* 0000800000001 *   DFD

CAMBRIDGE International Education

Cambridge International AS & A Level

CANDIDATE NAME					
CENTRE NUMBER					
CANDIDATE NUMBER					

* 7 8 4 3 4 4 9 4 1 2 *

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **February/March 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	

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 In this experiment you will determine the enthalpy change, ΔH_r, for the hydration reaction of anhydrous sodium carbonate with water.

$$Na_2CO_3(s) + 10H_2O(l) \rightarrow Na_2CO_3{\bullet}10H_2O(s) \qquad \text{enthalpy change} = \Delta H_r$$

You will react anhydrous sodium carbonate and hydrated sodium carbonate separately with excess dilute hydrochloric acid. You will determine the enthalpy changes for each reaction. You will use Hess's Law to calculate the enthalpy change, ΔH_r.

(a) Reaction of hydrated sodium carbonate with excess hydrochloric acid

FA 1 is hydrated sodium carbonate, $Na_2CO_3{\bullet}10H_2O$.
FA 2 is 3.00 mol dm^{-3} hydrochloric acid, HCl.

$$Na_2CO_3{\bullet}10H_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + 11H_2O(l) \qquad \text{enthalpy change} = \Delta H_1$$

Method

- Support a cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of **FA 2** into the cup.
- Place the thermometer into **FA 2** and tilt the cup, if necessary, so that the bulb is fully covered.
- Measure the temperature of the solution in the cup. Record this temperature.
- Weigh the container with **FA 1**. Record the mass.
- Transfer small quantities of **FA 1** into the cup containing **FA 2** until all the **FA 1** is added.
- Stir the mixture. Measure the minimum temperature reached. Record this value.
- Calculate and record the temperature change.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** used.

Results

I	
II	
III	
IV	

[4]

(b) Calculation

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

energy change = ... J [1]

(ii) Calculate the amount, in mol, of the hydrated sodium carbonate, the limiting reagent in your experiment.

amount of limiting reagent = ... mol [1]

(iii) Calculate the enthalpy change, ΔH_1, in $kJ\,mol^{-1}$, for the reaction of hydrated sodium carbonate with $HCl(aq)$.
Show your working.

ΔH_1 = ... $kJ\,mol^{-1}$ [1]
sign *value*

(c) Reaction of anhydrous sodium carbonate with excess hydrochloric acid

FA 2 is 3.00 $mol\,dm^{-3}$ hydrochloric acid, HCl.
FA 3 is anhydrous sodium carbonate, Na_2CO_3.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l) \quad \text{enthalpy change} = \Delta H_2$$

(i) Method

- Support the second cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 30.0 cm^3 of **FA 2** into the cup.
- Measure the temperature of the solution in the cup. Record this temperature.
- Weigh the container with **FA 3**. Record the mass.
- Adding small quantities at a time, transfer all the **FA 3** into the cup containing **FA 2**.
- Stir the mixture. Measure the maximum temperature reached. Record this value.
- Calculate and record the temperature change.
- Weigh the container with any residual **FA 3**. Record the mass.
- Calculate and record the mass of **FA 3** used.

Results

I	
II	

[2]

(ii) Calculation

Use your data to calculate the enthalpy change for the reaction of anhydrous sodium carbonate with hydrochloric acid, ΔH_2, in $kJ\,mol^{-1}$.
Show your working.

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

(d) Use your answers to **1(b)(iii)** and **1(c)(ii)** to calculate the enthalpy change, ΔH_r, for the hydration reaction of anhydrous sodium carbonate with water.

$$Na_2CO_3(s) + 10H_2O(l) \rightarrow Na_2CO_3{\bullet}10H_2O(s) \qquad \text{enthalpy change} = \Delta H_r$$

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

(e) A student suggests that the experiment in **(c)** will be more accurate if $30.0\,cm^3$ of $3.00\,mol\,dm^{-3}$ sulfuric acid is used instead of $30.0\,cm^3$ of $3.00\,mol\,dm^{-3}$ hydrochloric acid. All other conditions and apparatus are unchanged.

State whether the student's suggestion is correct.

Explain your answer.

....

....

....

.... [1]

[Total: 13]

2 **X** is a mixture of anhydrous sodium carbonate, Na_2CO_3, and anhydrous potassium carbonate, K_2CO_3. The percentage by mass of the anhydrous sodium carbonate present in **X** can be determined by titration.

FA 4 is a solution containing 5.85 g dm^{-3} of **X**.
FA 5 is 0.110 mol dm^{-3} hydrochloric acid, HCl.
FA 6 is bromophenol blue indicator.

(a) Method

- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Fill the burette with **FA 5**.
- Add a few drops of **FA 6** into the conical flask with **FA 4**.
- Carry out a rough titration. 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 provided, all your burette readings and the volume of **FA 5** 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 5**. [1]

(c) Calculations

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

(ii) Calculate the amount, in mol, of hydrochloric acid present in the volume of **FA 5** calculated in **2(b)**.

amount of HCl = ... mol [1]

(iii) Use the ionic equation given to calculate the total amount, in mol, of metal carbonate present in 1.00 dm^3 of **FA 4**.

$$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(aq) + H_2O(l)$$

total amount of metal carbonate = ... mol [1]

(iv) Use your answer to **2(c)(iii)** and the information given about **FA 4** to calculate the average M_r of the carbonates present in mixture **X**.

average M_r of the carbonates = ... [1]

(v) Calculate the percentage by mass of anhydrous sodium carbonate in **X**.

percentage by mass of Na_2CO_3 = ... % [1]

[Total: 13]

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 an anhydrous salt containing one cation and one anion, both of which are listed in the Qualitative analysis notes.

(i) Heat a **small** spatula measure of **FA 7** in a hard-glass test-tube.
Record **all** your observations.

....

....

....

.... [2]

(ii) Add a small quantity of **FA 7** to a 1 cm depth of dilute sulfuric acid in a test-tube.
Record your observations.

....

....

....

.... [2]

(b) **FA 8** is an aqueous solution of **FA 7**.
FA 9 is an aqueous solution containing one cation and one anion. The two ions are different from the ions present in **FA 8**.

(i) Carry out the following tests on **FA 8** and **FA 9**.
Use a 1 cm depth of **FA 8** or **FA 9** in a test-tube or boiling tube, unless stated otherwise.
Record your observations in Table 3.1.

Table 3.1

test	observations	
	FA 8	**FA 9**
Test 1 Add aqueous barium nitrate or barium chloride, then		
add dilute nitric acid or dilute hydrochloric acid.		
Test 2 Add a few drops of aqueous silver nitrate, leave to stand, then		
add dilute nitric acid.		
Test 3 Add an equal volume of **FA 9** in a boiling tube, then		
warm the mixture carefully.		
Test 4 To a 1 cm depth of aqueous zinc sulfate in a test-tube, add **FA 8** dropwise. Repeat with **FA 9**.		
Test 5 Test with red **and** blue litmus papers.		

[7]

(ii) Give the formulas of the ions present in **FA 8** and **FA 9** in Table 3.2.

If you are unable to identify an ion, write 'unknown'.

Table 3.2

compound	cation	anion
FA 8		
FA 9		

[2]

(iii) Give the equation for the thermal decomposition of **FA 7** in **3(a)(i)**.
Include state symbols.

.... [1]

[Total: 14]

BLANK PAGE

BLANK PAGE

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	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

BLANK PAGE

* 0000800000016 *

DFD

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group																	
1	2											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	3	4	5	6	7	8	9	10	11	12	13 A*l* aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 C*l* 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 T*l* 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 F*l* 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 –