

GCE A LEVEL

WJEC Eduqas GCE A LEVEL in
CHEMISTRY

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**SPECIMEN ASSESSMENT
MATERIALS**

Teaching from 2015



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Candidate Name	Centre Number				Candidate Number				

**A LEVEL CHEMISTRY****COMPONENT 1****Physical and Inorganic Chemistry****SPECIMEN PAPER****2 hours 30 minutes**

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
Section A Section B	1. to 11.	15
	12.	15
	13.	10
	14.	10
	15.	7
	16.	15
	17.	12
	18.	22
	19.	14
	Total	120

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a data sheet and a calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

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

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SECTION A

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

1. Explain the term *dynamic equilibrium*. [1]

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2. Place the following compounds in order of **increasing** bond angles. [1]



smallest *largest*

3. Draw a dot and cross diagram to show the bonding present in an ammonium ion, NH₄⁺. [1]

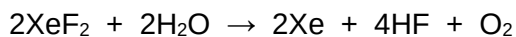
4. The table below gives the electronegativity values.

Atom	B	H	C	O	Cl
Electronegativity value	2.0	2.1	2.5	3.5	3.0

Use the data in the table to identify any dipoles present in the following bonds, marking their polarity clearly. [2]



5. XeF_2 is one of the few noble gas compounds known. It reacts with water in the presence of a base according to the equation below.



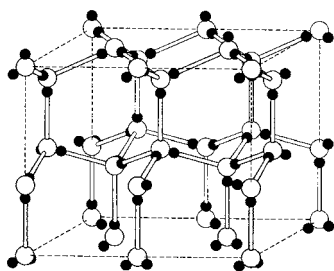
Complete the table below to give the initial and final oxidation states of the xenon and oxygen atoms, noting whether oxidation or reduction has occurred. [2]

Element	Initial oxidation state	Final oxidation state	Oxidation/Reduction
xenon			
oxygen			

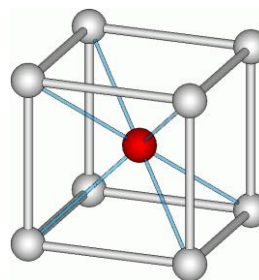
6. The reaction of magnesium metal with phosphoric acid, H_3PO_4 , produces magnesium phosphate. Give the formula of magnesium phosphate. [1]

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7. The diagrams below represent the arrangement of particles in two substances.



substance **A**



substance **B**

Choose the names of the substances represented from the following list:

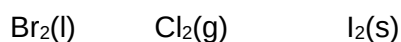
sodium chloride, diamond, ice, graphite, caesium chloride

[1]

Substance **A**

Substance **B**

8. Place the following in order of increasing entropy, giving a reason. [1]



Lowest entropy

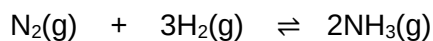
Highest entropy

.....

Reason.....

.....

9. Ammonia is produced from hydrogen and nitrogen in the Haber process.



Write the expression for the equilibrium constant in terms of pressure, K_p , for this reaction. Give the units for K_p assuming that pressures are given in atmospheres (atm).

[2]

Units

10. 1 mol of a gas occupies 24.0 dm³ at 298 K and 1 atm. Calculate the temperature at which it occupies 25.0 dm³ at the same pressure. [2]

Temperature = K

11. Write an ionic equation for the reaction of aqueous I⁻ and Cu²⁺ ions to form copper(I) iodide and iodine. [1]

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SECTION B

Answer all questions in the spaces provided.

12. Our current understanding of the structure of the atom is based on evidence that has been collected over many years and from many sources.

- (a) Rutherford introduced the idea of a small nucleus surrounded by a space where the electrons are found, based on an experiment where alpha particles fired at a thin gold film passed straight through it.
- (i) An isotope of gold, ^{190}Au , can be produced by the emission of an alpha particle from a radioactive atom. This in turn decays by positron emission. Deduce the mass number and symbol of the initial and final nuclides in this decay series. [2]

	Mass number	Symbol
Initial nuclide		
Final nuclide		

- (ii) Four other radioactive isotopes with the same mass are given in the table.

Isotope	Half-life	Radioactive emission
^{190}W	30 minutes	β
^{190}Re	3.1 minutes	β
^{190}Pt	6.5×10^{11} years	α
^{190}Bi	6.3 seconds	α

Describe why radioactivity is dangerous to living cells. Use all the data given to identify which of these isotopes would cause most damage to cells if consumed. [4]

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(b) The energy levels of electrons are quantised, with the higher energy levels becoming closer together. These energy levels form shells and there are fixed maximum numbers of electrons in each shell.

(i) Part of the evidence for this model comes from the atomic emission spectra of the elements. Describe the atomic emission spectrum of hydrogen and explain how this provides evidence for aspects of the model above. [6]

(Your ability to construct an extended response will be assessed in this question.)

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- (ii) Further evidence for this model comes from successive ionisation energies. Explain how these provide evidence for aspects of the model described. Sketch the expected pattern of successive ionisation energies for an atom of aluminium and use it to illustrate your answer. [3]

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13. Sodium and magnesium are both typical s-block metals while copper is a typical d-block metal.

(a) Describe what happens when sodium oxide and magnesium oxide are added **separately** to cold water. Your answer should be illustrated by relevant chemical equations. [2]

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(b) Describe **one** chemical test, other than a flame test, which would distinguish between unlabelled aqueous solutions of sodium chloride and magnesium chloride. Your answer should include reagent(s) used and **observations** in **each** case. [2]

Reagent(s)

Observation(s).....

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(c) Sodium ethanoate and sodium chloride are both salts of sodium. Explain why an aqueous solution of sodium ethanoate has a pH greater than 7 while the pH of aqueous sodium chloride is 7. [2]

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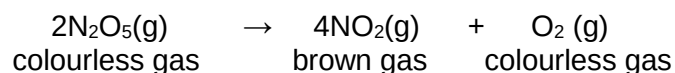
- (d) The enthalpy of formation of copper(II) fluoride, CuF_2 , can be determined indirectly using a Born-Haber cycle. Use the data given below to calculate the enthalpy change of formation of copper(II) fluoride in kJ mol^{-1} . [4]

Process	$\Delta H^\ominus$ (kJ mol^{-1})
$\text{Cu(s)} \longrightarrow \text{Cu(g)}$	339
$\frac{1}{2}\text{F}_2(\text{g}) \longrightarrow \text{F(g)}$	79
$\text{Cu(g)} \longrightarrow \text{Cu}^+(\text{g}) + \text{e}^-$	745
$\text{Cu}^+(\text{g}) \longrightarrow \text{Cu}^{2+}(\text{g}) + \text{e}^-$	1960
$\text{F(g)} + \text{e}^- \longrightarrow \text{F}^-(\text{g})$	-348
$\text{Cu}^{2+}(\text{g}) + 2\text{F}^-(\text{g}) \longrightarrow \text{CuF}_2(\text{s})$	-3037

Enthalpy change of formation = kJ mol^{-1}

10

14. Dinitrogen pentoxide, N_2O_5 , decomposes in the gas phase according to the equation below.



- (a) One method of studying the rate of this reaction is to measure the pressure of the gas at constant volume. State how the pressure will change during the reaction. Explain why this is the case. [2]

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- (b) The initial rates of this reaction for different concentrations of N_2O_5 were measured and are given in the table below.

Concentration of N_2O_5 (mol dm^{-3})	Initial rate ($\text{mol dm}^{-3} \text{ s}^{-1}$)
4.00×10^{-3}	5.97×10^{-5}
6.00×10^{-3}	8.98×10^{-5}
8.00×10^{-3}	1.19×10^{-4}

The rate equation for this reaction is:

$$\text{Rate} = k[\text{N}_2\text{O}_5]^1$$

- (i) Show that the rate equation is consistent with the data above. [2]

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- (ii) Two possible mechanisms have been suggested for this reaction. These are shown below.

Mechanism A	Mechanism B
$\text{N}_2\text{O}_5 \rightarrow \text{NO}_2 + \text{NO}_3^\bullet$	$2\text{N}_2\text{O}_5 \rightarrow 2\text{NO}_3^\bullet + \text{N}_2\text{O}_4$
$\text{NO}_3^\bullet \rightarrow \text{NO}^\bullet + \text{O}_2$	$\text{NO}_3^\bullet + \text{N}_2\text{O}_4 \rightarrow \text{NO}^\bullet + 2\text{NO}_2 + \text{O}_2$
$\text{NO}^\bullet + \text{N}_2\text{O}_5 \rightarrow 3\text{NO}_2$	$\text{NO}^\bullet + \text{NO}_3^\bullet \rightarrow 2\text{NO}_2$

Giving your reasons, state which of the mechanisms is compatible with the rate equation. [2]

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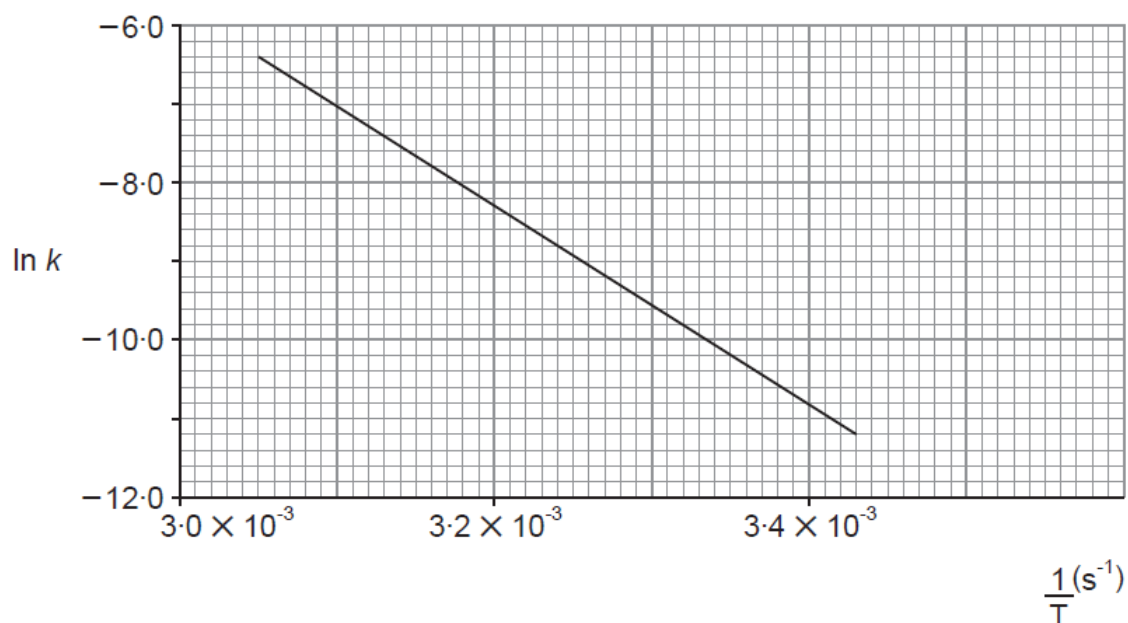
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- (c) The activation energy of the reaction can be calculated by finding the value of the rate constant, k , at a series of different temperatures, T .

The following graph shows a plot of $\ln k$ against $1/T$. The gradient, m , of the line is related to the activation energy, E_a .

$$m = \frac{-E_a}{R} \quad (R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1})$$

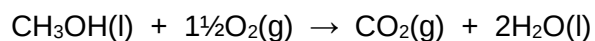


Find the activation energy for this reaction in kJ mol^{-1} .

[4]

Activation energy = kJ mol^{-1}

15. Methanol, CH₃OH, can be oxidised according to the equation below.



Substance	Standard enthalpy change of formation, $\Delta_f H^\ominus$ (kJ mol ⁻¹)	Entropy, S (J K ⁻¹ mol ⁻¹)
CH ₃ OH(l)	-239	127
O ₂ (g)	0	206
CO ₂ (g)	-394	214
H ₂ O(l)	-286	70

- (a) Use the information in the table to calculate the Gibbs free energy, ΔG , for this reaction at 298 K. You must show your working. [6]

$\Delta G = \dots\dots\dots$ kJ mol⁻¹

- (b) State what information your answer to part (a) gives about the feasibility of the reaction. [1]

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16. (a) (i) Bromine is obtained commercially by passing chlorine into sea water, which contains bromide ions. Write an ionic equation for this reaction. [1]

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- (ii) Describe a test to show that an aqueous solution contains bromide ions, stating reagent(s) and observation(s). [2]

Reagent(s).....

Observation(s).....

- (b) Sodium chloride and sodium bromide both react with concentrated sulfuric acid but with different results.

- (i) When **solid** sodium chloride reacts, a steamy gas is produced. Name this gas. [1]

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- (ii) When **solid** sodium bromide reacts, a steamy gas, a brown gas and a colourless gas are produced. Name the colourless gas. [1]

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- (c) Write the equation for the reaction of chlorine with aqueous sodium hydroxide at room temperature and explain why this is classified as a disproportionation reaction. [3]

Equation

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Explanation

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- (d) A buffer solution was made by adding 19.6 g of sodium 3-chloropropanoate, $\text{CH}_2\text{ClCH}_2\text{COONa}$, to 1 dm^3 of $0.100 \text{ mol dm}^{-3}$ 3-chloropropanoic acid, $\text{CH}_2\text{ClCH}_2\text{COOH}$, at 298 K.

(K_a for 3-chloropropanoic acid = $7.94 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K)

Calculate the pH of the buffer solution at 298 K.

[4]

pH =

- (e) Explain how an aqueous solution of 3-chloropropanoic acid and sodium 3-chloropropanoate can act as a buffer solution when a small amount of acid and alkali is **separately** added to it. You may assume that 3-chloropropanoic acid and sodium 3-chloropropanoate act in a similar way to ethanoic acid and sodium ethanoate.

[3]

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17. Schönite is a hydrated ionic compound with general formula $Q_2Z(SO_4)_y \cdot xH_2O$ where Q and Z are two different s-block metal ions with atomic numbers of less than 40.

(a) A flame test on a sample of schönite gives a lilac flame. State what information this test provides. [1]

(b) In order to find the value of x in the formula above a sample of schönite was heated and weighed several times until the sample reached constant mass.

(i) Give a reason why the sample is heated to constant mass. [1]

(ii) When a sample of 0.010 mol of schönite was heated to constant mass, the mass lost was 1.081 g. Use this information to calculate the value of x . [2]

$x =$

(c) 25.0 cm³ of a solution of schönite of concentration 0.100 mol dm⁻³ was treated with excess barium chloride solution, which produced a precipitate of barium sulfate.

