



Rewarding Learning

ADVANCED
General Certificate of Education
2023

Centre Number

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Candidate Number

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Chemistry

Assessment Unit A2 3

assessing

Further Practical Chemistry

Practical Booklet B (Theory)



[ACH32]

ACH32

TUESDAY 20 JUNE, MORNING

TIME

1 hour 15 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen or with a pencil.**

Answer **all four** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 60.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

A Periodic Table of Elements (including some data) is provided.

13624.07R



16ACH3201

- 1 (a) Describe, giving experimental details, how the concentration of a solution of hydrogen peroxide may be determined using sodium thiosulfate solution. Include all the colour changes which occur. No details of calculations are required.

[6]



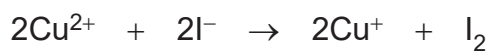
(b) Sodium thiosulfate solution may also be used in a redox titration to analyse the percentage purity of copper foil. A copper foil electrode from an electrochemical cell has a mass of 1.93 g. All of the copper metal in the electrode was converted into copper(II) ions in 250 cm³ of solution.

Excess potassium iodide was added to 25.0 cm³ samples of this solution and titrated against 0.1 mol dm⁻³ sodium thiosulfate solution. The average titre was 26.4 cm³.

(i) Write the ionic equation for the reaction between iodine and thiosulfate ions.

_____ [1]

(ii) The ionic equation for the reaction between copper(II) ions and iodide ions is:



Use the ionic equation and your answer to **(b)(i)** to state the ratio of copper(II) ions to thiosulfate ions.

_____ [1]

(iii) Calculate the percentage purity of the copper foil electrode. Give your answer to the nearest whole number.

Answer _____ % [5]

[Turn over

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16ACH3203

- 2 Electrochemical cells are made up of two half-cells. The table below gives some standard electrode potentials.

Half-equation	E^\ominus/V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	- 0.76
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+ 0.34
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+ 0.77

- (a) Draw a labelled diagram of the electrochemical cell which you would use to measure the emf between the Fe^{3+}/Fe^{2+} and the Cu^{2+}/Cu half-cells.

[5]



(b) Write the conventional cell representation of the electrochemical cell you have drawn in (a).

[2]

(c) Calculate the emf of the electrochemical cell in (a).

Answer _____ [1]

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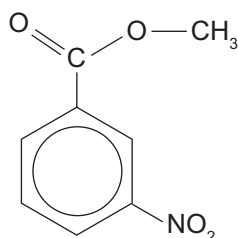
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16ACH3205

3 Methyl benzoate may be nitrated by the nitronium ion to form methyl 3-nitrobenzoate.

The structure of methyl 3-nitrobenzoate is shown below.



methyl 3-nitrobenzoate

Methyl 3-nitrobenzoate is prepared by the method below.

1. Dissolve methyl benzoate in concentrated sulfuric acid and cool the solution in ice.
2. Prepare the nitrating mixture by carefully adding concentrated sulfuric acid to concentrated nitric acid and then cool this mixture in ice.
3. Add the nitrating mixture drop by drop to the solution of methyl benzoate, stir with a thermometer and keep the temperature below 10 °C.
4. Pour the reaction mixture onto crushed ice and stir until all the ice has melted and solid methyl 3-nitrobenzoate forms.

(a) (i) Write an equation for the production of the nitronium ion.

_____ [2]

(ii) Explain why the nitrating mixture is added drop by drop and why the temperature is kept below 10 °C.

_____ [2]



(b) The product, methyl 3-nitrobenzoate, is purified by recrystallisation from ethanol.

(i) Describe the appearance of the product.

_____ [1]

(ii) Describe how you would determine the melting point of the recrystallised product.

_____ [3]

(iii) State how the melting point can be used to determine if the product is pure.

_____ [1]

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16ACH3207

(c) Methyl 3-nitrobenzoate may also be prepared from solid 3-nitrobenzoyl chloride and methanol.

(i) Write an equation for this reaction.

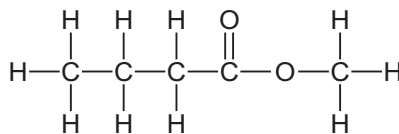
_____ [2]

(ii) Calculate the minimum volume of methanol which would be required to react with 14.4 g of 3-nitrobenzoyl chloride. The density of methanol is 0.79 g cm^{-3} . Give your answer to 2 significant figures.

Answer _____ cm^3 [3]

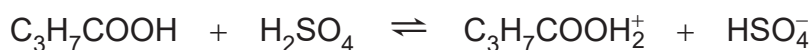


- 4 The liquid ester methyl butanoate, $C_3H_7COOCH_3$, is prepared by the esterification of butanoic acid with methanol in the presence of concentrated sulfuric acid. The crude ester is separated from the reaction mixture by distillation.



methyl butanoate

- (a) The first step in this esterification is shown below.



Write the formula of an acid and its conjugate base from the equation above.

acid _____ conjugate base _____ [2]

- (b) The crude ester is purified in a series of steps using sodium carbonate solution and anhydrous calcium chloride.

- (i) Identify an impurity in the crude ester which could be removed using sodium carbonate solution.

