failed to convert 200cm^3 correctly but has done everything else appropriately) <u>Examiner's Comments</u> This was the first question where candidates were required to carry out a multi-step calculation. It required them to rearrange a familiar equation, and then to convert the data provided into the required standard units. Whilst many candidates were able to carry out the first part of the task, there were many examples of candidates struggling with the conversion of units, particularly from cm^3 to m^3 for the volume of gas. In this instance credit was allowed where the candidate had rearranged the ideal gas equation correctly and had then used the correct equation to calculate the required mass of magnesium carbonate from their incorrectly calculated number of moles. Exemplar 1 $\text{Mg} \rightarrow \text{MgCO}_3$ $\text{MgCO}_3 \rightarrow \text{MgCO}_2$ What mass of MgCO_3 should they heat? $PV = nRT$ $n = \frac{PV}{RT}$ $n = 8.212 \text{ moles.}$ $M_r = 84.3$ $n = \frac{99 \times 10^3 \times 0.2}{8.314 \times 290}$ mass of $\text{MgCO}_3 = 692 \text{ g [3]}$ Example of the most common incorrect final answer, as a result of failing to convert 200cm^3 correctly.
		Total	5	

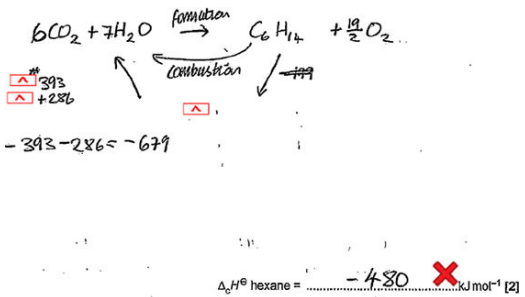
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
52	a		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 63(%) or rounds to 63.0(%) award 3 marks Moles of $C_{12}H_{26} = 1.5 \times 10^6 / 170 (=8.824 \times 10^3) \checkmark$ Expected yield of $C_6H_{12} = 8.824 \times 10^3 \times 86 (=7.589 \times 10^5 \text{ g or } 758.9 \text{ kg}) \checkmark$ % yield = $478 \times 100 / 758.9 = 63.0(\%)$ (2 or more sf) $\checkmark$	3	ALLOW alternative method: Moles of hexane = $478000 / 86 = (5.558 \times 10^3) \checkmark$ % yield = $5.558 \times 10^3 \times 100 / 8.824 \times 10^3 = 63.0 \checkmark$ A correctly rounded answer to 1sf scores 1 If units incorrectly converted ALLOW ECF for second mark <u>Examiner's Comments</u> It was good to see a number of completely correct responses, but also a significant number that had just used masses, not moles. Most were able to convert the units successfully.
	b	i	Set up: burning fuel under a container of water OR measure the temperature <u>increase</u> of water $\checkmark$	1	<u>Examiner's Comments</u> In these questions we wanted the idea of heating water with hexane for the first part which was well done. In part (ii) however we wanted the idea of $E=mc\Delta T$ for the energy transferred and then dividing by the number of moles for ΔH, including how the moles would be calculated, which was often not included. In part (iii) there were many possible improvements to the experimental procedure that were acceptable, nevertheless unacceptable answers were quite often given as seen in Exemplar 1.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 1 Measure the temperature rise of a known volume of water using a thermometer when a known amount of liquid fuel is burnt.  [1] (ii) Show how the result would be calculated from the measurements made when carrying out the experiment in part (b)(i). Q = mcΔT, calculate energy (in joules) given by 1000 and divide by the mass of fuel burnt to get energy in kJ/mol [1] 1. Place the water in a calorimeter (polystyrene cup)  to prevent heat loss 2. Use a digital thermometer to measure temperature change [2] In this answer the candidate does not say how the number of moles of fuel would be calculated in part (ii) and they have chosen inappropriate suggestions for improvements; the idea of a polystyrene cup was frequently seen, as were more precise forms of equipment such as balances, digital thermometers or pipettes to measure water. Doing the experiment under standard conditions was also seen.
ii	Find energy transferred to water using $Q = mc\Delta T$. AND Find energy that would be transferred per mole of fuel. ✓	1	Must make a comment about how the moles are obtained (i.e. using the mass of fuel burnt)
iii	Any two from: Have a lid on the container of water to reduce heat loss/stop water evaporating ✓ Use draught excluders OR insulate sides of calorimeter ✓ Allow enough air/oxygen to reach flame to minimise incomplete combustion OR Move burner closer to calorimeter ✓ Cover the wick of the burner when it is not in use to reduce evaporation of the fuel ✓ Use a bomb calorimeter ✓ Use copper calorimeter instead of beaker ✓ Make sure thermometer is not in contact with bottom of beaker ✓ Stir to improve heat distribution ✓	2	ALLOW well ventilated

