CAMBRIDGE International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **May/June 2026**

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. Do **not** use correction fluid or tape.
- 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	

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[Turn over

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 answer to **each** step of your calculations.

1 Magnesium reacts with different acids, including organic acids, to form a salt and hydrogen. You will measure the volume of hydrogen formed when a known mass of magnesium reacts with excess carboxylic acid.

FA 1 is magnesium, Mg.
FA 2 is a carboxylic acid, RCH_2COOH. R does **not** contain an acidic hydrogen.

(a) Method

- Weigh the container with **FA 1**. Record the mass in the space for results.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder completely with water. Holding a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 2** into the flask labelled **X**. Check that the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Add **all** the **FA 1** to the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp and leave until the fizzing stops. Swirl the flask occasionally.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** that reacts with the acid.
- When no more gas is collected, record the final volume of gas produced to the nearest cm^3.

You may wish to start Question 2 or Question 3 while the gas is being collected.

Keep FA 2 for use in Question 3.

Results

I	
II	
III	

[3]

(b) Calculations

(i) Calculate the amount, in mol, of magnesium added to flask **X**.

amount of Mg = ... mol [1]

(ii) Write an ionic equation for the reaction between magnesium and the carboxylic acid. Include state symbols.

.... [1]

(iii) Calculate the volume, in cm^3, of hydrogen expected to form in the reaction.

volume of H_2 = ... cm^3 [1]

(c) A student carries out the method in **1(a)**. The volume of hydrogen collected is smaller than expected.

Suggest **two** reasons why the student collected a smaller volume of hydrogen than expected.

reason 1 ....

....

reason 2 ....

....
[2]

(d) State the uncertainty in a single balance reading for the balance you used in **1(a)**.

uncertainty = ± .... g

Hence, calculate the maximum percentage error in the mass of magnesium, **FA 1**, used.

maximum percentage error = ...% [1]

[Total: 9]

2 Carboxylic acids may have other atoms or groups substituted for hydrogen in the chain. R'CH**Z**COOH is the monosubstituted acid of R'CH_2COOH, where **Z** is a halogen. R' may be H or C_nH_{2n+1}.

You will carry out a titration using sodium hydroxide of known concentration to find the relative molecular mass, M_r, of the monosubstituted carboxylic acid, R'CH**Z**COOH.

$$R'CHZCOOH(aq) + NaOH(aq) \rightarrow R'CHZCOONa(aq) + H_2O(l)$$

The end-point is the appearance of the first permanent blue colour. Assume that the sodium hydroxide is too dilute for any significant hydrolysis of the halogen.

FA 3 is 0.0950 mol dm^{-3} sodium hydroxide, NaOH.
FA 4 is 15.28 g dm^{-3} monosubstituted carboxylic acid, R'CH**Z**COOH.
FA 5 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add a few drops of **FA 5** to the same conical flask.
- Perform a rough titration and record your burette readings.

rough titre = ... 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 all your burette readings and the volume of **FA 3** 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 4** required .... cm^3 of **FA 3**. [1]

(c) Calculations

(i) Give your answers to **2(c)(ii)**, **2(c)(iii)** and **2(c)(iv)** to an appropriate number of significant figures. [1]

(ii) Calculate the amount, in mol, of sodium hydroxide in the volume of **FA 3** in **2(b)**.

amount of NaOH = ... mol [1]

(iii) Calculate the concentration, in $mol\,dm^{-3}$, of the monosubstituted carboxylic acid in **FA 4**.

concentration of R'CH**Z**COOH = ... $mol\,dm^{-3}$ [1]

(iv) Calculate the relative molecular mass, M_r, of the monosubstituted carboxylic acid in **FA 4**.
Show your working.

M_r of R'CH**Z**COOH = ... [1]

(d) (i) A fresh sample of **FA 4** reacts with excess hot aqueous sodium hydroxide. The resulting solution is neutralised with nitric acid. This solution is **FA 6**.
Carry out a test on **FA 6** to determine the identity of **Z**.

reagents ....

observations ....

....

identity of **Z** ....

[2]

(ii) Suggest why nitric acid is added to make **FA 6** before carrying out your test in **2(d)(i)**.

....

.... [1]

(e) Use your answers to **2(c)(iv)** and **2(d)(i)** to calculate the relative formula mass of group R'.
Hence, identify group R' in **FA 4**.

relative formula mass of R' = ...

R' in **FA 4** ....

[2]

(f) Two students correctly carry out the method in **2(a)** using the same concentrations of **FA 3** and **FA 4** in separate experiments. The difference between the students' mean accurate titres is $0.35\,cm^3$.

Suggest why the students identify the same R' group.
(Do **not** attempt a calculation.)

....

....

.... [1]

[Total: 18]

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. If any solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

3 Half-fill the 250 cm^3 beaker with water and place it on a tripod and gauze. Heat the water until boiling then switch off your Bunsen burner. This is your hot water-bath.

(a) Some organic acids contain an unsaturated hydrocarbon group.
Carry out an experiment using the reagents supplied to determine whether the R group in **FA 2** is unsaturated.
Record your test, observations and conclusion.

test ....

observations ....

....

conclusion ....
[2]

(b) **FA 7** and **FA 8** are aqueous solutions of ionic compounds.
FA 7 contains one cation and two anions.
FA 8 contains one cation and one anion.
Three of the five ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests and record your observations in Table 3.1.

Use a 1 cm depth of **FA 7** or **FA 8** in a test-tube for each test.

Table 3.1

test	observations	
	FA 7	**FA 8**
Test 1 Add aqueous sodium hydroxide, then		
pour the mixture into a boiling tube and heat gently, then		
add a piece of aluminium foil.		
Test 2 Add aqueous ammonia.		
Test 3 Add aqueous copper(II) sulfate.		
Test 4 Add aqueous barium chloride or aqueous barium nitrate, then		
add nitric acid.		
Test 5 Add aqueous silver nitrate.		
Test 6 Add **FA 8** until in excess.		

[7]

(ii) Identify the cations in **FA 7** and **FA 8**. If you are unable to positively identify an ion or ions, write ‘unknown’.

cation in **FA 7** .... cation in **FA 8** ....
[1]

(iii) Suggest the possible identities of the anions in **FA 7**. Give reasons for your answer.

....

....

.... [2]

(iv) Identify the anion in **FA 8**.

anion in **FA 8** .... [1]

[Total: 13]

Qualitative analysis notes

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

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, $S_2O_3^{2-}$(aq)	gives off-white / pale yellow ppt. slowly with H^+

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

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

The Periodic Table of Elements

Group

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0			**Key** atomic number atomic symbol name relative atomic mass								5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	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 –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 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
actinoids	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 –