_____ [1]

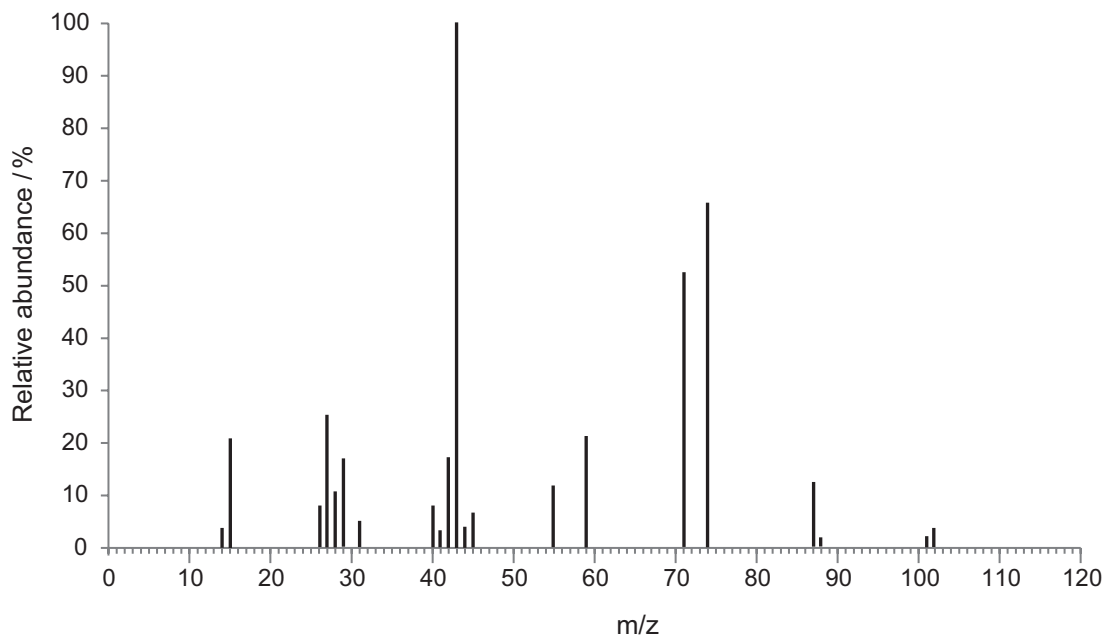
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16ACH3209

(c) A sample of pure methyl butanoate was analysed using mass spectrometry. The mass spectrum obtained is shown below.



(i) Explain what is meant by the term **base peak** and state the m/z value of the base peak in the spectrum above.

[2]

(ii) Identify two fragmentation ions, which could be responsible for the peaks at m/z values of 29 and 71.

29 _____

71 _____ [2]

[Turn over

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16ACH3211

- (d) Methyl butanoate produces four signals when analysed by nmr spectroscopy as shown in the table below.

Signal	A	B	C	D
Chemical shift /ppm	4.9	3.2	2.6	1.9
Integration	3	2	2	3
Spin-spin splitting pattern	singlet	triplet	multiplet	triplet

- (i) State the name of the compound used as a standard in nmr spectroscopy and state one reason why it is chosen.

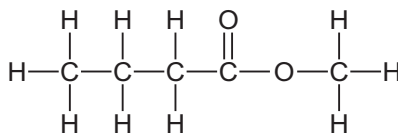
[2]

- (ii) Explain, with reference to the chemical shift and the structure of methyl butanoate, which hydrogen atoms produce the signal at **A**.

[3]

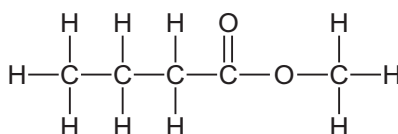


- (iii) On the structure below, circle all the hydrogen atoms which produce the signal at **B**.



[1]

- (iv) On the structure below, circle all the hydrogen atoms which produce the signal at **D**.



[1]

- (v) Suggest the structure of an ester which is an isomer of methyl butanoate which contains only two peaks, which are both singlets, in its nmr spectrum.

[2]

- (vi) State the integration ratio for the singlet peaks of the isomer drawn in (d)(v).

[1]

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Question Number	Examiner Mark	Remark
1		
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Total Marks		

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General Information

1 tonne = 10^6 g

1 metre = 10^9 nm

One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm³

Avogadro Constant = 6.02×10^{23} mol⁻¹

Planck Constant = 6.63×10^{-34} Js

Specific Heat Capacity of water = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light = $3 \times 10^8 \text{ ms}^{-1}$



Characteristic absorptions in IR spectroscopy

Wavenumber/cm ⁻¹	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C ₆ H ₅ –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C ₆ H ₅	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations

chemistry

THE PERIODIC TABLE OF ELEMENTS

Group

I II III IV V VI VII 0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

1 H Hydrogen 1																	4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 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
133 Cs Caesium 55	137 Ba Barium 56	139 La * Lanthanum 57	178 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
223 Fr Francium 87	226 Ra Radium 88	227 Ac † Actinium 89	261 Rf Rutherfordium 104	262 Db Dubnium 105	266 Sg Seaborgium 106	264 Bh Bohrium 107	277 Hs Hassium 108	268 Mt Meitnerium 109	271 Ds Darmstadtium 110	272 Rg Roentgenium 111	285 Cn Copernicium 112						

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series



a = relative atomic mass (approx)
x = atomic symbol
b = atomic number

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
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