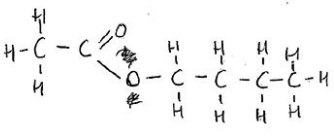
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
c	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $-14161 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks $\Delta_c H^\ominus \text{ hexane} = (6 \times -393) + (7 \times -286) - (-199)$ (expression must be correct) OR shown on an appropriate cycle ✓ $-4161 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	ALLOW ECF from incorrect cycle as long as some working is shown ALLOW -4160 (3sf based on question data) $2358 + 2002 - -199 = -4161$ -480 and a cycle scores 1 (+) 4161 scores 1 Examiner's Comments It was good to see so many perfectly correct answers here. Of those not getting full marks, the cycles were not clear enough to award 1 mark. Exemplar 2  $\Delta_c H^\ominus \text{ hexane} = -480 \text{ kJ mol}^{-1} [2]$ In this answer the value of -480 cannot be given 1 mark as the cycle is incomplete.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
d	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Deduces correct structure with detailed evidence referring to all three spectra. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Deduces correct structure using some evidence. OR Deduces compound A is an ester with evidence from at least two spectra. OR Gives detailed analysis of three spectra while failing to determine the structure of compound A. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Gives some evidence from two spectra. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	6	Indicative scientific points may include: Infrared spectrum: C=O as strong absorbance at approx 1750 cm^{-1} No O–H from carboxylic acid or alcohol C–H at approx. 2950 cm^{-1} possibly ester NMR: 5 proton environments as 5 peaks $\delta = 0.9, 1.1, 1.6$ H–CR. $\delta = 2.3$ HC–C=O $\delta = 4.0$ HC–O Splitting: 0.9, 1.1 and 4.0 triplets so 2 protons attached to adjacent C/ $\text{CH}_3\text{--CH}_2$ 2.3 quartet so 3 protons attached to adjacent C/ $\text{CH}_2\text{--CH}_3$ 1.6 multiplet, several protons attached to adjacent C, possibly $\text{CH}_3\text{CH}_2\text{CH}_2$ Mass Spectrum: Mol mass is 116 Extra detail Sensible discussion of at least 1 fragment e.g. peak at 87 loss of CH_3CH_2 or peak at 73 loss of $\text{CH}_3\text{CH}_2\text{CH}_2$ or peak at 57 due to $\text{CH}_3\text{CH}_2\text{C=O}^+$ OR $116 - 6\text{C} = 44$ (2O) possibly ester Structure is Examiner's Comments A significant number of candidates gave a Level 3 answer and an impressive number had the structure completely correct. An even greater number knew it was an ester. Of the lower scoring candidates, the C–H absorbance was wrongly attributed to O–H, and there were also suggestions of arenes not borne out by the spectroscopic data or the fact that it can be made from propene.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 8 The IR shows no O-H peak due to the lack of a broad peak at 3000 but a less broad peak shows C-H from alkanes are present. The peak 1700 shows a C=O is present and at 1750 shows an ester C=O is present. The ¹H NMR peak at 4.0 ppm shows there is 2 H on the carbon to the H-C=O of the ester. The multiplet H-C-R suggests a methyl CH₃ at the end of chain and the along side with the different shift shows the different hydrogen environments. The Quartet peak at 2.0 ppm shows 3 hydrogens on the carbon adjacent to the CH=O making it a methyl alkyl ester group. The Mass spec gives the Mr of 116 which when 6 carbons are known each have 12 Hydrogen and 2 oxygens present. Structure of compound A  [5] This candidate has correctly identified all the absorbances on the infra-red spectrum and did not confuse the C-H absorbance with O-H as some did. They have used the molecular ion peak on the mass spectrum with other data to get the molecular formula, although they have not considered the fragments. They have correctly identified the chemical shifts of protons next to the ester group and made an attempt at interpreting the splitting. They have deduced the structure is that of an ester, but they have not quite used the splitting pattern and the fact that it could be made from propene to get the correct ester. This response was therefore judged to be at Level 2, and credited 4 marks.
	Total	15	

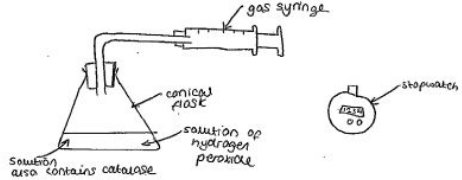
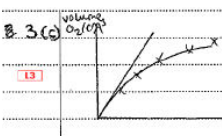
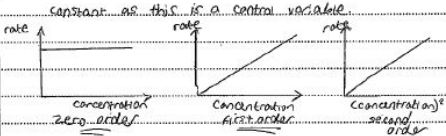
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
53	a	<i>Please refer to the marking instructions on page 6 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5 – 6 marks) Detailed procedure with most key variables identified and includes some relevant fine detail (may or may not include a diagram). AND Explains clearly how to process results. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Workable procedure with some variables identified may include some relevant fine detail (may or may not include a diagram). AND Attempts to explain how to process results. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Outline of procedure with some variables given (may or may not include a diagram). OR Attempts to explain how to process results. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 <i>No response or no response worthy of credit.</i>	6	Indicative scientific points include: AO3.3 Development of a practical procedure by analysing information <i>Key variables may include:</i> • flask with peroxide; • same volume of peroxide solutions • keep concentration (and volume) of catalase • constant • vary peroxide concentration; • volume of oxygen measured in gas syringe or • over water; <i>Fine detail may include:</i> • means of adding catalase / starting reaction; • time for certain volume of oxygen to be produced • record volume of oxygen produced at fixed time • intervals • suitable apparatus for measuring volumes of solutions • suggests appropriate volume of gas to be collected • suggests appropriate time intervals for measuring volume of gas AO3.1 Processing results <i>Makes reference to</i> (plots) graph of volume of oxygen produced • against time; • measures slope at the origin / time $t = 0$; • rate proportional to $1/\text{time}$ for a small volume of • oxygen to be produced • uses $\text{rate} = \text{vol of oxygen}/\text{time}$ • use of smallest rate value to calculate relative • rates NB: Some of the above indicative science may be addressed as part of a labelled

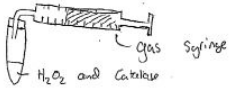
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Question			Answer/Indicative content	Marks	Guidance
					diagram – accept any relevant diagram even if poorly drawn. Allow sketch graph labelled as evidence of method used to process experimental data collected. <u>Examiner's Comments</u> This Level of Response question was well tackled by the vast majority of candidates. Most candidates scored at Level 2, with higher ability candidates regularly scoring at Level 3. There were two strands to this question that candidates needed to address; (i) designing a suitable procedure giving essential details (including some relevant fine detail), and (ii) explaining how they would process the data that they had collected. This is a practical procedure that candidates should be familiar with. Candidates should be able to describe a suitable workable method for this reaction, and indeed this was often the case. Many candidates produced diagrams of the apparatus which were a good indicator that their response was likely to be at least at Level 2 in the first strand. The second strand of this question provided an element of discrimination. Candidates were required to explain how they would process their results; some produced outlines of the graphs that they would plot indicating the tangent to be drawn, which again gave examiners a quick idea of what the appropriate level was likely to be. However, whilst many knew that they needed to produce a graph, they often suggested using a concentration vs rate graph, which was incorrect within the context of this question. This often meant that candidates who had produced a very detailed method were limited to Level 2 as the processing strand was weak. Where candidates did not address one of the strands within their response,