(i) Write an ionic equation for the reaction. [1]

(ii) Explain why an excess of barium chloride solution was needed and suggest how you could ensure that sufficient barium chloride had been added. [2]

- (iii) The barium sulfate produced was isolated and dried, and its mass was found to be 1.166 g. Calculate the value of y in the formula $Q_2Z(SO_4)_y \cdot xH_2O$. [3]

$y = \dots\dots\dots$

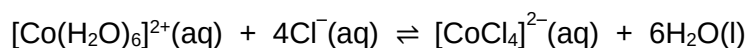
- (d) The M_r of the **anhydrous** schönite produced in part (c) was 294.7. Use all the information above to write the formula of schönite, explaining your reasoning. [2]

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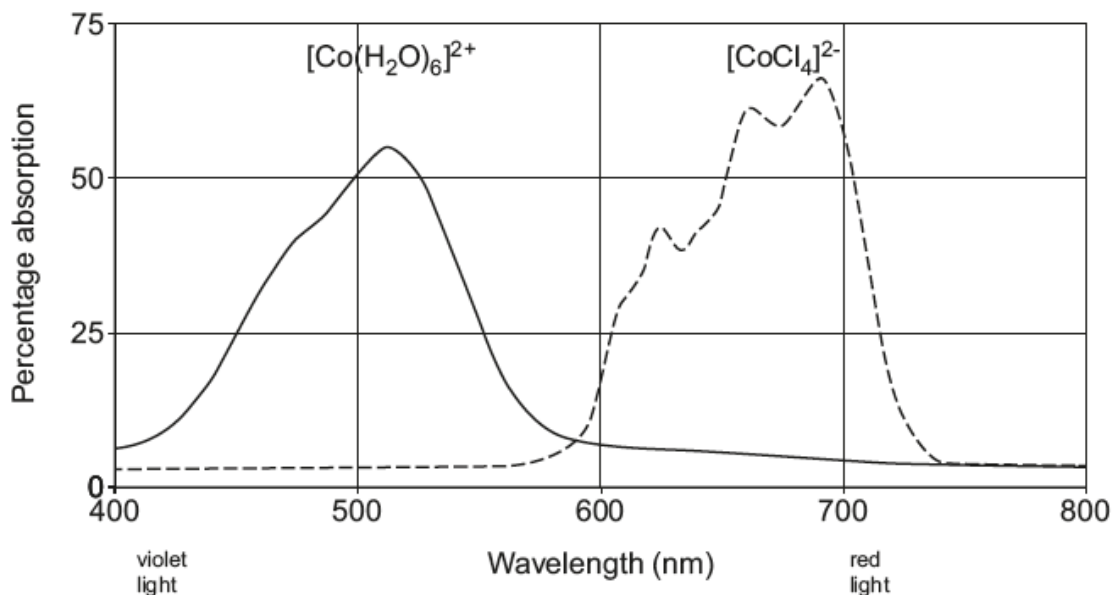
18. Cobalt forms the complex ions $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{CoCl}_4]^{2-}$.

(a) Draw the structures of these two complex ions. [2]

(b) The two different coloured Co(II) complex ions exist together in equilibrium in solution in the presence of chloride ions:



These complexes are coloured and the visible spectra below show the absorbance of light of different wavelengths by the two compounds.



(i) Both complexes have the same percentage absorption at 590 nm. Calculate the energy associated with this wavelength. [2]

$$h = 6.63 \times 10^{-34} \text{ J s}$$

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

Energy = J

- (ii) One of the two complexes is blue. State which complex this is, giving a reason for your choice. Explain why this complex ion is coloured.

[6]

(Your ability to construct an extended response will be assessed in this question.)

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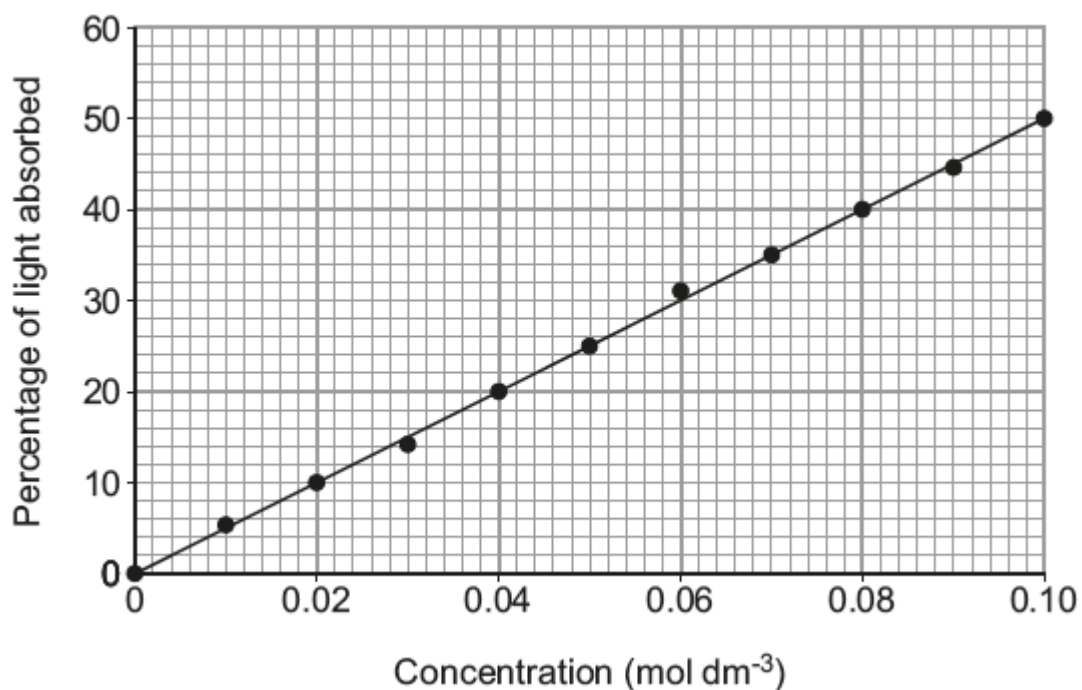
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- (iii) The relationship between the percentage of light absorbed and the concentration of a complex ion can be used to find the concentration of a given solution.

The graph below shows the relationship between the percentage of light of a particular wavelength absorbed and the concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.



This relationship can also be expressed as a mathematical equation:

$$\text{concentration of } [\text{Co}(\text{H}_2\text{O})_6]^{2+} = 1.942 \times 10^{-3} \times \text{percentage of light absorbed}$$

Determine a value for the concentration of a solution that absorbs 33.6 % of the light of this wavelength using the graph and another value using the equation. Comment on the values obtained. [3]

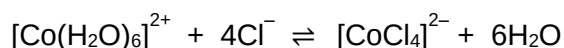
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- (c) (i) Write an expression for the equilibrium constant, K_c , for the equilibrium between $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{CoCl}_4]^{2-}$. [1]



- (ii) A non-aqueous solution initially containing $0.20 \text{ mol dm}^{-3} [\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and $0.50 \text{ mol dm}^{-3} \text{Cl}^-$ was allowed to come to equilibrium. The concentration of $[\text{CoCl}_4]^{2-}$ at equilibrium was 0.08 mol dm^{-3} . Calculate the value of K_c under these conditions and give its units. [4]

$K_c = \dots\dots\dots$

Units $\dots\dots\dots$

- (d) Silver nitrate solution is added to a solution containing $[\text{CoCl}_4]^{2-}$ ions which causes the solution to become cloudy and then change colour. Explain these observations. [4]

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19. A student was given a solution containing a mixture of Fe^{2+} and Fe^{3+} ions (solution **X**) and was asked to determine the concentrations of each ion in the solution. He followed Method **A** described below.

Method **A**

Part 1

Pipette 25.00 cm^3 of solution **X** into a conical flask and add 10 cm^3 of dilute sulfuric acid. Titrate this solution with a $0.0200 \text{ mol dm}^{-3}$ solution of potassium manganate(VII) until the first permanent pink colour remains in the solution. Repeat the titration as many times as necessary and calculate a mean titre.

The results of the titrations were 15.00 cm^3 , 14.90 cm^3 , 15.70 cm^3 and 14.95 cm^3 .

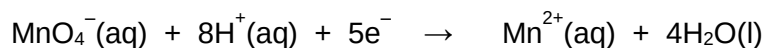
Part 2

Pipette 25.00 cm^3 of solution **X** into a conical flask and add acid and granulated zinc. Warm the flask for 10 minutes to allow the all of the Fe^{3+} ions to be reduced to Fe^{2+} ions. After the solution has cooled, remove the excess zinc by filtering and titrate it against the same manganate(VII) solution used in Part 1. This time 19.10 cm^3 of the manganate(VII) solution were required.

- (a) (i) Outline **two** safety precautions that the student would have taken during the experiment, giving a reason for each. [2]

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- (ii) The half-equations for the reaction between Fe^{2+} ions and acidified manganate(VII) ions are:



Use the titration results from Method **A** Part 1 to calculate the concentration, in mol dm^{-3} , of the Fe^{2+} ions in the mixture. [3]

Concentration $\text{Fe}^{2+} = \dots\dots\dots \text{mol dm}^{-3}$

- (iii) Use the results from Method **A** Part 2 to calculate the concentration, in mol dm^{-3} , of the total Fe^{2+} and Fe^{3+} content in the mixture. Hence calculate the concentration, in mol dm^{-3} , of the Fe^{3+} ions in the mixture. [3]

Concentration $\text{Fe}^{3+} = \dots\dots\dots \text{mol dm}^{-3}$

- (iv) Comment on the accuracy and reliability of the measurements in Method **A** Part 1 and suggest improvements that could be made to improve the accuracy of the results. [3]

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Method **B** includes an alternative to Part 2. The concentration of Fe^{3+} ions is determined by atomic absorption spectroscopy.

In this technique a sample of a solution is vaporised and atomised. A beam of light is passed through this and the absorbance of a specific wavelength of the light is measured using an electronic detector. This frequency is one of the absorption frequencies of the metal's atomic absorption spectrum.

To use this device, a control (usually a mixture of distilled water and another solution) is used in the spectrometer to calibrate the machine. After the device has been calibrated the concentration can be found by repeating the procedure using solution **X**.

- (b) Justify which of the two procedures would be likely to give the more accurate result for the concentration of Fe^{3+} ions in solution **X**. [3]

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Candidate Name	Centre Number				Candidate Number				

**A LEVEL CHEMISTRY****COMPONENT 2****Organic Chemistry and Analysis****SPECIMEN PAPER****2 hours 30 minutes**

Section A
Section B

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1. to 9.	15	
10.	18	
11.	18	
12.	17	
13.	11	
14.	14	
15.	15	
16.	12	
Total	120	

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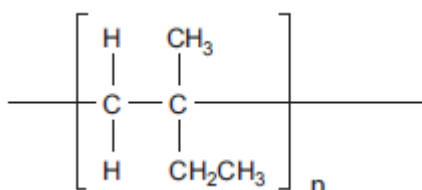
No certificate will be awarded to a candidate detected in any unfair practice during the examination.

SECTION A

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

1. Draw the structural formula of a compound that has the same molecular formula as pentane. [1]

2. Name the compound that can be polymerised to give



[1]

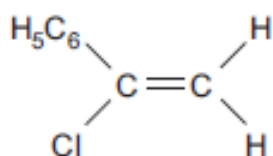
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3. In the upper atmosphere chlorofluoromethane undergoes homolytic fission of the C—Cl bond. Give the formulae of the resulting species. [1]

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4. The reaction of 2-methylpropene with hydrogen bromide is similar to that of propene with hydrogen bromide. Draw the structure of the main product of the reaction of 2-methylpropene with hydrogen bromide. [1]

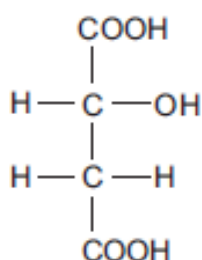
5. The formula for 1-phenyl-1-chloroethene is shown below.



State why this compound does not exist as *E-Z* isomers. [1]

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6. Malic acid, isolated from apples, is the enantiomer which has the structure



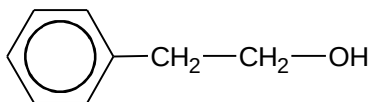
- (a) State why malic acid has two enantiomers. [1]

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- (b) State a physical property of the two enantiomers that could be used to distinguish between them. [1]

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7. (a) Use the formula of 2-phenylethanol below to state why it is a primary alcohol. [1]

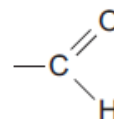


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- (b) Give the displayed formula of an isomer of formula $C_8H_{10}O$ that can be oxidised to a ketone. [1]

8. (a) Methanoic acid is unusual for a carboxylic acid because it contains a group.



This group will react with Tollens' reagent on warming. Give the result of this test and explain why it occurs. [2]

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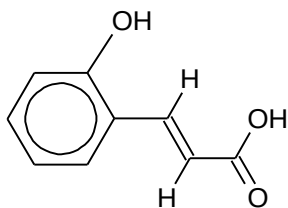
- (b) Use your answer to (a) to suggest why it is unlikely that silver methanoate, $HCOO^-Ag^+$, can exist. [1]

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9. Complete the table below to show how you would test for each of the **three** functional groups present in the following compound.

[3]

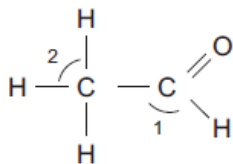


Reagent(s)	Functional group identified	Observation

SECTION B

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

10. (a) The displayed formula for ethanal is shown below.



The molecular shape of the aldehyde group is trigonal planar and the molecular shape of the methyl group is tetrahedral.
Suggest values for the

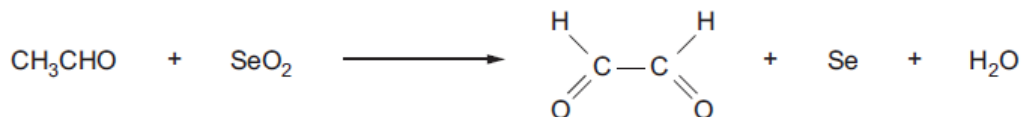
C – Ĉ – H angle 1

H – Ĉ – H angle 2 [2]

- (b) State a reagent that can be used to oxidise ethanal to ethanoic acid. [1]

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- (c) Ethanal can be oxidised to ethanedial by selenium dioxide.



- (i) Give the oxidation numbers of selenium in both selenium dioxide and selenium itself. State how this shows that reduction has occurred during this reaction. [2]

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- (ii) State a piece of evidence that suggests that selenium dioxide is a less powerful oxidising agent than the one used in (b) above. [1]

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- (iii) In an experiment 22.0 g of ethanal was oxidised by selenium dioxide to produce 20.0 g of ethanedial. Calculate the percentage yield of ethanedial. [3]

Percentage yield = %

- (d) One method of identifying aldehydes and ketones is to make a 2,4-dinitrophenylhydrazine derivative. The melting temperature of the purified derivative is then compared with its book value.

