* 0000800000001 *

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

7735418573

CHEMISTRY **9701/32**

Paper 3 Advanced Practical Skills 2 **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 **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 Acids donate H^+ in aqueous solution. The number of moles of H^+ donated per mole of acid is the **proticity** of the acid. For example, sulfuric acid is diprotic as it donates two moles of H^+ per mole of acid.

In this experiment you will carry out a titration to determine the proticity of citric acid, $C_6H_8O_7$.

FB 1 is aqueous citric acid containing 7.50 g dm^{-3} $C_6H_8O_7$.
FB 2 is aqueous sodium hydroxide containing 4.50 g dm^{-3} NaOH.
FB 3 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Add a few drops of **FB 3** 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, in a suitable form in the space below, all your burette readings and the volume of **FB 2** 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 cm^3 of **FB 1** required .... cm^3 of **FB 2**. [1]

(c) Calculations

(i) Calculate the amount, in mol, of citric acid in 25.0 cm^3 of **FB 1**.
Show your working.

amount of $C_6H_8O_7$ = ... mol [2]

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

amount of NaOH = ... mol [1]

(iii) Citric acid is triprotic.
Show whether your results in this experiment support this statement.

[1]

(iv) Complete the equation for the reaction of citric acid, $C_6H_8O_7$, with sodium hydroxide.

$C_6H_8O_7$ + …… NaOH $\rightarrow$ .... + ... [1]

(v) Citric acid does **not** contain a chiral carbon atom.
Draw a possible structural formula of a molecule of citric acid.

[1]

(d) A student uses a pipette labelled 25.0 ± 0.06 cm^3 to measure **FB 1**.
The student suggests that it is more accurate to measure the volume of **FB 1** with a burette instead of the pipette.

State whether the student's suggestion is correct. Explain your answer.

....

.... [1]

[Total: 15]

2 You will determine the enthalpy change for the reaction of aqueous citric acid with aqueous sodium hydroxide to form aqueous sodium citrate.

The procedure involves two experiments using solid citric acid.

FB 4 is citric acid, $C_6H_8O_7$. Use this for Experiment 1.
FB 5 is citric acid, $C_6H_8O_7$. Use this for Experiment 2.
FB 6 is 2.00 mol dm^{-3} sodium hydroxide, NaOH.

(a) **Experiment 1** is the determination of the enthalpy change of solution, ΔH_1, for citric acid. This is the enthalpy change when one mole of citric acid dissolves in water.

$$C_6H_8O_7(s) + aq \rightarrow C_6H_8O_7(aq) \qquad \Delta H_1$$

Method

- Support one of the cups in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of distilled water into the cup.
- Measure the temperature of the water in the cup. Record this temperature in the space for results.
- Weigh the container with **FB 4**. Record the mass.
- Tip all of the **FB 4** into the water in the cup.
- Stir the mixture until the minimum temperature is obtained. Record this temperature.
- Weigh the container with any residual **FB 4**. Record the mass.
- Calculate and record the mass of **FB 4** used.
- Calculate and record the temperature change.

Results

I	
II	
III	

[3]

(b) **Calculations**

(i) Calculate the energy change, in J, in your experiment.

energy change = ... J [1]

(ii) Calculate the enthalpy change of solution, ΔH_1, in kJ mol^{-1}, for dissolving 1.00 mol of solid citric acid, $C_6H_8O_7$, in water. Show your working.

ΔH_1 = ... kJ mol^{-1} [2]
sign *value*

(c) **Experiment 2** is the determination of the enthalpy change, ΔH_2, for the reaction of one mole of solid citric acid with aqueous sodium hydroxide. In this experiment, aqueous sodium hydroxide, **FB 6**, is used in excess.

Method

- Support the second cup in the beaker.
- Add 4.80–5.00 g of **FB 5** to the cup. Record your weighings.
- Measure and record the temperature of **FB 6** in its container.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FB 6** into the cup with **FB 5**.
- Stir the mixture until the maximum temperature is obtained. Record the maximum temperature.
- Calculate and record the mass of **FB 5** used.
- Calculate and record the temperature change.

Results

I	
II	
III	

[3]

(d) **Calculations**

Calculate the enthalpy change of reaction, ΔH_2, in kJ mol^{-1}, for the reaction of 1.00 mol of solid citric acid, $C_6H_8O_7$, with aqueous sodium hydroxide.
Show your working.

ΔH_2 = ... kJ mol^{-1} [2]
sign *value*

(e) Use your values for ΔH_1 and ΔH_2 to calculate the enthalpy change, ΔH_r, in kJ mol^{-1}, for the reaction of 1.00 mol of aqueous citric acid with aqueous sodium hydroxide.

ΔH_r = ... kJ mol^{-1} [1]
sign *value*

[Total: 12]

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) Solutions **FB 7** and **FB 8** each contain one cation 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 Table 3.1. Use a 1 cm depth of **FB 7** or **FB 8** in a test-tube for each test.

Table 3.1

test	*observations*	
	FB 7	**FB 8**
Test 1 Add an equal volume of aqueous potassium iodide, then		
add excess aqueous sodium thiosulfate.		
Test 2 Add a small spatula measure of zinc powder. Leave the mixture to stand.		
Test 3 Add a few drops of aqueous silver nitrate.		
Test 4 Add aqueous ammonia.		

[6]

(ii) Deduce the formula of **FB 8**.

FB 8 is .... [1]

(iii) For **FB 8**, state the numbers of **all** the tests from Table 3.1 that involve a redox reaction.

.... [1]

(iv) Give the ionic equation for **one** of the reactions in **Test 4**. Include state symbols.

.... [1]

(b) **(i)** Carry out tests to identify the anion in **FB 7**. The anion does **not** contain sulfur. Record your tests and observations in a suitable form in the space below.

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

[3]

(ii) Deduce the formula of **FB 7**.

FB 7 is ……………… . [1]

[Total: 13]

BLANK PAGE

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, $S_2O_3^{2-}$(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	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,mol^{-1}$
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	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

* 0000800000012 *

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
				Key			1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0		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 –