GCE AS/A LEVEL

WJEC GCE AS/S LEVEL in
CHEMISTRY

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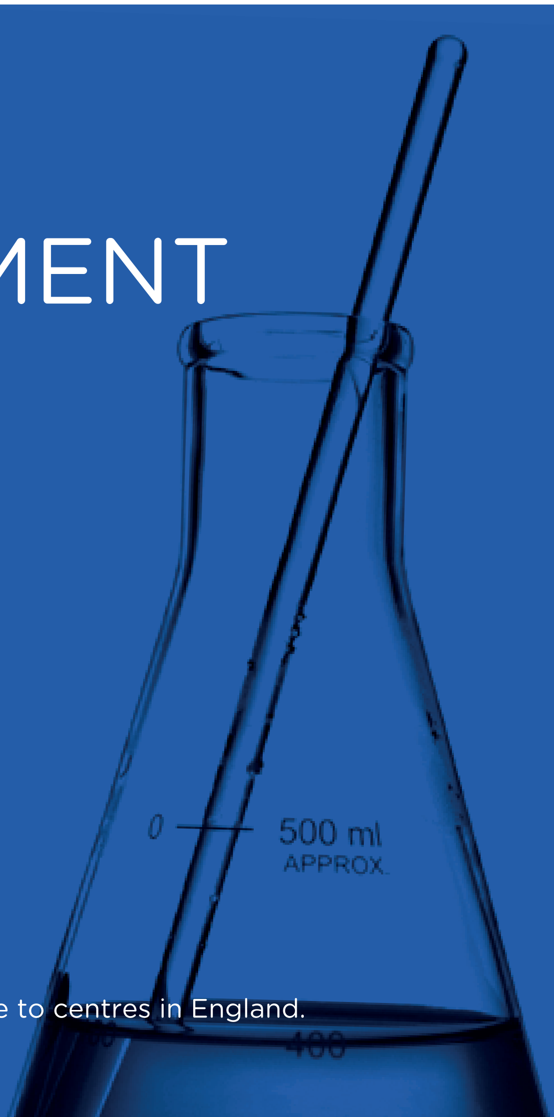
SPECIMEN ASSESSMENT MATERIALS

Teaching from 2015



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Contents

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Candidate Name	Centre Number					Candidate Number				
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GCE AS/A LEVEL CHEMISTRY

AS UNIT 1

The Language of Chemistry, Structure of Matter and Simple Reactions

SPECIMEN PAPER

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 6.**	**10**	
Section B	**7.**	**16**	
	8.	**15**	
	9.	**17**	
	10.	**15**	
	11.	**7**	
	Total	**80**	

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.

The assessment of the quality of extended response (QER) will take place in question 9.

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SECTION A

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

1. A radioactive isotope of boron has a half-life of 5×10^{-3} seconds. Calculate how long it will take for 0.32 g of the isotope to decay to 0.04 g. [1]

Time taken = …........…. s

2. *(a)* State the meaning of the term *dynamic equilibrium* for a chemical system. [1]

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(b) Explain how you would tell, from the properties of the system, that equilibrium has been reached. [1]

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3. Cyanogen is a compound containing only carbon and nitrogen.

It has a relative molecular mass of 52.

(a) State the molecular formula of cyanogen. ……………………………… [1]

(b) State the empirical formula of cyanogen. ……………………………… [1]

4. Sulfur hexafluoride reacts with hydrogen sulfide in a redox reaction.

$$SF_6 + 3H_2S \rightarrow 6HF + 4S$$

Complete the table below, giving the oxidation states of the sulfur atoms present and use these to explain how hydrogen sulfide is the reducing agent in this reaction. [2]

Oxidation state of sulfur in SF_6	Oxidation state of sulfur in H_2S	Oxidation state of sulfur in sulfur, S

……………………………………………………………………………………………

……………………………………………………………………………………………

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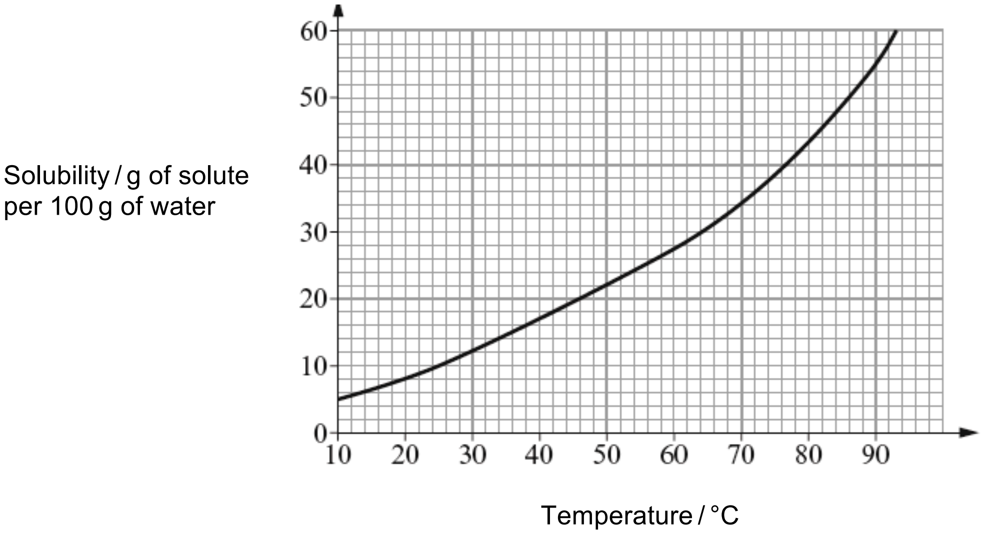
5. Calculate the pH of a 0.01 mol dm^{-3} solution of sulfuric acid. [2]

pH = ...

6. A solid was prepared in an impure state and it was then purified by recrystallisation. The solid was dissolved in the minimum amount of water at 90 °C and the solution was cooled to 25 °C.

The solubility curve for the solid in water is shown below.



Use the solubility curve to find the maximum mass of solid that would form from 20 g of water cooled from 90 °C to 25 °C. [1]

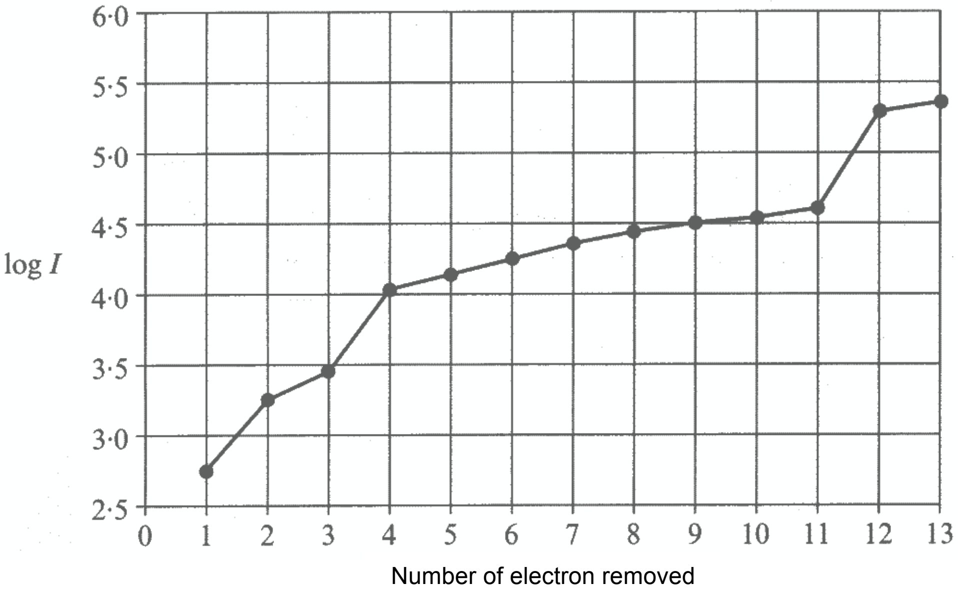
Maximum mass = ……………………………… g

10

SECTION B

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

7. *(a)* The graph below shows a plot of the logarithm of the successive ionisation energies of an element.



(i) State what this graph tells us about the way electrons are arranged in an atom. [1]

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(ii) Explain the significant difference in value between the energy required to remove the third and fourth electrons. [2]

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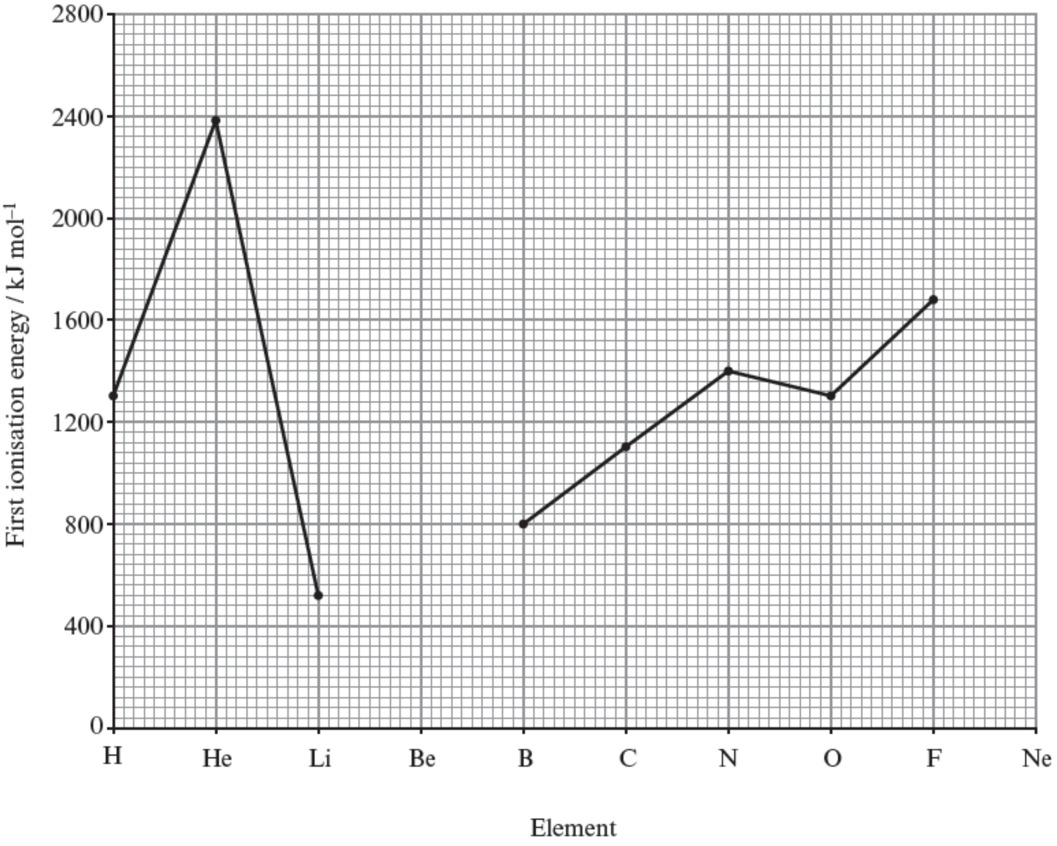
(b) The graph below shows the first molar ionisation energies for a selection of the first ten elements.



(i) Complete the graph by adding points that represent the first ionisation energies for the elements beryllium and neon. [1]

(ii) Write an equation to represent the first ionisation of a beryllium atom. [1]

....

(iii) Explain why nitrogen has a higher first ionisation energy than oxygen. [2]

....

....

(c) (i) Electrons are thought to exist in shells. Explain how **both** parts *(a)* and *(b)* provide evidence for this theory. [2]

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(ii) Compare the evidence for electronic structure from parts *(a)* and *(b)* to decide which gives a clearer picture of electronic structure. [1]

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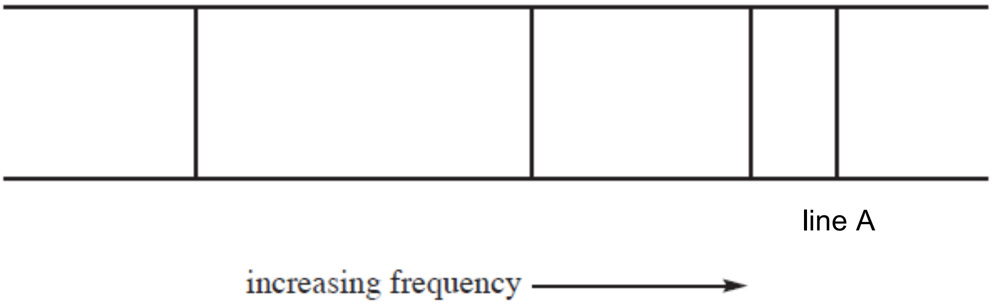
………………………………………………………………………………………

(d) The diagram below shows the first four lines of the atomic spectrum for hydrogen in the ultra-violet region of the electromagnetic spectrum (part of the Lyman series).



(i) Line A represents the convergence limit of this series and is found at a wavelength of 91.2×10^{-9} m.

Use the equation below to calculate the frequency, f, of line A and hence its energy, E, in Joules (J). Show your working. [3]

$$c = f \times \lambda$$

$$c = 2.99 \times 10^{8}\ \mathrm{m\,s^{-1}} \qquad h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$$

Energy = ……………………… J

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(ii) There are 6.02×10^{23} hydrogen atoms in 1 mol. Use your answer to part (i) and this information to calculate the energy in kJ mol^{-1}. [2]

Energy = ... kJ mol^{-1}

(iii) State the significance of the value calculated in part (ii) and represented by the convergence limit of the Lyman series. [1]

....

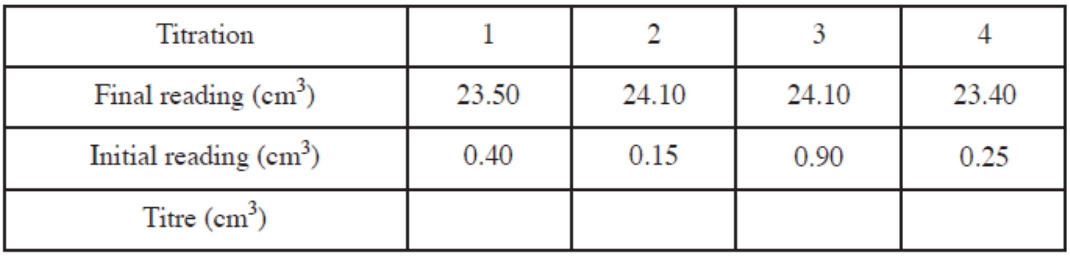
16

8. This question involves two different methods to determine the percentage of sodium carbonate in a mixture.

(a) Elinor is given the mixture and she carries out a two-step experiment to determine the percentage of sodium carbonate in the mixture.

In step 1, she accurately weighs 2.05 g of the mixture, transfers all of it to an appropriate container, adds 100 cm^3 of distilled water to ensure that it all dissolves and accurately makes up the solution to 250 cm^3 with distilled water.

In step 2, she pipettes 25.0 cm^3 of the solution into a container, adds 3 drops of an appropriate indicator and titrates this solution with hydrochloric acid of concentration 0.100 mol dm^{-3}. She repeats this procedure three times and obtains the following results.



Titration	1	2	3	4
Final reading (cm^3)	23.50	24.10	24.10	23.40
Initial reading (cm^3)	0.40	0.15	0.90	0.25
Titre (cm^3)				

(i) Name a suitable container to make up the solution that could be used in step 1. [1]

……………………………………………………………………………………………

(ii) Calculate the mean titre that Elinor should use in her calculations. [2]

Mean titre = ... cm^3

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(iii) The equation for the reaction between sodium carbonate and hydrochloric acid is given below.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

I. Use your answer to part (ii) to calculate the number of moles of HCl used in the titration and hence deduce the number of moles of Na_2CO_3 in 25.0 cm^3 of the solution in step 2. [2]

Number of moles of Na_2CO_3 = ... mol

II. Calculate the percentage of Na_2CO_3 in the original mixture. [3]

Percentage of Na_2CO_3 = …................................ %

(b) In a separate experiment Robert was asked to analyse the mixture by means of a precipitation reaction.

Robert measured exactly 2.1 g of the mixture and dissolved it in an excess of distilled water. To this solution he added an excess of barium nitrate solution. A precipitate of barium carbonate, $BaCO_3$, was formed according to the following equation.

$$Na_2CO_3(aq) + Ba(NO_3)_2(aq) \rightarrow BaCO_3(s) + 2NaNO_3(aq)$$

The precipitate was filtered. The mass of barium carbonate formed in the experiment was 2.3 g.

(i) Explain why the volume of distilled water used to dissolve the original mixture was not measured accurately. [1]

....

(ii) Use the mass of barium carbonate formed to calculate the mass of Na_2CO_3 in the original mixture and hence the percentage of Na_2CO_3 in the mixture. [3]

Percentage of Na_2CO_3 = ... %

(c) (i) Explain which of the two methods described in parts *(a)* and *(b)* is likely to give the more accurate results. [1]

....

....

....

....

(ii) Suggest possible improvements to the method which gave the less accurate result. [2]

....

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....

15

9. *(a)* The melting temperature and electrical conductivity were measured for the following five substances.

sodium chloride
diamond
graphite
iron
iodine

The results of the experiment are shown in the table:

Substance	Melting temperature / °C	Conditions required for electrical conductivity
A	3550	does not conduct in any state
B	801	conducts when molten
C	3642	conducts as a solid
D	1535	conducts as a solid
E	114	does not conduct in any state

(i) State, explaining how you reached your conclusion, which of the substances is sodium chloride. [2]

....

....

....

....

(ii) I. Identify the two substances which are diamond and iodine. [1]

…………… and ……………

II. State which of the above physical properties would allow you to distinguish between these two solids. Include in your answer the reasons for the two solids behaving differently. [2]

....

....

....

....

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(iii) Describe a **different** physical property which could be used to distinguish between iodine and sodium chloride. Include in your answer the reasons for the two solids behaving differently. [3]

....

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(b) Use the VSEPR theory to deduce the shapes of BF_3 and NH_3.
Explain the difference in the shapes of BF_3 and NH_3. [6 QER]

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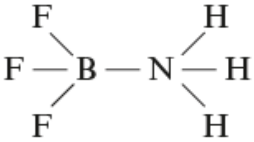
....

(c) Boron fluoride reacts with ammonia, NH_3, to make the compound shown in the following equation.

(i) Name the type of bond formed between N and B. [1]

………………………………………………………………………………………...

(ii) Suggest a value for the F–B–F bond angle in this molecule.



Bond angle ……………………………… [1]

(iii) Explain your answer to part (ii). [1]

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10. *(a)* Bromine is produced commercially from bromide ions in sea water by reaction with chlorine.

(i) Give the equation for this reaction. [1]

....

(ii) Using oxidation states, show that chlorine is behaving as the oxidising agent in this reaction. [2]

....

....

....

(iii) Air is then blown through the bromine-containing mixture to remove bromine as its vapour.

Iodine can be produced in a similar way from the iodide ions present in sea water but it is more difficult to produce iodine vapour from its solution because iodine is less volatile than bromine.

Explain, in terms of bonding, why iodine is less volatile than bromine. [2]

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(b) On Earth, iodine occurs as only one stable isotope, ^{127}I.

(i) Using your understanding of the mass spectrum of chlorine, Cl_2, sketch and label the mass spectrum of a sample of iodine. [2]

(ii) A sample of iodine extracted from a meteorite was found to have a relative atomic mass of 128.7. State what this tells you about the composition of the iodine within the meteorite. [1]

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(c) Edmund carries out some experiments with Group 2 metals.