- (i) State the type of reaction that occurs when an aldehyde or ketone reacts with 2,4-dinitrophenylhydrazine. [1]

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- (ii) The melting temperatures of some 2,4-dinitrophenylhydrazine derivatives are shown in the table.

Aldehyde / Ketone	Melting temperature (°C)
cyclopentanone	147
propanal	155
ethanal	168

A student made a 2,4-dinitrophenylhydrazine derivative of compound **A**, which is one of the three carbonyl compounds given in the table. The melting temperature of his derivative was 160-164 °C.

He decided that compound **A** must be ethanal. Comment on why he came to this conclusion and on the purity of his product. You should consider all three carbonyl compounds in your answer. [3]

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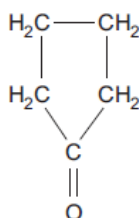
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- (e) State a test that would give a positive result with ethanal but **not** with propanal or cyclopentanone. [2]

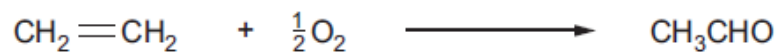


cyclopentanone

Reagent(s)

Observation with ethanal

- (f) In industry ethanal is made from ethene and air/oxygen by the Wacker process.



The process uses an aqueous solution containing palladium(II) chloride and copper(II) chloride. This corrosive solution acts as a homogeneous catalyst, as the gases react in the solution. A 95% yield of ethanal is obtained. As part of her research training, Emily was asked to evaluate this process with a view to any improvements that could be made.

Suggest **three** factors (apart from cost) that Emily would need to know before she could form an opinion about any possible improvements. [3]

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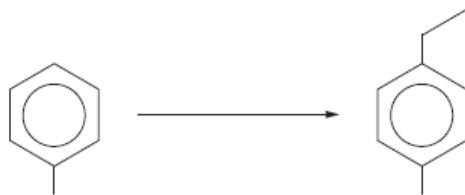
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11. (a) Aluminium chloride is used as a catalyst in the alkylation and acylation of aromatic hydrocarbons.

- (i) State the name of an organic compound that reacts with methylbenzene to produce compound **F**.

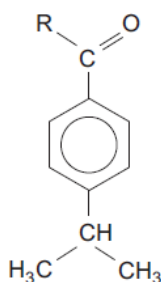


compound **F**

[1]

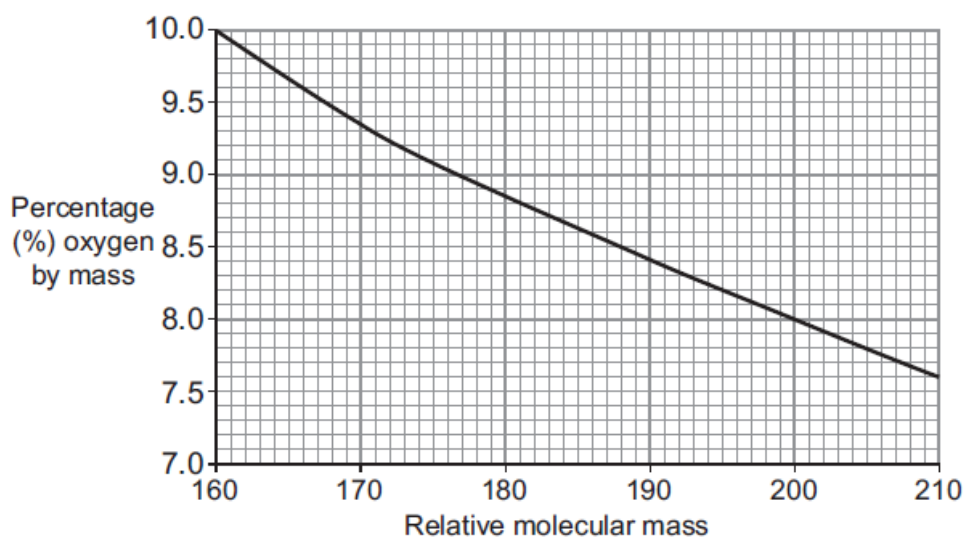
-
- (ii) Draw the **skeletal** formula of another possible organic product of this reaction. [1]

- (iii) Compound **H** is formed when the acid (acyl) chloride (RCOCl), compound **G**, reacts with 2-propylbenzene (M_r 120.1) in the presence of aluminium chloride.



compound **H**

Analysis of compound **H** showed that it contained 8.41% of oxygen by mass. Use the graph to help you find the formula of the alkyl group **R**.



[3]

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- (iv) The acid chloride used in (iii) opposite is a liquid with a boiling temperature of 102 °C. Before it was used in (iii) it was purified by fractional distillation.

I Suggest a method used to heat the flask containing the impure acid chloride, giving a reason for your answer. [2]

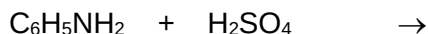
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II State why it was important to exclude moisture from the apparatus during the distillation of the acid chloride. [1]

.....

(b) Primary amines are organic compounds that contain the functional group –NH₂.

- (i) Amines can behave as bases. Complete the equations to show the reaction between amines and acids. [2]



- (ii) If the basic character of ethylamine (C₂H₅NH₂), ammonia (NH₃) and phenylamine (C₆H₅NH₂) is investigated, it is found that their strength as a base varies as shown.

strongest base weakest base

ethylamine ammonia phenylamine

Suggest why this is the order of basic character. [3]

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- (c) (i) A student was given the following reagents and a method in order to make an azo dye.

Reagents provided:

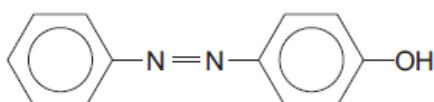
Phenylamine dissolved in ethanol

Solid sodium nitrite, NaNO_2

Dilute hydrochloric acid

Phenol dissolved in water

‘Add some sodium nitrite crystals to some hydrochloric acid in a beaker. Quickly add some of the phenylamine solution and stir well. Now add a little of the phenol solution to the mixture and stir. You should see a yellow precipitate of 4-(phenylazo)phenol.’



4-(phenylazo)phenol

The student tried this method and did not obtain any of the yellow azo dye. Assuming that he used the correct amounts of each reagent, state **two** other important details that are missing from these instructions, so that the experiment can be successful. [2]

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- (ii) The student was eventually successful in his preparation of the yellow dye and was asked to purify it using the following method.

‘Add a sample of the yellow dye to some aqueous sodium hydroxide and stir it until the dye dissolves. Now add dilute hydrochloric acid until no more yellow dye is precipitated. Filter off the yellow solid, wash and dry.’

- I Use the formula of 4-(phenylazo)phenol to help you suggest why the yellow dye is able to dissolve in aqueous sodium hydroxide. [2]

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- II State why the dye is again produced when dilute hydrochloric acid is added to the mixture. [1]

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12. (a) Draw diagrams to show the mechanism of the reaction between aqueous sodium hydroxide and 1-chloropropane. You should include relevant dipoles and curly arrows. [4]

- (b) State the type of reaction mechanism occurring in (a). [1]

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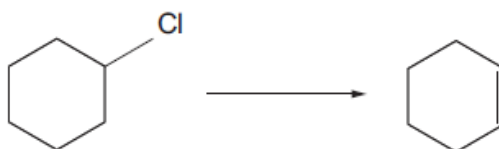
- (c) When 1-chloropropane, 1-bromopropane and 1-iodopropane are reacted separately with aqueous sodium hydroxide it is found that 1-iodopropane reacts most rapidly and 1-chloropropane reacts most slowly.

To make these results valid it is important that a number of experimental factors are kept constant. Identify these factors stating how they would affect the reaction. Consider how differences in the bonding present in each compound have led to the differences in observed reaction rates. [6]

(Your ability to construct an extended response will be assessed in this question).

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- (d) The equation shows the use of chlorocyclohexane to produce cyclohexene.



- (i) State the reagent and the conditions needed to convert chlorocyclohexane into cyclohexene. [1]

Reagent

Conditions

- (ii) What type of reaction is shown in the equation? [1]

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- (iii) Calculate the atom economy of this process. [2]

Atom economy = %

- (iv) When chlorobenzene, C_6H_5Cl , is treated in the same way as described in parts (a) and (d) no reaction occurs in either case. For **each** reagent explain the reason for this. [2]

Reason in (a)

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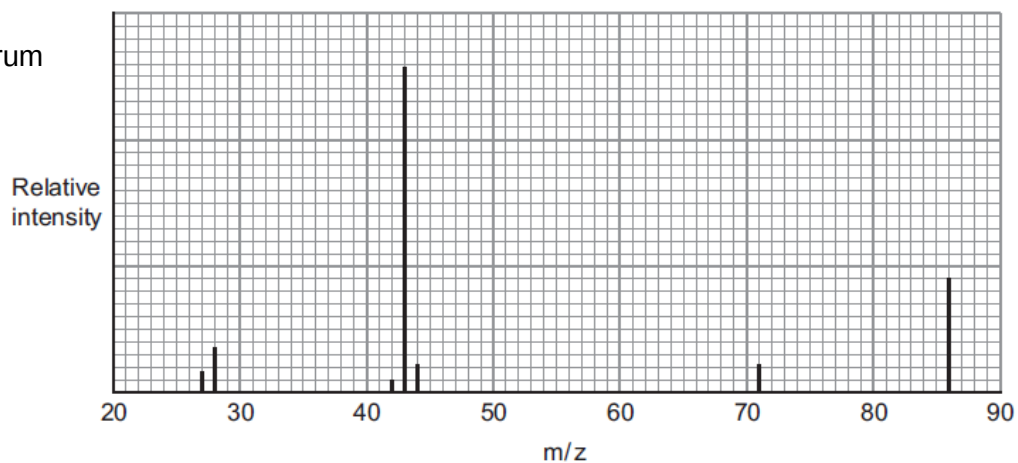
Reason in (d)

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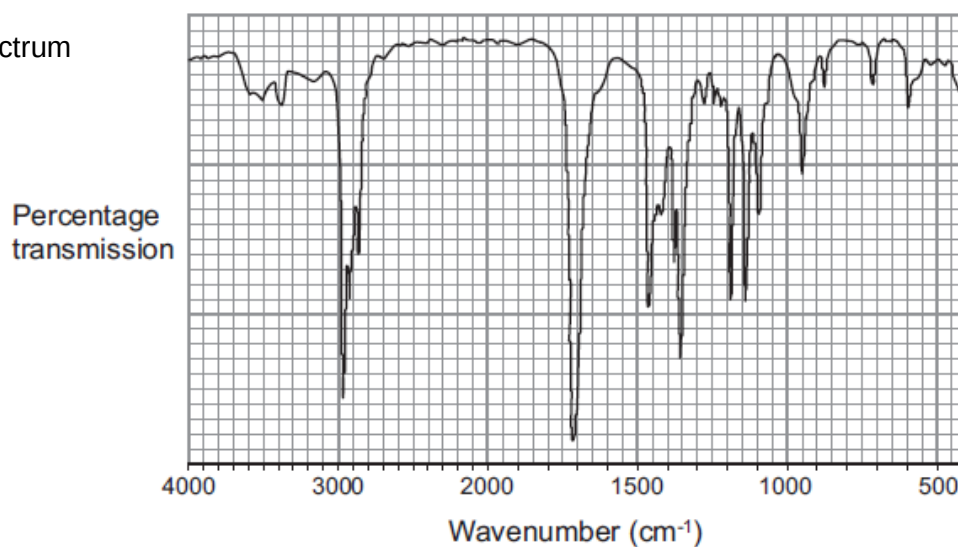
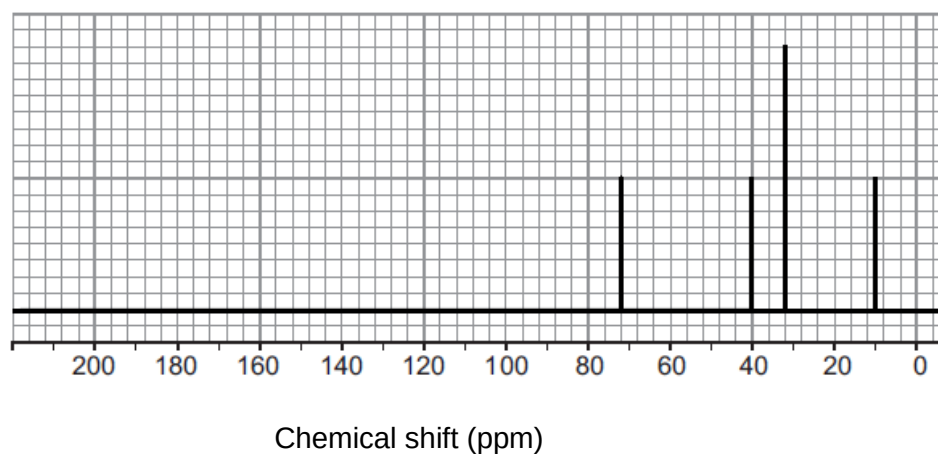
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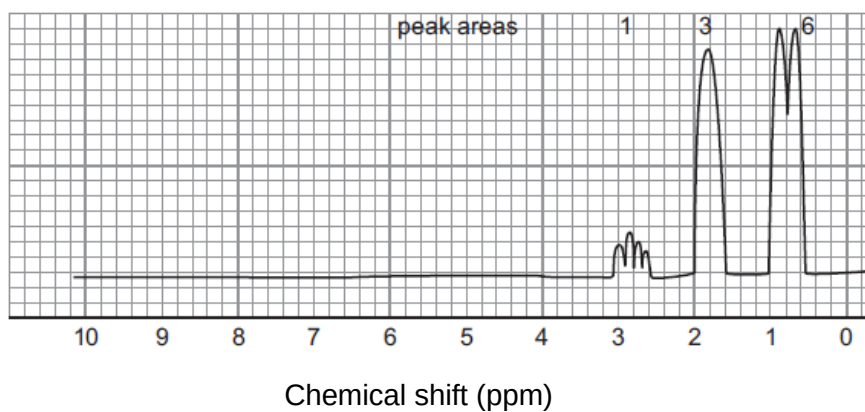
13. In recent times it has become more usual to identify compounds using various types of spectroscopic methods. The spectra below are all produced from the same organic substance, compound **T**, which contains only carbon, hydrogen and oxygen.