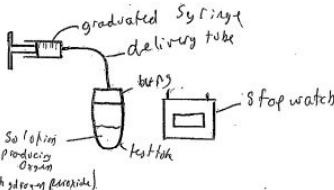
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			unfortunately this resulted in them being limited to Level 1. Exemplar 6  Known • Measure out equal volumes of different concentrations of hydrogen peroxide solution (eg. 25.0 cm³) using a burette or volumetric pipette. A clean, dry pipette can be used to run the solution into a clean conical flask. • Add a fixed volume of enzyme ~~catalase~~ catalase solution to the conical flask, stopper the flask and start the stop watch. The conical flask should be connected to a gas syringe to collect the oxygen gas formed. • At equal time intervals (eg. every 10 seconds) measure the volume of oxygen in the gas syringe to the nearest 0.05 cm³. • Keep doing this for 2 minutes, or until no more gas is produced. Repeat this procedure for all different concentrations of hydrogen peroxide. • Record results in a table of volume of oxygen (cm³) against time (s) and use this to plot a graph of volume of oxygen against time. * Please see back page for the rest *  Draw a line of best fit. Draw a tangent to the curve at time $t=0$ and use the gradient to work out the initial rate of reaction. Then plot a graph of initial rate (y-axis) against concentration of hydrogen peroxide. This will tell you the rate of reaction with H_2O_2. The amount of catalase needs to be kept constant as this is a control variable.  rate concentration zero order concentration first order concentration second order Level 3 response, scoring 6 marks. This includes all key variables, and a significant amount of fine detail, explaining clearly how to process the results collected. The answer continues onto additional space of answer booklet. Whilst this was a Level 3 response, the candidate could have made their answer more succinct. Candidates are advised that

Mark Scheme

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			the answer space provided should be sufficient to gain full marks for Level of Response questions, without needing to continue onto the additional answer space. In this case, the candidate could have omitted the superfluous discussion and diagrams of rate-concentration graphs they have included at the end of their response. The suggested procedure could also have been written more concisely whilst retaining sufficient detail to receive full credit. Exemplar 7  The student will firstly produce equal moles of Catalase and H_2O_2 and the same concentration of Catalase. They will be used. Produce at least 5 different H_2O_2 concentrations. The student will measure the volume of gas being produced for each different concentration of H_2O_2 for a set interval of time (2 mins) using a stopwatch. This means for each concentration of H_2O_2 you will know the volume of O_2 produced by the recordings of the gas syringe after the set time of 20 minutes. Repeat the procedure 10 times for each H_2O_2 concentration. The student can plot a graph of ~~concentration~~ volume of H_2O_2 produced vs time (x-axis). Next plot the volume of H_2O_2 concentration. Draw a line of best fit for each of the graphs produced for each H_2O_2 concentration. Next produce a tangent at $t=0$ for each H_2O_2 concentration graph and calculate gradient of tangents ($\frac{\Delta y}{\Delta x}$) and they will know the initial rate of reactions for each H_2O_2 concentration. Level 2 response, scoring 4 marks. A workable procedure is outlined, but lacks fine detail which would have allowed the candidate to progress to Level 3. Good explanation of processing of results.

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					Exemplar 8  Method 1) Place a known volume of hydrogen peroxide in the test tube. Add the catalyst. Start the timer and place the bung in the top of the test tube. 2) Record how long 50 cm³ of oxygen takes to be produced. Record the final time. 3) Repeat 3 times with the same volume. 4) Increase volume of hydrogen peroxide by 10 cm³ and repeat for 6 results. Process Results - 50 of oxygen = 1 cm³ - Find moles of O₂ produced with $n = \frac{p}{RT}$ - 1:2 ratio. ~~double~~ the n_a for moles of H₂O₂ - $n = cV$ - concentration of hydrogen peroxide = $\frac{\text{moles}}{\text{Volume}}$ Level 1 response scoring 2 marks. Provides an outline of a method that might work but makes no reference to the use of time to calculate a rate value.																
	b	i	<table><tr><th>[H₂O₂]/ mol dm⁻³</th><th>(relative) rate</th></tr><tr><td>0.05</td><td>1.0</td></tr><tr><td>0.10</td><td>2.1</td></tr><tr><td>0.15</td><td>3.0</td></tr><tr><td>0.20</td><td>3.8</td></tr><tr><td>0.25</td><td>4.0</td></tr><tr><td>0.30</td><td>4.1</td></tr><tr><td>0.35</td><td>4.1</td></tr></table>	[H ₂ O ₂]/ mol dm ⁻³	(relative) rate	0.05	1.0	0.10	2.1	0.15	3.0	0.20	3.8	0.25	4.0	0.30	4.1	0.35	4.1	2	First mark for labelled columns (or rows). ALLOW 'concentration of H₂O₂' for [H₂O₂], Evidence of units required for Hydrogen peroxide. Accept 'au/arb' for relative rate but no other units allowed. Other units = CON Second mark for correct values, all concentration values to 2 dp, rate values to 1dp. IGNORE inclusion of temperature
[H ₂ O ₂]/ mol dm ⁻³	(relative) rate																				
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0.30	4.1																				
0.35	4.1																				

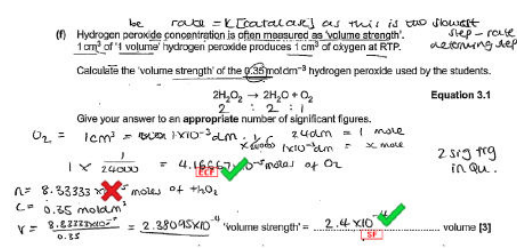
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		ii	labelled axes (ignore units) with rate as y-axis✓ plot points correctly✓ draws best fit line ✓ (must go through the origin) each scale chosen to take up more than half axis ✓	4	ALLOW +/- ½ small square Line should pass through at least 5 points / pass within 1 small square of their plotted points <u>Examiner's Comments</u> This question was generally well answered, with most candidates scoring at least 4 marks, and many scoring the full 6 marks. The only common errors were in part (i) the inclusion of some units for the rate of reaction column, and in (ii) reversing the x and y axis. Some candidates did lose one mark in part (ii) for failing to choose an appropriate scale to use that should have taken up a minimum of half the space available.
	c	i	Rate = $k[\text{H}_2\text{O}_2]$ ✓ [catalase] ✓ $\text{dm}_3 \text{ mol}^{-1} \text{ s}^{-1}$ ✓	2	ALLOW [enzyme] for [catalase], (must have 'rate =' at start of their expression) ALLOW units in any order <u>Examiner's Comments</u> This was a tricky question for many candidates. Most struggled to work out the units for the rate constant. The only other common error was the omission of "rate =" at the start of the rate equation.