(i) In the first experiment, he adds a piece of calcium to cold water.

I. State what he would **observe** in this reaction. [2]

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II. Write a balanced chemical equation for the reaction. [1]

……………………………………………………………………………………

……………………………………………………………………………………

III. The experiment is repeated with a piece of magnesium. State what he now observes. [1]

……………………………………………………………………………………

(ii) In the next experiment, Edmund reacts pieces of calcium with 19.4 cm^3 of 2.02 mol dm^{-3} hydrochloric acid.

$$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$$

I. Calculate the minimum mass of calcium needed to react completely with the acid. [2]

Mass of calcium = …....................g

II. Calculate the total volume of hydrogen evolved during this reaction when it is carried out at room temperature and pressure. [1]

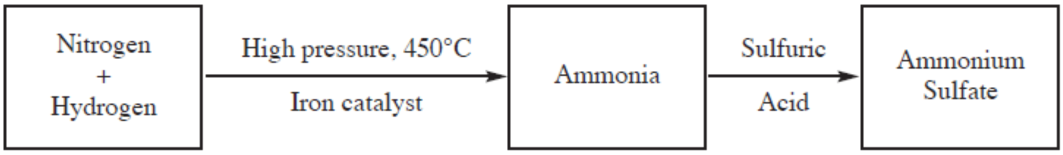
[1 mol of any gas occupies a volume of 24.0 dm^3 under these conditions]

Volume = …................... dm^3

15

11. Ammonia, a very important industrial product, is produced by the Haber process.

Ammonia can be converted to ammonium sulfate, $(NH_4)_2SO_4$, a common fertiliser, by reacting it with sulfuric acid, H_2SO_4.



(a) Explain why ammonia behaves as a base in the formation of ammonium sulfate. [1]

……………………………………………………………………………………………………

The Haber process can be represented by the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92\ \text{kJ mol}^{-1}$$

(b) For the equilibrium reaction, explain why

(i) a high pressure is used, [2]

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(ii) ammonia is removed from the equilibrium mixture as it forms. [2]

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(c) Predict and explain the effect of increasing the temperature of the surroundings on the value of the equilibrium constant, K_c, for the reaction. [2]

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Candidate Name	Centre Number					Candidate Number				
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GCE AS/A LEVEL CHEMISTRY

AS UNIT 2

SPECIMEN PAPER

Energy, Rate and Chemistry of Carbon Compounds

1 hour 30 minutes

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1. to 6.	10	
Section B	7.	14	
	8.	14	
	9.	12	
	10.	15	
	11.	15	
	Total	80	

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.

The assessment of the quality of extended response (QER) will take place in question 10.

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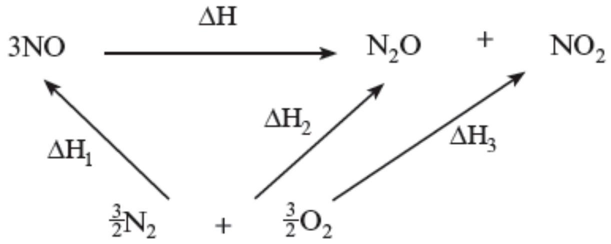
SECTION A

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

1. The energy cycle for a decomposition of nitrogen(II) oxide is shown below.



(a) Complete the equation to show ΔH in terms of ΔH_1, ΔH_2 and ΔH_3. [1]

ΔH =

(b) Write the chemical equation for the standard molar enthalpy change of formation of gaseous nitrogen(II) oxide, NO. [1]

………………………………………………………………………………………………..

2. A compound of carbon, hydrogen and oxygen has a relative molecular mass of 180.

The percentage composition by mass is C 40.0 %; H 6.70 %; O 53.3 %.

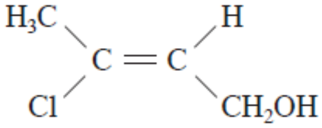
(a) Calculate the empirical formula of this compound. [2]

Empirical formula ....

(b) Determine the molecular formula of this compound. [1]

Molecular formula ....

3. *(a)* Explain why Compound **T** has *E*–*Z* isomers. [1]



Compound **T**

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(b) Explain why the enthalpy change to convert the *E*-isomer of compound **T** to the *Z*-isomer of compound T is 0 kJ mol^{-1} [1]

…………………………………………………………………………………………………

…………………………………………………………………………………………………

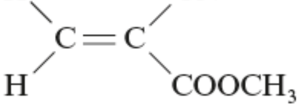
4. Draw the **skeletal** formula of 4-chloro-2-methylpentane. [1]

5. Ethanol is present in many intoxicating drinks. Give **one** health problem associated with the consumption of excess ethanol. [1]

…………………………………………………………………………………………………

6. ‘Superglue’ is a liquid containing methyl 2-cyanopropenoate. In the presence of moisture this alkene rapidly polymerises, in a similar way to ethene.

Complete the table showing the structure of the repeating unit. [1]

Monomer	Repeating unit
	

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SECTION B

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

7. *(a)* The reaction of methane with chlorine gives a wide array of products including chloromethane, dichloromethane, trichloromethane, tetrachloromethane and ethane. This reaction only occurs in the presence of ultraviolet light.

(i) Give a balanced equation for the formation of trichloromethane from dichloromethane and chlorine. [1]

....

(ii) Under similar conditions, pentane can be used to produce 1-chloropentane.

I. Explain how decane, $C_{10}H_{22}$, could be produced as one of the products of this reaction. [2]

....

....

II. Warming 1-chloropentane with aqueous sodium hydroxide produces pentan-1-ol. Use the infrared absorption frequencies given in the data sheet to explain how you could check spectroscopically that this reaction had converted **all** the 1-chloropentane into pentan-1-ol. [2]

....

....

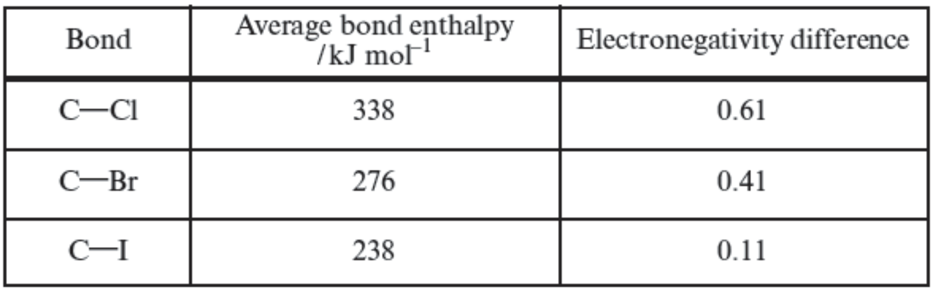
(iii) Gas **X** is another product of this reaction.

1.23 g of gas **X** occupies 1 dm^3 at a temperature of 308 K and pressure of 105000 Pa. Use this information to suggest its identity. [3]

Gas **X** ....

(b) It is possible to test for the presence of halogen atoms in a halogenoalkane by hydrolysing the molecule and testing for the halide ions released, using silver nitrate solution. This is a nucleophilic substitution reaction with the nucleophile attacking the $C^{\delta+}$ of the C–halogen bond. In each case, a precipitate is formed.

The carbon–halogen bond energies and the electronegativity differences for each bond are given below.



Bond	Average bond enthalpy /kJ mol^{-1}	Electronegativity difference
C—Cl	338	0.61
C—Br	276	0.41
C—I	238	0.11

Using the information in the table, state how you would expect the rate of hydrolysis to vary as the halogenoalkane is changed. [2]

…………………………………………………………………………………………

…………………………………………………………………………………………

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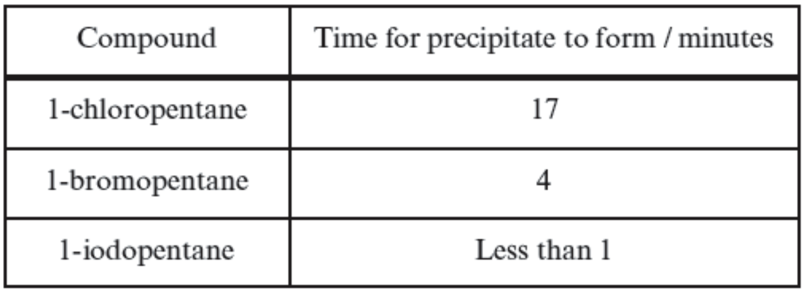
(c) The hydrolysis of three compounds was performed under identical conditions, and the time required for a precipitate of silver halide to form was measured.

The results were as follows:



Compound	Time for precipitate to form / minutes
1-chloropentane	17
1-bromopentane	4
1-iodopentane	Less than 1

(i) Use the tables to explain which of the factors does affect the rate of reaction. [2]

……………………………………………………………………………………………

……………………………………………………………………………………………

(ii) Briefly describe how you could gain further evidence to support the conclusion in part *(b)*. [2]

……………………………………………………………………………………………

……………………………………………………………………………………………

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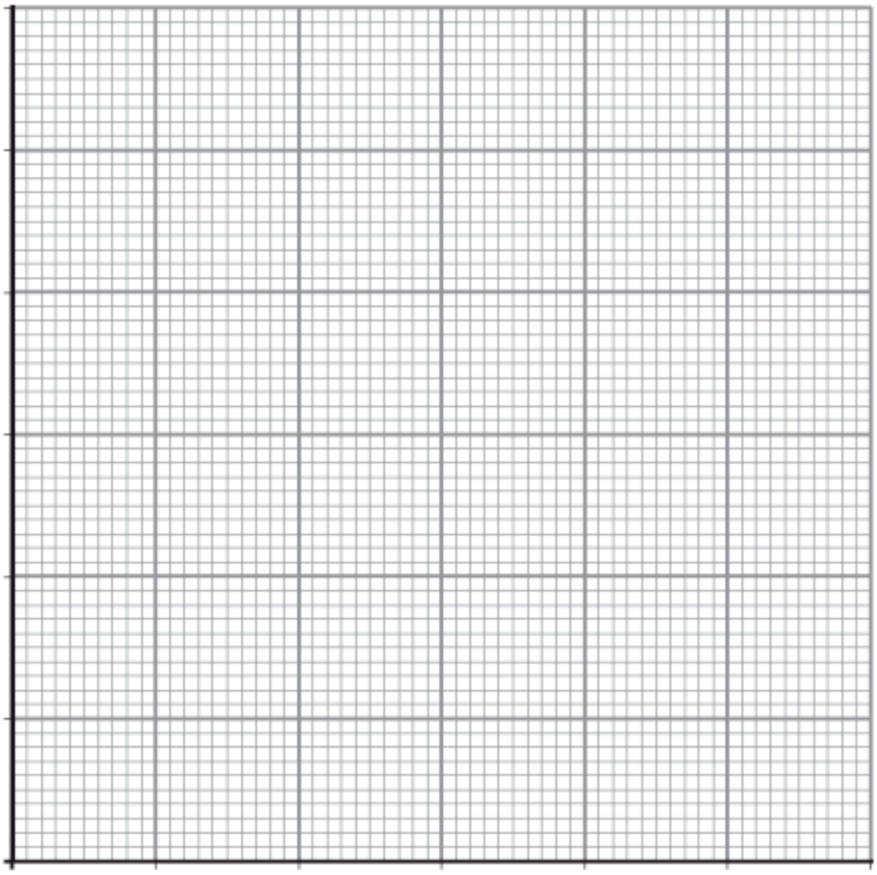
8. *(a)* Iodine is slowly produced, as a red-brown solution, by the reaction of aqueous peroxodisulfate ions, $S_2O_8^{2-}$, with a large excess of aqueous iodide ions,

$$\underset{\text{colourless}}{S_2O_8^{2-}(aq)} + \underset{\text{colourless}}{2I^-(aq)} \longrightarrow \underset{\text{colourless}}{2SO_4^{2-}(aq)} + \underset{\text{red-brown}}{I_2(aq)}$$

The following results were collected by a student.

Reaction time / min	0	1	2	3	4	5	6
Concentration of I_2(aq) / mol dm^{-3}	0	0.0043	0.0070	0.0088	0.0097	0.0102	0.0102

(i) Plot these results on the grid below.
Label the axes, select a suitable scale and draw the line of best fit.
[3]



(ii) Describe the key features of the method that would have been used to measure the rate of this reaction. [3]

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(iii) Explain, using particle theory, the effect of increasing temperature on the rate of this reaction. [2]

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(iv) State the concentration of the peroxodisulfate ions at the start of the reaction, explaining your answer. [2]

…………………………………………………………………………………………

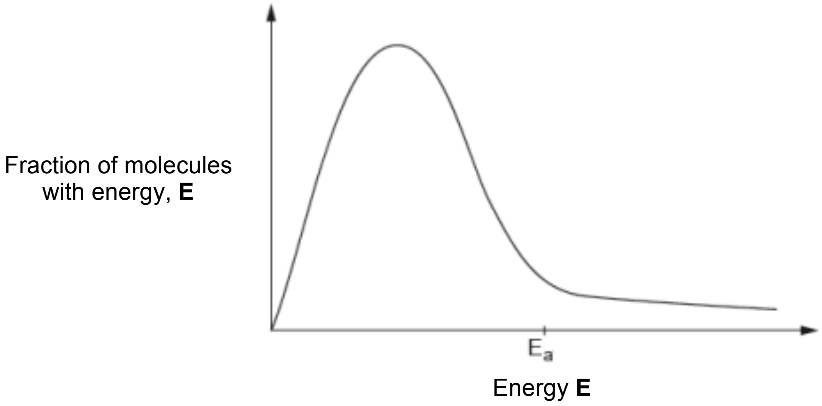
…………………………………………………………………………………………

(v) Use the graph to calculate the initial rate of the reaction, stating the units. [2]

Initial rate = ...

Units ....

(b) Use the diagram below to explain the effect of adding a catalyst on the rate of a chemical reaction. [2]



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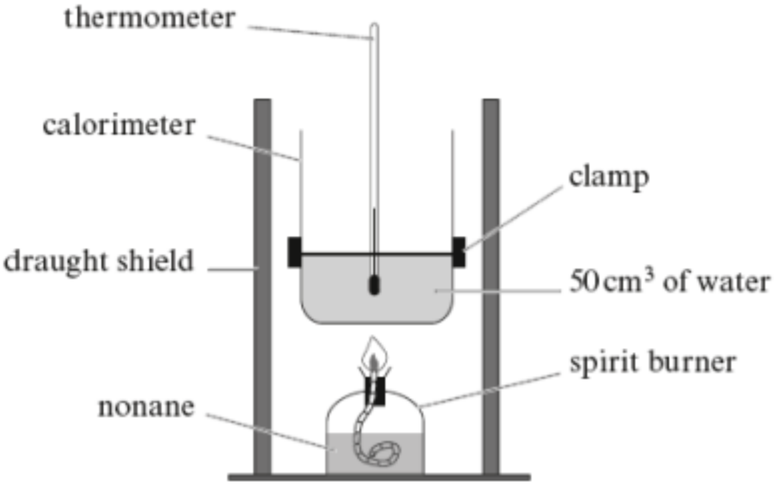
9. *(a)* Iwan used the apparatus below to find the enthalpy change of combustion of nonane ,C_9H_{20}.



(i) Iwan measured the mass of the spirit burner at the start and end of the experiment and found that 0.20 g of nonane had been burned.

Calculate the number of moles of nonane present in 0.20 g. [2]

Number of moles = ...…………………. mol

(ii) The initial temperature of the water was 22.5°C and the maximum temperature recorded during the experiment was 53.2°C. Calculate the enthalpy change of combustion of nonane, in kJ mol^{-1}.
Show your working. [3]

[*c* is the specific heat capacity of water which is 4.18 J $°C^{-1}$ g^{-1}]

Δ_cH = …………………… kJ mol^{-1}

(iii) Give the main reason why the experimental value that Iwan obtained differs from the literature value. Suggest any improvements to the experiment that would give a more accurate value. [2]

....

....

(b) In the complete combustion of nonane, carbon dioxide and water are formed.

(i) Balance the equation below which represents the combustion of nonane. [1]

$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ + ____ O_2 → ____ CO_2 + ____ H_2O

(ii) The theoretical value for the enthalpy change of combustion of nonane (Δ_cH) is –4666 kJ mol^{-1}.

Use this value and the average bond enthalpy values in the table to calculate the average bond enthalpy of an O—H bond.

[3]

Bond	Average bond enthalpy / kJ mol^{-1}
C—H	412
C—C	348
O=O	496
C=O	743

Average bond enthalpy of an O—H *bond* = ……......…. kJ mol^{-1}

(iii) Suggest why the value calculated above does not agree exactly with the literature value for an O—H bond in a water molecule. [1]

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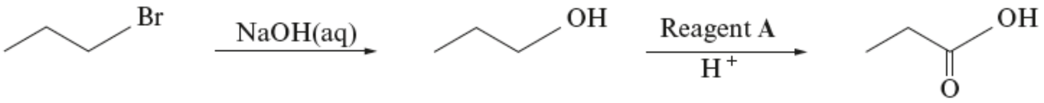
12

10. *(a)* 1-Bromopropane can be used to prepare propanoic acid in a two-stage process shown below.



(i) The first stage uses aqueous sodium hydroxide. Under alternative conditions 1-bromopropane produces a different product when it reacts with sodium hydroxide.

Give the alternative conditions required, and the product that would be formed from 1-bromopropane under these conditions. [2]

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(ii) For the second stage, state the **full name** of reagent **A** and classify the reaction occurring. [2]

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(b) Compound **B** is an isomer of formula $C_6H_{12}O_2$ which exists as a sweet-smelling liquid at room temperature. It can be made from two of the organic compounds found in part *(a)*.

(i) Elemental analysis of compound **B** shows that it has a composition of 62.1 % carbon, 10.3 % hydrogen and 27.6 % oxygen, by mass. Show that this composition is consistent with the formula above. [2]

(ii) Compound **B** shows five resonances in its ^{1}H nuclear magnetic resonance (NMR) spectrum. Apart from containing two CH_3– groups there are three –CH_2– groups. The peaks on the NMR spectrum due to these –CH_2– groups are found at 1.3 ppm, 2.1 ppm and 4.0 ppm.

The infrared spectrum of compound **B** shows absorptions at 2981 cm^{-1} and 1750 cm^{-1}.

These are the only significant absorptions above 1500 cm^{-1}.

