Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

* 2 4 4 8 9 6 4 8 4 7 *

CHEMISTRY **9701/36**

Paper 3 Advanced Practical Skills 2 **October/November 2022**

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.

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 In this experiment you will determine the concentration of dilute hydrochloric acid by further diluting it and then titrating with aqueous potassium carbonate.

FB 1 is dilute hydrochloric acid, HCl. This acid will also be used in **Question 2**.
FB 2 is 8.46 g dm^{-3} anhydrous potassium carbonate, K_2CO_3.
FB 3 is bromophenol blue indicator.

(a) Method

- Use the **10 cm³** pipette to transfer 10.0 cm³ of **FB 1** into the volumetric flask.
- Make this solution up to 250 cm³ using distilled water.
- Shake the volumetric flask and its contents thoroughly. Label this solution **FB 4**.
- Fill the burette with **FB 4**.
- Pipette **25.0 cm³** of **FB 2** into a conical flask.
- Add a few drops of **FB 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is .... cm³.

- 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 below all your burette readings and the volume of **FB 4** 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 be used in your calculations.
Show clearly how you obtained this value.

25.0 cm³ of **FB 2** required .... cm³ of **FB 4**. [1]

(c) Calculations

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

(ii) Use information on page 2 to calculate the amount, in mol, of potassium carbonate present in 25.0 cm^3 of **FB 2**.

amount of K_2CO_3 = ... mol [1]

(iii) Give the ionic equation for the reaction taking place in the titration in **(a)**.
Include state symbols.

.....CO_3^{2-}...... + ...H^+...... $\rightarrow$ .... + ... [1]

(iv) Calculate the concentration, in mol dm^{-3}, of HCl in **FB 4**.

concentration of HCl in **FB 4** = ... mol dm^{-3} [1]

(v) Calculate the concentration, in mol dm^{-3}, of HCl in **FB 1**.

concentration of HCl in **FB 1** = ... mol dm^{-3} [1]

(d) A student uses a solution containing 8.46 g dm^{-3} of **hydrated** potassium carbonate in the titration in **(a)** instead of **FB 2**.

State whether the student's titre would be larger or smaller than your titre. Explain your answer.

....

....

.... [1]

(e) A student carries out the titration described in **(a)**. By mistake, a 25 cm^3 pipette is used to transfer 25.0 cm^3 of **FB 1** into a volumetric flask. The solution is made up to 250 cm^3 with distilled water and labelled **FB 4**.

State how the subsequent experimental procedure could be modified so that the titre obtained in **(b)** is not altered by this mistake.

....

.... [1]

[Total: 15]

2 In this experiment you will determine the enthalpy change, ΔH, for the dehydration of hydrated sodium carbonate to anhydrous sodium carbonate.

$$Na_2CO_3{\bullet}10H_2O(s) \rightarrow Na_2CO_3(s) + 10H_2O(l)$$

You will determine the enthalpy changes for the reactions of anhydrous sodium carbonate and hydrated sodium carbonate with excess hydrochloric acid. Then you will use Hess's Law to calculate the enthalpy change for the reaction above.

FB 1 is dilute hydrochloric acid, HCl.
FB 5 is anhydrous sodium carbonate, Na_2CO_3.
FB 6 is hydrated sodium carbonate, $Na_2CO_3{\bullet}10H_2O$.

(a) Determination of the enthalpy change for the reaction of anhydrous sodium carbonate, FB 5, with excess hydrochloric acid.

Method

- Support a cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 30.0 cm^3 of **FB 1** into the cup.
- Measure and record the initial temperature of the acid.
- Weigh the container with **FB 5**. Record the mass.
- **Slowly** add all **FB 5** to the acid in the cup.
  Note that the reaction will be vigorous. Avoid inhaling any acid spray produced.
- Stir until the maximum temperature is reached. Measure and record this temperature.
- Weigh the container with any residual **FB 5**. Record the mass.
- Calculate and record the mass of **FB 5** used.
- Calculate and record the temperature change.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the energy change during this reaction.

energy change = ... J [1]

(ii) Calculate the amount, in mol, of anhydrous sodium carbonate, **FB 5**, used.
Show your working.

amount of Na_2CO_3 = ... mol [1]

(iii) Calculate the enthalpy change, in $kJ\,mol^{-1}$, for the reaction between **FB 5** and **FB 1**, shown below.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

enthalpy change for Na_2CO_3 = ... $kJ\,mol^{-1}$
sign *value* [1]

(c) A student alters the method for the experiment in **(a)** and uses **FB 1** at half its original concentration but doubles the volume used.

