



Cambridge International AS & A Level

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

May/June 2025

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

- You will determine the percentage purity of a sample of calcium carbonate by reacting it with excess hydrochloric acid and measuring the volume of carbon dioxide produced.



FA 1 is impure calcium carbonate, CaCO_3 .

FA 2 is $0.500 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

(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.
- Using the 50 cm^3 measuring cylinder, 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. Tip all of the **FA 1** into 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 is added to the acid.
- When no more gas is collected, record the final volume of gas.

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

Results

I	
II	
III	

[3]



(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder (at room conditions).

amount of CO_2 = mol

Hence, deduce the amount, in mol, of calcium carbonate present in the **FA 1** used.

amount of CaCO_3 = mol
[1]

- (ii) Use your answer to **(b)(i)** and the mass of **FA 1** used to calculate the percentage purity of calcium carbonate. Show your working.

purity of calcium carbonate = % [1]

- (c) A student carries out the experiment described in **(a)** using 25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid. The mass of **FA 1** is **not** changed.

Suggest the consequence of this change on the percentage purity of calcium carbonate calculated by placing **one** tick (✓) in Table 1.1.

Table 1.1

The percentage purity calculated would increase.	
The percentage purity calculated would stay the same.	
The percentage purity calculated would decrease.	

Explain your answer.

.....

.....

.....

.....

[2]





(d) The student repeats the method in (a) but the hydrochloric acid is **not** used in excess.

(i) State an observation that shows that the acid is **not** used in excess.

..... [1]

(ii) Explain what effect, if any, this would have on the percentage purity of calcium carbonate calculated in (b)(ii).

.....

.....

..... [2]

[Total: 10]



- 2 You will determine the percentage purity of another sample of calcium carbonate, CaCO_3 , by titration.

The experiment involves three steps.

- step 1 A known mass of the same impure calcium carbonate, **FA 1**, is reacted with an excess of hydrochloric acid to form **FA 3**. This step has been done for you.
- step 2 You will dilute the products of step 1 to a known volume.
- step 3 You will carry out a titration to find out how much acid remains after the reaction in step 1.

FA 3 has been prepared by reacting 19.0 g of **FA 1** with 250 cm^3 of 2.00 mol dm^{-3} hydrochloric acid, HCl .

FA 5 is $0.0900\text{ mol dm}^{-3}$ sodium hydroxide, NaOH .

FA 6 is bromophenol blue indicator.

(a) Method

step 2

- Pipette 25.0 cm^3 of **FA 3** into the 250 cm^3 volumetric flask.
- Make the solution up to 250 cm^3 with distilled water.
- Thoroughly mix the contents of the volumetric flask. This solution is **FA 4**.

step 3

- Fill the burette with **FA 5**.
- Rinse the pipette with distilled water and then with **FA 4**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add several drops of **FA 6**.
- 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 in the space below, all your burette readings and the volume of **FA 5** added in each accurate titration.

Results

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 cm³ of **FA 4** required cm³ of **FA 5**. [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii), (c)(iv) and (c)(v) to an appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of sodium hydroxide in the volume of **FA 5** in (b).

amount of NaOH = mol [1]

- (iii) Use your answer to (c)(ii) to calculate the amount, in mol, of hydrochloric acid in 250 cm³ of **FA 4**.

amount of HCl in 250 cm³ of **FA 4** = mol

Hence, calculate the amount, in mol, of hydrochloric acid present in 250 cm³ of **FA 3**.

amount of HCl in 250 cm³ of **FA 3** = mol [1]

- (iv) Calculate the amount, in mol, of hydrochloric acid used to prepare **FA 3**.

amount of HCl = mol [1]





- (v) Use your answers to (c)(iii) and (c)(iv) to calculate the amount, in mol, of hydrochloric acid that reacted with the **FA 1** in step 1.

amount of HCl that reacted with **FA 1** = mol [1]

- (vi) Use your answer to (c)(v) to calculate the amount, in mol, of calcium carbonate present in **FA 1**.



amount of CaCO_3 in **FA 1** = mol [1]

- (vii) Use your answer to (c)(vi) and the mass of **FA 1** used to calculate the percentage purity of calcium carbonate. Show your working.

purity of calcium carbonate = % [1]

- (d) The percentage purity of calcium carbonate in **FA 1** has been determined by two different methods, gas collection and titration. The gas collection method used in Question 1 is **less** accurate.