Using **all** the information supplied, deduce the structure of compound **B**. Give **reasons** in support of your answer. [6 QER]

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(iii) State how this product, compound **B**, could be separated from the starting materials from part *(a)*. Use your knowledge of intermolecular forces to explain why this method of separation would be suitable in this case. [3]

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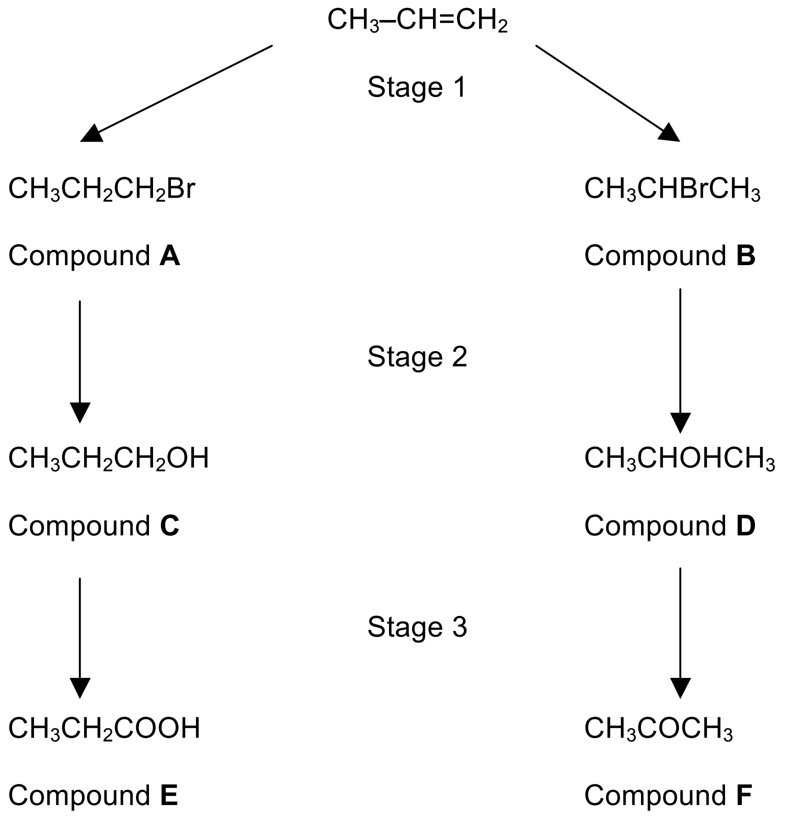
11. Alkenes can be the precursors to many organic compounds as shown below.



(a) (i) Draw the mechanism for the production of the major product in stage 1. In your answer you should classify the type of mechanism occurring. [4]

Type of mechanism ……………………………………………………………

(ii) Explain why two products are formed in stage 1 and why one of the products is favoured. [2]

………………………………………………………………………………………………

………………………………………………………………………………………………

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(b) In stage 3 a third product was also formed which is not shown above. This compound also has three carbon atoms and its NMR spectrum includes a peak at chemical shift, δ = 9.8 ppm. An absorption occurs in its infrared spectrum at 1715 cm^{-1}.

Use the information above to deduce whether this compound is a result of the reaction of compound **C** or compound **D**. In your answer you should also include the type of reaction occurring in stage 3. [4]

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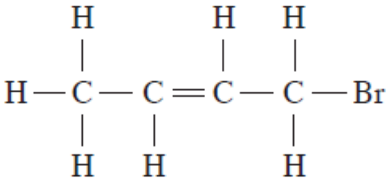
(c) As part of a project, two students were asked to report on tests for functional groups present in the compound below.



Nia reported that in testing for the C=C group:

- aqueous bromine should be added to the compound and if the test is positive, the colour of the mixture changes from purple to colourless;
- the name of the compound formed in this test is 2,3,4-tribromobutane.

(i) Correct the **two** mistakes in her report. [2]

I. ……………………………………………………………………………

……………………………………………………………………………………

II. ……………………………………………………………………………

……………………………………………………………………………………

David reported that in testing for bromine:

- dilute hydrochloric acid should be added to the compound;
- aqueous silver nitrate should then be added;
- you should see a cream precipitate.

(ii) I. State and explain the observations David would have made if he had carried out his test. [1]

……………………………....…………………………………………………..

....

II. Outline the correct method for carrying out a test for bromine in the compound. Include any reagents used in your answer. [2]

……………………………....…………………………………………………...

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15

Candidate Name	Centre Number					Candidate Number				
						0				

GCE A LEVEL CHEMISTRY

A2 UNIT 3

Physical and Inorganic Chemistry

SPECIMEN PAPER

1 hour 45 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 8.**	**10**	
Section B	**9.**	**17**	
	10.	**14**	
	11.	**8**	
	12.	**12**	
	13.	**19**	
	Total	**80**	

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.

The assessment of the quality of extended response (QER) will take place in question 10.

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SECTION A

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

1. Circle all the acids in the following equation.

$CH_3COOH + NH_3 \rightleftharpoons CH_3COO^- + NH_4^+$ [1]

2. The table shows some enthalpy change values for three compounds.

	Standard enthalpy change of hydration / kJ mol^{-1}	Standard enthalpy change of lattice breaking / kJ mol^{-1}
lithium fluoride	–1005	1032
potassium fluoride	–792	776
rubidium fluoride	–819	813

State which compound(s) you would expect to be soluble in water. [1]

....

3. *(a)* Balance the equation for the reaction of sodium hydroxide with chlorine. [1]

…….. Cl_2 + ……… NaOH → ……. NaCl + ……. $NaClO_3$ + …… H_2O

(b) Use oxidation states to show that this is a disproportionation reaction. [1]

....

....

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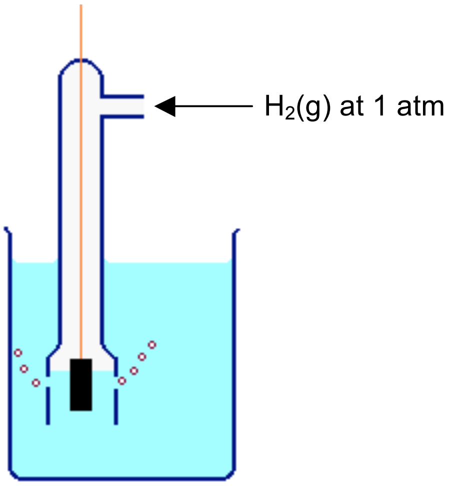
4. The standard electrode potential for a half-cell can be measured by connecting it to the standard hydrogen electrode shown below.



Name the solution in the beaker and state its concentration. [1]

....

5. Put the following species in order of increasing entropy. [1]

$Br_2(l)$ $Kr(g)$ $Se(s)$

lowest .... *highest*

6. Acidified potassium dichromate may be used to oxidize iron(II) ions. The two relevant half equations are shown below.

$$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O$$

$$Fe^{3+} + e \rightleftharpoons Fe^{2+}$$

Write the overall ionic equation for this reaction. [1]

....

7. Carbon tetrachloride does not react with cold water, however silicon(IV) chloride reacts violently. Explain why the reactivity of these compounds is so different. [1]

....

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....

8. Chromyl chloride is a compound containing chromium, oxygen and chlorine only. It contains 33.5 % chromium and 45.8 % chlorine by mass.

Calculate the empirical formula of chromyl chloride. [2]

Empirical formula ....

10

SECTION B

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

9. *(a)* (i) The boron in boron chloride, BCl_3, is described as electron deficient. State what is meant by the term *electron deficient*. [1]

....

....

(ii) When BCl_3 is mixed with ammonia a new species is formed. Identify the new species and explain how it forms. [2]

....

....

....

(b) Heating the species formed in *(a)*(ii) can be used to produce films of hexagonal boron nitride, BN.

(i) This form of BN has many similarities to the structure of graphite. Describe the **differences** between the structures of hexagonal boron nitride and graphite. [2]

....

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....

....

(ii) Graphite is commonly used as a lubricant as the layers slip over each other. It has been suggested that a significant factor in this softness is the presence of absorbed molecules such as O_2, H_2O and CO_2.

A sample of graphite was repeatedly exposed to a vacuum and then an atmosphere of pure $H_2O(g)$ to remove all traces of absorbed molecules other than H_2O, leaving a sample of mass 3.645g. This was then heated under vacuum until constant mass was reached, leaving a mass of 3.592 g.

I. Explain why the sample was heated to constant mass. [1]

....

....

II. Calculate the ratio of carbon atoms to water molecules in the graphite. [3]

Ratio carbon : *water* ....

(c) Phosphorus(III) chloride, PCl_3, can be produced in the equilibrium below:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

(i) A sample of PCl_5 is introduced into a sealed vessel with an initial pressure of 12.4×10^3 Pa, and the system is allowed to reach equilibrium where the partial pressure of Cl_2 is 6.0×10^3 Pa.

Calculate the value of K_p under these conditions, giving its units. [4]

K_p = ...

Units ....

(ii) When the temperature is increased by 50 °C, the value of the equilibrium constant K_p doubles. State and explain whether this reaction is endothermic or exothermic. [2]

....

....

....

(iii) Explain why phosphorus can form PCl_5 and PCl_3 but nitrogen can only form one chloride. [2]

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17

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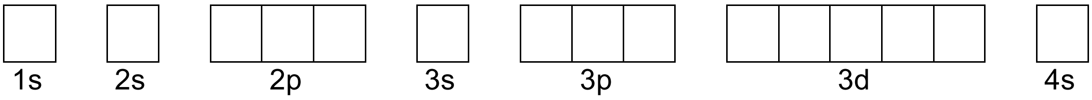
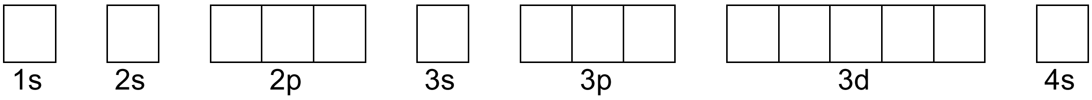
10. Cobalt, nickel and copper are metals which lie adjacent to each other in the Periodic Table.

(a) Use arrows in boxes to show the electronic structures of the copper atom and the Cu^{2+} ion. [2]

Copper atom, Cu



Copper(II) ion, Cu^{2+}



(b) Cobalt (II) compounds are often pink in aqueous solution as they contain the $[Co(H_2O)_6]^{2+}$ complex ion.

Addition of concentrated hydrochloric acid to a solution containing $[Co(H_2O)_6]^{2+}$ causes a colour change as a new species is formed. Give the colour and formula of the species formed and explain the origin of the colour in the complex $[Co(H_2O)_6]^{2+}$. [6QER]

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(c) Addition of ammonia solution to a pink solution of $[Co(H_2O)_6]^{2+}$ forms a yellow-brown solution of $[Co(NH_3)_6]^{2+}$, due to the reversible reaction:

$$[Co(H_2O)_6]^{2+} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+} + 6H_2O$$

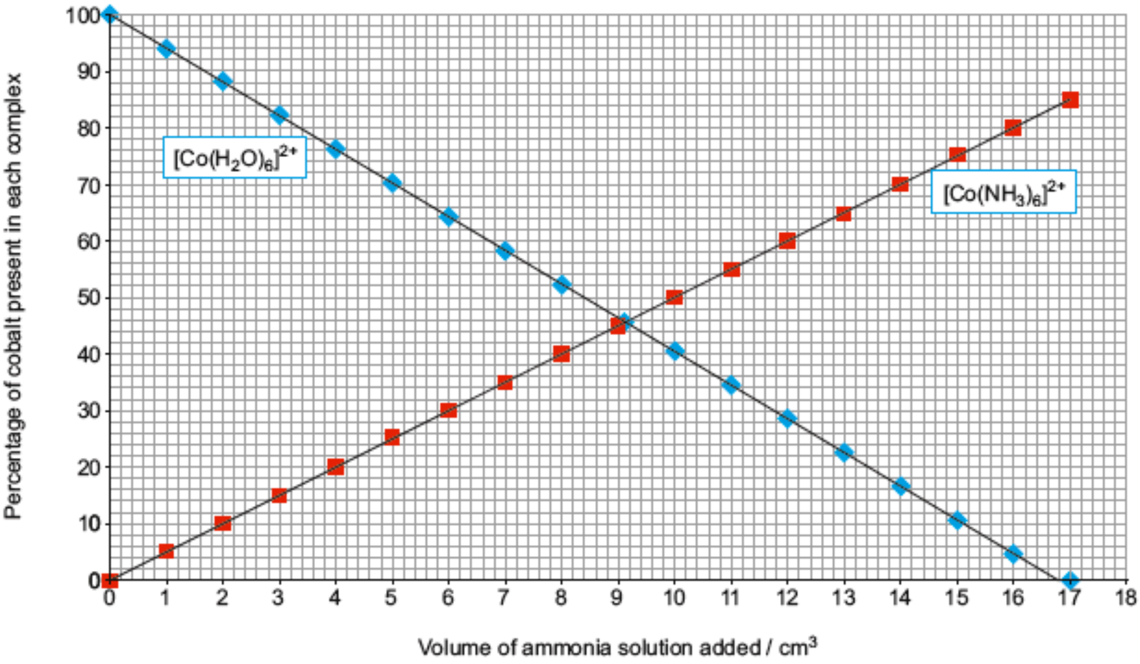
A student chose to study this change using colorimetry.

(i) The pink solution of $[Co(H_2O)_6]^{2+}$ absorbs light of wavelength 515 nm. Calculate the energy of the electron transition taking place, giving your answer in $kJ\ mol^{-1}$. [3]

$h = 6.63 \times 10^{-34}\ J\ s$ $c = 3.00 \times 10^{8}\ m\ s^{-1}$ $N_A = 6.02 \times 10^{23}$

Energy = ... $kJ\ mol^{-1}$

(ii) The results of the experiment are shown on the graph below.



Following the experiment the student decided that the reversible reaction shown did not fully reflect what was occurring during the experiment.

$$[Co(H_2O)_6]^{2+} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+} + 6H_2O$$

State whether you agree with her conclusion and explain your reasoning. [3]

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14

11. Some students are provided with five solutions labelled **A**–**E**.

(a) Flame tests were undertaken on all the solutions and a range of colours were seen, including lilac for one solution and apple green for another.

State what information is provided by these observations. [1]

....

....

The five solutions contain only common cations and anions that the students have met during their A-level studies. No two solutions contain the same cations or the same anions. One of the solutions is known to be aqueous sodium hydroxide, while another contains nitrate ions.

The students mixed each pair of solutions and recorded the following observations.

	Solution **A**	Solution **B**	Solution **C**	Solution **D**
Solution **E**	pale blue precipitate	no visible change	white precipitate formed that dissolves when extra solution **E** is added	no visible change
Solution **D**	thick white precipitate	no visible change	white precipitate	
Solution **C**	white precipitate	bright yellow precipitate		
Solution **B**	brown solution with a white solid formed			

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(b) Use **all** the information given to find the identities of solutions **A**–**E**.
Explain your reasoning for identification of the metal ion present in solution **C**.
[7]

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....

Solution **A**	
Solution **B**	
Solution **C**	
Solution **D**	
Solution **E**	

8

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12. A 25.00 cm^3 sample of sodium hydroxide solution was exactly neutralised by 24.25 cm^3 of sulfuric acid of concentration 0.176 mol dm^{-3}.

(a) Calculate the concentration of the sodium hydroxide solution, giving your answer to the appropriate number of significant figures. [3]

Concentration of sodium hydroxide = ... mol dm^{-3}

(b) An alternative method to calculate the concentration of the sodium hydroxide solution is to use its pH.

A student measures the pH of the same sodium hydroxide solution as being 13.5. Calculate the concentration of this sodium hydroxide solution. Show your working. [3]

$[K_w = 1.00 \times 10^{-14}\ mol^2\ dm^{-6}]$

Concentration of sodium hydroxide = ... mol dm^{-3}

(c) The two values calculated in *(a)* and *(b)* are consistent with each other. State and explain which method gives the more precise value. [1]

....

....

....

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(d) The titration was repeated using 25.00 cm^3 of the weak acid ethanoic acid with a concentration equal to that of the sodium hydroxide.

(i) Choose an appropriate indicator for this titration from the list below, giving a reason for your answer. [1]

Indicator	pH range
methyl red	4.2 - 6.3
methyl yellow	2.9 - 4.0
phenolphthalein	8.2 - 10.0

....

....

(ii) Give the expected pH of the solution when 12.50 cm^3 of sodium hydroxide had been added to 25.00 cm^3 of ethanoic acid. [2]

[K_a for ethanoic acid = 1.8×10^{-5} mol dm^{-3}]

pH = ...

(e) The reaction of aqueous sulfuric acid with the weak base ammonia produces ammonium sulfate solution. State and explain the pH you would expect for a solution of ammonium sulfate. [2]

....

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12

13. When a new substance is identified as having beneficial effects, chemists need to devise an appropriate route to synthesise the desired substance. They need to consider many factors, including the feasibility and rate of different routes.

(a) There are different ways to identify the feasibility of a chemical reaction. Two methods are the use of electrochemical data and the calculation of Gibbs' free energy.

(i) Use the data below to identify whether the reaction given is feasible at 298 K. Show your working in each case. [6]

$$2KMnO_4 + 5H_2O_2 + 6HCl \rightarrow 2MnCl_2 + 8H_2O + 5O_2 + 2KCl \qquad \Delta S^\theta = 9\ J\ K^{-1}\ mol^{-1}$$

Standard enthalpy changes of formation

Substance	Standard enthalpy change of formation, $\Delta_f H^\theta$ / kJ mol^{-1}
$KMnO_4(s)$	–813
$H_2O_2(l)$	–188
$HCl(g)$	–92
$MnCl_2(s)$	–482
$H_2O(l)$	–286
$O_2(g)$	0
$KCl(s)$	–436

Standard electrode potentials

Half-equation	E^θ / V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.52
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68

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(ii) In a laboratory the reaction is attempted by mixing a solution of acidified potassium manganate(VII) of concentration 0.5 mol dm^{-3} and hydrogen peroxide solution of the same concentration at 350 K.

State and explain which of the approaches in part (i) is most suitable for working out whether the reaction is feasible in this case and suggest how the experiment could be changed to ensure the feasibility calculation is valid. [3]

....

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(b) Reactions that are feasible are not always economically useful as the product may be formed too slowly. This can be helped by using a catalyst to increase the rate of the reaction.

(i) The table below gives data on the initial rates of reaction for an acid-catalysed bromination of propanone.

$$Br_2(aq) + CH_3COCH_3(aq) \rightarrow HBr(aq) + CH_3COCH_2Br(aq)$$

$[Br_2]$ / mol dm^{-3}	$[CH_3COCH_3]$ / mol dm^{-3}	pH	Initial rate of reaction / mol dm^{-3} min^{-1}
0.10	0.80	0	1.36×10^{-3}
0.10	0.80	1	1.36×10^{-4}
0.10	0.40	1	6.80×10^{-5}
0.10	0.80	2	1.36×10^{-5}
0.20	0.40	2	6.80×10^{-6}

I. Show that the reaction is first order with respect to $[H^+(aq)]$. [2]

....

....

....

II. Deduce a rate equation for this catalysed reaction, giving the value and units of the rate constant. [4]

k = ...

Units ....

III. A suggested mechanism for the process is given below.

$CH_3COCH_3 + Br_2 \rightarrow [CH_3COBrCH_3]^+ + Br^-$

$[CH_3COBrCH_3]^+ \rightarrow [CH_3COCH_2]^+ + HBr$

$[CH_3COCH_2]^+ + Br^- \rightarrow CH_3COCH_2Br$

State and explain whether this proposed mechanism is correct. [2]

....

....

....

(ii) Explain why the use of homogeneous catalysts can be an environmental advantage but a problem in the isolation of the final product. [2]

....

....

....

19

Candidate Name	Centre Number					Candidate Number				
						0				

GCE A LEVEL CHEMISTRY

A2 UNIT 4

Organic Chemistry and Analysis

SPECIMEN PAPER

1 hour 45 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 9.**	**10**	
Section B	**10.**	**15**	
	11.	**15**	
	12.	**13**	
	13.	**13**	
	14.	**14**	
	Total	**80**	

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.

The assessment of the quality of extended response (QER) will take place in question 14.

