



Cambridge International AS & A Level

CANDIDATE
NAME

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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

October/November 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	

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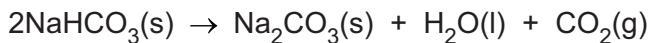
Quantitative analysis

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

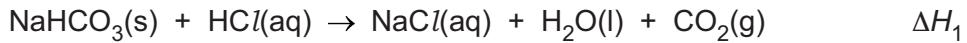
Show the precision of the apparatus you used in the data you record.

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

1 Sodium carbonate can be manufactured using a two-step process. The first step involves making sodium hydrogencarbonate, NaHCO_3 , which is then converted into sodium carbonate, Na_2CO_3 , in the second step of the process by the following reaction.



In this experiment you will determine the enthalpy change, ΔH_r , for this reaction. You will do this by calculating the enthalpy changes when separate samples of sodium hydrogencarbonate and sodium carbonate are added to excess hydrochloric acid, $\text{HCl}(\text{aq})$. You will then combine these values using Hess's law.



FB 1 is 2.0 mol dm^{-3} hydrochloric acid, HCl .

FB 2 is sodium hydrogencarbonate, NaHCO_3 .

FB 3 is sodium carbonate, Na_2CO_3 .

(a) Method

Experiment 1

- Support a cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FB 1** into the cup.
- Weigh the container with **FB 2**. Record the mass.
- Measure the temperature of the acid in the cup. Record this temperature.
- Carefully add all of the **FB 2**, in small portions to avoid acid spray. Stir to dissolve. Record the lowest temperature.
- Reweigh the container with any residual **FB 2**. Record the mass.
- Calculate and record the mass of **FB 2** used.
- Calculate and record the decrease in temperature.

Experiment 2

- Support the second cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FB 1** into the second cup.
- Weigh the container with **FB 3**. Record the mass.
- Measure the temperature of the acid in the cup. Record this temperature.
- Carefully add all of the **FB 3**, in small portions to avoid acid spray. Stir to dissolve. Record the highest temperature.
- Reweigh the container with any residual **FB 3**. Record the mass.
- Calculate and record the mass of **FB 3** used.
- Calculate and record the increase in temperature.

Keep FB 1 for use in Question 3.



Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the amount, in mol, of **FB 2** that reacts with **FB 1** and the amount, in mol, of **FB 3** that reacts with **FB 1**.

Experiment 1	Experiment 2
amount of FB 2 = mol	amount of FB 3 = mol

[2]

(ii) Calculate the energy changes, in J, for each reaction.

Experiment 1	Experiment 2
energy change = J	energy change = J

[1]

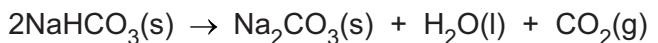
(iii) Calculate the enthalpy change, ΔH , in kJ mol^{-1} for each reaction.

Experiment 1	Experiment 2
ΔH_1 = sign value kJ mol^{-1}	ΔH_2 = sign value kJ mol^{-1}

[2]



(iv) Construct an enthalpy cycle and use Hess's law to determine the enthalpy change, ΔH_r , for the reaction shown.
Show your working.



(If you were unable to calculate values in (b)(iii) then assume that ΔH_1 is $+27.3 \text{ kJ mol}^{-1}$ and that ΔH_2 is $-24.9 \text{ kJ mol}^{-1}$. These may **not** be the correct values.)

$$\Delta H_r = \dots \text{ sign} \dots \text{ value} \text{ kJ mol}^{-1}$$

[2]

[Total: 11]



2 In this experiment you will determine the percentage by mass of a sodium halide impurity present in a sample of sodium hydrogencarbonate by titration.



FB 4 is an aqueous solution made by dissolving 17.20 g of the impure sodium hydrogencarbonate in each dm^3 of solution.

FB 5 is 0.200 mol dm^{-3} hydrochloric acid, HCl .

FB 6 is methyl orange indicator.

(a) Method

- Fill the burette with **FB 5**.
- Pipette 25.0 cm^3 of **FB 4** into a conical flask.
- Add several drops of **FB 6** to the conical flask.
- 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 all your burette readings and the volume of **FB 5** added in each accurate titration.

Keep FB 4 for use in Question 3.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FB 4** required cm^3 of **FB 5**. [1]



(c) Calculations

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

(ii) Use your answer to (b) to calculate the amount, in mol, of hydrochloric acid in your mean titre.

$$\text{amount of HCl} = \dots \text{ mol}$$

Hence determine the amount, in mol, of sodium hydrogencarbonate present in 25.0 cm³ of **FB 4**.

$$\text{amount of NaHCO}_3 = \dots \text{ mol}$$

(iii) Calculate the mass of sodium hydrogencarbonate present in each dm³ of solution.

$$\text{mass of NaHCO}_3 = \dots \text{ g}$$

Hence calculate the percentage by mass of the sodium halide impurity in **FB 4**.
Show your working.

$$\text{percentage by mass} = \dots \% \quad [2]$$

(d) A student carries out the experiment in Question 1 using the impure sodium hydrogencarbonate dissolved to make **FB 4**.