Mass spectrum



IR spectrum

 ^{13}C NMR spectrum

^1H NMR spectrum

Use these spectra to identify compound **T**. In your answer you should refer to **all** the spectra provided. In each case you should give an indication of what information about compound **T** is given by the spectrum and how you used this information to identify compound **T**. [11]

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14. (a) Gas oil is one of the fractions obtained from the distillation of crude oil. It consists largely of a mixture of alkanes of formulae $C_{14}H_{30}$ to $C_{20}H_{42}$. This fraction can be cracked in the presence of hydrogen (hydrocracking) to produce alkanes with a smaller relative molecular mass.

- (i) State why it is unlikely that an alkene would be produced as a result of hydrocracking. [1]

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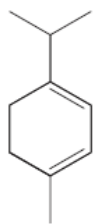
- (ii) Compound **X** is a gaseous branched-chain product of hydrocracking gas oil. 2.09 kg of compound **X** occupies 960 dm^3 at 101000 Pa and 323 K . Use all this information to identify compound **X**.

[4]

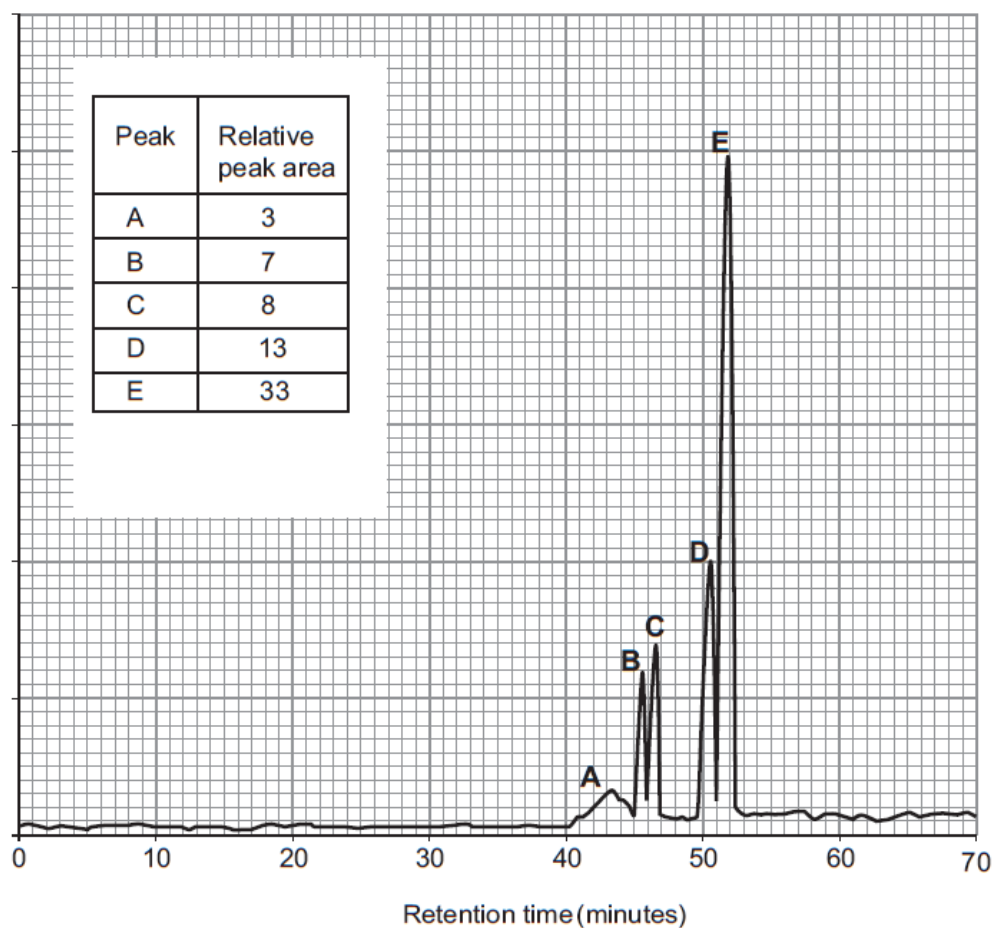
(gas constant, $R = 8.31\text{ J K}^{-1}\text{ mol}^{-1}$)

Compound **X**

- (b) Terpenes are an important group of compounds that are often found in plants. For example, α -terpinene is found in lemon peel.



- (i) The HPLC chromatogram of the hydrocarbon fraction of a citrus oil (extracted from lemon peel) is shown below.



The retention value for α -terpinene is 46.5 minutes. Calculate the percentage of α -terpinene in this hydrocarbon fraction.

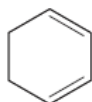
[2]

Percentage of α -terpinene = %

- (ii) Further analysis showed that 95 % of the compounds in the citrus oil were present in the hydrocarbon fraction and 5 % were present in an aqueous fraction. If 3.2 g of lemon peel was used to obtain the citrus oil, use your answer to (ii) to calculate the mass of α -terpinene in the peel. [2]

Mass of α -terpinene =g

- (c) α -Terpinene is a derivative of cyclohexa-1,3-diene.



cyclohexa-1,3-diene

Another student reacted a sample of cyclohexa-1,3-diene with an excess of bromine in an attempt to make 1,2,3,4-tetrabromocyclohexane, $C_6H_8Br_4$. A solid was obtained that contained 75.0 % of bromine by mass.

She suggested that this percentage of bromine was correct for the compound 1,2,3-tribromocyclohexane.

- (i) Discuss her conclusion and then use the information to suggest **your** answer to the probable compound(s) present, giving reasons for your answer. [3]

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- (ii) Name a technique that could be used to confirm your conclusion to part (i), giving the evidence that you would expect to find. [2]

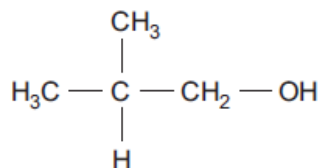
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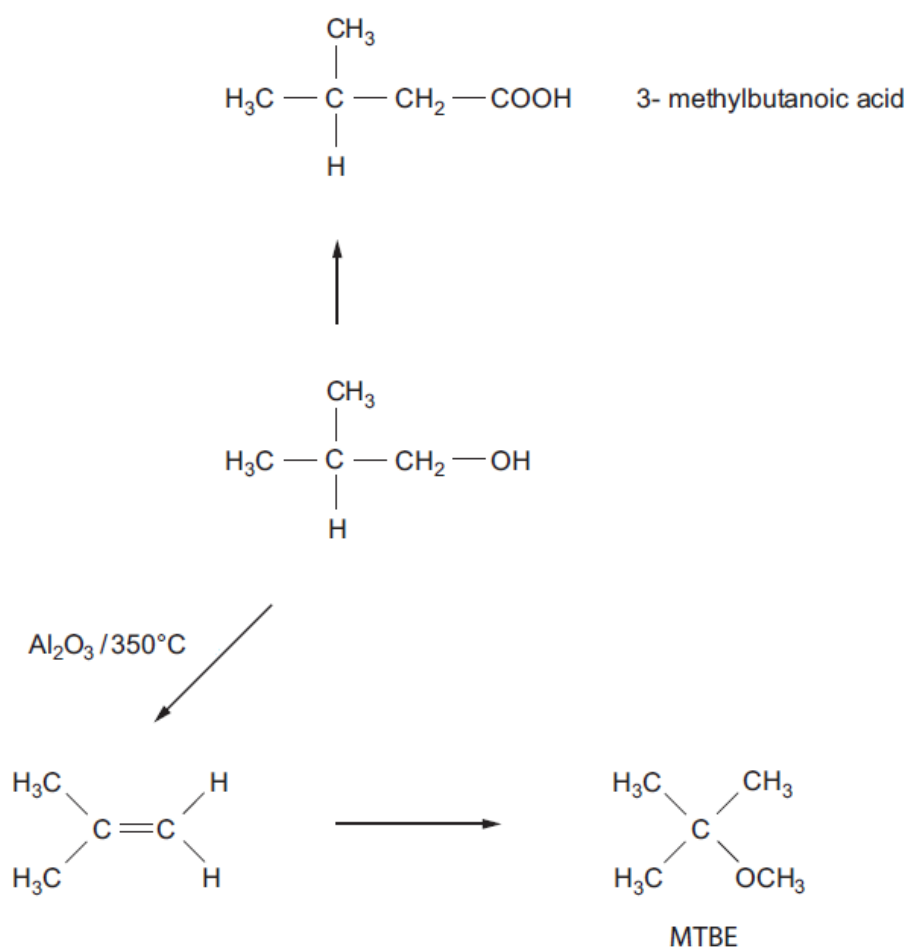
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15. There is increasing interest in developing biochemical processes for the manufacture of organic compounds that have traditionally been made from fossil fuels. One compound that can be made using biotechnology is 2-methylpropan-1-ol.



Study the reaction sequences below and then answer the questions that follow.



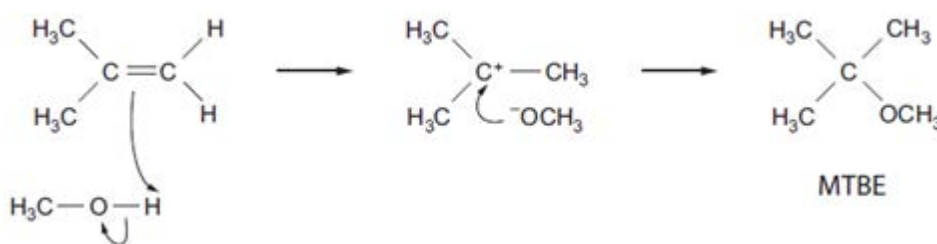
- (a) State the type of reaction that occurs when 2-methylpropan-1-ol vapour is passed over aluminium oxide at 350 °C. [1]

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- (b) State another reagent that could be used in place of aluminium oxide in the reaction in (a) above. [1]

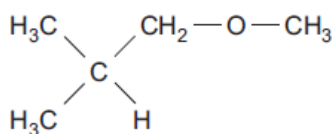
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- (c) The reaction of 2-methylpropene with methanol to produce MTBE is an example of an electrophilic addition reaction to an alkene. A possible mechanism for this reaction is shown below.



Comment on this proposed mechanism by considering the points below:

- any partial charges present in the reactants
- the name/type of the intermediate carbocation
- why the product is MTBE and not 1-methoxy-2-methylpropane, shown below. [5]



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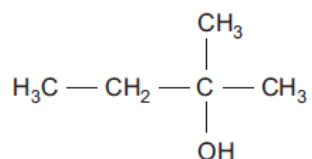
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- (d) Suggest and explain why MTBE has a boiling temperature of 55 °C but 2-methylbutan-2-ol has a boiling temperature of 102 °C. [2]



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- (e) 3-Methylbutanoic acid can be prepared in a three-stage reaction from 2-methylpropan-1-ol. Describe the basic details of each stage, identifying reagents, conditions and intermediate products. [6]

(Your ability to construct an extended response will be assessed in this question.)

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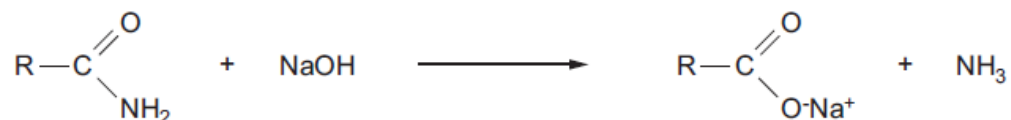
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16. (a) Amides are hydrolysed to the salts of carboxylic acids by warming them with aqueous sodium hydroxide. During this process ammonia gas is given off.



In an experiment Julie reacted a known mass of an aliphatic amide with an excess of aqueous sodium hydroxide. After the reaction was over, the excess sodium hydroxide was neutralised by hydrochloric acid. She obtained the following results.

Mass of the amide	= 2.34 g
Concentration of the aqueous sodium hydroxide	= 1.25 mol dm ⁻³
Volume of aqueous sodium hydroxide used	= 50.00 cm ³
Volume of hydrochloric acid used	= 30.50 cm ³
Concentration of hydrochloric acid	= 1.00 mol dm ⁻³

- (i) Find the relative molecular mass of the amide and hence its formula. [5]

Formula

- (ii) Edward repeated a similar experiment using benzamide ($\text{C}_6\text{H}_5\text{CONH}_2$). He carried out the calculations correctly but arrived at an incorrect value of 130 for the relative molecular mass.

Suggest **two** possible errors in his practical work. Explain how these errors would account for the value calculated. [5]

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- (b) Esters have extensive uses in the food industry as flavourings. One of these esters is 1-butyl methanoate. This ester can be made from butan-1-ol and methanoic acid in the presence of sulfuric acid, which acts as a catalyst.

1-Butyl methanoate and methanoic acid have similar boiling temperatures. As a result, when the ester is distilled from the reaction mixture, the ester may contain some unreacted methanoic acid. Give a chemical test, naming the reagent and stating the result, which will show that methanoic acid is present in this impure sample of 1-butyl methanoate. [2]

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Candidate Name	Centre Number				Candidate Number				

**A LEVEL CHEMISTRY****COMPONENT 3****Chemistry in Practice****SPECIMEN PAPER****1 hour 15 minutes**

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	13	
2.	10	
3.	10	
4.	8	
5.	10	
6.	9	
Total	60	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a data sheet and a calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

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

INFORMATION FOR CANDIDATES

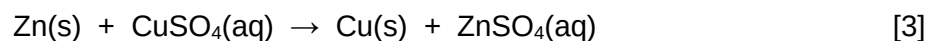
The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the need for good English and orderly, clear presentation in your answers.

