

Question 1

[28]

Quantitative analysis

In this experiment you will determine the percentage by mass of an impure sample of sodium carbonate, Na_2CO_3 . The impurity is sodium chloride, NaCl .

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.

SL 1 is impure anhydrous sodium carbonate, Na_2CO_3 .

SL 2 is $0.750 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

SL 4 is $0.100 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH .

Indicator is Bromophenol blue.

The experiment involves three steps:

Step 1 React a known mass of impure sodium carbonate, **SL 1**, with an excess of acid.

Step 2 Dilute the products of **Step 1** to a known volume.

Step 3 Carry out a titration to find out how much acid remained after the reaction **Step 1**.

The NaCl impurity in **SL 1** does not react with HCl or with NaOH .

(a) Method

Step 1

- Label a burette **SL 2** and fill this burette with **SL 2**.
- Run 45.00 cm^3 of **SL 2** into the 250 cm^3 beaker.
- Weigh the container with **SL 1**. Record the mass.
- Slowly, and in small portions, add **SL 1** to the acid.
- Stir the mixture until the fizzing has stopped. Leave the stirring rod in the beaker.
- Reweigh the container with any residue. Record the mass.

(i) Calculate and record the mass of **SL 1** added to the acid.

[2]

Step 2

- Stir the mixture from **Step 1** and ensure that the entire solid has reacted. Transfer this solution to the graduated flask.
- Rinse the beaker and stirring rod twice with distilled water, then add the washings into the graduated flask.
- Make the solution up to 250 cm³ with distilled water. Thoroughly mix the contents of the flask. This solution is **SL 3**.

Step 3

- Label the other burette **SL 4** and fill this burette with **SL 4**.
- Pipette 25.0 cm³ of **SL 3** into a conical flask.
- Add several drops of bromophenol blue indicator.

(ii) Perform a rough titration and record your burette readings in the space below.

The rough titre is cm³.

- Carry out as many titrations as you think are necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.

[1]

(iii) Record, in a suitable form in the space below, all of your burette readings and the volume of **SL 4** added in each accurate titration.

[10]

(b) From your accurate titration results, calculate a suitable mean titre value to use in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **SL 3** required cm³ of **SL 4**.

[1]

- (c) Calculate the number of moles of hydrochloric acid in the volume of **SL 2** used in **Step 1**.

moles of HCl in **SL 2** used in Step 1 = ... mol

[1]

- (d) Use your answer to (b) to calculate the number of moles of sodium hydroxide, **SL 4**, required to react with 25.0 cm³ of **SL 3** in **Step 3**.

moles of NaOH required = ... mol

Use this answer to deduce the number of moles of hydrochloric acid in 250 cm³ of **SL 3**.

[1]

moles of HCl in 250 cm³ of **SL 3** = ... mol

[2]

- (e) Use your answers to (c) and (d) to calculate the number of moles of hydrochloric acid that reacted with sodium carbonate in **SL 1**.

moles of HCl that reacted with **SL 1** = ... mol

[1]

- (f) Write an equation for the reaction of sodium carbonate with hydrochloric acid in **Step 1**. Include state symbols. [2]

- (g) Use the equation and your answer to (e) to determine the moles of sodium carbonate present in **SL 1**.

moles of Na_2CO_3 = ... mol [1]

- (h) Use your answer to (g) and your mass of **SL 1** to calculate the % by mass of anhydrous sodium carbonate in **SL 1**.

% by mass = ... [2]

- (i) A student decided to use a larger mass of **SL 1** when carrying out the same method. What effect would this have on the titre volume in **Step 3**? Explain your answer. [2]

- (j) A different impure sample of anhydrous sodium carbonate contains sodium hydrogen carbonate, NaHCO_3 , instead of sodium chloride as the impurity. [2]

Explain why the method used in this experiment could not be used to determine accurately the percentage by mass of sodium carbonate in this different sample.

Qualitative analysis

[12]

Question 2

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.

(a) **SL 5**, **SL 6** and **SL 7** each contain one cation and one anion. All the cations and anions are different. All the cations and two of the anions are listed in the Qualitative Analysis Notes.

SL 6 is an aqueous solution.

[6]

(i). Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>
Test 1 Dissolve a portion of SL 5 in water. Add aqueous NaOH solution drop wise, and then in excess.	
Test 2 To a fresh portion of SL 5 , add a few drops of barium nitrate solution followed by dilute hydrochloric acid.	
Test 3 Take small amount of SL 6 and add ammonia solution drop wise, and then in excess.	

Test 4 To a fresh portion of SL 6 , add aqueous silver nitrate, followed by aqueous ammonia.	
Test 5 To a small amount of SL 7 , add aqueous sodium hydroxide and warm. Test any gas produced.	
Test 6 To a fresh portion of SL 7 , add silver nitrate solution and then aqueous ammonia.	

(ii). From your test results, identify the cations in **SL 5**, **SL 6** and **SL 7**. If the tests do not allow you to positively identify a cation, write 'unknown'.

[3]

	SL 5	SL 6	SL 7
Formula of cation			

(iii). From your test results, identify the anions in **SL 5**, **SL 6** and **SL 7**. If the tests do not allow you to positively identify an anion, write 'unknown'.

[3]

	SL 5	SL 6	SL 7
Formula of anion			

Formulas

No. of Mole = Concentration $\times$ Volume

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

anion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream/off-white ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives pale yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; decolourises acidified aqueous KMnO_4
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids); gives white ppt. with high $[\text{Ca}^{2+}(\text{aq})]$
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO_4
thiosulfate, $\text{S}_2\text{O}_3^{2-}(\text{aq})$	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

The Periodic Table of Elements

Group																		
1	2	Key										13	14	15	16	17	18	
		1 H hydrogen 1.0																
3 Li lithium 6.9	4 Be beryllium 9.0	atomic number atomic symbol name relative atomic mass										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	57La	58Ce	59Pr	60Nd	61Pm	62Sm	63Eu	64Gd	65Tb	66Dy	67Ho	68Er	69Tm	70Yb	71Lu
	lanthanum	cerium	praseodymium	neodymium	promethium	samarium	eurogium	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
	138.9	140.1	140.9	144.4	–	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
	–	90	91	92	93	94	95	96	97	98	99	100	101	102	103
actinoids	89Ac	90Th	91Pa	92U	93Np	94Pu	95Am	96Cm	97Bk	98Cf	99Es	100Fm	101Md	102No	103Lr
	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium
	–	232.0	231.0	238.0	–	–	–	–	–	–	–	–	–	–	–
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