Mark Scheme

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		ii	peroxide: first order initially ✓ then zero order ✓ catalase: no evidence since concentration not changed (AW)✓	3	ALLOW concentration of catalase kept constant <u>Examiner's Comments</u> There were a lot of varied responses to this question. The majority of candidates scored at least one mark, but very few scored all three. Many candidates used the graph in d(ii) to state that 'up to 0.2mol dm^{-3} (or, at low concentration) the reaction is first order with respect to hydrogen peroxide as the graph is a straight line'. Some also scored a second mark for realising that when the graph levelled off the rate became zero order as no matter how the concentration of peroxide changed, there was no further change in rate. They then tended to link this to the idea of the active sites being saturated. Very few candidates identified that the statement was incorrect with regard to catalase as the catalase concentration was kept constant in this reaction.
	d		FIRST CHECK ANSWER ON ANSWER LINE If answer = 4.2 award 3 marks $(0.35/2 =) 0.175$ mol oxygen per dm^3 peroxide ✓ volume strength $(= 24 \times 0.175) = 4.2$ ✓ answer to 2sf ✓	3	If answer = 8.4 award 2 marks for candidate failing to convert 0.35 to 0.175 ALLOW ecf from incorrect calculation of number of moles Any calculated value to 2sf scores 1 mark. <u>Examiner's Comments</u> This question was a good discriminator , producing a full range of marks from 3 to 0. Lower ability candidates often struggled to score any marks here. Higher ability candidates also found this challenging. The most common mark was credited for

Mark Scheme

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					identifying that the molar ratio between the peroxide and oxygen was 2:1, and so the moles of O₂ should be 0.175 (or 1.75×10^{-4} if converted from dm³ to cm³). Where candidates subsequently lost marks was in the next step for not realising that because oxygen is a gas, they needed to multiply their calculated number of moles by 24(dm³) or 24000(cm³) to then arrive at the final answer. This question included a mark that was for displaying their working, in order that where a candidate had not spotted the molar ratio, or had calculated the number of moles of oxygen by a different method, then examiners could award a mark for the use of '× 24 (or 24,000)' as an error carried forward with the final mark being for converting their calculated value to 2 significant figures. A candidate who simply gave an incorrect final answer to this question scored 0, whereas candidates who did not arrive at the correct final answer but had displayed their working often scored 2 marks. Exemplar 9  Calculation showing working being given credit, even though final answer is incorrect.
	e		FIRST CHECK ANSWER ON ANSWER LINE If answer = 120 (cm³) award 2 marks (total volume =) $20 \times 0.35/0.05$ OR 140 (cm³) ✓ volume to add = 120 (cm³) ✓	2	ALLOW 140(cm³) even on the answer line for 1 mark Examiner's Comments Generally well answered. Most candidates scored at least one mark for arriving at an answer of 140 cm³, as they did not subtract the initial 20 cm³ of peroxide solution.
			Total	22	

Mark Scheme

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54			A	1 AO 1.1	<u>Examiner's Comments</u> This was a testing question and most candidates correctly identified A as the correct answer, although a significant number chose D as it fitted the general formula for alkanes but had the incorrect name.
			Total	1	
55			D	1 AO 2.2	<u>Examiner's Comments</u> There was clear evidence of candidates showing their working above the equations in many answers, leading to a large number of correct answers.
			Total	1	
56			A	1 AO 2.8	<u>Examiner's Comments</u> To answer this question correctly required spotting that HC/ was the limiting reagent and getting the ratio of moles correct. It proved difficult.
			Total	1	
57			B	1 AO 2.2	<u>Examiner's Comments</u> This question was intended as a stretch and challenge question and on that basis many candidates did well. Candidates realised A was not the answer as it was an equilibrium and many got the ratios of SO₂ and O₂ used, but not always the correct volume of product (C rather than B).
			Total	1	