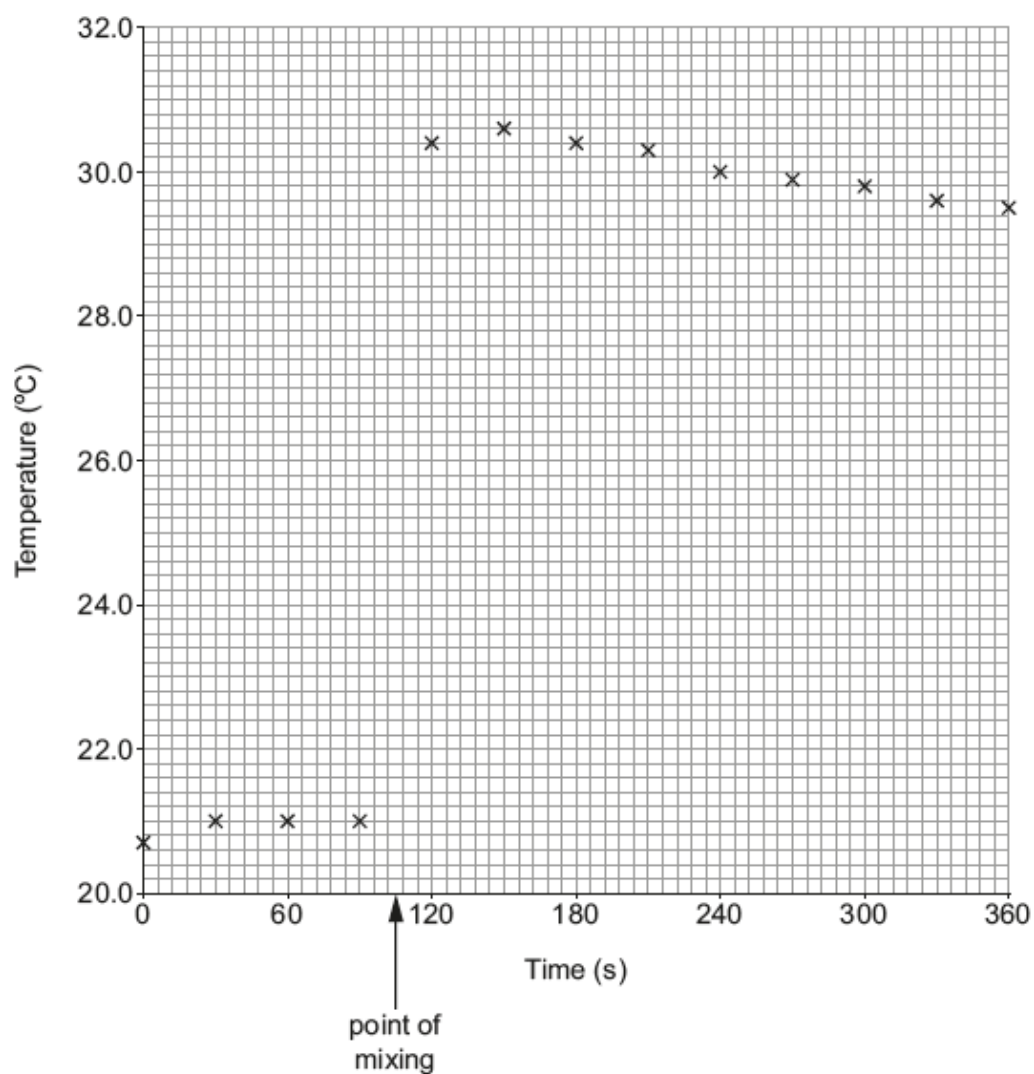
No certificate will be awarded to a candidate detected in any unfair practice during the examination.

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

1. (a) Draw and label a diagram of a simple apparatus that could be used in an experiment to determine the enthalpy change of the reaction of zinc with aqueous copper(II) sulfate. The equation for the reaction is given.



- (b) The results obtained in such an experiment have been plotted on the graph below.



- (i) Determine the maximum temperature **change** by drawing lines to complete the graph. [3]

Maximum temperature change (ΔT) = °C

- (ii) The experiment used 0.60 g of zinc ($A_r = 65$) and 50 cm³ of aqueous copper(II) sulfate (an excess). Calculate the enthalpy change for this reaction in kJ mol⁻¹. Use your value for ΔT from part (i). You must show your working.

The specific heat capacity of an aqueous solution is 4.2 J g⁻¹ °C⁻¹. Assume that 1.0 cm³ of an aqueous solution has a mass of 1.0 g. [4]

Enthalpy change of reaction = kJ mol⁻¹

- (c) (i) Explain what would be the effect on the reaction of using the same mass of zinc but as large lumps rather than zinc powder in this experiment. You should assume that all other conditions remain the same. [2]

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- (ii) What effect would using larger lumps have on the graph in (b)? [1]

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2. A student wanted to determine the concentration of aqueous sulfuric acid by titrating it against a standard solution of sodium carbonate. The student used the following instructions.

- Dissolve approximately 2.5 g of anhydrous sodium carbonate in distilled water to give 250 cm³ of solution.
- Rinse the burette with small volumes of acid and fill to just past the zero mark using a small funnel.
- Remove the funnel and adjust the acid in the burette so that it is exactly on the 0.00 cm³ mark.
- Pipette 25.0 cm³ of the sodium carbonate solution into a conical flask and add an indicator.
- Add the acid from the burette and, when the indicator shows signs of changing colour, wash the flask walls with water and continue the titration to the end-point.

- (a) The student carried out a rough titration and three further accurate titrations.

Construct a results table which would be suitable to record his burette readings and titres.

[2]

- (b) State why the burette was rinsed with acid before filling and explain the possible effect on the titre if this was not done.

[2]

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- (c) The student used 2.52 g of Na_2CO_3 to make 250 cm^3 of solution. The mean titre of his three concordant results was 20.10 cm^3 .

The equation for the reaction between sulfuric acid and sodium carbonate is as follows.



- (i) Use this information to calculate the concentration, in mol dm^{-3} , of the sulfuric acid. Record this value to the appropriate number of significant figures. [3]

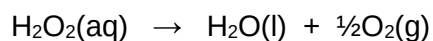
Concentration = mol dm^{-3}

- (ii) Calculate the maximum percentage error in the mean titre value and use this to justify the number of significant figures recorded in part (i). [3]

Maximum percentage error = %

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3. A student obtained the following results when measuring the initial rate of decomposition of aqueous hydrogen peroxide, as in the following equation.



Concentration of H_2O_2 (mol dm^{-3})	0.100	0.200	0.300	0.400	0.500
Rate ($\text{mol dm}^{-3} \text{s}^{-1}$)	0.0511	0.0982	0.148	0.220	0.252

- (a) (i) Briefly describe a method that could be used to study the rate of decomposition of hydrogen peroxide. [2]

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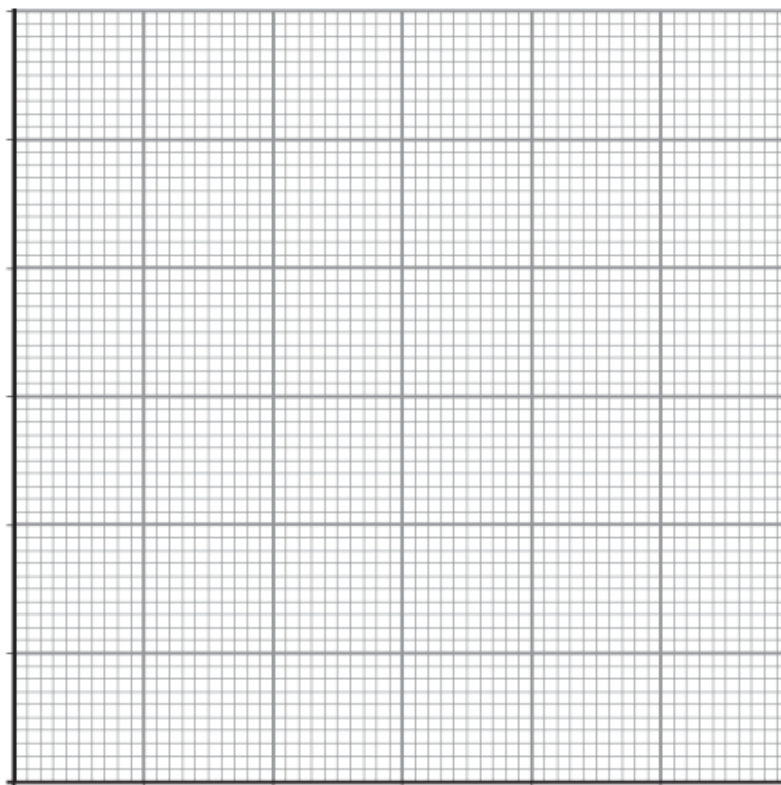
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- (ii) State the main factor that needs to remain constant in order to obtain valid results in this experiment. [1]

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- (b) Label the axes on the grid and plot the results from the table above. Draw the line of best fit. [3]



- (c) The reaction was catalysed by the iodide ions in a $0.103 \text{ mol dm}^{-3}$ solution of potassium iodide. The rate equation for the reaction is as follows.

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

Use the graph to deduce the order with respect to hydrogen peroxide, x , and calculate the value of the rate constant, k , under these conditions. Give your answer to the appropriate number of significant figures and state the units.

[4]

$k =$

Units

10

4. You are given the following five organic compounds in unlabelled bottles.

- 1-bromobutane
- butanone
- 1-chlorobutane
- pentan-3-one
- propanal

Plan a method to identify each compound using the fewest possible tests. All tests must be based on chemical reactions and not the physical properties of the compounds or any characteristic odours.

Your plan must include your tests, observations and conclusions.

[8]

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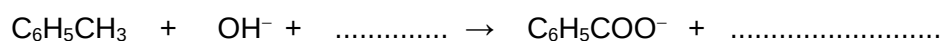
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5. Benzoic acid ($\text{C}_6\text{H}_5\text{COOH}$) is a solid that can be prepared from methylbenzene ($\text{C}_6\text{H}_5\text{CH}_3$) using an alkaline solution of potassium manganate(VII). In order to carry out this oxidation reaction the aqueous mixture needs to be heated for a prolonged period. After this oxidation reaction is complete, hydrochloric acid is added to the mixture to form the benzoic acid as an impure solid product.

(a) What practical technique would you use in the oxidation stage of this preparation? [1]

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(b) Complete the equations to show the reactions that occur in this preparation. You should use [O] to represent the oxidising agent. [2]



(c) The solid benzoic acid can be purified by recrystallisation. The solubility of benzoic acid in three solvents is given in the table.

Solubility of benzoic acid	Solvent A	Solvent B	Solvent C
in cold solvent	high	low	low
In hot solvent	high	high	low

(i) Select the appropriate solvent from the table and describe how you would carry out the recrystallisation to obtain a pure sample of benzoic acid. [6]

(Your ability to construct an extended response will be assessed in this question.)

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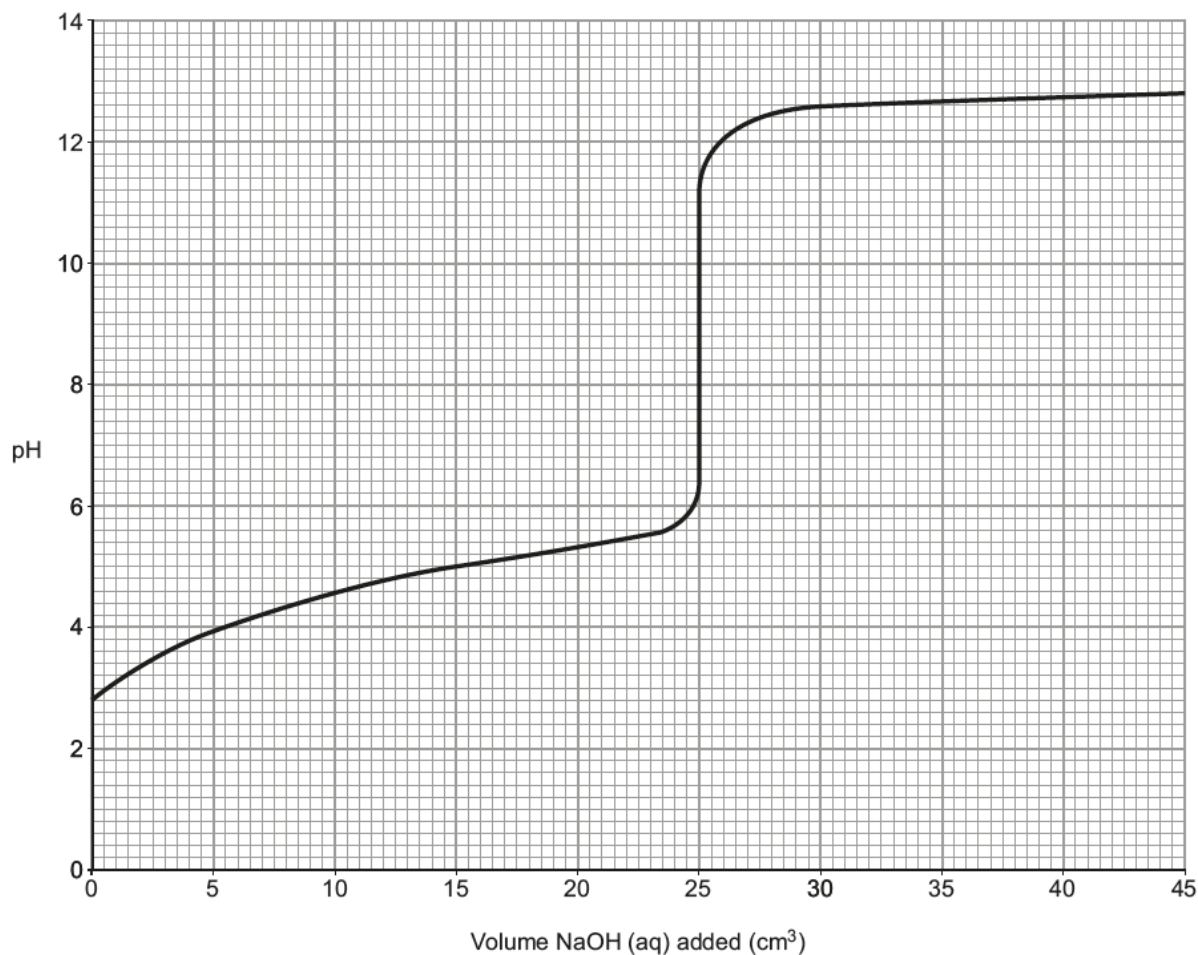
(ii) Describe what you would do to assess the purity of your recrystallised sample of benzoic acid. [1]

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6. (a) The graph below shows the change in pH during a reaction between 0.10 mol dm^{-3} sodium hydroxide and 0.10 mol dm^{-3} ethanoic acid at room temperature.



Using the details included in the description and graph, describe the experiment that was carried out in order to plot the graph.

[4]

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- (b) A student wanted to carry out a titration to find the concentration of a sample of aqueous sodium hydroxide. He used a known volume of 0.1 mol dm^{-3} ethanoic acid and added the sodium hydroxide. The table shows the pH ranges and the colour changes of some indicators.

Indicator	pH range	Colour in acid	Colour in alkali
thymol blue	1.2 - 2.8	red	yellow
bromophenol blue	3.0 - 4.6	yellow	blue
bromocresol green	4.0 - 5.6	yellow	blue
cresol red	7.2 - 8.8	yellow	red

State which indicator the student should choose to obtain an accurate end-point in this titration. Explain your choice.

[1]

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- (c) Use data from the graph in part (a) to calculate the acid dissociation constant, K_a , of ethanoic acid at room temperature.