State how this affects the value of ΔH_1 determined in **1(b)(iii)** compared to the value the student would get if pure sodium hydrogencarbonate were used.

.....
.....

State what assumption you have made about the sodium halide impurity.

.....
.....

[2]

[Total: 14]





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 (a) (i) To a 1 cm depth of **FB 4** in a boiling tube, slowly add a 1 cm depth of dilute nitric acid. Stir gently until the reaction is complete. Use this solution for your tests.
Select reagents to identify which sodium halide is present.
Record details of the reagents used and your observations.
Identify the sodium halide that is present as an impurity in **FB 4**.

The formula of the impurity is

[2]

(ii) Suggest why it is necessary to add the nitric acid to **FB 4** before carrying out your tests in (a)(i).

..... [1]



(b) **FB 7** contains a metal cation which is listed in the Qualitative analysis notes.

(i) Place half the sample of **FB 7** in a hard-glass test-tube. Heat gently at first and then more strongly.
Record your observations.

.....
.....
.....

[2]

(ii) Use the 25 cm³ measuring cylinder to measure 20 cm³ of **FB 1**.
Place the remaining sample of **FB 7** in a boiling tube and add portions of **FB 1** from the measuring cylinder until all the **FB 7** has reacted. Stir until the reaction is complete.
Record your observations.

Keep this solution for use in (b)(iii).

.....
.....
.....
.....

[2]

(iii) Carry out the following tests. For each test use a 1 cm depth of the solution from (b)(ii) in a test-tube.
Record your observations in Table 3.1.
Identify the metal ion present in **FB 7**.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide.	
Test 2 Add aqueous ammonia.	
Test 3 Add a piece of aluminium foil.	

The formula of the metal ion in **FB 7** is

[4]



(c) **FB 8** is an acidified aqueous solution containing a metal cation which is listed in the Qualitative analysis notes.

(i) Carry out the following tests. For each test use a 1 cm depth of **FB 8** in a test-tube. Record your observations in Table 3.2. Identify the metal ion present in **FB 8**.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide.	
Test 2 Add a 1 cm depth of acidified aqueous potassium manganate(VII).	

The formula of the metal ion in **FB 8** is

[3]

(ii) State the type of reaction between the metal ion in **FB 8** and acidified aqueous potassium manganate(VII). Explain how your observations support your answer.

.....
.....
.....

[1]

[Total: 15]





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 J g ⁻¹ K ⁻¹)





The Periodic Table of Elements

1		2		Group																															
1		2		Group																															
1		2		Group																															
Key	atomic number name relative atomic mass	atomic symbol	1	H hydrogen 1.0	2	He helium 4.0	3	Li lithium 6.9	4	Be beryllium 9.0	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													
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	Zn zinc 65.4	30	Ga gallium 69.7	31	Ge germanium 72.6	32	As arsenic 74.9	33	Se selenium 79.0	34	Br bromine 79.9	35	Kr krypton 83.8		
37	Rb rubidium 85.5	38	Sr strontium 87.6	39	Y yttrium 88.9	40	Nb niobium 91.2	41	Tc technetium 95.9	42	Mo molybdenum 95.9	43	Ru ruthenium 101.1	44	Pd palladium 106.4	45	Ag silver 107.9	46	Cd cadmium 112.4	47	In indium 114.8	48	Ge germanium 114.8	49	Sn tin 118.7	50	Te tellurium 121.8	51	Te iodine 127.6	52	I iodine 126.9	53	Xe xenon 131.3		
55	Cs caesium 132.9	56	Ba barium 137.3	57–71	lanthanoids 138.9	72	Ta tantalum 180.9	73	W tungsten 183.8	74	Re rhenium 186.2	75	Ir iridium 190.2	76	Os osmium 192.2	77	Pt platinum 195.1	78	Hg mercury 200.6	79	Pb lead 197.0	80	Tl thallium 204.4	81	Bi bismuth 207.2	82	Po polonium 209.0	83	At astatine –	84	Rn radon –	85	At astatine –	86	Rn radon –
87	Fr francium –	88	Ra radium –	89–103	actinoids –	104	Rf rutherfordium –	105	Ds dubnium –	106	Sg seaborgium –	107	Bh bohrium –	108	Hs hassium –	109	Mt meitnerium –	110	Ds darmstadtium –	111	Nh roentgenium –	112	Cn copernicium –	113	Ft flerovium –	114	Mt moscovium –	115	Lv livornium –	116	Ts tennesine –	117	Og oganesson –	118	–
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	Fm einsteinium –	100	Md mendelevium –	101	No nobelium –	102	–	103	Lr lawrencium –	–	–		

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