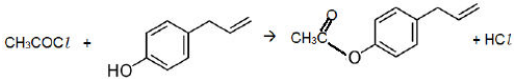
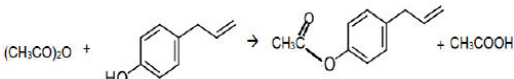
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
58	a	i	FIRST CHECK ANSWER ON ANSWER LINE If answer = 7.8×10^{-4} (mol) award 2 marks Use of $n = PV/RT$ ✓ $n = (1100 \times 1.5 \times 10^{-3}) / (8.314 \times 253) = 7.84 \times 10^{-4}$ (mol) ✓	2 AO 2.6 x 2	ALLOW 2 or more sf <u>Examiner's Comments</u> Unit conversions are usually a difficulty with questions of this type, and it was pleasing to see so many fully correct answers.
		ii	FIRST CHECK ANSWER ON ANSWER LINE If answer is 20 (cm³) award 2 marks Use of $V = nRT/P$ ✓ Ans to (d)(i) $\times 8.314 \times 298/97 \times 10^3 = 2.00 \times 10^{-5} \text{ m}^3 = 20(\text{cm}^3)$ (2sf) ✓	2 AO 2.6 x 2	Allow ECF from (i) Mp2 is only scored if answer is given to 2sf <u>Examiner's Comments</u> Unit conversions created difficulties for some candidates here, as did deciding on the correct number of significant figures.
	b	i	Oxygen and nitrogen from the air ✓ react in the high temp in engine ✓	2 AO 1.1	ALLOW 'heat' for high temperature IGNORE 'pressure' <u>Examiner's Comments</u> This is a question that has not been asked for a number of years. Candidates did not always make it clear that the nitrogen and oxygen had come from the atmosphere.
		ii	Brown (gas) ✓	1 AO 1.1	ALLOW 'goes brown' (AW) <u>Examiner's Comments</u> A significant number of candidates knew that nitrogen dioxide was a brown gas. Some had the colour change the wrong way round and some answers were vague, such as 'smog'.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
59	a		FIRST CHECK ANSWER ON ANSWER LINE If answer = $-1273.3 \text{ (kJmol}^{-1}\text{)}$ award 3 marks Correct multiplication of ΔH_f values ✓ $6(-285.8) + x - 6(-393.5) - 12(-20.6) = -379.9$ OR $x = -379.9 + 6(285.8) - 6(393.5) - 12(20.6)$ ✓ Evaluation with sign ✓	3 AO 2.6 x 3	Mp1 $6(-285.8) = -1714.8$ AND $6(-393.5) = -2361$ $12(-20.6) = -247.2$ OR $-2361 + -247.2 = -2608.2$ Mp2 Correct expression of correct ΔH values -893.4 scores 2 (no use of ΔH_f) (+)1273.3 scores 2 (Incorrect sign) (+) 839.4 scores 1 <u>Examiner's Comments</u> Many candidates scored the full 3 marks for this question even though there are many ways to make a mistake. The work was often well set out, so it was easy to give credit for correct parts. The most common sources of error were not using the overall enthalpy change or getting the incorrect sign for some of the terms.
	b		$1s^2 2s^2 2p^6 3s^2 3p^6$ ✓	1 AO 1.1	[Ne]... or [Ar] score 0. e numbers must be superscript and shell designation must be lower case. <u>Examiner's Comments</u> Almost half the candidates did not get this mark, despite a chloride ion being a relatively straightforward configuration. There were some instances of subscripts or upper-case letters, but the most common errors were giving the configuration of the atom, having not read the question carefully, or removing an electron from chlorine rather than adding one.
			Total	4	

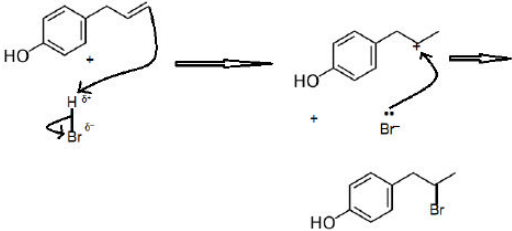
Mark Scheme

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60	a		Orange/brown to colourless ✓	1 AO 1.1	IGNORE yellow
	b		Contains a benzene ring ✓	1 AO 1.1	ALLOW arene, IGNORE phenol NOT conjugated/delocalised ring/cyclic system without further qualification Hydrocarbon is a CON Examiner's Comments This was well answered, although some answers lacked clarity, such as 'delocalised electrons' or 'cyclic rings'.
	c	i	H₂, Ni 'heat and pressure' (or specified sensible values) OR H₂, Pt, room temp ✓	1 AO 1.1	ALLOW Ni/Pt as reagent or conditions Any other reagent is a CON Examiner's Comments This was a question where knowledge of factual details of organic reactions was not always strong enough. Many candidates gave the nickel catalyst but omitted the reagent, hydrogen.
		ii	Use of ethanoyl chloride or ethanoic anhydride ✓ Rest of equation correct ✓  ✓ OR  ✓	2 AO 2.7 x 2	If ethanoic acid is used SCORE 0 ALLOW any unambiguous structures Examiner's Comments Most candidates had forgotten that ethanoyl chloride or ethanoic anhydride were the reagents needed to esterify a phenol. Many of those who did remember used generic acyl chlorides or forgot the HCl or ethanoic acid product.

Mark Scheme

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	d	i	Reagents and conditions: steam AND phosphoric acid (adsorbed onto silica) High T and P OR Conc sulfuric acid followed by water ✓ Conditions: Al₂O₃/alumina catalyst, heat. OR Conc sulfuric acid, (heat under) reflux AND Product (on equation) H₂O ✓	1 1 AO 1.2 x 3	If conc sulfuric acid is used in first reaction the water MUST clearly be added later to score mp1 Other reagents in either box is CON IGNORE pressure Check equation for product. State symbol not required but if given must be (l) or (g). (s) is CON <u>Examiner's Comments</u> This was also a low scoring question due to lack of detailed knowledge of reaction conditions studied at the beginning of the course.
		ii	The dehydration of the secondary alcohol could give the double bond either in the new position or the original position ✓ A mixture of products (AW) ✓	2 AO 3.2 x 2	IGNORE references to position of equilibrium. Clear implication that both isomers would form is required for mp2 <u>Examiner's Comments</u> This was intended to be a testing question. A significant number of candidates were able to suggest that the double bond might re-form in the original place but did not always make clear that a mixture of the two products would form.

Mark Scheme

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e i	 Both curly arrows and partial charges on HBr ✓ Intermediate and attack of Br⁻ ✓	2 AO 1.2 x 2	Curly arrows must start on the bond concerned (or the lone pair or minus sign of Br⁻). They must point to the atom concerned or the bond that is to be formed. ALLOW R- for rest of structure Lone pair is not required on Br⁻ but if not present curly arrow must start at minus sign. Product is not required but if it is shown it must be correct for mp2 A valid mechanism leading to the anti Markownikov product scores 1 <u>Examiner's Comments</u> Although many candidates scored at least 1 mark, it proved difficult for others. In some cases the arrows were in the wrong direction or unclearly drawn. Some answers had the + charge on the incorrect carbon in the intermediate leading to the wrong product or attacked with the Br^{δ-} first.

