Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

4902328418

CHEMISTRY **9701/36**

Paper 3 Advanced Practical Skills 2 **October/November 2020**

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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

Session
Laboratory

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.
- Notes for use in qualitative analysis are provided in the question paper.

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages. 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 your working and appropriate significant figures in the final answer to **each** step of your calculations.

1 Many salts occur in a hydrated form such as hydrated potassium carbonate, $K_2CO_3{\bullet}xH_2O$, where x is an integer. You will determine the formula of a sample of hydrated potassium carbonate by adding it to an excess of hydrochloric acid and collecting the gas produced.

$$K_2CO_3{\bullet}xH_2O(s) + 2HCl(aq) \rightarrow 2KCl(aq) + (x+1)H_2O(l) + CO_2(g)$$

FB 1 is hydrated potassium carbonate, $K_2CO_3{\bullet}xH_2O$.
FB 2 is 0.50 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a 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.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FB 2** into the flask labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Weigh the container with **FB 1** and record the mass.
- Remove the bung from the neck of the flask. Tip **all** of **FB 1** into the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents. Swirl the flask occasionally until no more gas is produced. Replace the flask in the clamp after each swirl.
- Measure and record the final volume of gas in the measuring cylinder.
- Weigh the container and any residual **FB 1** and record the mass.
- Calculate and record the mass of **FB 1** added.

Results

[3]

(b) Calculations

(i) Calculate the number of moles of carbon dioxide collected in the measuring cylinder. Assume 1 mol of gas occupies 24.0 dm^3.

moles of CO_2 = ... mol [1]

(ii) Use your answer to **(b)(i)** and the information on page 2 to calculate the relative formula mass, M_r, of **FB 1**.

M_r of $K_2CO_3{\bullet}xH_2O$ = ... [1]

(iii) Calculate the value of x in the formula of the hydrated potassium carbonate, $K_2CO_3{\bullet}xH_2O$. Show your working.

x = ...
[2]

(c) One of the errors associated with this method is caused by the solubility of carbon dioxide in water.

Suggest **two** modifications which could reduce this error.

modification 1 ....

....

modification 2 ....

....
[2]

[Total: 9]

2 You will determine the enthalpy change of hydration of anhydrous sodium carbonate.

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

You will do this by measuring the changes in temperature when samples of anhydrous sodium carbonate and hydrated sodium carbonate are added separately to excess hydrochloric acid.

FB 3 is anhydrous sodium carbonate, Na_2CO_3.
FB 4 is hydrated sodium carbonate, $Na_2CO_3{\bullet}10H_2O$.
FB 5 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

Experiment 1

- Weigh the container with **FB 3** and record the mass in the space below.
- Support the plastic cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FB 5** into the plastic cup.
- Place the thermometer in the solution and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature.
- Tip **all** of **FB 3** into the acid in the cup and stir the mixture.
- Record the highest or lowest temperature of the mixture.
- Calculate and record the change in temperature.
- Weigh the container with any residual **FB 3** and record the mass below.
- Calculate and record the mass of **FB 3** used.

Experiment 2

- Repeat the method given above using the second plastic cup, but this time use **FB 4** in place of **FB 3**.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) Calculations

(i) Calculate the heat energy transferred, in J, in each experiment.
Assume 4.2 J of heat energy changes the temperature of 1.0 cm^3 of the solution by 1.0 °C.

Experiment 1 with FB 3	**Experiment 2 with FB 4**
heat energy = ... J	heat energy = ... J

[1]

(ii) Calculate the enthalpy change, ΔH, in kJ mol^{-1}, when 1.00 mol of solid reacts with hydrochloric acid.

Experiment 1 with FB 3	**Experiment 2 with FB 4**
ΔH_1 = ... kJ mol^{-1} (*sign* / *value*)	ΔH_2 = ... kJ mol^{-1} (*sign* / *value*)

[3]

(iii) Use your answers to **(b)(ii)** to calculate the enthalpy change when 1.00 mol of anhydrous sodium carbonate is hydrated to form 1.00 mol of hydrated sodium carbonate.

Show clearly, by a Hess' diagram or other suitable means, how you calculated your answer.

(If you were unable to complete the calculations in **(b)(ii)** then assume the enthalpy change for **Experiment 1** = –33.7 kJ mol^{-1} and for **Experiment 2** = +39.2 kJ mol^{-1}. These may not be the correct values.)

enthalpy change of hydration of Na_2CO_3 = ... kJ mol^{-1}
sign *value*

[2]

(c) A student carrying out the experiment with anhydrous sodium carbonate, **FB 3**, could not find 2.00 mol dm^{-3} hydrochloric acid. The student used the same volume of 1.0 mol dm^{-3} sulfuric acid instead.

How would the change in temperature obtained by the student compare with the change that you obtained? Assume the same mass of **FB 3** was used.

Explain your answer.

....

....

.... [1]

[Total: 14]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

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

No additional tests for ions present should be attempted.

3 **FB 6**, **FB 7** and **FB 8** are aqueous solutions of salts. Each contains one cation and one anion. All the anions and two of the cations are listed in the Qualitative Analysis Notes.

(a) **(i)** Use a 1 cm depth of each solution in a test-tube and record your observations in the table.

test	*observations*		
	FB 6	**FB 7**	**FB 8**
Test 1 Add aqueous ammonia.			
Test 2 Add dilute sulfuric acid.			
Test 3 Add a few drops of acidified aqueous potassium manganate(VII).			
Test 4 Add a 1 cm depth of **FB 6**.			

[7]

(ii) Write an ionic equation for the reaction between **FB 6** and sulfuric acid. Include state symbols.

.... [2]

(iii) Use your observations to identify the cations present in **FB 6**, **FB 7** and **FB 8**. Write the formula of each ion in the table. If the tests you carried out did not allow you to identify any of the ions, write 'unknown'.

	FB 6	**FB 7**	**FB 8**
cation			

[2]

(b) (i) You will now investigate the identity of the anions present in **FB 7** and **FB 8**. Neither of the anions contains a nitrogen atom.
Select reagents that you would need to use in order to carry out tests that give positive results for these ions.
Record suitable reagents and the ions for which they would test.

[1]

(ii) Carry out **all** of your tests on **FB 7** and **FB 8** and record your observations in the space below.

[4]

(iii) Use your observations in **(b)(ii)** to identify the anions present in **FB 7** and **FB 8**. Write the formula of each ion in the table.

	FB 7	**FB 8**
anion		

[1]

[Total: 17]

Qualitative Analysis Notes

1 Reactions of aqueous cations

ion	*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 heating	–
barium, Ba^{2+}(aq)	faint white ppt. is nearly always observed unless reagents are pure	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	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

ion	*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 ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$)
iodide, $I^-(aq)$	gives 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
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (soluble in excess dilute strong acids)

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 (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	‘pops’ with a lighted splint
oxygen, O_2	relights a glowing splint

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 –		114 Fl flerovium –		116 Lv livermorium –		

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 –