Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME					
CENTRE NUMBER					
CANDIDATE NUMBER					

2539748931

CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **October/November 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 10 and 11.
A copy of the Periodic Table is printed on page 12.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Session
Laboratory

For Examiner's Use	
1	
2	
Total	

This document consists of **12** printed pages.

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[Turn over

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 In this experiment you will determine the percentage purity of a sample of impure anhydrous sodium carbonate. You will use two different methods to measure the enthalpy change of reaction when a sample of impure anhydrous sodium carbonate reacts with excess dilute hydrochloric acid.

FA 1 is a sample of the impure anhydrous sodium carbonate.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.
FA 3 is a second sample of the impure anhydrous sodium carbonate used in **FA 1**.

(a) Method 1

- Weigh the container with **FA 1**. Record this mass.

mass of container with **FA 1** = ... g

- Support one of the plastic cups in the 250 cm^3 beaker.
- Use the measuring cylinder to place 25 cm^3 of **FA 2** into the cup.
- Measure the temperature of the **FA 2** in the cup. Tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record this temperature at time t = 0.
- Start the stopclock and leave it running for the whole experiment.
- Measure and record the temperature of **FA 2** in the cup every half minute for 2 minutes.
- At $t = 2\frac{1}{2}$ minutes tip all the **FA 1** into the cup. Stir the contents of the cup.
- Measure and record the temperature of the contents of the cup at t = 3 minutes and then every half minute up to t = 9 minutes.
- Weigh the container with any residual **FA 1**. Record this mass.

I	
II	
III	
IV	
V	

mass of container with residual **FA 1** = ... g
[5]

(b) (i) On the grid on page 3, plot a graph of temperature (y-axis) against time (x-axis). You should choose a scale that allows you to plot 2 °C above the maximum temperature reached.

On your graph, draw two straight lines of best fit. One line is for the temperature before adding **FA 1** and the other line for the cooling of the solution once reaction is complete.

Extrapolate these two lines to $t = 2\frac{1}{2}$ minutes. [4]

I	
II	
III	
IV	

(ii) From your graph, find the theoretical temperature rise at $t = 2\frac{1}{2}$ minutes.

theoretical temperature rise = ... °C [1]

(c) **(i)** Calculate the energy released in the reaction.

(Assume 4.2 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.)

energy released = ... J [1]

(ii) The equation for the reaction between anhydrous sodium carbonate and hydrochloric acid is shown.

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

The literature value for the enthalpy change of this reaction is –27.0 kJ mol^{-1}.

Use this figure, and the value that you found in **(i)**, to find the mass of anhydrous sodium carbonate you used in **(a)**. You should assume that no energy was lost to the surroundings in your experiment.

mass Na_2CO_3 = ... g [2]

(iii) Calculate the percentage of anhydrous sodium carbonate present in **FA 1**.

percentage Na_2CO_3 in **FA 1** = ... % [1]

(d) In your calculation in **(c)**, what assumption have you made about the impurity present in **FA 1**?

....

.... [1]

(e) **Method 2**

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.70 g and 1.90 g of **FA 3** to the plastic cup and record the mass.
- Support the plastic cup in the 250 cm^3 beaker.
- Pour 25 cm^3 of **FA 2** into the measuring cylinder.
- Measure and record the initial temperature of **FA 2** in the measuring cylinder.
- Pour the 25 cm^3 of **FA 2** into the plastic cup.
- Stir the contents of the cup and record the maximum temperature. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Calculate and record the mass of **FA 3** used and the change in temperature.

[2]

(f) Use the temperature rise in **(e)**, and the fact that the enthalpy change for the reaction between anhydrous sodium carbonate and hydrochloric acid is –27.0 kJ mol^{-1}, to calculate the percentage of anhydrous sodium carbonate in **FA 3**.

percentage Na_2CO_3 in **FA 3** = ... % [2]

(g) **FA 1** and **FA 3** are both samples of the same impure anhydrous sodium carbonate and so the percentage of anhydrous sodium carbonate found using **Method 1** and **Method 2** should be the same. In practice the percentages are sometimes different from each other.

In both methods, percentage errors occur due to measuring the mass of solid and the temperature rise.

Ignoring these errors, which method is more accurate?
Tick the correct box and explain your answer.

Method 1 more accurate ☐

Method 2 more accurate ☐

Method 1 and Method 2 equally accurate ☐

....

....

....
[1]

(h) A student decided to confirm by experiment the literature value for the enthalpy change of the reaction between anhydrous sodium carbonate and hydrochloric acid. By mistake the student weighed a sample of hydrated sodium carbonate, $Na_2CO_3.10H_2O$, instead of anhydrous sodium carbonate, Na_2CO_3.

State what effect this would have on the calculated value of the enthalpy change for the reaction. Explain your answer.

....

....

....

.... [2]

(i) A student used 3.00 g of anhydrous sodium carbonate that was 80.0% pure by mass.

Calculate the minimum volume of 2.00 mol dm^{-3} hydrochloric acid that would be needed to react completely with this sample of impure anhydrous sodium carbonate.

volume of HCl = ... cm^3 [3]

[Total: 25]

Qualitative Analysis

Where reagents are selected for use in a test, the **full 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.

2 **(a)** **(i)** **FA 4** is a sodium compound that was the impurity in the **FA 1** and **FA 3** that you used in **Question 1**. The anion in **FA 4** is one of those listed in the Qualitative Analysis Notes.

Carry out appropriate tests to allow you to positively identify the anion in **FA 4**.

For the test that gives a positive result, record the test and the results of it.
State the name of the anion in **FA 4**.

anion in **FA 4** = ...

[2]

(ii) Write the ionic equation for the reaction that you have used to identify the anion in **FA 4**. Include state symbols.

.... [1]

(b) **FA 5** is a mixture that contains two cations and three anions from those listed in the Qualitative Analysis Notes.

A sample of **FA 5** was added to water and the water stirred. The mixture produced was filtered to give a solid residue, **FA 6**, and a filtrate, **FA 7**.

(i) Carry out the following tests on **FA 6** and record your observations.

test	*observations*
To a small spatula measure of **FA 6** in a test-tube add dilute hydrochloric acid, then	
add aqueous ammonia.	
Place a small spatula measure of **FA 6** in a hard-glass test-tube and heat gently.	

[4]

(ii) Carry out the following tests on **FA 7** and record your observations.

test	*observations*
To a 1 cm depth of **FA 7** in a test-tube add aqueous sodium hydroxide.	
To a 1 cm depth of **FA 7** in a test-tube add aqueous ammonia.	
To a 1 cm depth of **FA 7** in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of **FA 7** in a test-tube add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add dilute nitric acid.	
To a 0.5 cm depth of **FA 7** in a boiling tube add a 2 cm depth of aqueous sodium hydroxide and warm, then	
add a small piece of aluminium foil.	

[5]

(iii) From your observations, identify the two cations present in **FA 5**.

cations .... and .... [1]

(iv) From your observations, identify two anions present in **FA 5**.

.... [1]

(v) From your observations, identify two anions that could be present in **FA 5**.

.... [1]

[Total: 15]

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 –