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SECTION A

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

1. Give the structural formula of a compound that will give a diazonium compound when treated with cold nitric(III) acid. [1]

2. Write the displayed formula of the organic compound obtained when phenylamine reacts with ethanoyl chloride. [1]

3. The melting temperature of a pure compound is 113 °C.

   State the effect on the melting temperature of adding a small quantity of another compound to a sample of the pure material. [1]

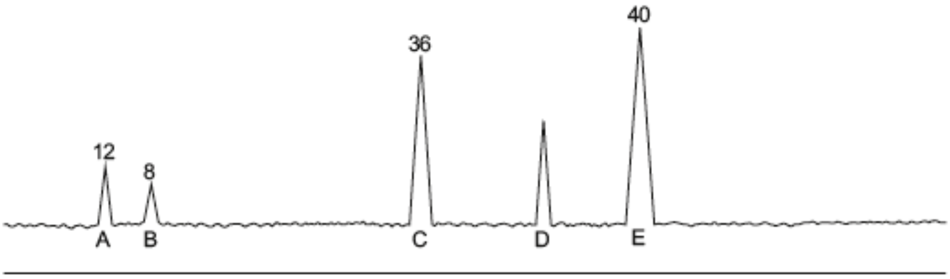
   ....

   ....

   ....

4. The gas chromatogram of a mixture of hydrocarbons is shown below. The peak areas represent the relative amount of each compound present. Compound **D** makes up 20 % of the mixture.

   Calculate the relative peak area of compound **D**. [1]



Relative peak area = ...

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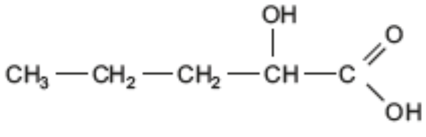
5. The nitrile that has the formula C_6H_5CN is reduced by lithium tetrahydridoaluminate(III).

State the systematic name of the organic **product**. [1]

....

6. Compound **P** reacts with hydrogen cyanide and the product is then hydrolysed to give compound **Q**.



compound **Q**

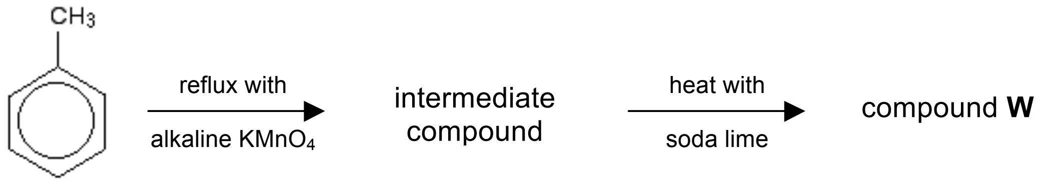
(a) State the type of reaction mechanism occurring when compound **P** reacts with hydrogen cyanide. [1]

....

(b) State the **name** of compound **P**. [1]

....

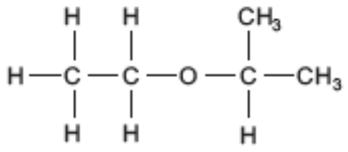
7. Methylbenzene undergoes the reactions below.



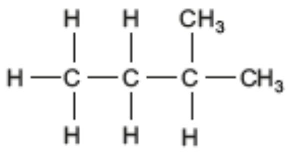
State the molecular formula of compound **W**. [1]

....

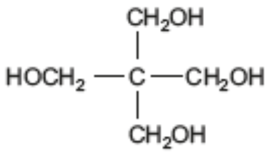
8. Arrange the compounds shown below in order of **increasing** solubility in water. [1]



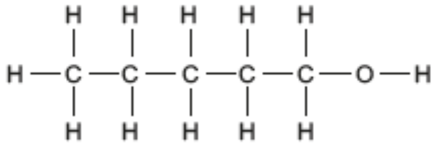
A



B



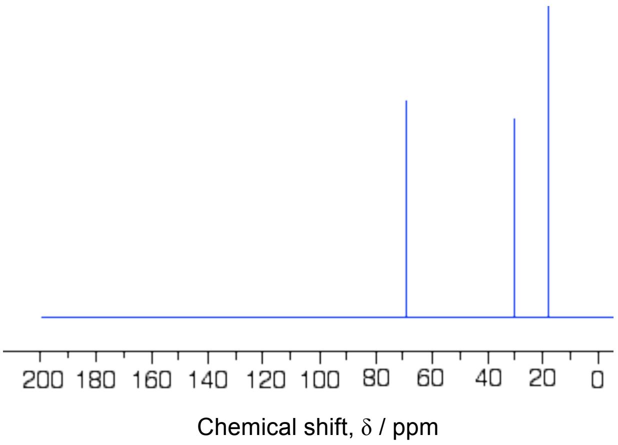
C



D

least soluble .... *most soluble*

9. State the **systematic name** of the alcohol of formula $C_4H_{10}O$ that has the ^{13}C NMR spectrum shown below. [1]



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10

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SECTION B

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

10. *(a)* Propene is obtained by the cracking of a larger molecule hydrocarbon.
In a particular cracking process two thirds of the product was propene and the rest was propane.

Give the formula of a hydrocarbon that could be cracked in this way. [1]

....

(b) Propenoic acid is produced from propene by oxidation.

This reaction uses a heterogeneous catalyst at a temperature of about 600 K.

State and explain whether the use of this catalyst will affect the enthalpy change for this reaction. [2]

....

....

....

(c) Compound **F** is produced by the reaction of propenoic acid and hydrogen bromide. This product does not exist as enantiomers.

Suggest a displayed formula for compound **F**, giving a reason for your choice. [2]

....

....

....

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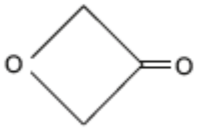
(d) Both propenoic acid and 3-oxetanone are isomers of formula $C_3H_4O_2$.



3-oxetanone

These two compounds have different infrared absorption spectra.

Use the Data Sheet to state the differences in the bonds present, stating their absorption values. [2]

....

....

....

(e) Propenoic acid is neutralised by sodium hydroxide to produce sodium propenoate.

Calculate the mass of sodium propenoate that will be formed from 38.3 kg of propenoic acid, assuming that complete neutralisation occurs. [2]

Mass of sodium propenaoate = ... kg

(f) Sodium propenoate can be polymerised to give 'sodium polyacrylate'.

Give the repeating unit of this addition polymer. [1]

(g) A solid polymer is made by polymerising a mixture of propenoic acid and sodium propenoate. This product is sold as a superabsorbent polymer that will absorb 300 times its volume of water without a significant increase in volume. The water is held in the polymer structure by hydrogen bonding.

Draw a diagram to show how water molecules can hydrogen bond to propenoic acid molecules. In your answer you should use at least two molecules of each reactant, showing necessary dipoles and relevant lone pairs of electrons. [2]

(h) Propenenitrile, $H_2C{=}CH{-}C{\equiv}N$, is used as the starting material to make 'acrylic' fibres. It is made from propene, ammonia and oxygen from air, in the presence of a suitable catalyst.

$$H_2C{=}CH{-}CH_3 \quad + \quad NH_3 \quad + \quad 1\tfrac{1}{2}\,O_2 \quad \longrightarrow \quad H_2C{=}CH{-}C{\equiv}N \quad + \quad 3\,H_2O$$

A modification of this method has been developed using propane as the starting material, and a different catalyst.

$$H_3C{-}CH_2{-}CH_3 \quad + \quad NH_3 \quad + \quad 2\,O_2 \quad \longrightarrow \quad H_2C{=}CH{-}C{\equiv}N \quad + \quad 4\,H_2O$$

Suggest **three** important factors that should be taken into account when considering adoption of the modified method using propane. Each of your comments should consider both routes. [3]

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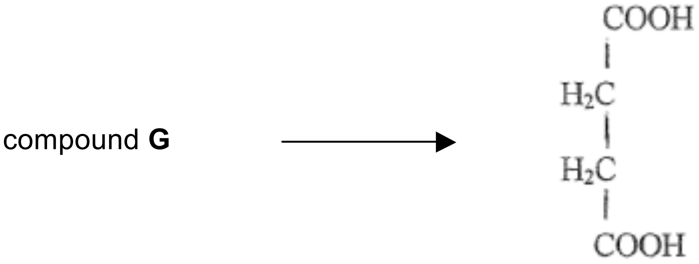
15

11. *(a)* There is an increasing interest in biochemical routes to compounds that were previously produced from fossil fuels. One of these compounds is butane-1,4-dicarboxylic acid.

$HOOC–CH_2–CH_2–COOH$

One route involves the oxidation of compound **G**.



(i) Suggest a formula for compound **G** giving a suitable oxidising agent for the reaction. [2]

Oxidising agent ....

(ii) One biochemical route being developed starts from sugars such as glucose. This process also uses carbon dioxide and can be represented by the following equation.

$$7C_6H_{12}O_6 + 6CO_2 \rightarrow 12(CH_2)_2(COOH)_2 + 6H_2O$$

M_r 180 M_r 118

I. Calculate the yield (in kilograms) of butane-1,4-dicarboxylic acid that would be obtained if 1.00 kg of glucose was completely converted to the acid. [3]

Yield = ... kg

II. Use the chemical equation to help you suggest why this reaction can be considered to be a *green* process.

A reference to the exclusion of fossil fuels in this process is not required. [1]

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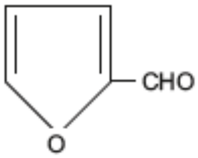
(b) Furfural is an aldehyde that is produced from agricultural by-products. One method is the hydrolysis of certain polysaccharides to give the sugar xylose, which is then itself hydrolysed to give furfural.



furfural

In a large scale laboratory experiment 750 g of corn cobs were refluxed with 2.5 dm^3 of aqueous sulfuric acid of concentration 1.2 mol dm^{-3}. After neutralisation of the acid, 100 g of furfural was obtained.

(i) Calculate the volume of sulfuric acid needed to make 2.5 dm^3 of the aqueous solution. [2]

[density of sulfuric acid = 1.84 g cm^{-3}]

Volume of sulfuric acid = ... cm^3

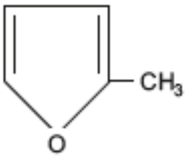
(ii) Suggest **two** ways in which this method might be modified so that a higher percentage yield of furfural could be obtained. [2]

....

....

....

(iii) The boiling temperature of furfural is 162 °C.
Comment on why the boiling temperature of 2-methylfuran may be different from this value, explaining your answer. [3]



2-methylfuran

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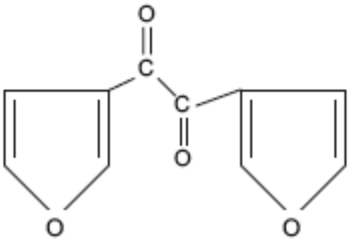
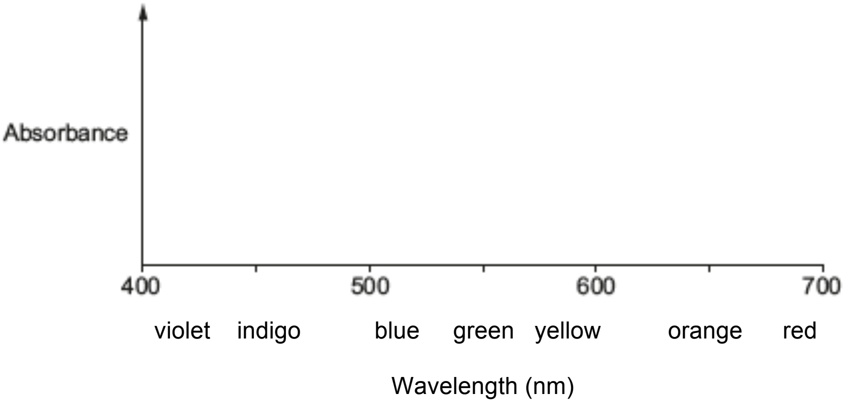
(iv) Under certain conditions furfural can be converted into the yellow compound, furil.



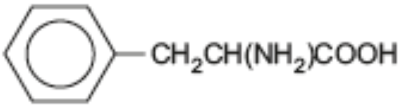
furil

Use the diagram below to draw a line that shows the visible absorption spectrum for furil. [2]



15

12. *(a)* The artificial sweetener aspartame is a dipeptide. One of its hydrolysis products is phenylalanine.



phenylalanine

(i) Give the formula of the dipeptide formed from phenylalanine. [1]

(ii) The formula of an α-amino acid can be written in an ionic form.

Write the formula of the ionic form of phenylalanine present in a strongly acidic solution. [1]

(b) Data about three derivatives of propanoic acid are given in the table.

Name	Formula	Melting temperature / °C
3-phenylpropanoic acid	$C_6H_5CH_2CH_2COOH$	< 20
3-phenyllactic acid	$C_6H_5CH_2CH(OH)COOH$	122
phenylalanine	$C_6H_5CH_2CH(NH_2)COOH$	270

Discuss the relative melting temperatures of the acids in terms of the intermolecular bonding between the molecules. [4]

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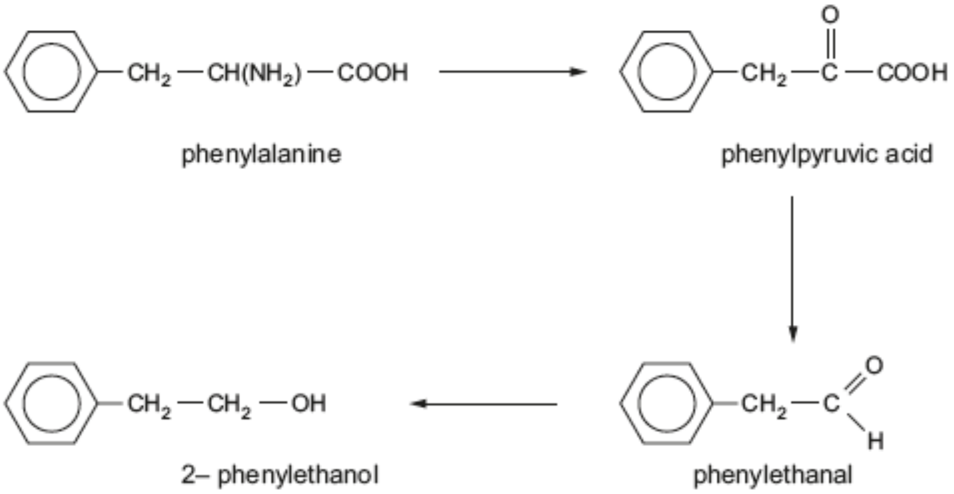
(c) The isolation of flavours and fragrances from plants has been practised for many years. However, this extraction is often expensive and produces only small quantities. There is therefore an increasing interest in biochemical routes that do not rely on oil based products. In a recent study phenylalanine has been converted to the important perfumery chemical, 2-phenylethanol, via a route using enzymes. This is summarised below.



(i) Describe a test that will distinguish between phenylpyruvic acid and phenylethanal, stating the reagent(s) used and the observation with each compound. [2]

Reagent(s)

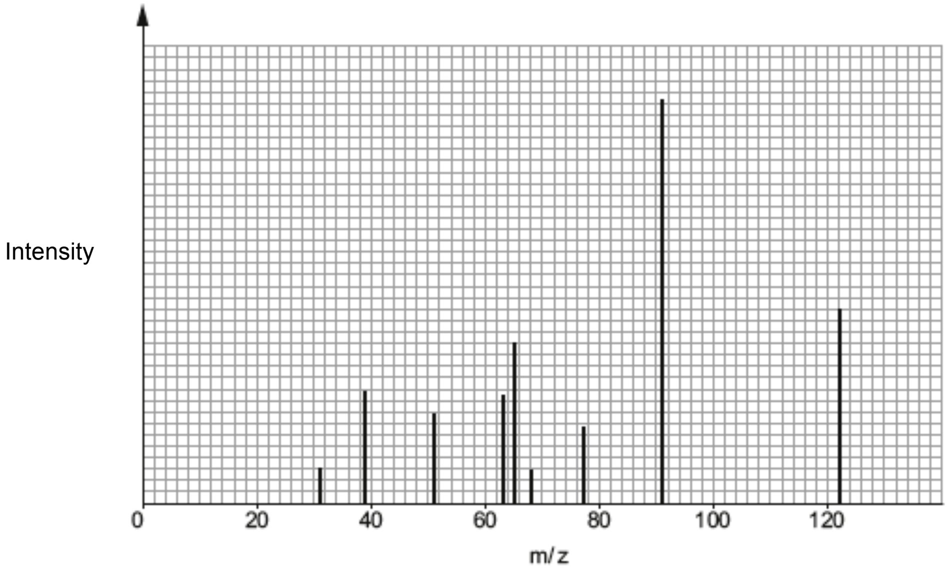
....

Observation with each compound

....

....

(ii) In this study 2-phenylethanol was separated by gas chromatography and identified by mass spectroscopy. The mass spectrum of 2-phenylethanol is shown below.



Suggest a formula for the ion fragment at m/z 91, giving your reasoning. [2]

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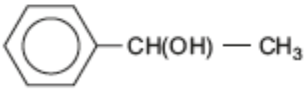
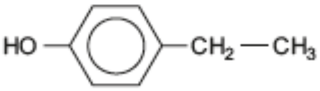
(iii) 1-Phenylethanol, 2-phenylethanol and 4-ethylphenol are isomers of formula of $C_8H_{10}O$.



1-phenylethanol



4-ethylphenol

State which one of these three compounds can be identified by the triiodomethane (iodoform) test giving the reagent(s) used, the observation and the reason for your choice of compound. [3]

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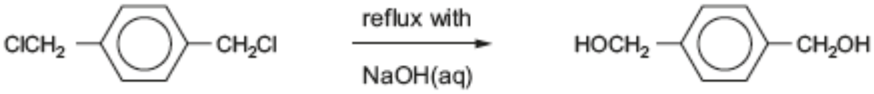
13

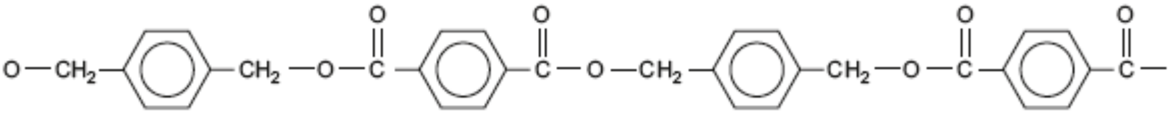
13. *(a)* 1,4-Di(chloromethyl)benzene can be used as a starting material for the production of polyesters.

1,4-di(chloromethyl)benzene

It is converted into 1,4-di(hydroxymethyl)benzene via a reaction with aqueous sodium hydroxide.



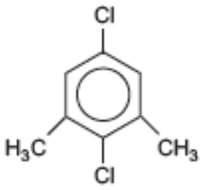
1,4-Di(hydroxymethyl)benzene can then be used to produce the polyester drawn below.



State the name of the other compound that is used to make this polyester. [1]

....

(b) Explain why refluxing 2,5-dichloro-1,3-dimethylbenzene, shown below, with aqueous sodium hydroxide does not result in the replacement of the chlorine atoms by hydroxide groups. [2]



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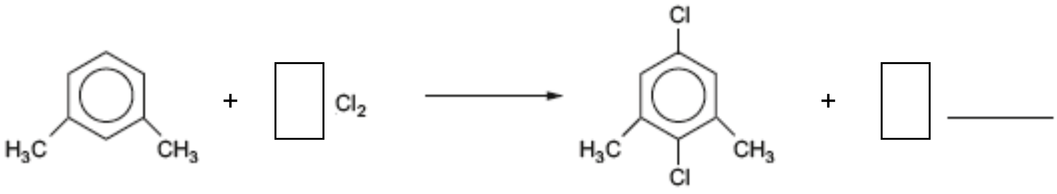
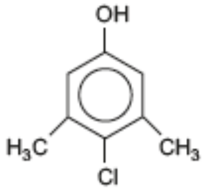
(c) 2,5-Dichloro-1,3-dimethylbenzene can be formed from 1,3-dimethylbenzene by a Friedel-Crafts reaction.