Mark Scheme

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		ii	H must add first (in either reaction) ✓ Product 1 cannot form as $H^{\delta+}$ as it is the only electrophile (ORA) ✓ Product 2 could form as Cl^- can react with the carbocation (once the $H^{\delta+}$ has reacted) ✓	3 AO 3.2 x 3	Mp1 for clear implication of electrophilic reaction involving HBr Mp2 for identifying $H^{\delta+}$ as the only electrophile OR by stating that Br^- AND H_2O (NOT OH^-) are nucleophiles / not electrophiles. (IGNORE Cl^-) IGNORE comments comparing reactivity or steric factors in halide ions for mp3 <u>Examiner's Comments</u> This was designed to be a stretching question and proved predictably difficult. This idea is studied in connection with establishing the mechanism of addition to alkenes (DFq), but with bromine and other anions and water. It was more difficult to apply the idea to addition of HBr. Many candidates could explain that product 2 could be formed by the reaction of Cl^- ions to the carbocation. Sometimes this included the irrelevant comparison of reactivity of chlorine and bromine. Candidates found it less easy to explain why product 1 could not form as it involved the addition of 2 nucleophiles (Br^- and H_2O).
			Total	14	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
61	a	$\text{C}_2\text{H}_2(\text{g}) + 2.5\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g/l})$ $\Delta_f H \text{ C}_2\text{H}_2$ $2\Delta_f H \text{ CO}_2$ $\Delta_f H \text{ H}_2\text{O} \checkmark$ $2\text{C}(\text{s}) + 2.5\text{O}_2(\text{g}) + \text{H}_2(\text{g}) \checkmark$ $\Delta_c H = 2\Delta_f H \text{ CO}_2 + \Delta_f H \text{ H}_2\text{O} - \Delta_f H \text{ C}_2\text{H}_2 \checkmark$	3(AO2.1) (AO2.1) (AO2.1)	First mark for correct elements Second mark for correct $\Delta_f H$ descriptions and top equation ALLOW $\Delta_f H \text{ 2CO}_2$ IGNORE $\Delta_f H \text{ O}_2$ Third mark for correct expression for $\Delta_c H$ <i>Allow use of definitions/symbols from enthalpy cycle</i> Examiner's Comments The evidence from this question suggests that candidates need more practice drawing Hess's cycles as part of their revision and preparation for their examination. Very few candidates scored more than one mark in this question. The most common error was the failure to include relevant state symbols for the reactants and products of the substances involved. This immediately meant that candidates could not score marking points one and two. However, even where a candidate did include state symbols, they usually did not label the reactions appropriately to indicate whether a step involved an enthalpy change of formation, or was the enthalpy change of combustion. They instead labelled the changes as $\Delta H_1, \Delta H_2$, etc. If they then used these symbols in a correct expression they could still score marking point three, which allowed most candidates to score one mark.

Mark Scheme

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b	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 1.9 (times greater) award 4 marks Equation: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ ✓ $5/0.2 = 25$ (moles 'air') ✓ 12.5 moles 'air' for acetylene ✓ $26/13.5 = 1.9$ (times greater) ✓	4 (AO2.5) (AO2.5) (AO2.6) (AO2.6)	ALLOW 3 marks if mole fraction route not used ie; Correct equation for propane ✓ Scaled equation for acetylene so that moles of O_2 are identical in both equations / acetylene needs 2.5 moles O_2 and propane needs 5 moles O_2 ✓ Ratio of acetylene to propane = 2 identified ✓ ALLOW ECF from an incorrect equation <u>Examiner's Comments</u> Very few candidates scored full marks on this question as most candidates adopted a rather simple approach to the calculation. They recognised that the fully balanced equation for the combustion of propane when compared to the fully balanced equation for the combustion of acetylene showed a simple 2:1 ratio and so often suggested that the number of acetylene molecules combusting was 2 times greater than for propane. Provided that the candidate had written down the equation for the combustion of propane and showed some evidence of using the acetylene equation then an answer of 2 times greater was given 3 marks. Exemplar 3 shows the most commonly seen response which took this approach. Exemplar 3 (Assume air contains 20% oxygen by volume.) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ $C_2H_2 + 2.5O_2 \rightarrow 2CO_2 + H_2O$ $120 dm^3$ $80 dm^3$ $20 dm^3$ $140 dm^3$ $5 \div 2.5 = 2$

Mark Scheme

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	c	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5 – 6 marks) Gives a detailed account of controlling flame temperature, small molecule reactions and competing reactions, exemplified by the use of at least one appropriate equation. <i>There is a well-developed line of reasoning which is clear and logically structured.</i> Level 2 (3 – 4 marks) Gives an outline account of controlling flame temperature, small molecule reactions and competing reactions. OR Gives a detailed account of two of the following areas, controlling flame temperature, small molecule reactions, or competing reactions <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Gives an outline account of two of the following areas, controlling flame temperature, small molecule reactions or competing reactions OR Gives a detailed account of one area <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6(AO3.1 x 6)	Indicative scientific points include: Flame temp: • saturated hydrocarbons need more oxygen per mole • fewer saturated hydrocarbon molecules in the same volume; • hence lower flame temp; • pure oxygen produces higher flame temperatures; • example comparison equations (Allow ORA for arguments in favour of unsaturated hydrocarbons) Small molecule reactions: • oxygen atoms/ molecules produce hydrogen atoms • use of appropriate equation(s), eg $\text{CH} + \text{O} \rightarrow \text{CO} + \text{H}$ or $\text{CH}_2 + \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}$ • more hydrogen atoms abstracted from growing PAH • balance entropy AW Competing reactions: • production of acetylene vs CO_2; • saturated hydrocarbons produce more CO_2; • unsaturated hydrocarbons produce acetylene; • acetylene leads to soot formation • soot formation vs CO_2 production <u>Examiner's Comments</u> The final question on the paper was the second Level of Response question. It is pleasing to note that there were very few scripts where no attempt had been made to answer this question. Even lower ability candidates who find this type of question particularly challenging made an attempt and often scored some marks at Level 1. There were however very few scripts that progressed beyond Level 2. The main