The student suggests that the temperature change measured using their method would be more accurate than using the method in **(a)**.

State if you agree with the student. Explain your answer.

....

....

.... [1]

(d) Determination of the enthalpy change for the reaction of hydrated sodium carbonate, FB 6, with excess hydrochloric acid, FB 1.

Method

- Support the second cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 30.0 cm^3 of **FB 1** into the cup.
- Measure and record the initial temperature of the acid.
- Weigh the container with **FB 6**. Record the mass.
- Slowly add all the **FB 6** to the acid in the cup.
  Note that the reaction will be vigorous. Avoid inhaling any acid spray produced.
- Stir until the minimum temperature is reached. Measure and record this temperature.
- Weigh the container with any residual **FB 6**. Record the mass.
- Calculate and record the mass of **FB 6** used.
- Calculate and record the temperature change.

Results

I	
II	
III	

[3]

(e) Calculations

(i) Calculate the enthalpy change, in $kJ\,mol^{-1}$, for the reaction.

$$Na_2CO_3{\bullet}10H_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + 11H_2O(l)$$

enthalpy change for $Na_2CO_3{\bullet}10H_2O$ = ... $kJ\,mol^{-1}$

sign *value* [2]

(ii) Use the enthalpy changes calculated in **(b)(iii)** and **(e)(i)** to calculate the enthalpy change, in $kJ\,mol^{-1}$, for dehydration of hydrated sodium carbonate.

$$Na_2CO_3{\bullet}10H_2O(s) \rightarrow Na_2CO_3(s) + 10H_2O(l)$$

enthalpy change for dehydration = ... $kJ\,mol^{-1}$

sign *value* [1]

[Total: 14]

  [Turn over

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.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** **FB 7** is an aqueous solution containing two anions listed in the Qualitative analysis notes. Neither of the anions contains nitrogen.

(i) To a 1 cm depth of **FB 7** in a test-tube add a few drops of acidified aqueous potassium manganate(VII). Record your observations.

observations .... [1]

(ii) Carry out further tests to identify both anions in **FB 7**.
Use a 1 cm depth of **FB 7** in a test-tube for each test.
Name the reagents you used and record the observations made in your tests.

The anions present in **FB 7** are .... and .... [4]

(b) **FB 8** is a compound which contains one cation and one anion.
Both ions are listed in the Qualitative analysis notes.

(i) Transfer a small spatula measure of **FB 8** into a hard-glass test-tube.
Heat gently, then strongly, until no further change occurs.
Allow the test-tube with the residue to cool for approximately 2 minutes.

Record **all** your observations.

....

....

....

.... [2]

(ii) Pour a 2 cm depth of dilute hydrochloric acid into a test-tube.
Carefully, add a **small** spatula measure of **FB 8** to the acid.

Record your observations.
Retain the mixture obtained for use in **(b)(iii)**.

....

....

.... [1]

(iii) Add an equal volume of distilled water to the mixture obtained from **(b)(ii)**. Mix thoroughly.
Carry out suitable tests to identify the cation in **FB 8**.
Use a 1 cm depth of the solution in a test-tube for each test you carry out.
Name the reagents you use.
Record your observations.

[2]

(iv) From your observations in tests **(b)(i)**, **(b)(ii)** and **(b)(iii)**, deduce the formula of **FB 8**.

FB 8 is .... [1]

[Total: 11]

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	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Faraday constant	$F = 9.65 \times 10^4\ \mathrm{C\,mol^{-1}}$
Avogadro constant	$L = 6.022 \times 10^{23}\ \mathrm{mol^{-1}}$
electronic charge	$e = -1.60 \times 10^{-19}\ \mathrm{C}$
molar volume of gas	$V_m = 22.4\ \mathrm{dm^3\,mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\ \mathrm{dm^3\,mol^{-1}}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\ \mathrm{mol^2\,dm^{-6}}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\ \mathrm{kJ\,kg^{-1}\,K^{-1}}$ ($4.18\ \mathrm{J\,g^{-1}\,K^{-1}}$)

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 144.4	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 –