State a catalyst for this reaction and complete the equation below. [2]



Catalyst ....

(d) The active compound in Dettol® is PCMX.



PCMX

(i) State what will be seen when PCMX reacts with iron(III) chloride solution. [1]

....

(ii) Aqueous bromine was added to PCMX resulting in the colour of the bromine disappearing.

Suggest what else would be seen during this reaction and draw the formula of a possible organic product. [2]

....

(iii) There are 12.0 g of PCMX in a bottle containing 250 cm^3 of Dettol®.

Calculate the concentration of PCMX in mol dm^{-3}. [2]

Concentration = ... mol dm^{-3}

(iv) Describe and explain the **low** resolution ^1H NMR spectrum of PCMX. No reference to the relative position of the peaks in the spectrum is required. [3]

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13

14. *(a)* In a project some students were asked to prepare 1-butyl ethanoate from butan-1-ol and ethanoic acid. One method found in the literature is given below.

‘Mix together 18.0 cm^3 / 14.6 g of butan-1-ol with 8.5 cm^3 / 8.9 g of ethanoic acid in a pear-shaped flask. Reflux the mixture for 20 minutes.
Remove the condenser and distil the mixture, collecting the mixture that boils at 115–130 °C. After purification, the yield of 1-butyl ethanoate is about 25 g’.

Some necessary data is given in the table.

Name	M_r	Boiling temperature / °C
butan-1-ol	74	117
ethanoic acid	60	118
1-butyl ethanoate	116	126

(i) Give the equation for the reaction. [1]

....

(ii) The students thought that the theoretical yield of 1-butyl ethanoate was less than the actual yield stated in the method.

Calculate the theoretical yield in grams that should be formed. [3]

Yield = ... g

(iii) The students ran a chromatogram of their distillate. They found besides 1-butyl ethanoate, some butan-1-ol and ethanoic acid were present together with a little water.

A student suggested that some solid sodium hydrogencarbonate was added to the distillate.

Describe what would be seen when this substance was added and state why this observation occurred. [2]

....

....

(iv) After further purification the 1-butyl ethanoate was checked for traces of butan-1-ol.

State an instrumental method, other than chromatography, that could be used for this purpose and explain how any traces of butan-1-ol would be indicated. [2]

....

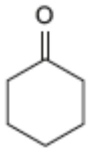
....

....

(b) An ant pheromone has been isolated and studied. Some details of the compound are given below.

1. The % of oxygen by mass is 16.3
2. It can be reduced to a primary alcohol
3. It will decolourise aqueous bromine
4. The ^{1}H NMR spectrum suggests six different proton environments.
5. The ^{13}C NMR spectrum suggests six different carbon environments.

Gareth suggested that the pheromone was cyclohexanone.



Study the information provided and discuss, giving reasons, whether each statement fits the suggested compound. [6 QER]

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14

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GCE A LEVEL CHEMISTRY

A2 UNIT 5

Practical Examination

Experimental Task
TESTS 1 and 2

INSTRUCTIONS TO TEACHERS / EXAMS OFFICERS

SPECIMEN PAPER

Confidential

To be opened on receipt for immediate use by
TEACHERS / EXAMS OFFICERS

This document should be stored securely by the exams officer when not in use by the teacher. Its contents should not be divulged except to those concerned with the preparation of the assessment.

A. General Instructions

1. The Experimental Task will be completed in one session of up to 3 hours. Two versions of the test will be set for use on the following dates:

Test 1 (date)
Test 2 (date)

Each candidate may undertake only one of these tests. Where all the candidates can be accommodated in a single session, centres are advised to use Test 1 during the morning session on day 1. Where centres require more than one session, they may choose to use an additional session on day 1 and/or day 2. Where a second session is used on a single day, centres must ensure that learners in the later session have no opportunity to communicate with those who have already taken the test.

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2. The test must be supervised at all times by a member of staff responsible for teaching A level Chemistry. Centres may use multiple laboratories, provided that a subject teacher is available to supervise all groups at all times.

3. Teachers must ensure that all candidates have adequate working space and that they are set a reasonable distance apart. Each candidate must have a complete set of glassware and ready access to weighing and heating apparatus.

4. Centres will receive sufficient copies of the candidate booklets for Tests 1 and 2.

5. Teachers may open the "**Setting up Instructions**" document one week before Test 1 (i.e. date). **This is for the purpose of preparing the necessary solutions and apparatus.** The candidate booklets must not be opened until the day of the test.

6. Candidates should write their answers in the spaces provided in the candidate booklet. Should there be a need for additional space a standard extension/answer booklet should be provided.

7. Marks will be awarded by teachers for up to three aspects directly observed whilst candidates carry out practical work. These marks must be entered in each candidate's booklet. Guidance on the awarding of these marks will be provided in the "**Setting up Instructions**" document.

8. Completed candidate booklets must be securely stored by the exams officer until examiner details are received in late April. They should be posted to the allocated examiner as soon as possible and no later than (date). Teachers must not be given access to the completed booklets after they have been handed to the exams officer.

9. Examiners will require teachers' results for the experiments carried out. These must be recorded clearly on the appropriate form and given to the exams officer with candidates' work. When different groups of candidates have been given different solutions separate teacher results forms must be completed and steps taken to clearly identify which candidates' work should be marked against which teacher results. This information must be provided to examiners along with candidates' work.

10. The experimental task will be externally marked by a WJEC examiner. The name and address of the examiner will be issued to centres by the end of April.

11. WJEC monitors will visit a random sample of centres to ensure the experimental task is being administered correctly. Visiting monitors will require access to candidates' "lab books".

B. Specific Instructions

Details of the apparatus and chemicals required for the tests follow.

WJEC should be informed immediately of any difficulty in providing the required apparatus or chemicals.

Contacts:

Subject Officer	**Jonathan Owen** **jonathan.owen@wjec.co.uk**	**029 2026 5057**
Subject Support Officer	**Matthew Roberts** **matthew.roberts@wjec.co.uk**	**029 2026 5380**

Apparatus and chemicals required

Test 1

Apparatus

Each candidate will need safety goggles and the following apparatus:

1 x weighing bottle + lid containing approximately 1.5 g of aspirin tablets (pre-weighed)
1 x 50 cm^3 burette
2 x 25 cm^3 pipettes
2 x 250 cm^3 standard flasks
2 x 250 cm^3 conical flasks
1 x 25 cm^3 measuring cylinder
1 x filter funnel
1 x spatula
1 x stirring rod
1 x wash bottle

Ready access to a 3 decimal place weighing balance and heating apparatus (electric hotplate/Bunsen burner)

Chemicals

Each candidate will need:

4 x aspirin tablets 300 mg
150 cm^3 sodium hydroxide solution (approx 1 mol dm^{-3})
300 cm^3 standard sulfuric acid (0.05 mol dm^{-3})
phenolphthalein
de-ionised water

Test 2

The task is the same as that in Test 1 but candidates here use a different brand of aspirin tablets with a different amount of 2-ethanoyloxybenzenecarboxylic acid e.g. 250 mg.

GCE A LEVEL CHEMISTRY

A2 UNIT 5

Practical Examination

Experimental Task
TESTS 1 and 2

SETTING UP INSTRUCTIONS

SPECIMEN PAPER

Confidential

To be opened on (date) by TEACHERS / TECHNICIANS

This document should be stored securely by the exams officer when not in use by the teacher. Its contents should not be divulged except to those concerned with the preparation of the assessment.

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Apparatus and chemicals required

Test 1

Apparatus

Each candidate will need safety goggles and the following apparatus:

1 x weighing bottle + lid containing approximately 1.5 g of aspirin tablets (pre-weighed)
1 x 50 cm^3 burette
2 x 25 cm^3 pipettes
2 x 250 cm^3 standard flasks
2 x 250 cm^3 conical flasks
1 x 25 cm^3 measuring cylinder
1 x filter funnel
1 x spatula
1 x stirring rod
1 x wash bottle

Ready access to a 3 decimal place weighing balance and heating apparatus (electric hotplate/Bunsen burner)

Chemicals

Each candidate will need:

150 cm^3 sodium hydroxide solution (approx 1 mol dm^{-3})
300 cm^3 standard sulfuric acid (0.05 mol dm^{-3})
phenolphthalein
de-ionised water

Procedure

1. Transfer your aspirin tablets to a 250 cm^3 conical flask and add **exactly** 25.0 cm^3 of sodium hydroxide solution (approximately 1 mol dm^{-3}) and about the same volume of de-ionized water. Simmer gently for about 10 minutes to hydrolyse the aspirin.

2. Weigh the empty weighing bottle and lid.

3. Leave the reaction mixture to cool and carefully transfer to a 250 cm^3 standard flask. Rinse the conical flask several times transferring all washings to the standard flask. Make the solution up to 250 cm^3.

4. Titrate 25.0 cm^3 samples of the diluted reaction mixture with standard sulfuric acid (0.05 mol dm^{-3}) using 3 drops of phenolphthalein indicator (Titration B).

5. Standardise the sodium hydroxide solution (approximately 1 mol dm^{-3}) after suitable exact dilution in a standard flask, using the standard sulfuric acid and phenolphthalein indicator (Titration A). This step can be carried out at any convenient time.

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Test 2

The task is the same as that in Test 1 but candidates here use a different brand of aspirin tablets with a different amount of 2-ethanoyloxybenzenecarboxylic acid e.g. 250 mg.

Technicians

Tablets should be placed in weighing bottles and lids closed. The total mass (to min 3 dp) should be marked on each bottle.

NaOH solution should be labelled 'NaOH approx 1 mol dm^{-3}'

H_2SO_4 should be standardised and labelled with precise concentration

You should prepare between 50 and 100 % more of each solution than should be required according to the volumes needed by each candidate.

PLEASE NOTE

Marks will be awarded for the proximity of candidate results to those of the teacher. When more than one batch of solutions is prepared it is vital that teacher results are obtained for each batch.

Teacher-awarded marks

A mark of 0 or 1 must be awarded by the teacher for three aspects relating to the practical work carried out by each candidate. These should be recorded as work proceeds and added to candidates' booklets at the end of the session.

Working safely – 1 mark to be awarded unless intervention is required to ensure safety

Efficient use of time – 1 mark to be awarded for carrying out standardisation at a convenient time e.g. whilst hydrolysis is taking place

Dilution – 1 mark to be awarded for ten-fold dilution of sodium hydroxide for standardisation, 25 cm^3 transferred to a 250 cm^3 standard flask using a pipette

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GCE A LEVEL CHEMISTRY

A2 UNIT 5

Practical Examination

Experimental Task

Teacher-awarded marks

Record sheet – to be completed by teachers during the Experimental Task

Candidate Name	Working safely	Efficient use of time	Dilution

A mark of 0 or 1 should be awarded for each of the three aspects included. These should be recorded in the candidates' booklets at the end of the session.

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Surname	Centre Number	Candidate Number
Other Names		

GCE A LEVEL CHEMISTRY

A2 UNIT 5

Practical Examination

Experimental Task

TEST 1

SPECIMEN PAPER

3 hours

For Examiner's use only		
	Maximum Mark	Mark Awarded
Total	30	

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Pencil may be used to draw tables and graphs.
Write your name, centre number and candidate number in the spaces at the top of this page.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The total number of marks available for this task is 30.
The number of marks is given in brackets at the end of each question or part question.
You are reminded of the necessity for orderly presentation in your answers.

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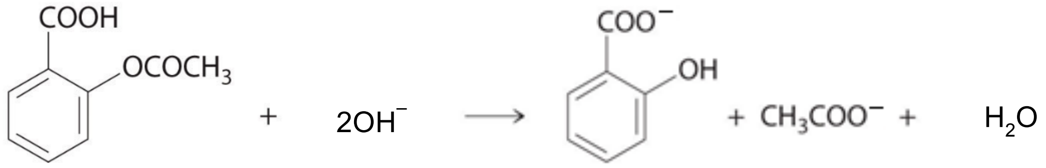
Analysis of aspirin tablets

The active ingredient in aspirin is 2-ethanoyloxybenzenecarboxylic acid (acetyl salicylic acid). The object of this task is to determine the percentage of this compound in aspirin tablets.

The first part of the experiment involves the alkaline hydrolysis of 2-ethanoyloxybenzenecarboxylic acid with excess sodium hydroxide.



The amount of excess sodium hydroxide is then determined by titration with standard sulfuric acid (0.05 mol dm^{-3}) using phenolphthalein as indicator.

Apparatus

You will need safety goggles and the following apparatus:

1 x weighing bottle + lid containing approximately 1.5 g of aspirin tablets (pre-weighed)
1 x 50 cm^3 burette
2 x 25 cm^3 pipettes
2 x 250 cm^3 standard flasks
2 x 250 cm^3 conical flasks
1 x 25 cm^3 measuring cylinder
1 x filter funnel
1 x spatula
1 x stirring rod
1 x wash bottle

You will also need access to a 3 decimal place weighing balance and an some heating apparatus

Chemicals

150 cm^3 sodium hydroxide solution (approx 1 mol dm^{-3})
300 cm^3 standard sulfuric acid (0.05 mol dm^{-3})
phenolphthalein
de-ionised water

Procedure

1. Transfer your aspirin tablets to a 250 cm^3 conical flask and add **exactly** 25.0 cm^3 of sodium hydroxide solution (approximately 1 mol dm^{-3}) and about the same volume of de-ionised water. Simmer gently for about 10 minutes to hydrolyse the aspirin.
2. Weigh the empty weighing bottle and lid.
3. Leave the reaction mixture to cool and carefully transfer to a 250 cm^3 standard flask. Rinse the conical flask several times transferring all washings to the standard flask. Make the solution up to 250 cm^3.
4. Titrate 25.0 cm^3 samples of the diluted reaction mixture with standard sulfuric acid (0.05 mol dm^{-3}) using 3 drops of phenolphthalein indicator (Titration B).
5. Standardise the sodium hydroxide solution (approximately 1 mol dm^{-3}) after suitable exact dilution in a standard flask, using the standard sulfuric acid and phenolphthalein indicator (Titration A). This step can be carried out at any convenient time.

A mark is awarded for suitable dilution of the sodium hydroxide solution. You may ask your supervisor for guidance with this but the mark will not then be awarded.

Teacher marks – 0 or 1 mark awarded for each aspect

Working safely ☐

Efficient use of time ☐

Dilution ☐

[3]

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Results

Record your results below drawing suitable tables to record both sets of titration data.

Mass of weighing bottle + lid + aspirin tablets = ____________ g

Mass of weighing bottle + lid = ____________ g

Mass of aspirin tablets = ____________ g [1]

Titration A Standardisation of sodium hydroxide solution

Titration B Aspirin/sodium hydroxide mixture against sulfuric acid

[5]

For titration A, select the appropriate values for calculation of the mean titre. Indicate clearly which values these are, calculate the mean titre and record it in the table below.

Repeat these steps for titration B. [3]

Examiner only	
Teacher value	Mark
cm^3	
cm^3	

Mean titre A	cm^3
Mean titre B	cm^3

[10]

Analysis of results

1. Calculate the exact concentration of the sodium hydroxide solution from the results of titration A.
2. Determine the number of moles in 25.0 cm^3 of the sodium hydroxide solution.
3. Determine the number of moles of sodium hydroxide which were in excess and hence the number of moles which reacted with the aspirin.
4. Determine the number of moles and hence the mass of 2-ethanoyloxybenzenecarboxylic acid present in the aspirin tablets weighed out.
5. Determine the percentage of 2-ethanoyloxybenzenecarboxylic acid in the aspirin.

[8]

Percentage of 2-ethanoyloxybenzenecarboxylic acid in the aspirin = ____________ %

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Analysis of aspirin tablets

Teacher Results Sheet

Centre Name ____________________________________ Centre Number ___________

The following teacher results apply for candidates in Group __________.

Titration A Standardising sodium hydroxide

Mean volume of NaOH needed for 25.0 cm^3 of H_2SO_4

= ____________________ cm^3

Titration B Aspirin/sodium hydroxide mixture against sulfuric acid

Mean volume of H_2SO_4 needed for 25.0 cm^3 of diluted reaction mixture (aspirin/NaOH)

= ____________________ cm^3

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Surname	Centre Number	Candidate Number
Other Names		

GCE A LEVEL CHEMISTRY

A2 UNIT 5

Practical Examination

Practical Methods and Analysis Task

SPECIMEN PAPER

1 hour

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**7**	
2.	**6**	
3.	**6**	
4.	**11**	
Total	**30**	

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Pencil may be used to draw tables and graphs.
Write your name, centre number and candidate number in the spaces at the top of this page.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The total number of marks available for this task is 30.
The number of marks is given in brackets at the end of each question or part question.
You are reminded of the necessity for orderly presentation in your answers.

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

1. *(a)* Draw a labelled diagram of a simple apparatus that could be used in an experiment to determine the enthalpy change for the reaction between sodium hydroxide and benzoic acid.

$$C_6H_5COOH \;+\; NaOH \;\rightarrow\; C_6H_5COO^{-}Na^{+} \;+\; H_2O$$ [2]

(b) 5.00 g of benzoic acid was added to 50 cm^3 of NaOH solution, with the alkali in excess. The maximum temperature increase in the solution was 10.3 °C. Calculate the enthalpy change for this reaction.

The specific heat capacity of the solution is 4.18 J g^{-1} $°C^{-1}$ and you should assume that 1.0 cm^3 of the solution has a mass of 1.0 g.

[3]

Enthalpy change = _____________ kJ mol^{-1}

(c) Suggest how a dry solid sample of benzoic acid could be obtained from this reaction mixture. [2]

....

....

....

7

2. You are provided with **five** colourless liquids in separate unlabelled bottles. They are the following organic compounds.