Mark Scheme

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					reason for this was that most candidates discussed the idea of flame temperature in terms of whether or not complete or incomplete combustion of the fuel had taken place. This was not a route that was deemed to be creditworthy given the context of the article and so if this was their only reason for suggesting why the flame temperature varied then it was not possible to reach to Level 3. To access Level 3 candidates needed to give a detailed account of how oxygen controls flame temperatures by reference to the concentration (percentage) of oxygen present, or to the mole ratio of oxygen required by saturated or unsaturated hydrocarbons. For example, candidates could quote that acetylene burns at 3500°C in pure oxygen but only at 2000°C in air and could state that air is only 20% oxygen. Additionally by giving reference to the number of acetylene molecules that could burn compared to for example ethane molecules they would have been at a point of being able to access Level 3. They also needed to give a detailed account about the small molecule reactions that occur that lead to the growth of PAH molecules via HACA, which many did by use of the appropriate equations contained in the article. Finally, they needed a detailed account of the competing reactions that could occur. These include production of soot from acetylene type molecules versus production of CO_2 when a higher proportion of oxygen molecules was present, or the idea that combustion of saturated molecules produces CO_2, but the combustion of unsaturated molecules leads to the production of acetylene and then to soot formation. Even where candidates had avoided the idea of complete and incomplete combustion in controlling flame temperatures they often fell into the trap of describing this as an example of the

Mark Scheme

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					competing reactions that could occur to produce either soot or CO₂, which again meant that Level 3 could not be accessed. At Level 2 it was more common to see responses where candidates had addressed all three areas but often by giving an outline of the three areas. For example, they regularly quoted that the flame temperature was dependent on the amount of oxygen present by quoting the data for acetylene burning in air and in pure oxygen. They would then describe how oxygen was needed for the small molecule reactions needed to produce hydrogen atoms required for the growth of PAH molecules, or they would quote examples of the small molecule reactions from the article. Finally they would state that there were competing reactions occurring that decided whether or not soot or CO₂ would be produced but without expanding on this any further. Candidates at this level often gave a brief outline of two areas and may have expanded into greater detail in one area which would be a secure Level 2 but was insufficient to progress to Level 3. At Level 1 many lower ability candidates accessed this by quoting the data for the flame temperature dependency for acetylene linked to pure oxygen and air, and then identified that one reaction produced soot, while another reaction produced CO₂. These responses were often contained very little detail. There were, however, a few responses where a candidate gave a detailed account of one area but did not address the other areas, possibly as a result of running out of time on the paper, but these were exceptional cases. Exemplar 4

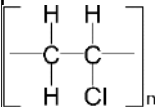
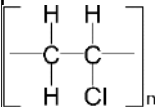
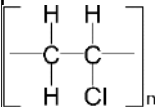
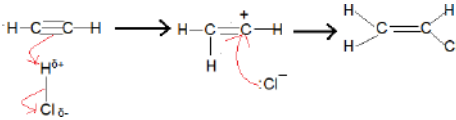
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Question			Answer/Indicative content	Marks	Guidance
					Oxygen is very important when causing small molecule reactions. Oxygen reacts with CH₄ to produce CO₂H and CH₄ to produce CO₂ and 2H₂. This is crucial in the formation of soot as hydrogen atoms are produced which are needed to help abstract H atoms from the PAHs. Oxygen is also responsible for complete or incomplete combustion. If enough oxygen is in burning, complete combustion occurs to form CO₂ and H₂O. Lack of oxygen causes incomplete combustion and the formation of C or CO and H₂O. When more fuel is exposed to less oxygen they burn with a much higher temperature than when exposed to just air (at 21% oxygen at 350°C in O₂ and 250°C in air) due to the fact air is approximately 21% oxygen. The less oxygen the lower the flame temperature. Additional answer space if required Oxygen provides two competing routes – one to oxidise the fuel to CO₂ and H₂O and the other to the formation of soot from PAHs. The rate taken depends on how unsaturated the molecule is. Oxygen burns unsaturated fuels with a higher temperature than saturated fuels do. Exemplar 4 is a good example of a typical Level 2 response that addressed all three areas but was lacking in detail, and scored 4 marks.
			Total	13	

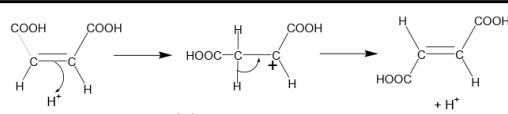
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
62	a		FIRST CHECK ANSWER ON THE ANSWER LINE If answer = -1520 / -1518 (kJmol^{-1}) award 3 marks $q = mc\Delta T = 100 \times 4.18 \times 11.5 = 4807$ (J) ✓ moles of fuel burnt = $0.19/60 = 0.00317$ / 0.00316 ✓ enthalpy change per mole = $4807/0.00317 = -1520$ / -1518 (kJmol^{-1}) ✓	3 (AO2.8×3)	ALLOW 2 or more sf, rounding in different steps ALLOW 4.2 negative sign needed for final mark
	b	i	Any two from: incomplete combustion ✓ evaporation of fuel ✓ evaporation of water ✓ non-standard condition ✓	2 (AO3.3 × 2)	
		ii	Any one from: a top for spirit burner when flame out ✓ Insulate(d) container ✓ draft shields ✓ lid on metal can ✓	1 (AO3.4)	ALLOW minimising distance between flame and can “lid” alone is enough
	c	i	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$ propan-1-ol $\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{O} & \text{H} \\ & & \\ & \text{H} & \end{array}$ propan-2-ol ✓	1 (AO1.2)	
		ii	(average) bond enthalpies give energy required / given out to break / form a particular bond ✓ same number <u>and</u> type of bonds (broken and formed) ✓ energy given out when new bonds form greater than energy taken in to break old bonds ✓	3 (AO1.2) (AO2.1) (AO2.1)	ALLOW listing of all the bonds (broken and made)
			Total	10	

