Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER			

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CHEMISTRY **9701/34**

Paper 3 Advanced Practical Skills 2 **May/June 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 **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 final answer to **each** step of your calculations.

1 Calcium carbonate reacts with hydrochloric acid to release carbon dioxide.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

The concentration of the hydrochloric acid can be determined by reacting it with calcium carbonate and measuring the volume of carbon dioxide formed.

FB 1 is hydrochloric acid, HCl.
FB 2 is calcium carbonate, $CaCO_3$.

(a) Method

- Fill the tub with tap water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Using the 50 cm^3 measuring cylinder, transfer 50 cm^3 of **FB 1** into the flask. Check that the bung fits tightly into the neck of the flask, clamp the flask and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip all the **FB 2**, from the container, into the acid in the flask and replace the bung immediately. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp. Leave for several minutes, swirling the flask occasionally.

You may wish to start Question 3 while the gas is being produced.

- When the reaction stops producing gas, record the final volume of gas in the measuring cylinder.

Keep the flask and contents for use in 1(c)(i).

volume of gas = ... cm^3 [2]

(b) Calculations

(i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder. (Assume that 1 mol of gas occupies 24.0 dm^3 under these conditions.)

amount of CO_2 = ... mol [1]

(ii) Use your answer to **(b)(i)** and the equation on page 2 to calculate the concentration, in mol dm^{-3}, of hydrochloric acid in **FB 1**. Show your working.

concentration of HC*l* = ... mol dm^{-3}
[2]

(c) (i) A student thinks that the mass of **FB 2** should be measured.

Explain, by observing the contents of the flask, why this is not necessary.

....

....

.... [2]

(ii) In this experiment some carbon dioxide is lost before the bung is replaced.

Suggest a change that could be made to minimise the loss of gas. Explain how this change minimises the loss of gas.

....

....

.... [1]

[Total: 8]

2 In this experiment you will use a thermometric method to determine the concentration of a sample of alkali. You will mix varying volumes of acid with a fixed volume of the alkali and measure the temperature rises that occur.

You will use your experimental data to calculate the enthalpy change for the neutralisation of the acid with alkali.

FB 3 is aqueous sodium hydroxide, NaOH.
FB 4 is 2.20 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Use the thermometer to measure the initial temperature of **FB 3**.

initial temperature of **FB 3** = ... °C

- Fill a burette with distilled water.
- Fill the other burette with **FB 4**. Label this burette **FB 4**.
- For **Experiment 1**, use the 10 cm^3 pipette to transfer 10.0 cm^3 of **FB 3** into the cup.
- Add 9.00 cm^3 of distilled water from the burette into the same cup.
- Add 1.00 cm^3 of **FB 4** from the other burette into the same cup.
- Stir the mixture and use the thermometer to measure the maximum temperature obtained.
- Record the maximum temperature in the table.
- Empty and shake dry the cup ready for use in **Experiment 2**.
- Repeat the method using 10.0 cm^3 of **FB 3** for each experiment and the volumes of water and **FB 4** shown in the table. In each case, measure and record the maximum temperature.

Table 2.1

experiment	volume water / cm^3	volume **FB 4** / cm^3	maximum temperature / °C
1	9.00	1.00	
2	7.00	3.00	
3	5.00	5.00	
4	3.00	7.00	
5	1.00	9.00	
6			
7			

I	
II	
III	
IV	
V	

Carry out **two** further experiments which will enable you to determine more precisely the volume of **FB 4** that gives the highest maximum temperature.

Record your measurements for these **two** experiments in the table. [5]

(b) Plot a graph of the maximum temperature reached (*y*-axis) and the volume of **FB 4** used (*x*-axis).
The scale on the *y*-axis should include a temperature 2 °C above the highest maximum temperature reached. Circle any points you consider to be anomalous.

I	
II	
III	
IV	

Draw two straight lines of best fit on your graph. One line should show where the maximum temperature recorded was increasing. The other line should be after the highest maximum temperature. Extrapolate both lines so that they intersect.
Use your graph to determine the volume of **FB 4** that reacts with 10.00 cm^3 of **FB 3**.

volume of **FB 4** = ... cm^3 [4]

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

(ii) Calculate the amount, in mol, of hydrochloric acid in the volume of **FB 4** in **(b)**.
If you were unable to determine an answer to **(b)** use 4.10 cm^3 as the volume of **FB 4**.

amount of HCl = ... mol [1]

(iii) Use your answer to **(c)(ii)** and the information on page 4 to calculate the concentration, in mol dm^{-3}, of sodium hydroxide in **FB 3**.

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

(iv) Calculate the energy released when the volume of **FB 4** in **(b)** is neutralised by sodium hydroxide. Show your working.
(Assume that 4.18 J of energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.)

energy released = ... J [2]

(v) Use your answers to **(c)(ii)** and **(c)(iv)** to calculate the enthalpy change of neutralisation, in kJ mol^{-1}, for 1.0 mol of hydrochloric acid.

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

(d) **(i)** The theoretical value of the enthalpy change of neutralisation is –57.6 kJ mol^{-1}.

Calculate the percentage error in your value of the enthalpy change from **(c)(v)**.
Show your working.

(Assume that the conditions under which you carried out your experiment in **(a)** are identical to the conditions used to determine the theoretical value.)

percentage error = ... % [1]

(ii) Suggest **one** modification to the procedure used in **(a)** that would give a more accurate value for the enthalpy change of neutralisation.

Do **not** suggest any modifications to apparatus in your answer.

....

....

....

.... [1]

[Total: 17]

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 Half fill the 250 cm^3 beaker with water, heat until the water is nearly boiling and then turn off the Bunsen burner. This is your hot water bath for use in **(a)(i)**.

(a) You are provided with aqueous solutions **FB 5**, **FB 6**, **FB 7** and **FB 8**. The solutions are known to be hydrochloric acid, hydrogen peroxide, methanoic acid and sulfuric acid. All the solutions have the same concentration.

Note: the order of **FB 5** to **FB 8** does **not** correspond to the order of identities given above.

(i) Carry out the following tests using a 2 cm depth of each reagent in a test-tube. Record your observations in Table 3.1.

Table 3.1

test	*observations*			
	FB 5	**FB 6**	**FB 7**	**FB 8**
Test 1 Add a piece of magnesium.				
Test 2 Add a few drops of acidified aqueous potassium manganate(VII). Place the test-tube in the hot water bath.				

[5]

(ii) Use your observations to complete the sentences. Explain your answer.

FB 7 is ....

FB 8 is ....

explanation ....

....
[2]

(iii) Carry out **one** additional test that allows you to distinguish between **FB 5** and **FB 6**.

Record your test and the result you obtained.

FB 5 is ....

FB 6 is ....

[2]

(iv) Write an **ionic** equation for the reaction of magnesium with **FB 5**. Include state symbols.

.... [1]

(v) Describe the observations that you would expect to see if the tests in **(a)(i)** were repeated using aqueous ethanoic acid.

observation with magnesium ....

....

observation with acidified aqueous potassium manganate(VII) ....

....
[2]

(b) **FB 9** is an aqueous solution containing one cation from those listed in the Qualitative analysis notes.

Carry out tests that would identify the cation present in **FB 9**. Record your tests, observations and the identity of the cation.

The cation is .... [3]

[Total: 15]

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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											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 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 –