[4]

$K_a = \dots\dots\dots \text{mol dm}^{-3}$



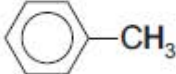
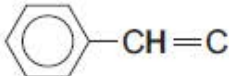
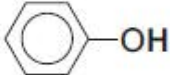
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Data Booklet

Infrared absorption values

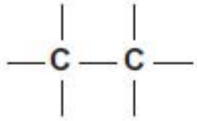
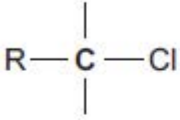
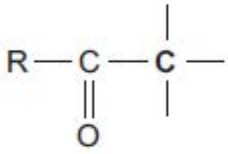
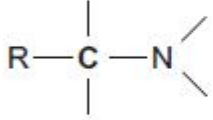
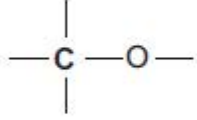
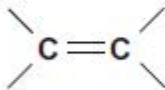
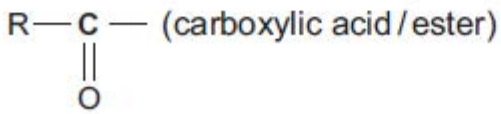
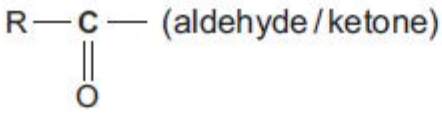
Bond	Wavenumber (cm ⁻¹)
C — Br	500 to 600
C — Cl	650 to 800
C — O	1000 to 1300
C = C	1620 to 1670
C = O	1650 to 1750
C ≡ N	2100 to 2250
C — H	2800 to 3100
O — H (carboxylic acid)	2500 to 3200 (very broad)
O — H (alcohol/ phenol)	3200 to 3550 (broad)
N — H	3300 to 3500

¹H NMR chemical shifts relative to TMS = 0

Type of proton	Chemical shift, δ (ppm)
$-\text{CH}_3$	0.1 to 2.0
$\text{R}-\text{CH}_3$	0.9
$\text{R}-\text{CH}_2-\text{R}$	1.3
$\text{CH}_3-\text{C}\equiv\text{N}$	2.0
$\text{CH}_3-\text{C}(=\text{O})$	2.0 to 2.5
$-\text{CH}_2-\text{C}(=\text{O})$	2.0 to 3.0
	2.2 to 2.3
$\text{R}-\text{CH}_2\text{Cl}$	3.3 to 4.3
$\text{R}-\text{OH}$	4.5 *
$-\text{C}=\text{CH}-\text{CO}$	5.8 to 6.5
	6.5 to 7.5
	7.0 *
$\text{R}-\text{C}(=\text{O})\text{H}$	9.8 *
$\text{R}-\text{C}(=\text{O})\text{OH}$	11.0 *

*variable figure dependent on concentration and solvent

¹³C NMR chemical shifts relative to TMS = 0

Type of carbon	Chemical shift , δ (ppm)
	5 to 40
	10 to 70
	20 to 50
	25 to 60
	50 to 90
	90 to 150
$R-C \equiv N$	110 to 125
	110 to 160
 (carboxylic acid / ester)	160 to 185
 (aldehyde / ketone)	190 to 220

3 4 5 6 7 0

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COMPONENT 1: PHYSICAL AND INORGANIC CHEMISTRY

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

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One tick must equate to one mark, apart from extended response questions where a level of response mark scheme is applied.

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A level of response mark scheme is applied. The complete response should be read in order to establish the most appropriate band. Award the higher mark if there is a good match with content and communication criteria. Award the lower mark if either content or communication barely meets the criteria.

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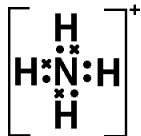
Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao	=	correct answer only
ecf	=	error carried forward
bod	=	benefit of doubt

Credit should be awarded for correct and relevant alternative responses which are not recorded in the mark scheme.

Section A

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1.				a <u>reversible</u> reaction where the forward and reverse reactions occur at the <u>same rate</u>	1			1		
2.				H ₂ O NH ₃ CH ₄ BF ₃ must be in this order		1		1		
3.				 showing four shared pairs including one where both electrons have come from the nitrogen atom (ignore charge)		1		1		
4.				δ^- O—H δ^+ δ^- C—H δ^+ δ^+ B—Cl δ^- δ^+ C=O δ^- any two correct (1) all four correct (2)		2		2		
5.				xenon +2 0 reduction oxygen -2 0 oxidation each correct row (1) total (1) if all oxidation states correct but one or more error in oxidation/reduction column		2		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6.				Mg ₃ (PO ₄) ₂		1		1		
7.				A ice B caesium chloride - both correct (1)	1			1		
8.				I ₂ < Br ₂ < Cl ₂ correct reason needed for credit greater degree of freedom leads to greater entropy / solids have lowest entropy and gases have highest entropy	1			1		
9.				K _p = $\frac{(\text{NH}_3)^2}{(\text{N}_2)(\text{H}_2)^3}$ (1) atm ⁻² (1)	1	1		2	1	
10.				$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$ (1) T ₂ = $\frac{25}{24} \times 298 = 310 \text{ K}$ (1)	1	1		2	1	
11.				2Cu ²⁺ + 4I ⁻ → 2CuI + I ₂		1		1		
				Section A total	5	10	0	15	2	0

Section B

Question				Marking details	Marks available														
					AO1	AO2	AO3	Total	Maths	Prac									
12.	(a)	(i)		<table><tr><td></td><td>Mass number</td><td>Symbol</td></tr><tr><td>Initial nuclide</td><td>194</td><td>Tl</td></tr><tr><td>Final nuclide</td><td>190</td><td>Pt</td></tr></table>		Mass number	Symbol	Initial nuclide	194	Tl	Final nuclide	190	Pt		2		2		
					Mass number	Symbol													
				Initial nuclide	194	Tl													
				Final nuclide	190	Pt													
		(ii)		radioactivity causes mutations / destroys or damages DNA (1) alpha radiation most damaging / most ionising (1) platinum has a long half-life so it emits radioactivity very slowly / bismuth emits radioactivity much more quickly (1) ¹⁹⁰ Bi is the most damaging (1)	2			2	4										
	(b)	(i)		Indicative content - atomic spectrum contains series of discrete lines on a dark background - these lines get closer together at higher energy until they overlap - there are several series of lines credit could be from a diagram - energy released when electron falls to lower energy state - discrete lines correspond to specific energies - this suggests that electrons can only move between certain fixed levels - frequency of light emitted corresponds to the difference between energy levels - the lines get closer together at higher energy within a series because the electron energy levels get closer together	4			2	6										

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
				5-6 marks: Each point included clear link between observations and the proposed model <i>The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.</i> 3-4 marks: Sound description of spectrum (could be missing reference to several series); clear understanding that discrete lines correspond to specific energies <i>The candidate constructs a coherent account including most of the key elements of the indicative content and little irrelevant material. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.</i> 1-2 marks: Attempt at description of spectrum; some reference to electron transitions and energy changes <i>The candidate attempts to link at least two relevant points from the indicative content. Coherence is limited by omission and/or inclusion of irrelevant material. There is some evidence of appropriate use of scientific conventions and vocabulary.</i> 0 marks: <i>The candidate does not make any attempt or give an answer worthy of credit.</i>						

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
12.	(b)	(ii)		aluminium has gradual increase in ionisation energies (1) with jumps between 3 rd and 4 th ionisations and 11 th and 12 th ionisations (1) jumps occur as electrons are in different shells / link between 2,8,3 and graph arrangements (1)	1	2		3		
				Question 12 total	7	4	4	15	0	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
13.	(a)			sodium oxide gives colourless solution, magnesium oxide forms white precipitate (1) $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$ (1) (accept $\text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2$)	1	1		2		1
	(b)			add $\text{CO}_3^{2-}(\text{aq}) / \text{OH}^-(\text{aq})$ (1) NaCl gives colourless solution, MgCl_2 gives white precipitate (1)		2		2		2
	(c)			$\text{Na}^+(\text{aq})$ and $\text{Cl}^-(\text{aq})$ do not react with H_2O , therefore pH is 7 (1) $\text{CH}_3\text{COO}^-(\text{aq})$ reacts with H_2O forming CH_3COOH and OH^- , therefore pH is greater than 7 (1)	2			2		
	(d)			$\Delta_{\text{f}}H = \Delta_{\text{at}}H \text{ Cu} + \text{I.E. Cu} + \Delta_{\text{at}}H \text{ F}_2 + \text{E.A.F} + \Delta_{\text{lat form}}H \text{ CuF}_2$ (1) doubling value for forming 2F and 2F ⁻ (1) (accept from Born-Haber cycle) $\Delta_{\text{f}}H \text{ CuF}_2 = 339 + 2705 + 158 - 696 - 3037$ (1) $\Delta_{\text{f}}H \text{ CuF}_2 = -531 \text{ kJ mol}^{-1}$ (1) award (4) for correct answer only (cao) error carried forward (ecf) possible		4		4	4	
				Question 13 total	3	7	0	10	4	3

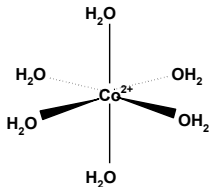
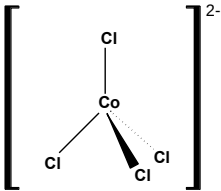
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14.	(a)			pressure increases (1) number of gas molecules increases / more moles of gas on product side of equation (1)		2		2		
	(b)	(i)		when concentration doubles, rate doubles (1) therefore first order or rate is proportional to concentration (<i>must give reason to get this mark</i>) (1) or calculate values for <i>k</i> or rate/concentration ratios (1) state that these are constant (1)			1 1	2	1	
		(ii)		rate determining step must have one N ₂ O ₅ molecule as reactant (1) mechanism A matches this rate equation (1) (<i>must give reason to get this mark</i>)			2	2		
	(c)			appropriate readings correctly made from graph e.g. $y = 4.4$; $x = 0.35 \times 10^{-3}$ (1) gradient = -12500 ± 500 (1) (<i>accept positive value</i>) $E_a = 12500 \times 8.31 = 103875$ (1) $E_a = 104 \text{ (kJ mol}^{-1}\text{)}$ (1) award (4) for cao award (3) for negative value or answer in J mol ⁻¹ ecf possible		1 1	1 1	4	4	
				Question 14 total	0	4	6	10	5	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
15.	(a)			$\Delta H = 2 \times -286 + (-394) - (-239)$ (1) $= -727 \text{ (kJ mol}^{-1}\text{)}$ (1) $\Delta S = 2 \times 70 + 214 - 127 - 1\frac{1}{2} \times 206$ (1) $= -82 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ (1) $\Delta G = [-727 - (298 \times -0.082)]$ (1) $= -703 \text{ (kJ mol}^{-1}\text{)}$ (1) award (5) for cao – AO1 mark withheld ecf possible	1	4		6	1	
	(b)			negative ΔG means reaction is feasible	1			1		
				Question 15 total	2	5	0	7	4	0

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
16.	(a)	(i)		$\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$		1		1		
		(ii)		acidify with $\text{HNO}_3(\text{aq})$, then add $\text{AgNO}_3(\text{aq})$ (1) cream precipitate is formed (1)	2			2		2
	(b)	(i)		hydrogen chloride	1			1		1
		(ii)		sulfur dioxide	1			1		1
	(c)			$\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$ (1) chlorine is simultaneously oxidised and reduced (1) from oxidation state 0 to -1 and $+1$ (1)		3		3		
	(d)			$K_a = \frac{[\text{H}^+][\text{CH}_2\text{ClCH}_2\text{COO}^-]}{[\text{CH}_2\text{ClCH}_2\text{COOH}]}$ (1) $[\text{CH}_2\text{ClCH}_2\text{COO}^-] = 0.150 \text{ mol dm}^{-3}$ (1) $[\text{H}^+] = \frac{(7.94 \times 10^{-5})(0.1)}{0.150}$ (1) $[\text{H}^+] = 5.29 \times 10^{-5}$ $\text{pH} = -\log 5.29 \times 10^{-5} = 4.28$ (1) ecf possible	1	1 1 1		4	1 1 1	4

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
16.	(e)			solution contains a large amount of $\text{CH}_2\text{ClCH}_2\text{COOH}$ and $\text{CH}_2\text{ClCH}_2\text{COO}^-$ ions (accept correct equations) (1) when an acid is added, the $\text{CH}_2\text{ClCH}_2\text{COO}^-$ ions react with the H^+ ions, removing them from solution and keeping the pH constant (1) when an alkali is added, the $\text{CH}_2\text{ClCH}_2\text{COOH}$ reacts with the OH^- ions, removing them from solution and keeping the pH constant (accept answer in terms of H^+ ions reacting with OH^- ions) (1)	3			3		
				Question 16 total	8	7	0	15	3	8

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
17.	(a)			sample contains potassium ions / Q or Z are potassium / K			1	1		1
	(b)	(i)		to ensure that all the water has been lost	1			1		1
		(ii)		1.081 / 18.02 = 0.06 mol (1) 0.06 moles water in 0.01 mol compound, so $x = 6$ (1) no ecf			2	2	2	
	(c)	(i)		$\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$		1		1		
		(ii)		excess needed to ensure that all the sulfate has been precipitated (1) add more barium chloride to filtrate to ensure there is no more precipitate formed / calculate volume needed and measure and add excess (1)		2		2		2
		(iii)		$25 \times 0.1 \div 1000 = 0.0025$ mol of schönite (1) moles barium sulfate = $1.166 / 233.1 = 0.005$ (1) $y = 0.005 / 0.0025 = 2$ (1)			3	3	3	
	(d)			formula is $\text{K}_2\text{Mg}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ (2) award (1) for identification of Mg if answer incorrect			2	2		
				Question 17 total	1	3	8	12	5	4

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
18.	(a)			 (1)  (1) award (1) only if ligands correct but no attempt at 3D representation of bonds	2			2		
	(b)	(i)		$f = \frac{3.00 \times 10^8}{590 \times 10^{-9}} = 5.08 \times 10^{14} \text{ (Hz)} \quad (1)$ $E = 3.37 \times 10^{-19} \text{ (J)} \quad (1)$ award (2) for cao ecf possible		2		2	2	
		(ii)		Indicative content • $[\text{CoCl}_4]^{2-}$ – red light is absorbed (shown in spectrum) • ligands cause splitting of <i>d</i>-orbitals into higher and lower energy levels • Co has a vacancy in the higher energy level • electrons in the lower level can absorb energy to move to the higher level • energy difference between higher and lower energy levels corresponds to the frequency/wavelength of red light credit awarded for an appropriately labelled diagram	5		1	6		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
				5-6 marks: Each point addressed, including one reference to red light; explanation in correct order; no reference to emission of blue light <i>The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.</i> 3-4 marks: Reference to splitting of <i>d</i>-orbitals by ligands; absorption of energy corresponding to difference between levels <i>The candidate constructs a coherent account including most of the key elements of the indicative content and little irrelevant material. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.</i> 1-2 marks: Splitting of d-orbitals; electrons move to another energy level; energy change corresponds to colour <i>The candidate attempts to link at least two relevant points from the indicative content. Coherence is limited by omission and/or inclusion of irrelevant material. There is some evidence of appropriate use of scientific conventions and vocabulary.</i> 0 marks: <i>The candidate does not make any attempt or give an answer worthy of credit.</i>						