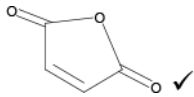
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance				
63			C	1 (AO1.2)					
			Total	1					
64			B	1 (AO2.3)					
			Total	1					
65			A	1 (AO2.8)					
			Total	1					
66	a		<table border="1"><tr><td>Repeat unit</td><td>Type of polymerization</td></tr><tr><td></td><td>Addition</td></tr></table> ✓ ✓	Repeat unit	Type of polymerization		Addition	2 (AO1.2)	IGNORE brackets and 'n'.
Repeat unit	Type of polymerization								
	Addition								
	b		 Dipole on HCl ✓ Curly arrows ✓ Intermediate and product ✓	3 (AO2.1 × 3)	Curly arrows must start on bonds (or the lone pair or negative sign on chloride).				
			Total	5					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
67	a	i	(C=C) decolorises bromine water ✓ (COOH / acid) will fizz with carbonate / appropriate colour with (named) indicator ✓	2 (AO1.2 × 2)	ALLOW gas produced turns limewater cloudy(AW) if carbonate test used Examiner's Comments In part (i) and (ii) most candidates scored 3 or 4 marks, usually missing the final conversion from amount of NaOH to volume of NaOH by failing to include the reaction stoichiometry in their calculation.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 5 (cm³) award 3 marks conc maleic acid = (2.32/116) OR 0.02 (mol dm ⁻³) ✓ amt NaOH = 2 × 250 × 0.02/1000 OR 0.01 (mol) ✓ vol NaOH = 1000 × 0.01/2 = 5	3 (AO2.4 × 3)	2.5 scores 2 marks ALLOW ecf Allow wrong answers (after ecf) to 2 or more sig figs.
	b	i	CHO ✓	1 (AO1.2)	ALLOW elements in any order
		ii	Z ✓ butenedioic acid ✓	2 (AO1.1 × 2)	ALLOW 'butendioic acid'
	c		Description of groups being spatially different across C=C ✓ Lack of free rotation of C=C / groups in a fixed position ✓	2 (AO1.2 × 2)	ALLOW they are stereoisomers.
	d	i	 one for each arrow ✓ ✓	2 (AO2.5 × 2)	One arrow must start) on the double bond and end pointing to H ⁺ (or to the bond being formed) The other arrow must start and end on the bonds shown. Other arrows are CON
		ii	(Electrophilic) Elimination	1 (AO1.1)	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	No, either of the Hs on the left C (of carbocation) could leave ✓ some ^2H / D would be incorporated ✓	2 (AO3.2 × 2)	Examiner's Comments In this part, the mechanism in (e)(i) was found challenging by many candidates. Common errors included the inclusion of additional arrows in the first step and the arrow in the second step going to the carbocation rather than to the desired location to form the final double bond.
	e			1 (AO2.1)	
	f	i	Atom economies $(98/170) = 58\%$ AND $(98/222) = 44\%$ ✓ Identifies butane / reaction 1 should be used because it has the larger atom economy / produces less waste ✓	2 (AO2.6) (AO3.1)	ALLOW 0.58 AND 0.44 Examiner's Comments Parts(i) and (ii) were well answered by most candidates, although (iii) saw marks being lost for use of an inappropriate number of significant figures in the final answer.
		ii	Benzene toxic / more expensive / butane more available from cracking / doesn't produce CO_2 (ORA for reaction 2)✓	1 (AO3.1)	ALLOW ecf from (i) eg butane more flammable
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 61 (kg) award 2 marks amt butane = $15000/24 = 625 \text{ mol}$ ✓ mass maleic anh = $625 \times 98/1000 = 61(\text{kg})$ (2sf) ✓	2 (AO2.8 × 2)	61.3 or 61.2 score 1 Correct use of gas equation can score both marks
			Total	21	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
68		i	unsaturated...C=C / CC double bonds ✓ cis adjacent parts of chain next to each other around double bond (AW) ✓	2 (AO1.1×2)	i.e. avoids giving mark for C=O ALLOW π bonds in chains NOT just double bonds ALLOW H's / groups on same side / AW NOT in same 'plane'
		ii	instantaneous dipole – induced dipole between (non-polar) chains ✓ permanent dipole-permanent dipole between C=O / C–O bonds (AW) ✓	2 (AO2.1×2)	ALLOW both types of bond with inadequate locations for 1 mark NOT id-id? NOT pd-pd, unless correct term has to be used once; then allow pd
		iii	(Chains in) Structure A pack better / closer together / more;points of contact ✓ Stronger imb / id-id ✓ More energy / higher temperature required to break bonds ✓	3 (AO2.5×3)	ORA throughout. AW close enough No need to specify but for example H bonding would be a CON . ALLOW id-id. NOT fewer bonds
			Total	7	
69	a		$C_{16}H_{34} + 24\frac{1}{2} O_2 \rightarrow 16CO_2 + 17H_2O$ ✓	1 (AO2.5)	ALLOW multiples. IGNORE state symbols
	b	i	Heterogeneous ✓ catalyst and reagents are in different states. ✓	2 (AO1.1 × 2)	Mark independently States, if given, must be correct, (g) and (S) for catalyst
		ii	Provides a route of lower E_A ✓	1 (AO1.1)	Must mention activation, not just energy / enthalpy and alternate route.
	c	i	Colourless gas ✓ turns brown ✓	2 (AO1.1 × 2)	
		ii	$N_2 + O_2 \rightarrow 2NO$ ✓	1 (AO1.1)	If state symbols are shown they must be correct (all (g))
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
70		i	Orange / brown solution forms ✓	1 (AO1.1)	IGNORE starting colour if green / colourless/yellow NOT Red
		ii	$\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$ ✓	1 (AO1.1)	IGNORE state symbols
		iii	Chlorine better able to attract electrons than bromine / Cl better oxidising agent so removes electrons from Br ✓	1 (AO1.1)	Must be comparative
		iv	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $5.70 \times 10^4 \text{ (dm}^3\text{)}$ award 4 marks Volume of water electrolysed = $1000/1.24 = 806.45\text{dm}^3$ ✓ Moles of Cl^- ions = $806.45 \times 208/35.5 = 4725.12$ ✓ Volume of chlorine = $4725.12 \times 24/2 = 56701 \text{ dm}^3$ ✓ = $5.70 \times 10^4 \text{ (dm}^3\text{)}$ ✓	4 (AO2.6 × 4)	ALLOW 2 or more sf 57000, 1.13×10^5 , 8.72×10^4 score 3 marks.
			Total	7	