* 0000800000001 *

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **October/November 2024**

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.

1 The neutralisation of an acid by an alkali is an exothermic reaction. The concentration of an acid can be found by measuring the temperature change when the acid reacts with an alkali.

You will determine the concentration of sulfuric acid by adding aqueous sodium hydroxide of known concentration to the sulfuric acid and measuring the temperature change.

FA 1 is 2.01 mol dm^{-3} sodium hydroxide, NaOH.
FA 2 is sulfuric acid, H_2SO_4.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Pipette 25.0 cm^3 of **FA 1** into the cup.
- Place the thermometer into the **FA 1** in the cup. Tilt the cup if necessary to ensure the bulb of the thermometer is fully covered. Record the temperature of **FA 1** in Table 1.1. This is the temperature when the volume of **FA 2** is 0.00 cm^3.
- Fill the burette with **FA 2**.
- Run 5.00 cm^3 of **FA 2** into the cup containing **FA 1**.
- Stir the mixture and record the maximum temperature in Table 1.1.
- Run further 5.00 cm^3 portions of **FA 2** into the same cup.
- After each addition of **FA 2** stir the contents of the cup. Record the maximum temperature for each addition.

Table 1.1

total volume of **FA 2** / cm^3	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
temperature / °C									

I	
II	
III	
IV	

[4]

Keep the rest of FA 2 for use in Question 2.

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(b) Plot a graph of temperature of solution (*y*-axis) against total volume of **FA 2** added (*x*-axis) on the grid. Select a scale for the *y*-axis to include a value 3 °C above your maximum temperature reading. Label any points you consider to be anomalous.

Draw **two** lines of best fit through the points on your graph. Draw the first line for the increase in temperature and the second line after the maximum temperature was reached. Extrapolate the lines so they intersect. This intersection corresponds to the volume of **FA 2** needed to neutralise the **FA 1** in your experiment in **(a)**.

I	
II	
III	
IV	
V	

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

[5]

(c) **(i)** Calculate the amount, in mol, of sodium hydroxide, **FA 1**, pipetted into the cup.

amount of NaOH = ... mol [1]

(ii) The equation for this neutralisation reaction is shown.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

Calculate the concentration, in $mol\,dm^{-3}$, of sulfuric acid in **FA 2**.

Show your working.

concentration of H_2SO_4 = ... $mol\,dm^{-3}$ [2]

[Total: 12]

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2 Acids react with carbonates to produce carbon dioxide gas.

$$Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(l)$$

This reaction can be used to determine the concentration of acid, using the mass of carbon dioxide released.

You will determine the concentration of sulfuric acid in **FA 2**.

FA 2 is the solution used in **Question 1**.
FA 3 is sodium carbonate, Na_2CO_3.

(a) Method

- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 2** into the conical flask.
- Weigh the flask with the acid. Record the mass.
- Weigh the container with **FA 3**. Record the mass.
- Carefully tip all of **FA 3** into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand with occasional swirling until the fizzing stops.
- Weigh the container with any residual **FA 3**. Record the mass.
- Calculate and record the mass of **FA 3** added to the flask.
- Calculate and record the total mass of flask + acid + **FA 3**.
- Weigh the flask and contents when the fizzing has stopped. Record the mass.
- Calculate and record the mass of carbon dioxide given off during the experiment.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

(i) Calculate the amount, in mol, of carbon dioxide given off in the reaction.

amount of CO_2 = ... mol [1]

(ii) The sodium carbonate, **FA 3**, was in excess in the reaction with sulfuric acid. Show by calculation that the sodium carbonate was in excess. Use your answer to **(b)(i)**.

[2]

(iii) Calculate the concentration, in mol dm^{-3}, of sulfuric acid in **FA 2**.

concentration of H_2SO_4 = ... mol dm^{-3} [1]

(c) **(i)** A student does not have a conical flask and uses a small beaker for the reaction. Explain why a conical flask is better.

....

.... [1]

(ii) Two students made suggestions of how they thought the experiment in **(a)** could be adapted to determine the concentration of sulfuric acid, **FA 2**, by using other reactions. In each case their teacher told them that this method was not suitable.

Explain, in each case, why the method is **not** suitable. Do **not** consider factors based on quantities of any reagent.

Student 1 suggested using magnesium in place of sodium carbonate.

....

....

Student 2 suggested using calcium carbonate in place of sodium carbonate.

....

....

[3]

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

uncertainty = ± .... g

Calculate the maximum percentage error in the mass of **FA 3** that you weighed out in **(a)**.

maximum percentage error = ... % [1]

[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 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 **FA 4**, **FA 5** and **FA 6** are compounds of the same metal in different oxidation states.

(a) **(i)** Place a small spatula measure of **FA 4** in a hard-glass test-tube. Heat the tube gently at first and then more strongly.

Record all your observations.

Leave the tube and contents to cool and keep for use in (a)(iii).

....

....

....

.... [2]

(ii) Dissolve a **small** spatula measure of **FA 4** in approximately 5 cm depth of distilled water in a boiling tube and add approximately 1 cm depth of dilute sulfuric acid.

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

Table 3.1

test	*observations*
Test 1 To a 1 cm depth of aqueous **FA 4** in a test-tube add aqueous iron(II) sulfate.	
Test 2 To a 1 cm depth of aqueous **FA 4** in a test-tube add hydrogen peroxide.	

[2]

(iii) To the cooled test-tube in **(a)(i)** add a 5 cm depth of distilled water. Observe and record the colour formed.

.... [1]

(b) Dissolve a small spatula measure of **FA 5** in a boiling tube half-filled with distilled water. Warming may be needed to dissolve the **FA 5**.

Carry out the following tests and record your observations in Table 3.2.

For each of the tests use a 1 cm depth of this **FA 5** solution in a test-tube.

Table 3.2

test	*observations*
Test 1 Add dilute nitric acid, then	
add aqueous silver nitrate.	
Test 2 Add aqueous barium chloride or barium nitrate, then	
add dilute nitric acid.	
Test 3 Add aqueous sodium hydroxide, then	
add hydrogen peroxide.	

[3]

(c) Carry out the following tests and record your observations in Table 3.3. Identify any gases produced.

For each of the tests use a small spatula measure of **FA 6** in a test-tube.

Table 3.3

test	*observations and gases produced*
Test 1 Add a 1 cm depth of dilute nitric acid.	
Test 2 Add a few drops of concentrated hydrochloric acid. **CARE** Hydrochloric acid is corrosive. Fill the test-tube with water as soon as you have made your observation.	
Test 3 Add a 1 cm depth of hydrogen peroxide.	

[3]

(d) **(i)** Use your observations from the tests on **FA 4**, **FA 5** and **FA 6** to suggest the identity of the metal present in all 3 compounds.

Metal identity .... [1]

(ii) Identify the oxidation state of the metal in each compound.

FA 4 ....

FA 5 ....

FA 6 ....

[2]

[Total: 14]

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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, $S_2O_3^{2-}$(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	$L = 6.022 \times 10^{23}\,mol^{-1}$
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

Key

atomic number
atomic symbol
name
relative atomic mass

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											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											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 –