



Cambridge International AS & A Level

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**CHEMISTRY****9701/31**

Paper 3 Advanced Practical Skills 1

May/June 2022**2 hours**

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session

Laboratory

For Examiner's Use

1	
2	
3	
Total	

This document has **12** pages. Any blank pages are indicated.

Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 In this experiment you will identify a straight-chain carboxylic acid by titrating an aqueous solution of this acid with aqueous sodium hydroxide. 1 mole of the carboxylic acid reacts with 1 mole of sodium hydroxide. The carboxylic acid contains C, H and O atoms only and has no C=C bonds.

FA 1 is an aqueous solution of the carboxylic acid, containing 10.50 g dm^{-3} .

FA 2 is $0.110 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH.

FA 3 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Add approximately 8 drops of **FA 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FA 1** required cm^3 of **FA 2**. [1]

(c) Calculations

- (i) Calculate the amount, in mol, of sodium hydroxide present in the volume of **FA 2** calculated in (b).

amount of NaOH = mol [1]

- (ii) Use your answer to (c)(i) and the information on page 2 to calculate the relative formula mass of the carboxylic acid in **FA 1**.

M_r of carboxylic acid = [1]

- (iii) Identify the carboxylic acid in **FA 1**.
Draw its skeletal formula.

skeletal formula

name of acid [2]

- (d) A student carries out a similar titration to the titration you carried out in (a). The only difference is that a solution of aminoethanoic acid, $\text{NH}_2\text{CH}_2\text{CO}_2\text{H}$, containing 10.50 g dm^{-3} is used instead of the acid in **FA 1**.

- (i) Construct an equation for the reaction taking place in the student's titration.
Include state symbols.

..... [1]

- (ii) State whether the student's titre will be larger or smaller than your titre. Explain your answer.

The student's titre will be than mine.

explanation

.....

..... [1]

[Total: 14]

4

- 2 In this experiment you will identify a magnesium compound by thermal decomposition. When heated this compound decomposes to give magnesium oxide.

FA 4 is the magnesium compound.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**. Record the mass.
- Calculate the mass of **FA 4**. Record the mass.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, without the lid, for approximately 2 minutes.
- Heat strongly for a further 4 minutes.
- Place the lid on the crucible and leave it to cool for at least 5 minutes.

During the cooling period, you may wish to begin work on Question 3.

- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, without the lid, for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate the mass of residue obtained. Record the mass.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Calculate the amount, in mol, of magnesium oxide produced in your experiment.

amount of MgO = mol [1]

5

- (ii) 1 mole of **FA 4** decomposes on heating to produce 1 mole of MgO and 1 mole of gas **X**.

Calculate the relative formula mass, M_r , of **X**.

M_r of **X** = [1]

- (iii) **X** contains one or more oxygen atoms.

Suggest the identity of **X**.

X is [1]

- (iv) Deduce the name of **FA 4**.

FA 4 is [1]

- (c) A student suggests that this experiment will be more accurate if **FA 4** is heated throughout the experiment with a lid on the crucible.

State whether the student is correct. Explain your answer.

.....
.....
..... [1]

- (d) State the uncertainty in a single reading of your balance.

uncertainty = $\pm$ g

Calculate the maximum percentage error in the mass of residue that you obtained.
Show your working.

maximum percentage error =%
[1]

[Total: 11]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 (a) FA 5 is an ionic solid containing two ions. It contains one or more ions that contain nitrogen.

- (i) Carry out suitable tests to identify the anion. Reserve a small amount of **FA 5** for use in (a)(ii).

Record the tests you carry out and the observations you make, in a table, in the space below.

You **must** use a boiling tube if any liquid is heated.

anion in **FA 5** = [4]

7

- (ii) Heat a small spatula measure of **FA 5** in a hard-glass test-tube. When no further change occurs, allow the tube and its contents to cool completely.

Record **all** the observations you make and any subsequent conclusions.

.....

.....

.....

..... [2]

- (b) **FA 6** is a solution of a compound containing one cation and one anion, both of which are in the Qualitative analysis notes.

FA 7 is an aqueous mixture of two substances. **FA 7** contains one potassium-containing compound and one other substance. All substances are listed in the Qualitative analysis notes.

- (i) Carry out the following tests. Complete the table below.
Use a 1 cm depth of **FA 6** or **FA 7** in a test-tube for each test.

Table 3.1

test	observations	
	FA 6	FA 7
Test 1 Add aqueous sodium hydroxide.		
Test 2 Add aqueous barium chloride or aqueous barium nitrate, then add dilute hydrochloric acid.		
Test 3 Add a few drops of aqueous starch, then add aqueous sodium thiosulfate.		
Test 4 Add a few drops of aqueous silver nitrate, then add a few drops of aqueous sodium hydroxide.		
Test 5 Add aqueous ammonia.		

[5]

8

(ii) Give the formulae of the substances in **FA 6** and **FA 7**.

FA 6 is

FA 7 contains and [3]

(iii) Give the ionic equation for **one** of the reactions taking place in **Test 1**.
Include state symbols.

..... [1]

[Total: 15]

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Qualitative analysis notes**1 Reactions of cations**

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	no ppt. ammonia produced on warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

57	La	lanthanum	138.9
58	Ce	cerium	140.1
59	Pr	praseodymium	140.9
60	Nd	neodymium	144.4
61	Pm	promethium	—
62	Sm	samarium	150.4
63	Eu	euroium	152.0
64	Gd	gadolinium	157.3
65	Tb	terbium	158.9
66	Dy	dysprosium	162.5
67	Ho	holmium	164.9
68	Er	erbium	167.3
69	Tm	thulium	168.9
70	Yb	ytterbium	173.1
71	Lu	lutetium	175.0
72	Hf	hafnium	178.5
73	Ta	tantalum	180.9
74	W	tungsten	183.8
75	Re	rhenium	186.2
76	Os	osmium	190.2
77	Ir	iridium	192.2
78	Pt	platinum	195.1
79	Au	gold	197.0
80	Hg	mercury	200.6
81	Tl	thallium	204.4
82	Pb	lead	207.2
83	Bi	bismuth	209.0
84	Po	polonium	—
85	At	astatine	—
86	Rn	radon	—
87	Fr	francium	—
88	Ra	radium	—
89	Ac	actinium	—
90	Th	thorium	232.0
91	Pa	protactinium	231.0
92	U	uranium	238.0
93	Np	neptunium	—
94	Pu	plutonium	—
95	Am	americium	—
96	Cm	curium	—
97	Bk	berkelium	—
98	Cf	californium	—
99	Es	einsteinium	—
100	Fm	fermium	—
101	Md	mendelevium	—
102	No	nobelium	—
103	Lr	lawrencium	—

actinoids

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