   - ethanal
   - propanone
   - 1-chlorobutane
   - pentan-3-one
   - ethanoic acid

   Plan a series of chemical tests in the form of a flow diagram by which each of the compounds can be identified. State the observations made at each stage.
   The first part has been done for you. [6]

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Test 1 – gently warm each compound with 2,4-dinitrophenylhydrazine

Positive observation

……………………………………………………

Compounds giving positive result

……………………………………………………

……………………………………………………

Negative observation

……………………………………………………

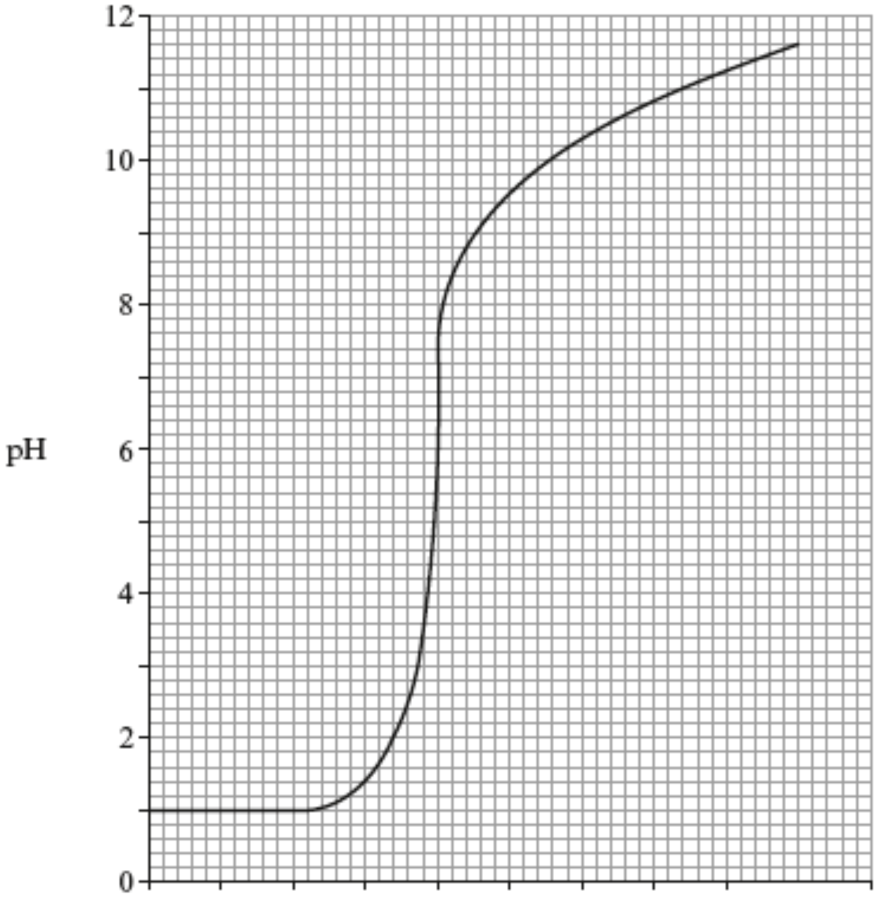
Compounds giving negative result

……………………………………………………

……………………………………………………

6

3. *(a)* The graph below shows the change in pH during a reaction between solutions of ammonia and hydrochloric acid.



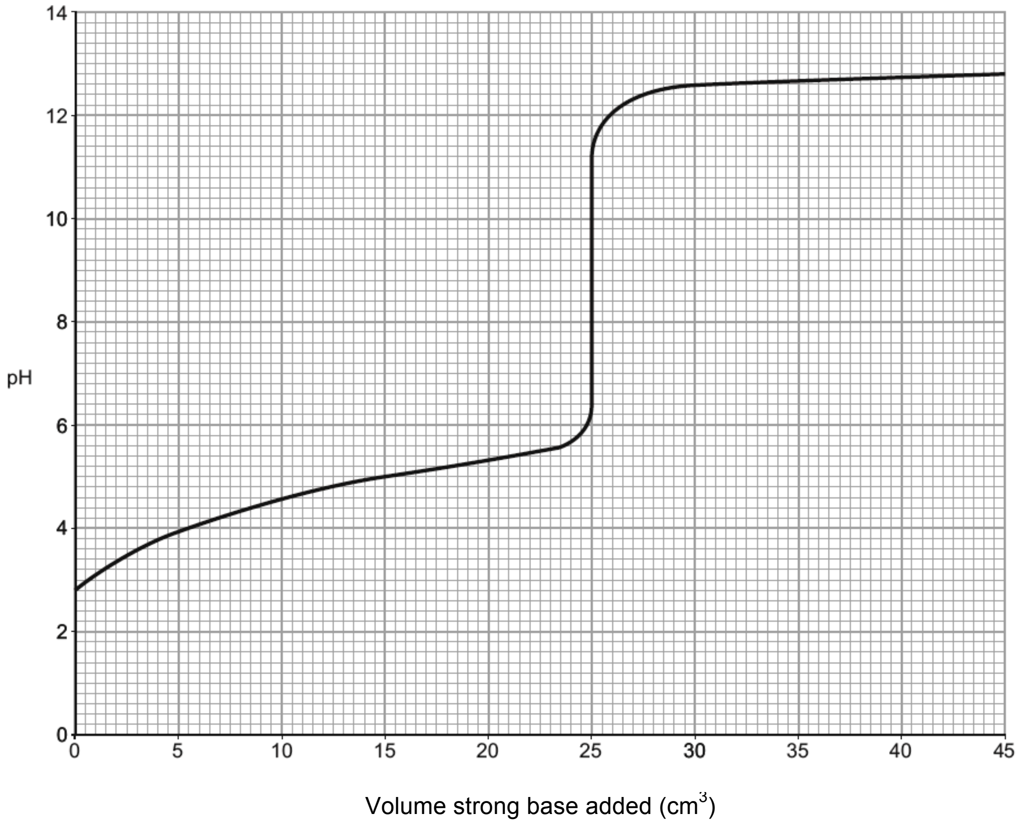
Describe the experiment that was carried out in order to obtain the data needed to plot this graph. [3]

....

....

....

(b) The following graph shows the change in pH when a 0.10 mol dm^{-3} solution of weak acid HA reacts with a strong base. Calculate the acid dissociation constant (K_a) of HA. Give the units, if any.



[3]

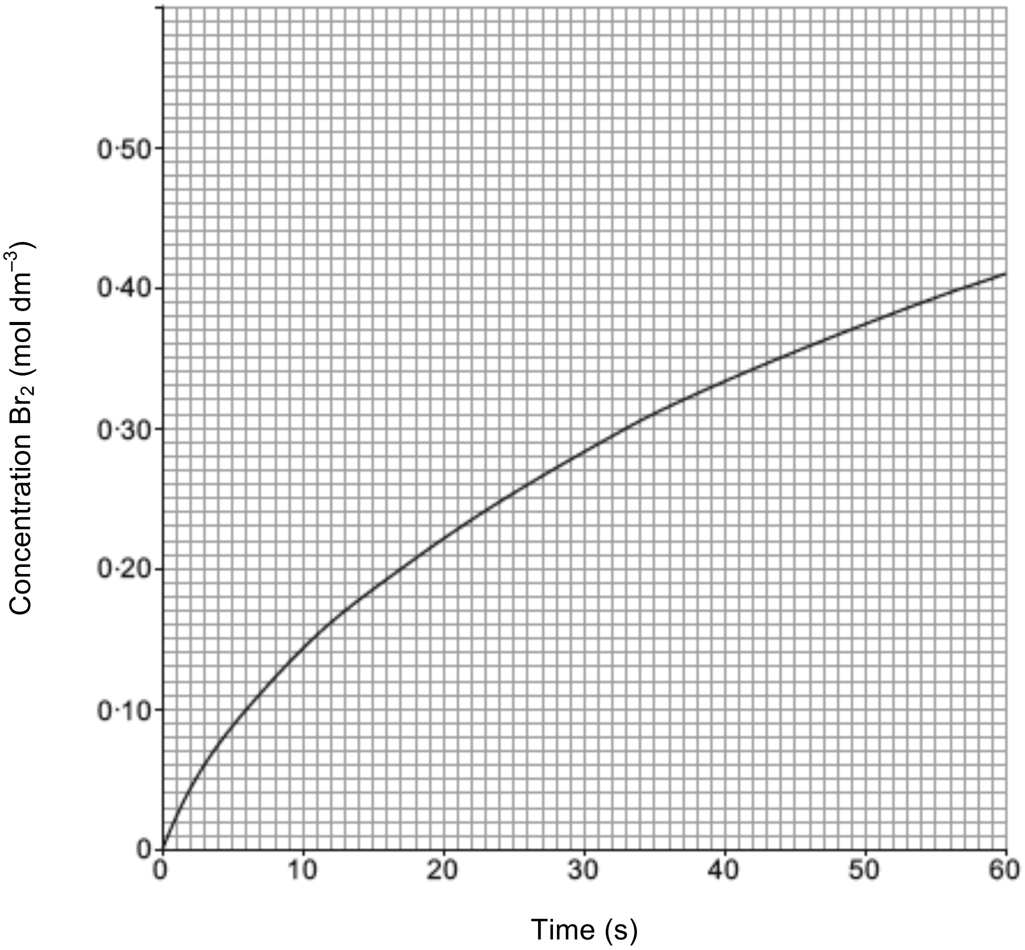
K_a = ...

Units ....

6

4. A student obtained the following graph by plotting data collected in the study of the reaction between chlorine and bromide ions.

$$Cl_2(aq) + 2Br^-(aq) \rightarrow Br_2(aq) + 2Cl^-(aq)$$



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(a) (i) The rate at concentration 0.100 mol dm^{-3} is 1.17×10^{-2} mol dm^{-3}s^{-1}. Draw a tangent to the curve at 0.300 mol dm^{-3} and calculate the rate at this point. [1]

Rate = ... mol dm^{-3}s^{-1}

(ii) In terms of particles, explain why there is a difference between the two rates in (i). [2]

....

....

....

(b) A proposed catalyst for the process is Fe^{3+}, which initially reacts with Br^{-} ions. Suggest two ionic equations to show how the Fe^{3+} ion can behave as a catalyst. [2]

....

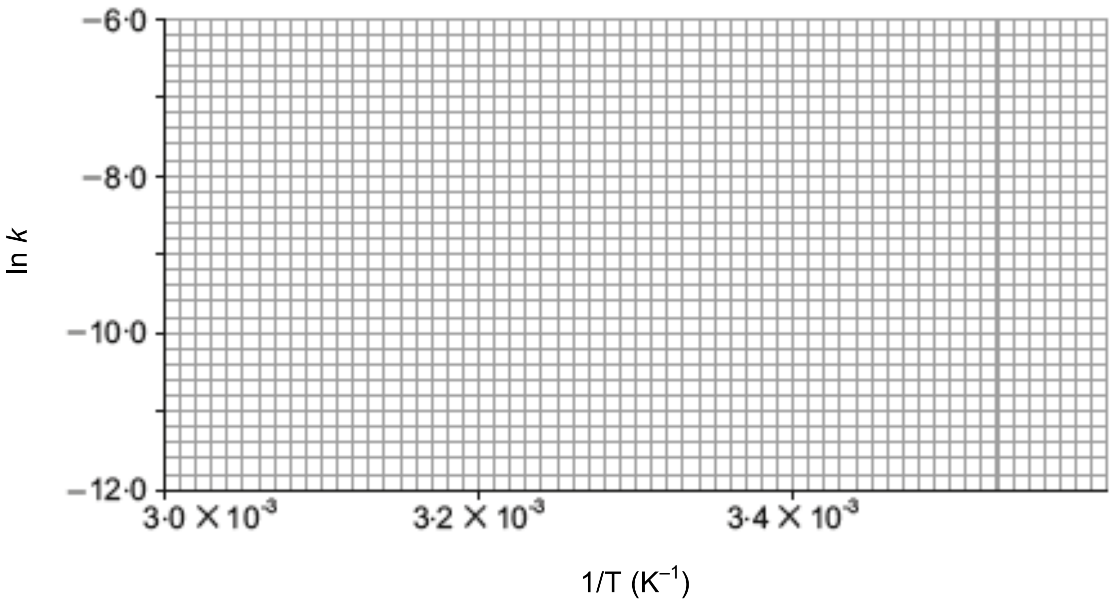
....

....

(*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.

(i) Complete the table and plot a graph of ln k against 1/T. [2]

Temperature, T (K)	1/T (K^{-1})	Rate constant, *k*	ln *k*
290		1.51×10^{-5}	
300		5.55×10^{-5}	
310		1.67×10^{-4}	
320		5.53×10^{-4}	
330		2.24×10^{-3}	



(ii) The gradient, m, of the line is related to the activation energy, E_a.

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

Find the activation energy for this reaction in kJ mol^{-1}. [4]

Activation energy = ... kJ mol^{-1}

11

GCE AS/A LEVEL CHEMISTRY

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

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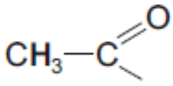
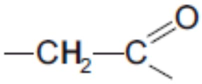
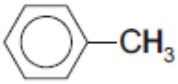
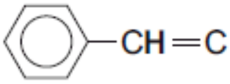
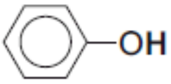
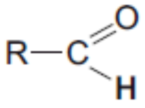
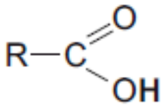
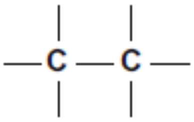
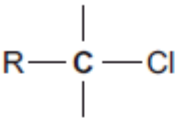
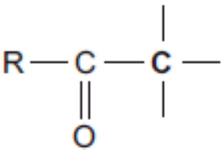
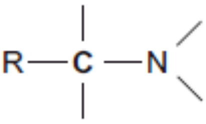
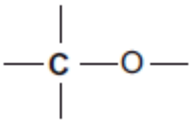
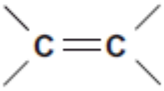
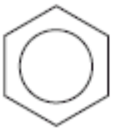
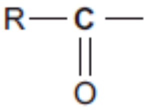
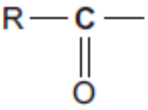
^{1}H NMR chemical shifts relative to TMS = 0

Type of proton	Chemical shift, δ (ppm)
$-CH_3$	0.1 to 2.0
$R-CH_3$	0.9
$R-CH_2-R$	1.3
$CH_3-C\equiv N$	2.0
	2.0 to 2.5
	2.0 to 3.0
	2.2 to 2.3
$R-CH_2Cl$	3.3 to 4.3
$R-OH$	4.5 *
$-C=CH-CO$	5.8 to 6.5
	6.5 to 7.5
	7.0 *
	9.8 *
	11.0 *

*variable figure dependent on concentration and solvent

^{13}C 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
$R{-}\mathbf{C}{\equiv}N$	110 to 125
	110 to 160
 (carboxylic acid / ester)	160 to 185
 (aldehyde / ketone)	190 to 220

THE PERIODIC TABLE

Group

s Block

d Block

p Block

Key

A_r — relative atomic mass

Symbol

Name

Z — atomic number

Period	1	2											3	4	5	6	7	0
1	1.01 H Hydrogen 1																	4.00 He Helium 2
2	6.94 Li Lithium 3	9.01 Be Beryllium 4											10.8 B Boron 5	12.0 C Carbon 6	14.0 N Nitrogen 7	16.0 O Oxygen 8	19.0 F Fluorine 9	20.2 Ne Neon 10
3	23.0 Na Sodium 11	24.3 Mg Magnesium 12											27.0 Al Aluminium 13	28.1 Si Silicon 14	31.0 P Phosphorus 15	32.1 S Sulfur 16	35.5 Cl Chlorine 17	40.0 Ar Argon 18
4	39.1 K Potassium 19	40.1 Ca Calcium 20	45.0 Sc Scandium 21	47.9 Ti Titanium 22	50.9 V Vanadium 23	52.0 Cr Chromium 24	54.9 Mn Manganese 25	55.8 Fe Iron 26	58.9 Co Cobalt 27	58.7 Ni Nickel 28	63.5 Cu Copper 29	65.4 Zn Zinc 30	69.7 Ga Gallium 31	72.6 Ge Germanium 32	74.9 As Arsenic 33	79.0 Se Selenium 34	79.9 Br Bromine 35	83.8 Kr Krypton 36
5	85.5 Rb Rubidium 37	87.6 Sr Strontium 38	88.9 Y Yttrium 39	91.2 Zr Zirconium 40	92.9 Nb Niobium 41	95.9 Mo Molybdenum 42	98.9 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
6	133 Cs Caesium 55	137 Ba Barium 56	139 La ▸ Lanthanum 57	179 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	(210) Po Polonium 84	(210) At Astatine 85	(222) Rn Radon 86
7	(223) Fr Francium 87	(226) Ra Radium 88	(227) Ac ▸▸ Actinium 89															

f Block

▸ Lanthanoid elements	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(147) Pm Promethium 61	150 Sm Samarium 62	(153) Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	163 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
▸▸ Actinoid elements	232 Th Thorium 90	(231) Pa Protactinium 91	238 U Uranium 92	(237) Np Neptunium 93	(242) Pu Plutonium 94	(243) Am Americium 95	(247) Cm Curium 96	(245) Bk Berkelium 97	(251) Cf Californium 98	(254) Es Einsteinium 99	(253) Fm Fermium 100	(256) Md Mendelevium 101	(254) No Nobelium 102	(257) Lr Lawrencium 103

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AS UNIT 1: THE LANGUAGE OF CHEMISTRY, STRUCTURE OF MATTER AND SIMPLE REACTIONS

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark, apart from questions where a banded 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.

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AS UNIT 1: THE LANGUAGE OF CHEMISTRY, STRUCTURE OF MATTER AND SIMPLE REACTIONS

MARK SCHEME

Section A

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1.				1.5×10^{-2} (accept 15×10^{-3})		1		1	1	
2.	*(a)*			rate of the forward reaction is equal to the rate of the reverse reaction	1			1		
	(b)			no change in properties (named property)	1			1		
3.	*(a)*			C_2N_2		1		1		
	(b)			CN		1		1		
4.				oxidation states $SF_6 \rightarrow +6$; $H_2S \rightarrow -2$; $S \rightarrow 0$ all 3 correct (1) oxidation state of S in SF_6 decreases which is reduction therefore H_2S must be reducing agent (1)		2		2		
5.				$[H^+] = 0.02$ (1) pH = 1.7 (1) award (2) for correct answer only (cao)		1 1		2	1	2
6.				9.0 ± 0.2		1				
				Section A total	**2**	**8**	**0**	**10**	**2**	**2**

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Section B

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
7.	*(a)*	(i)		electrons exist in shells	1			1		
		(ii)		fourth electron attracted much more strongly by the nucleus (1) fourth electron is closer to the nucleus / has less shielding from inner electrons (1)		2		2		
	(b)	(i)		Be point plotted between B and C Ne point plotted between F and He	1			1		
		(ii)		$Be(g) \rightarrow Be^{+}(g) + e^{-}$		1		1		
		(iii)		extra electron in oxygen paired in an orbital (1) greater electron-electron repulsion (1)	2			2		
	(c)	(i)		significant changes in successive ionisation energies seen in part *(a)* (1) big fall from He to Li / general increase from Li to Ne in part *(b)* (1)	2			2		
		(ii)		part *(b)* provides additional evidence i.e. for the existence of orbitals			1	1		

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Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
7.	*(d)*	(i)		f = c / λ = 3.28×10^{15} (1)		1				
				E = hf (1)	1				1	
				2.17×10^{-18} (1)		1		3	1	
				error carried forward (ecf) possible award (3) for cao						
		(ii)		for 1 mol = $N_A \times 2.17 \times 10^{-18}$ = 1305024 (1)					1	
				energy = 1305 (1)		2		2		
				ecf possible award (2) for cao						
		(iii)		ionisation energy	1			1		
				Question 7 total	**8**	**7**	**1**	**16**	**3**	**0**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
8.	*(a)*	(i)		volumetric flask / standard flask	1			1		1
		(ii)		identification of 23.95 as an anomalous result (1) $23.15\,cm^3$ (1) award (2) for correct answer only (cao) award (1) for correctly calculated mean based on all four titres		1	1	2		2
		(iii)	I	n(HCl) = 2.315×10^{-3} (1) n(Na_2CO_3) = 1.16×10^{-3} (1)		2		2	2	
			II	n(Na_2CO_3) = 1.16×10^{-2} (1) mass = 0.0116 × 106 = 1.23 g (1) % by mass = (1.23 / 2.05) × 100 = 60 % (1)		3		3	3	
	(b)	(i)		only mass of solid needed / all carbonate precipitated out of solution			1	1		1
		(ii)		n($BaCO_3$) = 1.15×10^{-2} (1) from equation n(Na_2CO_3) = 1.15×10^{-2} (1) mass of Na_2CO_3 = 1.22g % by mass = (1.22 / 2.05) × 100 = 60% (1)			3	3	3	