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
18.	(b)	(iii)		value determined from graph – 0.067 ± 0.001 (1) calculated value = 0.06525 (given to min 3 sig figs) (1) graph does not give as precise an answer / precision lost using graph / mathematical equation gives answer to the same number of significant figures as absorption (1)		2	1	3	1	3
	(c)	(i)		$K_c = \frac{[(\text{CoCl}_4)^{2-}] [\text{H}_2\text{O}]^6}{[(\text{Co}(\text{H}_2\text{O})_6)^{2+}] [\text{Cl}^-]^4}$		1		1		
		(ii)		concentration of $\text{H}_2\text{O} = 0.48 \text{ mol dm}^{-3}$ concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+} = 0.12 \text{ mol dm}^{-3}$ concentration of $\text{Cl}^- = 0.18 \text{ mol dm}^{-3}$ all three concentrations stated explicitly or shown in equation (2) any one (1) $K_c = 7.77$ (1) award (3) for cao $\text{mol}^2 \text{ dm}^{-6}$ (1)	1	3		4	4	
	(d)			cloudiness is white precipitate / precipitate formed by reaction of chloride with silver ions/ insoluble silver chloride (1) concentration of chloride ions decreased significantly (1) equilibrium will shift to left hand side according to Le Chatelier's principle / to produce more chloride ions / to replace chloride ions removed (1) more $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ formed / $[\text{CoCl}_4]^{2-}$ converted to $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and these are different colours / leading to colour change (1)		1 1	1 1	4		4
				Question 18 total	8	10	4	22	7	7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
19.	(a)	(i)	any two for (1) each up to max 2 - eye protection for solution spillage when filling burette (1) - care to avoid burns whilst heating (1) - wear lab coat as sulfuric acid is corrosive, potassium manganate(VII) stains clothing (1)	2			2		2
		(ii)	mean titre = $(15.00 + 14.90 + 14.95) \div 3 = 14.95$ (1) moles $\text{MnO}_4^- = 0.020 \times 0.01495 = 2.99 \times 10^{-4}$ moles $\text{Fe}^{2+} = 1.495 \times 10^{-3}$ (1) conc $\text{Fe}^{2+} = 1.495 \times 10^{-3} / 0.025 = 0.0598 \text{ mol dm}^{-3}$ (1) award (3) for cao ecf possible		1 1 1		3	1 1	3
		(iii)	moles $\text{MnO}_4^- = 0.020 \times 0.0191 = 3.82 \times 10^{-4}$ (1) moles $\text{Fe}^{2+} = 1.91 \times 10^{-3}$ moles $\text{Fe}^{3+} = 1.91 \times 10^{-3} - 1.495 \times 10^{-3} = 4.15 \times 10^{-4}$ (1) conc $\text{Fe}^{3+} = 4.15 \times 10^{-4} / 0.025 = 0.0166 \text{ mol dm}^{-3}$ (1) award (3) for cao ecf possible or conc $\text{Fe}^{2+} = 1.91 \times 10^{-3} / 0.025 = 0.0764 \text{ mol dm}^{-3}$ (2) conc $\text{Fe}^{3+} = 0.0764 - 0.0598 = 0.0166 \text{ mol dm}^{-3}$ (1)		1	1 1	3	3	3

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
19.	(a)	(iv)		burette accurate to ± 0.10 , therefore apparatus error about 1% (1) three results are reliable since they are within 0.10 cm^3 of each other (1) improve accuracy by using an instrument to measure permanent colour change rather than visual estimation (1)			3	3		3
	(b)			any three for (1) each up to max 3 Method A would produce a result with a low Fe^{2+} concentration since: • reduction of Fe^{3+} might not be complete (1) • Fe^{2+} might re-oxidise to Fe^{3+} prior to titration (1) • there is no guarantee of complete transfer of Fe^{2+} following reduction (1) • Method B depends on use of digital apparatus so should be more accurate (1)			3	3		3
				Question 19 total	2	4	8	14	5	14

COMPONENT 1: PHYSICAL AND INORGANIC CHEMISTRY

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	Total	Maths	Prac
Section A	5	10	0	15	2	0
12.	7	4	4	15	0	0
13.	3	7	0	10	4	3
14.	0	4	6	10	5	0
15.	2	5	0	7	4	0
16.	8	7	0	15	3	8
17.	1	3	8	12	5	4
18.	8	10	4	22	7	7
19.	2	4	8	14	5	14
Totals	36	54	30	120	35	36

COMPONENT 2: ORGANIC CHEMISTRY AND ANALYSIS

MARK SCHEME

GENERAL INSTRUCTIONS

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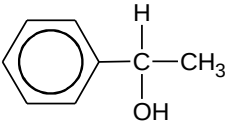
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Section A

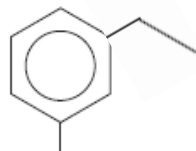
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1.				$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{CH}_2-\text{CH}-\text{CH}_3 \end{array} \quad \text{or} \quad \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$		1		1		
2.				2-methylbut-1-ene		1		1		
3.				•CH₂F and Cl• accept structural formula for fluoromethyl radical		1		1		
4.				$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}-\text{CH}_3 \\ \\ \text{Br} \end{array}$		1		1		
5.				one of the carbon atoms of the double bond has two atoms the same		1		1		
6.	(a)			the CH(OH) carbon atom is a chiral centre (could be shown on the formula)		1		1		
	(b)			the enantiomers will rotate the plane of polarised light in the opposite direction	1			1		
7.	(a)			it contains the CH ₂ OH group	1			1		
	(b)						1	1		

Question				Marking details	Marks available																	
					AO1	AO2	AO3	Total	Maths	Prac												
8.	(a)			silver mirror (1) the aldehyde group acts as a reducing agent and reduces Ag ⁺ to Ag (1)	2			2		1												
	(b)			an aldehyde group is present in the methanoate group and will reduce Ag ⁺ to Ag			1	1														
9.				<table border="1"><thead><tr><th>Reagent(s)</th><th>Functional group identified</th><th>Observation</th></tr></thead><tbody><tr><td>sodium carbonate</td><td>carboxylic acid</td><td>effervescence</td></tr><tr><td>iron(III) chloride (aq)</td><td>phenol</td><td>purple colouration</td></tr><tr><td>bromine (aq)</td><td>alkene</td><td>bromine decolourised</td></tr></tbody></table> (1) for each correct row	Reagent(s)	Functional group identified	Observation	sodium carbonate	carboxylic acid	effervescence	iron(III) chloride (aq)	phenol	purple colouration	bromine (aq)	alkene	bromine decolourised	3			3		3
Reagent(s)	Functional group identified	Observation																				
sodium carbonate	carboxylic acid	effervescence																				
iron(III) chloride (aq)	phenol	purple colouration																				
bromine (aq)	alkene	bromine decolourised																				
				Section A total	7	6	2	15	0	4												

Section B

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10.	(a)			angle 1 $\text{C}-\hat{\text{C}}-\text{H} \sim 120^\circ$ (1) angle 2 $\text{H}-\hat{\text{C}}-\text{H} \sim 109.5^\circ$ (1)	2			2		
	(b)			acidified (sodium/potassium) dichromate / H^+ , $\text{Cr}_2\text{O}_7^{2-}$ or acidified potassium manganate(VII) / H^+ , MnO_4^-	1			1		1
	(c)	(i)		$\text{SeO}_2 + 4 \text{Se} \rightarrow 0$ (1) oxidation number becoming less positive is reduction (1)	1	1		2		
		(ii)		SeO_2 only oxidises to an aldehyde / SeO_2 does not produce a carboxylic acid			1	1		
		(iii)		$M_r \text{CH}_3\text{CHO}$ 44.04 / 44 $M_r \text{CHO}-\text{CHO}$ 58.0 / 58 (1) moles of ethanal = $\frac{22.0}{44.04} = 0.500$ moles of ethanedial = $\frac{20.0}{58.0} = 0.345$ (1) (mole ratio is 1:1) % yield = $\frac{0.345 \times 100}{0.500} = 69.0$ (1) award (3) for correct answer only (cao) error carried forward (ecf) possible		3		3	1 1	
	(d)	(i)		nucleophilic addition-elimination / condensation	1			1		
		(ii)		the melting temperature cannot be higher than the book value $\therefore$ compound A cannot be propanal or cyclopentanone (1) if impure the compound will melt at a lower temperature than the expected value (1) and over a range of temperatures (1)		3		3		3

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(e)			test it with I ₂ / NaOH or NaOCl / KI (1) yellow precipitate / solid (1)		2		2		2
	(f)			any three for (1) each up to max 3 - the temperature / pressure at which the system operates (1) - how the ethanal is separated from the other products / catalyst (1) - if the use of a heterogenous catalyst is feasible (1) - how the catalyst is recovered (1) - the nature of the corrosion proof reactor lining (1) accept other sensible answers			3	3		
				Question 10 total	5	9	4	18	2	6

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11.	(a)	(i)		chloroethane / bromoethane		1		1		
		(ii)		 or in position 2 with respect to methyl group		1		1		
		(iii)		correct value of M_r from the graph (190) (1) correct deduction of ' M_r ' of R group (43.1) (1) correct formula of R group ($\text{CH}_3\text{CH}_2\text{CH}_2$ / $(\text{CH}_3)_2\text{CH}$) (1) no ecf		1 1	1	3	1	
		(iv)	I	electrical heating / oil bath (1) to avoid danger of fire / boiling temperature is greater than $100\text{ }^\circ\text{C}$ so a water bath cannot be used (1)	2			2		2
			II	acid chlorides are hydrolysed by moisture	1			1		1
	(b)	(i)		$\text{C}_2\text{H}_5\text{NH}_2 + \text{CH}_3\text{COOH} \rightarrow \text{C}_2\text{H}_5\text{NH}_3^+\text{CH}_3\text{COO}^-$ (1) $\text{C}_6\text{H}_5\text{NH}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{C}_6\text{H}_5\text{NH}_3^+\text{HSO}_4^-$ or $2\text{C}_6\text{H}_5\text{NH}_2 + \text{H}_2\text{SO}_4 \rightarrow (\text{C}_6\text{H}_5\text{NH}_3^+)_2\text{SO}_4^{2-}$ (1) (accept if charges omitted)		2		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11.	(b)	(ii)		they all act as bases by donating lone pair to H ⁺ (1)	1					
				the more available the lone pair, the stronger the base (1)	1					
				sensible comment on the order e.g. lone pair on nitrogen in phenylamine is delocalised to the ring electron system / ethyl group is electron releasing (1)		1		3		
	(c)	(i)		the phenol needs to be in alkaline solution (1)						
				the temperature needs to be 10 °C or less (1)	2			2		2
		(ii)	I	the yellow dye contains a phenolic OH group and this acidic group is neutralised by aqueous sodium hydroxide (1)						
				giving the (soluble) anion / ~~~ O ⁻ Na ⁺ (1)		2		2		
			II	when the solution becomes acidic, the (soluble) anion is replaced by the OH group to restore the insoluble yellow dye		1		1		
				Question 11 total	7	10	1	18	1	5

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
12.	(a)			dipoles shown i.e. $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$ (1) curly arrow shown from OH^- to $\text{C}^{\delta+}$ (1) curly arrow from bond to Cl (1) products are propan-1-ol and Cl^- (1)	4			4		
	(b)			nucleophilic substitution	1			1		
	(c)			Indicative content - The concentration of the sodium hydroxide solution in each case needs to be kept constant, otherwise the rate of substitution will be affected by the $[\text{OH}^-]$ present - The temperature of each reaction must be kept the same as reaction rate changes markedly with changes in temperature - The bonding between the carbon and halogen atom in each compound is covalent but each bond is a polar covalent bond - Polarisation for the C-Cl bond is the greatest suggesting that 1-chloropropane should react most quickly - The C-I bond is the weakest in terms of bond enthalpy suggesting that 1-iodopropane should react most quickly - The overriding factor in these reactions is the bond enthalpy	2	2	2	6		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
				5-6 marks: Each point included; clear understanding of link between observations and conclusion <i>The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.</i> 3-4 marks: Effect of at least one of general factors affecting rate included; reference to bond polarity and bond strength; attempt at comparison of their effect on rate <i>The candidate constructs a coherent account including most of the key elements of the indicative content and little irrelevant material. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.</i> 1-2 marks: Reference to one general factor affecting rate; conclusion in terms of bond enthalpy <i>The candidate attempts to link at least two relevant points from the indicative content. Coherence is limited by omission and/or inclusion of irrelevant material. There is some evidence of appropriate use of scientific conventions and vocabulary.</i> 0 marks: <i>The candidate does not make any attempt or give an answer worthy of credit.</i>						

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(d)	(i)		sodium / potassium hydroxide in ethanol	1			1		1
		(ii)		elimination / dehydrohalogenation	1			1		
		(iii)		(mass of required product ÷ total mass of reactants) × 100 or (82 ÷ 118.5) × 100 (1) = 69.2 % (1) award (2) for cao ecf possible if error in calculating one of masses		2		2		
		(iv)		Reasons in (a) – carbon is not δ^+ since electrons from chlorine pulled towards delocalised ring / C—Cl bond is strengthened since electrons from chlorine pulled towards delocalised ring (1) Reasons in (d) – there is no suitable hydrogen atom (to allow elimination of HCl) (1)		1	1	2		
				Question 12 total	9	5	3	17	0	1

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
13.				Mass spectrum M_r is 86 (1) link between mass and identity of any fragment e.g. 43 is CH_3CO / C_3H_7 (1) IR spectrum peak at $\sim 1700\text{ cm}^{-1}$ due to $\text{C}=\text{O}$ (1) no O-H peak (1) compound T is a carbonyl compound / aldehyde / ketone (not a carboxylic acid) (1) ^{13}C NMR four different carbon environments (1) ^1H NMR three different hydrogen environments (1) ratio of peak areas / hydrogen environments is 6:3:1 (1) any two for (1) each up to max 2 • splitting shows $\rightarrow$ 1 H on C next to C with multiple hydrogen atoms (1) • 6 protons on C next to C with 1 proton (1) • 3 protons on C next to C with no protons (1) Conclusion compound T is 3-methylbutanone (1)		1	1			
				Question 13 total	0	6	5	11	0	0