- (i) Suggest **two** reasons why the gas collection method is less accurate.

1

 2
 [2]

- (ii) Describe a change to the gas collection method that would improve the accuracy of the percentage purity determined in Question 1.

.....

 [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 a 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 (a) FA 7 is a solution containing two cations and one anion. All of the ions are listed in the Qualitative analysis notes.

- (i) Carry out the following tests and record your observations in Tables 3.1 and 3.2. For each test use a 1 cm depth of **FA 7** in a test-tube unless the solution requires heating.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous ammonia.	
Test 2 To a 1 cm depth of FA 7 in a boiling tube, add aqueous sodium hydroxide, then	
warm the mixture carefully.	
Test 3 Add a few drops of silver nitrate.	





Table 3.2

<i>test</i>	<i>observations</i>
Test 4 Add a 1 cm depth of aqueous barium chloride or aqueous barium nitrate.	
Test 5 Add a 1 cm depth of dilute nitric acid, then ----- leave to stand for a few minutes.	
Test 6 Add a 1 cm depth of aqueous potassium iodide, then ----- add a few drops of starch solution.	

[5]

- (ii) Write an ionic equation for a reaction in **(a)(i)** that resulted in the formation of a precipitate. Include state symbols.

..... [1]

- (iii) Give the formula of each ion present in **FA 7**. If you cannot identify an ion, write 'unknown.'

cations and

anion

[2]





(b) **FA 8** is an anhydrous sodium compound.

- (i) Transfer a spatula measure of **FA 8** to a hard-glass test-tube. Heat the test-tube gently at first, then more strongly until no further change occurs. Record your observations.

.....
 [1]

- (ii) The **FA 9** provided is a sample of the residue obtained from heating **FA 8**. To a 2 cm depth of nitric acid in a test-tube, slowly add a small spatula measure of **FA 9**. Record your observations.

.....

 [2]

- (iii) Deduce the formula of **FA 8**.

FA 8 is [1]

[Total: 12]











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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 $\text{J g}^{-1} \text{ K}^{-1}$)





The Periodic Table of Elements

Group																			
1	2													13	14	15	16	17	18
		Key																	
		atomic number atomic symbol name relative atomic mass																	
3	4											5	6	7	8	9	10	11	12
Li	Be											B	C	N	O	F	Ne		
lithium	beryllium											boron	carbon	nitrogen	oxygen	fluorine	neon		
6.9	9.0											10.8	12.0	14.0	16.0	19.0	20.2		
11	12											13	14	15	16	17	18		
Na	Mg											Al	Si	P	S	Cl	Ar		
sodium	magnesium											aluminium	silicon	phosphorus	sulfur	chlorine	argon		
23.0	24.3											27.0	28.1	31.0	32.1	35.5	39.9		
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
potassium	calcium	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton		
39.1	40.1	45.0	47.9	50.9	52.0	54.9	55.8	58.9	58.7	63.5	65.4	69.7	72.6	74.9	79.0	79.9	83.8		
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
rubidium	strontium	yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium	indium	tin	antimony	tellurium	iodine	xenon		
85.5	87.6	88.9	91.2	92.9	95.9	—	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3		
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86		
Cs	Ba	lanthanoids	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
caesium	barium		hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury	thallium	lead	bismuth	polonium	astatine	radon		
132.9	137.3		178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	—	—	—		
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118		
Fr	Ra	actinoids	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og		
francium	radium		rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	darmstadtium	roentgenium	copernicium	nihonium	flerovium	moscovium	livermorium	tennessine	oganesson		
—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		

lanthanoids

actinoids

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
lanthanum	cerium	praseodymium	neodymium	promethium	samarium	europlum	gadolinium	terbium	dysprosium	holmium	erbium	thulium	yterbium	lutetium
138.9	140.1	140.9	144.2	—	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—

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