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Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
8.	*(c)*	(i)		titration gives more accurate value as it is a mean value calculated from concurrent results / uses more accurate or more precise apparatus or technique			1	1		1
		(ii)		repeat precipitation / wash precipitate / heat to constant mass / use a more precise balance any 2 for (1) each			2	2		2
				Question 8 total	**1**	**6**	**8**	**15**	**8**	**7**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
9.	*(a)*	(i)		**B** (1) conducts when molten (1)	2			2		2
		(ii)	I	**A** and **E**	1			1		
			II	melting point – no mark diamond has four strong covalent bonds holding each carbon in place – lot of energy needed to overcome (1) iodine has weak id-id forces between molecules – require much less energy to overcome (1)	1 1			2		
		(iii)		solubility in water (1) sodium chloride soluble – electrostatic forces between ions and polar water molecules strong enough to overcome electrostatic forces inside the lattice (1) iodine insoluble – weak id-id forces between separate molecules too weak to overcome hydrogen bonding between water molecules (1)	1 1	1		3		

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="4">Marks available</th><th rowspan="2">Maths</th><th rowspan="2">Prac</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th></tr>
<tr><td>9.</td><td>(b)</td><td></td><td>Indicative content
• BF_3 is trigonal planar
• 3 bonding pairs and no lone pairs
• NH_3 trigonal pyramidal
• 3 bonding pairs and one lone pair
• extra lone pair on N which is absent from B
• different number of electron pairs around central atom

5-6 marks
Each point included; clarity in description of bonding/lone pairs
<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
Both shapes described/drawn/named; reference to bonding and lone pairs and to different numbers of electron pairs around central atom
<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 both molecules; link between number of electron pairs and shape
<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></td><td>2</td><td>4</td><td></td><td>6</td><td></td><td></td></tr>
</table>

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
9.	*(c)*	(i)		coordinate / dative (covalent)	1			1		
		(ii)		109.5 °	1			1		
		(iii)		4 bonding pairs on B (3 + extra coordinate bonding pair)			1	1		
				Question 9 total	**11**	**5**	**1**	**17**	**0**	**2**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
10.	*(a)*	(i)		$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$		1		1		
		(ii)		oxidation state of Br goes from –1 to 0 (1) which is oxidation therefore chlorine must be the oxidising agent (1) accept oxidation state of Cl goes from 0 to –1 which is reduction (1) oxidising agents are reduced in reaction (1)	1	1		2		
		(iii)		iodine is a larger molecule (1) greater id-id forces than bromine (1)	2			2		
	(b)	(i)		peak at 127 (1) peak at 254 (1) ignore peak heights			2	2		
		(ii)		must contain an isotope with a higher relative mass than the stable ^{127}I isotope			1	1		
	(c)	(i)	I	cloudy solution (1) bubbles (1)	2			2		2
			II	$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$		1		1		
			III	no reaction / very slow formation of bubbles	1			1		1
		(ii)	I	n(HCl) = 0.0392 from equation n(Ca) = 0.0196 (1) mass = 0.784 g (1)		2		2	2	2
			II	0.470 dm^3		1		1	1	1
				Question 10 total	**6**	**6**	**3**	**15**	**3**	**6**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11.	*(a)*			accepts a proton /H^+	1			1		
	(b)	(i)		fewer gas particles in products (1) equilibrium shifts towards products to reduce pressure (1)		2		2		
		(ii)		equilibrium shifts towards products (1) ammonia replaced (1)		2		2		
	(c)			rate of reverse endothermic reaction increases		1				
				equilibrium shifts towards reactants therefore K_c decreases			1	2		
				Question 11 total	**1**	**5**	**1**	**7**	**0**	**0**

AS UNIT 1: THE LANGUAGE OF CHEMISTRY, STRUCTURE OF MATTER AND SIMPLE REACTIONS

SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
Section A	2	8	0	10	2	2
7.	8	7	1	16	3	0
8.	1	6	8	15	8	7
9.	11	5	1	17	0	2
10.	6	6	3	15	3	6
11.	1	5	1	7	0	0
TOTAL	**29**	**37**	**14**	**80**	**16**	**17**

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AS UNIT 2: ENERGY, RATE AND CHEMISTRY OF CARBON COMPOUNDS

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark, apart from questions where a banded 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.

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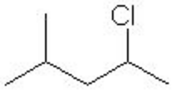
AS UNIT 2: ENERGY, RATE AND CHEMISTRY OF CARBON COMPOUNDS

MARK SCHEME

Section A

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1.	*(a)*			$\Delta H_2 + \Delta H_3 - \Delta H_1$		1		1		
	(b)			$\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightarrow NO(g)$		1		1		
2.	*(a)*			n(C) = 3.33; n(H) = 6.63; n(O) = 3.33 (1) CH_2O (1)		2		2	2	
	(b)			$C_6H_{12}O_6$		1		1		
3.	*(a)*			due to the presence of two different groups on each carbon of the C=C bond	1			1		
	(b)			the bonds of the two isomers are identical / only the arrangement in space has changed between the two isomers		1		1		
4.						1		1		

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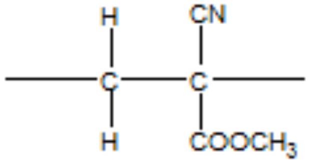
Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
5.				damage to heart / liver etc. accept other sensible answers	1			1		
6.						1		1		
Section A total					**2**	**8**	**0**	**10**	**2**	**0**

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Section B

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7.	*(a)*	(i)		$CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$		1		1		
		(ii)	I	2 pentyl radicals (1) combine to form decane / in termination reaction (1) credit 2 marks for correct equation e.g. $2\ \bullet C_5H_{11} \rightarrow C_{10}H_{22}$		2		2		
			II	no C—Cl bond (1) at 650cm^{-1} (1)		2		2		
		(iii)		$n = \frac{pV}{RT} = \frac{105000 \times 0.001}{8.31 \times 308}$ (1) M = 30.0 (1) error carried forward (ecf) possible award (2) for correct answer only (cao) C_2H_6 / ethane (1)	1	1	1	3	1 1	
	(b)			rate increases as bond gets weaker i.e. Cl to Br to I bond polarity (1) rate increases as bond gets more polar i.e. I to Br to Cl (1)			2	2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7.	*(c)*	(i)		bond energy (1) since data shows that rate increases from Cl to Br to I (1)			2	2		
		(ii)		any two for (1) each up to max 2 • try an identical experiment with a different halogenoalkane e.g. halogenobutane • repeat experiment • try a control experiment			2	2		2
				Question 7 total	**1**	**6**	**7**	**14**	**2**	**2**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
8.	*(a)*	(i)		labelled axes with units (1) at least 5 points plotted correctly – within half a small square (1) appropriate curve drawn (1)	1 1		1	3	1 1	3
		(ii)		colorimetry method (1) calibrate colorimeter with iodine solution of known concentration (1) measure light passing through to determine concentration at intervals (1)	1	1 1		3		3
		(iii)		more particles have an energy greater than the activation energy (1) greater fraction of collisions are effective (1)	2			2		
		(iv)		0.0102 mol dm^{-3} (1) this is the end concentration of I_2 and these species are present in a 1:1 ratio (1)			2	2		
		(v)		0.005 (1) mol dm^{-3} min^{-1} (1)	1	1		2	2	
	(b)			activation energy for catalysed reaction marked to the left of E_a on plot (1) more particles have an energy greater than the activation energy / greater fraction of collisions are effective therefore rate increases (1)	2			2		
				Question 8 total	**8**	**3**	**3**	**14**	**4**	**6**

Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
9.	*(a)*	(i)		$M_r(C_9H_{20})$ = 128 (1)						
				1.563 × 10^{-3} mol (1)		2		2	1	
		(ii)		temperature increase = 30.7 °C (1)		1				
				50 × 4.18 × 30.7 (1)	1				1	
				$\Delta H = -4105$ kJ mol^{-1} (1)		1		3	1	3
		(iii)		heat loss (1)		1				
				can be reduced by increasing insulation e.g. lagging calorimeter or putting lid on it (1)			1	2		2
	(b)	(i)		14 O_2 9 CO_2 10 H_2O		1		1		
				all must be correct						
		(ii)		bonds broken = 2784 + 8240 + 6944 = 17968						
				bonds formed = 13374 + 20(O—H) (1) **both** required						
				4666 = [13374 + 20(O—H)] – 17968 (1)						
				(O—H) = 463 kJ mol^{-1} (1)		3		3	3	
		(iii)		the enthalpy of the O—H bond in other compounds is slightly different	1			1		
				Question 9 total	**2**	**9**	**1**	**12**	**6**	**5**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10.	*(a)*	(i)		NaOH in ethanol (1) propene (1)	2			2		2
		(ii)		sodium / potassium dichromate(VI) (1) oxidation (1)	2			2		2
	(b)	(i)		n(C) = 5.18; n(H) = 10.2: n(O) = 1.73 (1) ratio = 3:6:1 which is consistent with formula (ratio = 6:12:2) (1)		1	1	2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10.	*(b)*	(ii)	Indicative content • δ 1.3 = R–CH_2–R δ 2.1 = –CH_2–C=O δ 4.0 = –CH_2–O • IR peaks for C–H and C=O but not O–H • sweet smelling suggests ester • 2 compounds from part *(a)* are propan-1-ol and propanoic acid • structure is $CH_3CH_2COOCH_2CH_2CH_3$ **5-6 marks** Correct structure given; reference to all information provided *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.* **3-4 marks** Spectral data interpreted correctly; structure given fits interpretation *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.* **1-2 marks** Two correct conclusions drawn from spectral data or other information provided *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.* **0 marks** *The candidate does not make any attempt or give an answer worthy of credit.*		3	3	6		1
		(iii)	distillation (1) boiling temperature of product much lower than either reactant (1) no hydrogen bonding in product (present in both reactants) (1)	1	2		3		3
			Question 10 total	**5**	**6**	**4**	**15**	**2**	**8**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
11.	*(a)*	(i)		dipoles marked (1) electron movement from H–Br onto Br and electron movement from C=C to $H^{\delta+}$ (1) correct carbonium ion formed (1) electrophilic addition (1)	4			4		
		(ii)		atom of Br can be added to either carbon of C=C (1) secondary carbonium ions are more stable than primary carbonium ions (1)	2			2		
	(b)			IR 1715 cm^{-1} due to C=O (1) δ 9.8 due to R–CHO (1) molecule must be propanal (1) arises from compound C as aldehydes formed from primary alcohols only (1)		1 1	1 1	4		
	(c)	(i)		orange/brown to colourless (1) 1,2,3-tribromobutane (1) **either** order	1	1		2		1
		(ii)	I	white precipitate due to the use of HCl			1	1		1
			II	(warm) with aqueous NaOH (1) acidify with HNO_3 then add aqueous $AgNO_3$ (1)	2			2		2
				Question 11 total	**9**	**3**	**3**	**15**	**0**	**4**

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AS UNIT 2: ENERGY, RATE AND CHEMISTRY OF CARBON COMPOUNDS

SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
Section A	2	8	0	10	2	0
7.	1	6	7	14	2	2
8.	8	3	3	14	4	6
9.	2	9	1	12	6	5
10.	5	6	4	15	2	8
11.	9	3	3	15	0	4
TOTAL	**27**	**35**	**18**	**80**	**16**	**25**

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A2 UNIT 3: PHYSICAL AND INORGANIC CHEMISTRY

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark, apart from questions where a banded 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.

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A2 UNIT 3: PHYSICAL AND INORGANIC CHEMISTRY

MARK SCHEME

Section A

Question				Marking details	Marks Available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
1.				CH_3COOH and NH_4^+ identified – both required		1		1		
2.				potassium fluoride and rubidium fluoride – both required accept correct formulae do not accept if lithium fluoride included do not accept ‘potassium’ and ‘rubidium’		1		1		
3.	*(a)*			$3Cl_2 + 6NaOH \rightarrow 5NaCl + (1)NaClO_3 + 3H_2O$		1		1		
	(b)			<u>chlorine</u> oxidation state at <u>start is 0</u> and at <u>end is</u> –<u>1 and +5</u> so it has been both oxidised and reduced		1		1		
4.				HCl at 1 mol dm^{-3} **or** H_2SO_4 at 0.5 mol dm^{-3}	1			1		1
5.				*lowest* Se(s) Br_2(l) Kr(g) *highest*		1		1		
6.				$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$		1		1		
7.				silicon possess available *d*-orbitals whilst there are none in the outer shell of carbon (therefore oxygen cannot bond)	1			1		
8.				oxygen 20.7% (1) formula CrO_2Cl_2 (1)		2		2	1	
				Section A total	**2**	**8**	**0**	**10**	**1**	**1**

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Section B

Question				Marking details	Marks Available					
					AO1	AO2	AO3	Total	Maths	Prac
9.	(a)	(i)		<u>outer</u> shell of electrons is not full / has fewer than 8 electrons	1			1		
		(ii)		$NH_3.BCl_3$ (1) coordinate bond forms between lone pair on N and electron deficient BCl_3 (1)	1 1			2		
	(b)	(i)		any two for (1) each up to max 2 • delocalised electrons in graphite and none in BN (1) • all atoms the same in graphite, alternating in BN (1) • atoms in planes lie above each other (in register) for BN and out of register for graphite (1)	2			2		
		(ii)	I	to ensure all the water molecules have been removed	1			1		1
			II	moles water = 0.053 / 18.02 = 2.94×10^{-3} (1) moles carbon = 3.592 / 12 = 0.299 (1) ratio C: H_2O = 102: 1 [or 1: 9.82×10^{-3}] (1)		3		3	3	

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Question				Marking details	Marks Available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
9.	*(c)*	(i)		$K_p = \frac{p_{PCl_3} p_{Cl_2}}{p_{PCl_5}}$		1				
				at equilibrium $P_{PCl3} = 6.0 \times 10^3$ Pa and $P_{PCl5} = 6.4 \times 10^3$ Pa (1)			1		1	
				$K_p = 5625$ (1)		1			1	
				error carried forward (ecf) possible award (3) for correct answer only (cao)						
				Pa (1)	1			4	1	
		(ii)		increase in K_p indicates an increase in products when temperature is increased (1) endothermic [need reason for mark] (1)			2	2		
		(iii)		phosphorus can expand its octet but nitrogen cannot / phosphorus has *d*-orbitals in its valence shell nitrogen does not (1) this allows phosphorus to have more than 10 electrons in outer shell and form PCl_5 (1)	2			2		
				Question 9 total	**9**	**5**	**3**	**17**	**6**	**1**

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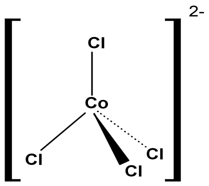
Question				**Marking details**	**Marks Available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
10.	*(a)*			Cu – all boxes doubly filled apart from one in last (1) Cu^{2+} – all boxes doubly filled apart from empty 4s and one in one *d*-orbital (1)	1	1		2		
	(b)			Indicative content • $[CoCl_4]^{2-}$ is complex formed  • colour of complex is blue • *d*-orbitals split by ligands • electrons absorb light to move from lower to higher level • colour seen is colour not absorbed points 3 and 4 can be obtained from a labelled diagram	6			6		

Question				Marking details	Marks Available					
					AO1	AO2	AO3	Total	Maths	Prac
10.	*(b)*			**5-6 marks** Each point included; no reference to emission of blue light *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.* **3-4 marks** Colour and formula of species; reference to splitting of *d*-orbitals by ligands; absorption of energy corresponding to difference between levels *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.* **1-2 marks** Colour or formula of species; splitting of *d*-orbitals; electrons move to another energy level *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.* **0 marks** *The candidate does not make any attempt or give an answer worthy of credit.*						

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Question				**Marking details**	**Marks Available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
10.	*(c)*	(i)		$f = \frac{3.00 \times 10^{8}}{515 \times 10^{-9}} = 5.83 \times 10^{14}$ (1)	1					
				$E = 3.87 \times 10^{-19}$ (1)		1				
				233 kJ mol^{-1} (1)			1	3	3	
				ecf possible award (3) for cao						
		(ii)		agree because total percentage of cobalt decreases / is less than 100 % after the addition of ammonia (1)		1				
				the equation shows cobalt will be in one of the two species / if the equation was correct the percentage in each complex would always add up to 100 % (1)			1		1	
				there must be another cobalt complex / an intermediate (1)			1	3		
				Question 10 total	**8**	**3**	**3**	**14**	**4**	**1**

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<table>
<tr><th colspan="4" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks Available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>11.</td><td><i>(a)</i></td><td></td><td></td><td>lilac – contains potassium ions
apple green – contains barium ions both needed</td><td>1</td><td></td><td></td><td>1</td><td></td><td>1</td></tr>
<tr><td></td><td><i>(b)</i></td><td></td><td></td><td>
<table>
<tr><td>Solution A</td><td>copper(II) sulfate</td></tr>
<tr><td>Solution B</td><td>potassium iodide</td></tr>
<tr><td>Solution C</td><td>lead(II) nitrate</td></tr>
<tr><td>Solution D</td><td>barium chloride</td></tr>
<tr><td>Solution E</td><td>sodium hydroxide</td></tr>
</table>
all five correct (4)
four correct (3)
three correct (2)
two correct (1)

any three for (1) up to max 3

• bright yellow precipitate is probably lead(II) iodide (1)
• so solution C must contain lead ions or iodide ions (1)
• solution C giving a white precipitate which dissolves in excess solution E suggests an amphoteric metal (1)
• this confirms that solution C contains lead(II) ions (1)</td><td></td><td>3</td><td>4</td><td>7</td><td></td><td>7</td></tr>
<tr><td colspan="5" align="right">Question 11 total</td><td>1</td><td>3</td><td>4</td><td>8</td><td>0</td><td>8</td></tr>
</table>

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Question				Marking details	Marks Available					
					AO1	AO2	AO3	Total	Maths	Prac
12.	*(a)*			H_2SO_4 + 2NaOH → Na_2SO_4 + $2H_2O$ / 1 mol H_2SO_4 : 2 mol NaOH (1)		1				
				0.341 mol dm^{-3} (1)		1			1	
				answer given to 3 significant figures (1)			1	3	1	3
	(b)			$[H^+] = 10^{-pH}$ (1)		1				
				$[H^+] = 3.1623 \times 10^{-14}$ (1)		1				
				$[NaOH] = 1.00 \times 10^{-14} \div 3.1623 \times 10^{-14} = 0.316$ mol dm^{-3}		1		3	3	3
	(c)			titration is more precise as a change of 0.1 in pH gives a large change in concentration / the resolution of the burette or pipette is much greater than that of the pH probe			1	1		1
	(d)	(i)		phenolphthalein as the titration curve will be vertical in the range 8.2-10.0 / will not be vertical in the range 2.9-6.3 (1)			1	1		1
		(ii)		after addition of half the volume of sodium hydroxide there will be equal concentrations of ethanoic acid and sodium ethanoate / [ACID] = [SALT] / $[H^+] = K_a$ (1)	1					
				pH = 4.7 (1)		1		2	2	
	(e)			any pH value in the range 3.0-6.8 (1)				2		
				the ammonium ion exists in equilibrium with NH_3 and H^+ so it increases $[H^+]$ in solution / some NH_4^+ breaks down releasing H^+ (1)		2				
				Question 12 total	**1**	**8**	**3**	**12**	**7**	**8**

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Question				**Marking details**	**Marks Available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
13.	*(a)*	(i)		$\Delta_f H_{products} = [(2 \times -482) + (8 \times -286) + (2 \times -436)]$ (1) $\Delta_f H_{reactants} = [(2 \times -813) + (5 \times -188) + (6 \times -92)]$ (1) $\Delta H = -4016 - (-3118) = -1006$ kJ mol^{-1} (1) $\Delta G = \Delta H - T\Delta S = -1006 - [298 \times (9 \div 1000)] = -1009$ kJ mol^{-1} (1) emf for the reaction = 1.52 – 0.68 = 0.84 V (1) reaction is feasible as the value of ΔG is negative and the value of the emf is positive (1)		5	1	6	4	
		(ii)		electrochemical as this is a solution reaction whilst the Gibbs' free energy data is for the solids/liquids (1) should use standard conditions of 1 mol dm^{-3} concentration (1) and 298K temperature (1)			3	3		3

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Question				Marking details	Marks Available					
					AO1	AO2	AO3	Total	Maths	Prac
13.	*(b)*	(i)	I	increase in pH by one unit is a decrease in $[H^+]$ by a factor of 10 (1) between lines 1 and 2 $[H^+]$ decreases by a factor of 10 and the rate decreases by a factor of 10 therefore it is first order with respect to $[H^+]$ (1)			2	2	2	
			II	rate = $k\,[H^+]^1\,[CH_3COCH_3]^1\,[Br_2]^0$ (1) $[H^+] = 10^{-pH}$ for any relevant pH value (1) $k = 1.7 \times 10^{-3}$ (1) units = $mol^{-1}\,dm^3\,s^{-1}$ (1)	1	1 1	1	4	4	
			III	incorrect – gains no credit credit for explanation rate equation shows that rate determining step must involve **one** CH_3COCH_3 and **one** H^+ (which is not present in this mechanism) (2) **or** rate equation shows that rate determining step must involve CH_3COCH_3 and H^+ (which is not present in this mechanism) (1)			2	2		
		(ii)		less energy needed as you can use lower temperature or pressure (1) homogenous catalysts in same phase as reactants so difficult to separate (1)	2			2		1
				Question 13 total	**3**	**7**	**9**	**19**	**10**	**4**

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A2 UNIT 3: PHYSICAL AND INORGANIC CHEMISTRY

SUMMARY OF ASSESSMENT OBJECTIVES

Question	**AO1**	**AO2**	**AO3**	**TOTAL MARK**	**MATHS**	**PRAC**
Section A	2	8	0	10	1	1
9.	9	5	3	17	6	1
10.	8	3	3	14	4	1
11.	1	3	4	8	0	8
12.	1	8	3	12	7	8
13.	3	7	9	19	10	4
TOTAL	**24**	**34**	**22**	**80**	**28**	**23**

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A2 UNIT 4: ORGANIC CHEMISTRY AND ANALYSIS

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark, apart from questions where a banded 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.