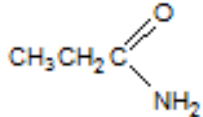
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14.	(a)	(i)		any alkene molecules produced would react with hydrogen (forming the corresponding alkane)			1	1		
		(ii)		$n = \frac{pV}{RT} = \frac{101000 \times 0.96}{8.31 \times 323}$ (1) $n = 36.1$ (1) $M = 57.9$ (1) methylpropane / $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_3$ (1)	1	1 1	1	4	1 1 1	
	(b)	(i)		relative peak area α -terpinene = 8 total relative peak area = 64 both required (1) $\therefore \text{percentage of } \alpha\text{-terpinene} = \frac{8 \times 100}{64} = 12.5$ (1)			2	2		
		(ii)		total percentage of α -terpinene in the citrus oil $= \frac{95 \times 12.5}{100} = 11.9$ (1) mass of α -terpinene in the citrus oil $= \frac{11.9 \times 3.2}{100} = 0.38 \text{ g}$ (1) award (2) for cao ecf possible from (ii)		2		2	2	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14.	(c)	(i)		1,2,3-tribromocyclohexane cannot be a product as addition of bromine / Br₂ is taking place and the only possible products are 1,2-dibromocyclohexane or 1,2,3,4-tetrabromocyclohexane (1) the percentage of bromine in the tetrabromo-compound is 80.0 and for the dibromo-compound it is 66.7 (1) one conclusion is that not every double bond has been brominated (and the product is a mixture of the dibromo- and tetrabromo- compounds) (1)			3	3		
		(ii)		answers based on any of the following techniques infrared (absorption) spectroscopy (1) look for C = C at 1620-1670 cm⁻¹ (1) proton NMR spectroscopy (1) look for HC = CH protons at ~4.8 δ (1) GLC / HPLC (1) compare retention times with standard materials (1) mass spectroscopy (1) look for fragmentation pattern / M⁺ signals (1)	1	1		2		2
				Question 14 total	2	5	7	14	5	2

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
15.	(a)			dehydration / elimination	1			1		
	(b)			(concentrated) sulfuric acid / (concentrated) phosphoric acid	1			1		1
	(c)			methanol contains a (polar) $\text{O}^{\delta-}-\text{H}^{\delta+}$ bond (could be shown in a formula) (1) the 'H' of the OH group acts as an electrophile (1) reacting with the alkene to give the 2-methyl-2-propyl carbocation / tertiary carbocation (1) if 1-methoxy-2-methylpropane was the product, then the intermediate carbocation would be the 2-methyl-1-propyl carbocation which is a primary carbocation (1) less stable / not so easily formed as the tertiary 2-methyl-2-propyl carbocation (1)		1 1 1	1 1	5		
	(d)			the alcohol can hydrogen bond between its molecules but MTBE cannot (1) more energy is needed to break these hydrogen bonds therefore a relatively higher boiling temperature (1)		2		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
15.	(e)			Indicative content • 2-methylpropan-1-ol / the alcohol is treated with HCl / hydrogen chloride in the presence of (anhydrous) zinc chloride • to give 1-chloro-2-methylpropane / (CH₃)₂CHCH₂Cl • this chloro-compound then reacts with potassium cyanide / KCN • giving 3-methylbutanenitrile / (CH₃)₂CHCH₂CN • this is then hydrolysed by, for example, aqueous sulfuric acid (to give the carboxylic acid) 5-6 marks: Each step included in the correct order; reagents and intermediate products identified <i>The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.</i> 3-4 marks: General description of each stage; reagents/products identified for two stages <i>The candidate constructs a coherent account including most of the key elements of the indicative content and little irrelevant material. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.</i>	2	2	2	6		6

			1-2 marks: Description or reagents given for one step; one intermediate product identified <i>The candidate attempts to link at least two relevant points from the indicative content. Coherence is limited by omission and/or inclusion of irrelevant material. There is some evidence of appropriate use of scientific conventions and vocabulary.</i> 0 marks: <i>The candidate does not make any attempt or give an answer worthy of credit.</i>						
			Question 15 total	4	7	4	15	0	7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
16.	(a)	(i)	moles of NaOH used = $\frac{1.25 \times 50.00}{1000} = 0.0625$ (1) moles of HCl used = $\frac{1.00 \times 30.50}{1000} = 0.0305$ (1) since 1 mol of HCl reacts with 1 mol of NaOH moles of NaOH that reacted with the amide = $0.0625 - 0.0305 = 0.0320$ (1) since 1 mol of NaOH reacts with 1 mol of the amide moles of the amide present = 0.0320 $\therefore M_r$ of the amide = $\frac{\text{mass}}{\text{moles}} = \frac{2.34}{0.032} = 73.1$ (1) ecf possible up to this point but not for incorrect alkyl group 'M_r' CONH₂ = 12 + 16 + 2.02 = 44.02 'M_r' R = 73.1 – 44.02 = 29.08 → an alkyl group $\therefore$ C₂H₅ formula of the amide is  (1)					4	
					5		5		5

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
16.	(a)	(ii)		M_r of benzamide is 121 (the value obtained is too high) (1) not all the ammonia had been expelled (1) $\therefore$ more HCl was used to neutralise this $\therefore$ the titration indicated that apparently relative less of the NaOH reacted with the amide $\therefore$ number of moles is apparently less $\therefore M_r$ higher (1) (accept 'some HCl reacted with the ammonia' as a weaker answer for the second point) mass used was lower than the recorded mass (2) [incorrect recording of the mass of amide used (1)]		1	2	5		5
	(b)			add NaHCO_3 (1) effervescence (1) or universal indicator (1) turns red (1)	2			2		2
				Question 16 total	2	6	4	12	4	12

COMPONENT 2: ORGANIC CHEMISTRY AND ANALYSIS**SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES**

Question	AO1	AO2	AO3	Total	Maths	Prac
Section A	7	6	2	15	0	4
10.	5	9	4	18	2	6
11.	7	10	1	18	1	5
12.	9	5	3	17	0	1
13.	0	6	5	11	0	0
14.	2	5	7	14	5	2
15.	4	7	4	15	0	7
16.	2	6	4	12	4	12
Totals	36	54	30	120	12	37

COMPONENT 3: CHEMISTRY IN PRACTICE

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark, apart from extended response questions where a level of response mark scheme is applied.

Question totals should be written in the box at the end of the question.

Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

Extended response questions

A level of response mark scheme is applied. The complete response should be read in order to establish the most appropriate band. Award the higher mark if there is a good match with content and communication criteria. Award the lower mark if either content or communication barely meets the criteria.

Marking rules

All work should be seen to have been marked.

Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.

Crossed out responses not replaced should be marked.

Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao	=	correct answer only
ecf	=	error carried forward
bod	=	benefit of doubt

Credit should be awarded for correct and relevant alternative responses which are not recorded in the mark scheme.

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1.	(a)			diagram with labels calorimeter / polystyrene cup (1) thermometer (1) allow (1) if both drawn but neither labelled copper(II) sulfate (1) must be labelled	3			3		3
	(b)	(i)		straight line of best fit through ‘after reaction’ points (1) higher line extrapolated to point of mixing (1) ΔT determined from graph (1) error carried forward (ecf) possible		1 1	1	 3	1	 3
		(ii)		moles of Zn = $0.60/65$ (1) $50 \times 4.2 \times \Delta T$ [from (i)] (1) calculation of enthalpy change of reaction $= \frac{50 \times 4.2 \times \Delta T \times 65}{1000 \times 0.60}$ (1) $= -227.5$ must be negative value (1) award (3) for correct answer only (cao) – AO1 mark withheld ecf possible	1	1 1 1		 4	1 1	 4
	(c)	(i)		reaction slower because surface area is less (1) fewer collisions per unit time / less chance of collisions (1)	2			2		
		(ii)		it would take more time for the graph to reach its maximum after mixing / graph will not rise as steeply accept sensible alternatives			1	1		
				Question 1 total	6	5	2	13	3	10

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2.	(a)			final volume/ burette reading, initial volume/ burette reading and titre/ volume added headings in first column with units (1) titre/ volume added in bottom row of table (1)	2			2		2
	(b)			to avoid dilution of the acid (1) leading to a larger than expected titre (1)			2	2		2
	(c)	(i)		2.52/106 = 0.0238 moles of Na ₂ CO ₃ in 25.0 cm ³ = 0.00238 (1) 1mol H ₂ SO ₄ : 1mol Na ₂ CO ₃ therefore 0.00238 mol H ₂ SO ₄ in 20.10 cm ³ (1) conc. = $\frac{0.00238 \times 1000}{20.1}$ = 0.118 (1) award (3) for cao allow ecf or c ₁ V ₁ = c ₂ V ₂ c ₁ = 0.0951 (1) 0.0951 × 0.025 = c ₂ × 0.0201 (1) c ₂ = 0.118 (1)		1 1 1		3	1	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2.	(c)	(ii)		burette measures $\pm 0.05 \text{ cm}^3$ but initial and final readings compound error giving $\pm 0.10 \text{ cm}^3$ (1) max % error = $\frac{0.1}{20.1} \times 100 = 0.50 \text{ (\%)} (1)$ (accept calculation based on only one reading and on burettes with $\pm 0.10 \text{ cm}^3$ precision) this is less than 1% error (but more than 0.1%) so record to 3 significant figures (1)			3	3	2	3
				Question 2 total	2	3	5	10	4	7

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3.	(a)	(i)		measure the volume of gas given off (1) in a certain time period (1) or measure the decrease in mass (of the reaction mixture) (1) in a certain time period (1)		2		2		2
		(ii)		temperature	1			1		1
	(b)			labelled axes with units (1) points correctly plotted – within half a small square (1) line drawn through points – should miss point at conc = 0.400 (1)	2		1	3	2	
	(c)			rate reaction (directly) proportional to concentration H_2O_2 therefore first order with respect to H_2O_2 / $x = 1$ (1) $k = \frac{0.0511}{[0.100][0.103]}$ (1) $k = 4.96$ (1) (answer must be given to 3 sig figs) $\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$ (1) (accept $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$) credit similar calculation based on other set of results ecf possible	1	1	1	4	4	4
				Question 3 total	4	3	3	10	6	7

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4.				award (1) for each relevant test linked to functional group / named compound(s) up to maximum of 3 marks – general description of test rather than exact reagents is sufficient for example 2,4 DNPH identifies carbonyl compounds (1) Tollens' identifies aldehyde (1) iodoform identifies methyl ketone (1) hydrolysis/Ag ⁺ identifies halogenoalkane (1) all 3 could be awarded by implication is a well-constructed plan maximum of 2 marks if any irrelevant/unnecessary test included [AO3 mark withheld] all 5 compounds identified with clear rationale including all observations and conclusions (4) all 5 compounds identified with some missing detail in rationale (3) at least three compounds identified with some missing detail in rationale (2) at least two compounds identified (1) strategy clearly indicating that tests are only carried out on compounds that remain unidentified (1) for example 2,4 DNPH test on all compounds – orange/yellow/red ppt with 3 compounds and no reaction with 2 compounds; Tollens' test on 3 compounds giving positive 2,4 DNPH – silver mirror with propanal and no reaction with 2 compounds; iodoform test on 2 compounds giving negative Tollens' – pale yellow ppt with butanone and no reaction with pentan-3-one hydrolysis/Ag ⁺ test on 2 compounds giving negative 2,4 DNPH – white ppt with 1-chlorobutane and cream ppt with 1-bromobutane	2		1			
						2	2	8		8
							1			
				Question 4 total	2	2	4	8	0	8

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5.	(a)			reflux	1			1		1
	(b)			$\text{C}_6\text{H}_5\text{CH}_3 + \text{OH}^- + 3[\text{O}] \rightarrow \text{C}_6\text{H}_5\text{COO}^- + 2\text{H}_2\text{O} \text{ (1)}$ $\text{C}_6\text{H}_5\text{COO}^- + \text{H}^+ \rightarrow \text{C}_6\text{H}_5\text{COOH} \text{ (1)}$		2		2		
	(c)	(i)		Indicative content - solvent B selected - dissolve solid in minimum amount of hot solvent B - filter mixture whilst hot and cool until solid recrystallises - filter again, wash with cold solvent B and dry crystals Missing steps or an incorrect order of steps should be considered as ‘significant omissions’ and credit must be limited to the 1-2 marks band 5-6 marks: Each point included in the correct order; details in bold essential <i>The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.</i> 3-4 marks: Correct solvent; correct order; reference to ‘hot’ at dissolving and filtering stages <i>The candidate constructs a coherent account including most of the key elements of the indicative content and little irrelevant material. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.</i>	4		2	6		6

			1-2 marks: Minimum of two from correct solvent, dissolve in hot solvent, filter hot, cool, filter <i>The candidate attempts to link at least two relevant points from the indicative content. Coherence is limited by omission and/or inclusion of irrelevant material. There is some evidence of appropriate use of scientific conventions and vocabulary.</i> 0 marks: <i>The candidate does not make any attempt or give an answer worthy of credit.</i>						
		(ii)	measure the melting temperature and check against literature value	1			1		1
			Question 5 total	6	2	2	10	0	8

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6.	(a)			sodium hydroxide added to ethanoic acid (1) ethanoic acid in (conical) flask / beaker and sodium hydroxide in burette (1) 25 cm ³ of acid (1) measure pH with pH probe/ meter after each (small volume) addition / continuous measurement with data logger or computer (1)		1	1			
	(b)			cresol red because indicator needs to change colour in pH range of vertical section on graph			1	1		1
	(c)			$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} \quad (1)$ (from graph) pH = 2.9 (1) $[H^+] = 1.26 \times 10^{-3} \quad (1)$ $K_a = \frac{(1.26 \times 10^{-3})^2}{0.1} = 1.6 \times 10^{-5} \quad (1)$ award (4) for cao ecf possible accept answer based on $pK_a = \text{pH}$ at half neutralisation		1	1			
						1			1	
						1		4	1	
				Question 6 total	0	5	4	9	2	5

COMPONENT 3: CHEMISTRY IN PRACTICE**SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES**

Question	AO1	AO2	AO3	Total	Maths	Prac
1.	6	5	2	13	3	10
2.	2	3	5	10	4	7
3.	4	3	3	10	6	7
4.	2	2	4	8	0	8
5.	6	2	2	10	0	8
6.	0	5	4	9	2	5
Totals	20	20	20	60	15	45