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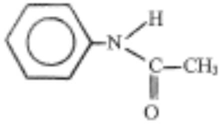
A2 UNIT 4: ORGANIC CHEMISTRY AND ANALYSIS

MARK SCHEME

Section A

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
1.				$C_6H_5NH_2$ or other primary aromatic amine	1			1		
2.					1			1		
3.				melts over a range of lower temperatures	1			1		
4.				total peak area excluding compound **D** is 96 – equivalent to 80 % peak area compound **D** (20%) is 96 / 4 = 24		1		1		
5.				phenylmethylamine / benzylamine		1		1		
6.	*(a)*			nucleophilic addition	1			1		
	(b)			butanal		1		1		
7.				C_6H_6		1		1		
8.				*least soluble* **B A D C** *most soluble*		1		1		
9.				2-methylpropan-1-ol		1		1		
				Section A total	**4**	**6**	**0**	**10**	**0**	**0**

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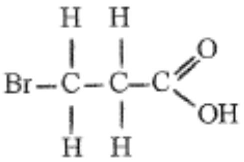
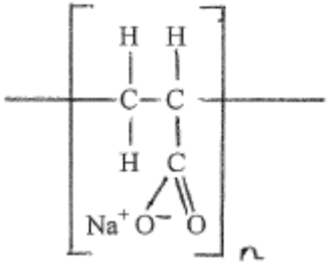
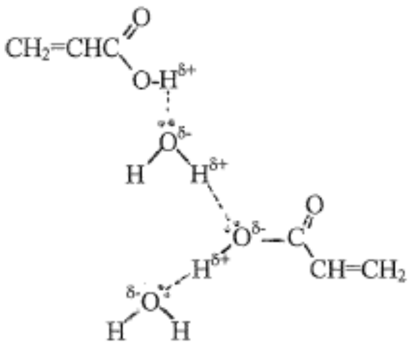
Section B

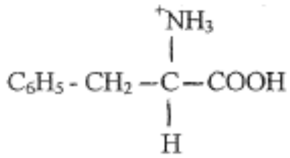
Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
10.	*(a)*			C_9H_{20}		1		1		
	(b)			use of a catalyst will not affect the enthalpy change of reaction (1) Hess's law states that the overall enthalpy change is independent of the pathway taken (1)	2			2		
	(c)			 (1) this compound does not contain a chiral centre / an asymmetric carbon atom (which would give rise to enantiomers) (1)			1 1	2		
	(d)			propenoic acid contains a C=C bond at 1620-1670 cm^{-1} (not present in 3-oxetanone) (1) propenoic acid contains an O–H bond at 2500-3550 cm^{-1} (not present in 3-oxetanone) (1)		2		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10.	*(e)*			M_r sodium propenoate 94.0 (1) moles of propenoic acid = $\frac{38.3 \times 1000}{72.0}$ = 532 ∴ moles of sodium propenoate = 532 ∴ mass of sodium propenoate = 532 × 94.0 = 50.0 (kg) (1) alternatively M_r sodium propenoate 94.0 (1) mass of sodium propenoate = $\frac{38.3 \times 94.0}{72.0}$ = 50.0 (kg) (1)		2		2	1	
	(f)					1		1		

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
10.	*(g)*			for example  correct atoms involved in hydrogen bonding (1) lone pairs and dipoles correctly shown (1)		2		2		
	(h)			any three valid considerations for (1) each up to max 3 for example • cost of propane v cost of propene • yield of propenenitrile in each method • effectiveness of catalyst(s)			3	3		
				Question 10 total	**2**	**8**	**5**	**15**	**1**	**0**

Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
11.	*(a)*	(i)		butane-1,4-diol / butan-1,4-dial (1)		1				
				acidified potassium dichromate / $H^+,Cr_2O_7^{2-}$ (1)	1			2		1
		(ii)	I	7 mol glucose give 12 mol butane-1,4-dicarboxylic acid (1) 7 × 180 g glucose give 12 × 118 g butane-1,4-dicarboxylic acid ∴ 1 g glucose gives $\frac{12 \times 118}{7 \times 180}$ g butane-1,4-dicarboxylic acid (1) = 1.12 (kg) (1) **or** 7 mol glucose give 12 mol butane-1,4-dicarboxylic acid (1) 1 mol glucose gives 12/7 mol butane-1,4-dicarboxylic acid = 1.71 mol moles glucose used = 1000/180 = 5.56 moles butane-1,4-dicarboxylic acid obtained = 1.71 × 5.56 = 9.51 (1) ∴ mass of butane-1,4-dicarboxylic acid = $\frac{9.51 \times 118}{1000}$ = 1.12 kg (1)		3		3	3	
			II	carbon dioxide is used and this helps to reduce the greenhouse effect			1	1		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11.	*(b)*	(i)		mass H_2SO_4 = 294 g (1) volume H_2SO_4 = 160 cm^3 (1) ecf possible award (2) for cao		2		2	2	
		(ii)		e.g. reflux for longer (1) use stronger / weaker / more aqueous sulfuric acid (1)			2	2		2
		(iii)		there will be less dipole / dipole forces between molecules of 2-methylfuran than between molecules of furfural (1) therefore less energy (1) will be needed to separate them / overcomes these intermolecular forces, giving a lower boiling temperature for 2-methylfuran (1)		3		3		
		(iv)		absorption strongest around 430 nm in the blue-violet (1) low absorption for yellow / in the green to orange region (1)			2	2		2
				Question 11 total	**1**	**9**	**5**	**15**	**5**	**5**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
12.	*(a)*	(i)		$C_6H_5–CH(COOH)–NH–C(O)CH(NH_2)C_6H_5$		1		1		
		(ii)		 $C_6H_5-CH_2-C(^{+}NH_3)(H)-COOH$		1		1		
	(b)			3-phenylpropanoic acid has largely van der Waals forces between molecules (1) hydrogen bonding between the acid groups has only a limited effect as these are a small part of a larger molecule, therefore melting temperature is relatively low (1) in 3-phenyllactic acid the hydrogen bonding has a greater contribution to the overall intermolecular bonding as both –OH and –COOH groups can participate, therefore its melting temperature is relatively higher (1) phenylalanine exists as a zwitterion structure as a solid this structure has a strongly bonded ionic style lattice and therefore its melting temperature is much higher / very high (1)		1 1	1 1	4		

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Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
12.	*(c)*	(i)		Tollens' (1) silver mirror with phenylethanal but no change with phenylpyruvic acid (1) accept Fehling's test or sodium hydrogencarbonate test	1	1		2		2
		(ii)		2-phenylethanol M_r 122 $122 - 91 \rightarrow 31$ (1) (loss of 31 could be CH_2OH^+), fragment could be $C_6H_5CH_2^+$ (1)			2	2		
		(iii)		reagents used are I_2/NaOH or NaOCl/KI (1) yellow solid forms (1) only 1-phenylethanol has a $CH_3C{=}O$ or $CH_3CH(OH)$ group present (1)	1 1		1	3		2
				Question 12 total	**3**	**5**	**5**	**13**	**0**	**4**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
13.	*(a)*			benzene-1,4-dicarboxylic acid / terephthalic acid		1		1		
	(b)			bond between the chlorine atom(s) and the ring is strong(er) (1) because of the interaction of chlorine's lone pair of electrons with the π-electron system of the ring (1)	2			2		
	(c)			e.g. $AlCl_3$ / $FeCl_3$ / Fe (1)	1					
				----------- + **2**Cl_2 → --------------- + **2HCl** (1)		1		2		
	(d)	(i)		purple solution	1			1		1
		(ii)		white precipitate / solid (1)	1					
				2,6-dibromo-4-chloro-3,5-dimethylphenol (1)		1		2		2
		(iii)		PCMX → C_8H_9ClO → M_r 157 / 156.6 (1) 250 cm^3 → 12.0 g $\therefore$ 1000 cm^3 → 48.0 g molar concentration = 48.0 / 157 = 0.307 (mol dm^{-3}) (1) ecf possible award (2) for cao		2		2	2	
		(iv)		three peaks (1)		1				
				as there are three different environments for the protons (1)	1					
				peak areas are: CH_3 protons – 6 CH aromatic protons – 2 OH proton – 1 (1)			1	3		
				Question 13 total	**6**	**6**	**1**	**13**	**2**	**3**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14.	*(a)*	(i)		$CH_3COOH + C_4H_9OH \rightarrow CH_3COOC_4H_9 + H_2O$		1		1		
		(ii)		moles of butan-1-ol 0.20 moles of ethanoic acid 0.15 (1) butan-1-ol is in excess and yield should be based on the CH_3COOH (1) from the equation (mole ratio 1:1) 0.15 moles of the ester should be formed = 0.15 × 116 = 17.4 g (1)		1 1	1	3	3	3
		(iii)		CH_3COOH is neutralised by sodium hydrogencarbonate (1) giving bubbles (of carbon dioxide) (1)	2			2		2
		(iv)		IR spectrum (1) → OH peak at 2500-3550 cm^{-1} (1) **or** mass spectrum (1) → molecular ion at m/z 74 (1)			2	2		2

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
14.	*(b)*			Indicative content • M_r of cyclohexanone $C_6H_{10}O$ is 98.1 • % oxygen is $\frac{16 \times 100}{98.1} = 16.3$ • this information agrees with the compound suggested • cyclohexanone is a ketone and will be reduced to a secondary alcohol; this does **not** fit the compound given • cyclohexanone does not contain a C=C and will **not** therefore decolourise aqueous bromine • cyclohexanone has three proton environments and therefore will **not** give 6 discrete peaks in the ^{1}H NMR spectrum • cyclohexanone has four carbon environments and will give four separate peaks in its ^{13}C spectrum; this does **not** fit the compound suggested **5-6 marks** Correct conclusions relating to all information *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.* **3-4 marks** Oxygen content calculated; correct conclusions relating to one reaction and one piece of spectral data *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.*	3		3	6	2	1

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14.	*(b)*			**1-2 marks** Relative mass of compound calculated; correct conclusion relating to one reaction or one piece of spectral data *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.* **0 marks** *The candidate does not make any attempt or give an answer worthy of credit.*						
				Question 14 total	**5**	**3**	**6**	**14**	**5**	**8**

A2 UNIT 4: ORGANIC CHEMISTRY AND ANALYSIS

SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
Section A	4	6	0	10	0	0
10.	2	8	5	15	1	0
11.	1	9	5	15	5	5
12.	3	5	5	13	0	4
13.	6	6	1	13	2	3
14.	5	3	6	14	5	8
TOTAL	**21**	**37**	**22**	**80**	**13**	**20**

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A2 UNIT 5: PRACTICAL EXAMINATION

EXPERIMENTAL TASK

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

The mark total should be entered onto the grid on the front cover.

Marking rules

All work should be seen to have been marked.

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

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A2 UNIT 5: PRACTICAL EXAMINATION

EXPERIMENTAL TASK

MARK SCHEME

Skill	**Marking details**	**Marks available**					
		AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
Teacher-awarded marks	working safely (1) efficient use of time (1) dilution (1)	3			3		3
Weighings	all masses recorded to precision of balance **and** precise mass of aspirin correctly calculated (should be at least 3 decimal places)	1			1		1
Titration data – recording	appropriate tables drawn (1) titles and units included (1) at least three sets of readings for titration A (1) at least three sets of readings for titration B (1) all readings recorded to 0.05 cm^3 (1)		5		5		5
Titration data – means	concordant titres selected for titration A (1) concordant titres selected for titration B (1) mean values for both titres calculated (1)			3	3		3

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Skill	**Marking details**	**Marks available**					
		AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
Titration data – accuracy	titration A – comparison with teacher's results ±0.2 cm^3 5 marks ±0.3 cm^3 4 marks ±0.4 cm^3 3 marks ±0.5 cm^3 2 marks ±0.6 cm^3 1 mark titration B – comparison with teacher's results corrected for different masses of aspirin ±0.2 cm^3 5 marks ±0.3 cm^3 4 marks ±0.4 cm^3 3 marks ±0.5 cm^3 2 marks ±0.6 cm^3 1 mark		10		10		10
Analysis of results	concentration of NaOH solution (2) number of moles of NaOH in 25.0 cm^3 (1) number of moles of NaOH in excess (1) number of moles of NaOH reacted (1) number of moles of 2-ethanoyloxybenzenecarboxylic acid in the tablets (1) mass of 2-ethanoyloxybenzenecarboxylic acid in the tablets (1) percentage of 2-ethanoyloxybenzenecarboxylic acid in the tablets (1)		3	5	8	5	8
	Total	**4**	**18**	**8**	**30**	**5**	**30**

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A2 UNIT 5: PRACTICAL EXAMINATION

PRACTICAL METHODS AND ANALYSIS TASK

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark.

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.

Marking rules

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Marking abbreviations

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A2 UNIT 5: PRACTICAL EXAMINATION

PRACTICAL METHODS AND ANALYSIS TASK

MARK SCHEME

Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
1.	*(a)*			simple diagram – marks awarded for labelling any two for (1) each up to max 2 • calorimeter / polystyrene cup • thermometer • sodium hydroxide (solution)	2			2		2
	(b)			$\frac{m \times c \times \Delta T}{n}$ (1) accept $\frac{50 \times 4.18 \times 10.3}{0.041}$ $M_r(C_6H_5COOH) = 122$ (1) $\Delta H = -52.53$ (1) **must** be negative value	1	1 1		3	1	3
	(c)			add dilute acid (1) filter and dry (1)	1	1		2		2
				Question 1 total	**4**	**3**	**0**	**7**	**1**	**7**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
2.				positive observation – orange precipitate negative observation – no change/precipitate **both** required (1) compounds giving positive result – ethanal, propanone and pentan-3-one **all three and no others** required (1) for compounds giving positive 2,4-DNPH test • positive silver mirror test (or Fehling's test) for ethanal (1) • iodoform test gives yellow precipitate with propanone (1) • pentan-3-one is the other (1) for compounds giving negative 2,4-DNPH test • sodium bicarbonate causes effervescence in ethanoic acid but not in 1-chlorobutane (1) or • (warming with) sodium hydroxide followed by nitric acid and Ag+(aq) produces white precipitate with 1-chlorobutane but not with ethanoic acid (1)		2	4	6		6
				Question 2 total	**0**	**2**	**4**	**6**	**0**	**6**

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Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3.	*(a)*			ammonia added to hydrochloric acid (1)			1			
				hydrochloric acid in (conical) flask / beaker and ammonia in burette (1)	1					
				measure pH with pH probe/ meter after each (small volume) addition / continuous measurement with a data logger or computer (1)	1			3		3
	(b)			from graph pH = 2.8						
				$[H^+] = 1.58 \times 10^{-3}$ (1)			1			
				$K_a = \frac{(1.58 \times 10^{-3})^2}{0.1} = 2.50 \times 10^{-5}$ (1)		1				
				award (2) for correct answer only ecf possible						
				accept answer based on pK_a = pH at half neutralisation						
				mol dm^{-3} (1)	1			3	3	
				Question 3 total	**3**	**1**	**2**	**6**	**3**	**3**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
4.	*(a)*	(i)		0.0055 [accept 0.0053 – 0.0057]		1		1	1	1
		(ii)		concentration of reactants decrease at time proceeds (1) therefore frequency of successful collisions / number of successful collisions per unit time decreases (1)	1		1	1		
	(b)			$2Br^- + 2Fe^{3+} \rightarrow Br_2 + 2Fe^{2+}$ (1) $Cl_2 + 2Fe^{2+} \rightarrow 2Cl^- + 2Fe^{3+}$ (1)			2	2		
	(c)	(i)		1/T and ln k values calculated (1) all points plotted correctly (1)	1	1		2	2	
		(ii)		appropriate readings correctly made from graph e.g. $y = 3.8$; $x = 0.32 \times 10^{-3}$ (1) gradient = –12000 ± 500 (1) (*accept positive value*) $E_a = 12000 \times 8.31 = 99720$ (1) $E_a = 97$ (kJ mol^{-1}) (1) award (4) for cao award (3) for negative value or answer in J mol^{-1} ecf possible		1 1	1 1	4	4	4
				Question 4 total	**2**	**4**	**5**	**11**	**7**	**5**

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A2 UNIT 5: PRACTICAL EXAMINATION

SUMMARY OF ASSESSMENT OBJECTIVES

	Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
Experimental Task	**Total**	**4**	**18**	**8**	**30**	**5**	**30**
Practical Methods and Analysis Task	**1.**	4	3	0	7	1	7
	2.	0	2	4	6	0	6
	3.	3	1	2	6	3	3
	4.	2	4	5	11	7	5
	Total	**9**	**10**	**11**	**30**	**11**	**21**

	OVERALL TOTAL	**13**	**28**	**19**	**60**	**16**	**51**

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