Cambridge Assessment International Education

# Cambridge International AS & A Level

| CANDIDATE NAME | |
|---|---|

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*5609029097*

**CHEMISTRY** **9701/33**

Paper 3 Advanced Practical Skills 1 **October/November 2021**

**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. Any blank pages are indicated.


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**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** Group 1 metal carbonates have the formula $\mathbf{M}_2CO_3$. The identity of the metal ion, $\mathbf{M}^+$, may be determined by a gravimetric method. The metal carbonate is reacted with excess acid and the mass of carbon dioxide given off is measured.

$$\mathbf{M}_2CO_3(s) + 2HCl(aq) \rightarrow 2\mathbf{M}Cl(aq) + H_2O(l) + CO_2(g)$$

**FA 1** is a Group 1 metal carbonate, $\mathbf{M}_2CO_3$.
**FA 2** is 2.0 mol dm$^{-3}$ hydrochloric acid, $HCl$.

**(a) Method**

- Use the 25 cm$^3$ measuring cylinder to transfer 25.0 cm$^3$ of **FA 2** into a conical flask. Weigh the flask with the acid and record the mass.
- Weigh the container with **FA 1** and record the mass.
- **Carefully** tip all of **FA 1** into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** added to the conical flask.
- Calculate and record the theoretical initial mass of flask + acid + **FA 1**.
- Swirl the flask occasionally while leaving it to stand for approximately 5 minutes.

**During this step you may wish to start Question 2 or Question 3.**

- Weigh the flask and contents and record this mass.
- Calculate and record the mass of carbon dioxide given off during the experiment.

**Results**

| | |
|---|---|
| I | |
| II | |
| III | |
| IV | |

[4]

**(b) Calculations**

**(i)** Calculate the number of moles of carbon dioxide given off in the experiment.

moles of $CO_2$ = ..... mol [1]

**(ii)** Calculate the relative formula mass, $M_r$, of $\mathbf{M}_2CO_3$.

$M_r$ of $\mathbf{M}_2CO_3$ = ..... [1]

**(iii)** Identify the Group 1 cation, $\mathbf{M}^+$, in **FA 1**.
Show your working.

$\mathbf{M}^+$ is ..... . [1]

**(c)** One source of error in this experiment is the solubility of carbon dioxide in water.

**(i)** Suggest **one** modification, to the method in **(a)**, to reduce the solubility of carbon dioxide in the solution in the flask.

.....

..... [1]

**(ii)** An assumption made in the method in **(a)** is that the acid is in excess.

Show by calculation that this assumption is true.

[2]

[Total: 10]

**2** The identity of a Group 1 metal carbonate may also be found by a titration method.

**M**$^+$ in this question may or may not be the same cation as that in **Question 1**.

$$\mathbf{M}_2CO_3(s) + 2HCl(aq) \rightarrow 2\mathbf{M}Cl(aq) + H_2O(l) + CO_2(g)$$

**FA 3** is an aqueous solution containing 7.46 g dm$^{-3}$ of a Group 1 metal carbonate, $\mathbf{M}_2CO_3$.
**FA 4** is 0.110 mol dm$^{-3}$ hydrochloric acid, $HCl$.
bromophenol blue indicator

**(a) Method**

- Fill the burette with **FA 4**.
- Pipette 25.0 cm$^3$ of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is ..... cm$^3$.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the accuracy of your practical work.
- Record, in a suitable form below, all your burette readings and the volume of **FA 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 use in your calculations. Show clearly how you obtained this value.

25.0 cm$^3$ of **FA 3** required ..... cm$^3$ of **FA 4**. [1]

**(c) Calculations**

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

**(ii)** Calculate the number of moles of hydrochloric acid present in the volume of **FA 4** calculated in **(b)**.

moles of $HCl$ = ..... mol [1]

**(iii)** Calculate the number of moles of Group 1 metal carbonate, $\mathbf{M}_2CO_3$, present in 25.0 $cm^3$ of **FA 3**.

moles of $\mathbf{M}_2CO_3$ in 25.0 $cm^3$ = ..... mol [1]

**(iv)** Calculate the relative formula mass, $M_r$, of $\mathbf{M}_2CO_3$.

$M_r$ of $\mathbf{M}_2CO_3$ = ..... [1]

**(v)** Identify the cation, $\mathbf{M}^+$.
Show your working.

$\mathbf{M}^+$ is ..... . [1]

**(d)** A student carrying out a similar experiment, using the same method, found the cation in **Question 2** to be $Rb^+$. The student is told that the acid provided, **FA 4**, was incorrectly prepared. The cation in the student's experiment should have been identified as $K^+$.

State whether the acid supplied is more, or less, concentrated than 0.110 mol $dm^{-3}$.
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** **(a)** **FA 5** is a salt containing one cation and one anion, both of which are listed in the Qualitative Analysis Notes.

**(i)** Place a small spatula measure of **FA 5** into a hard-glass test-tube and heat the tube, gently at first and then more strongly.
Record **all** your observations.

.....

.....

.....

..... [2]

**(ii)** Place the remaining **FA 5** into a 100 $cm^3$ beaker and add approximately 15 $cm^3$ of distilled water. Stir to make a solution. This solution is **FA 6**.
You will use portions of **FA 6** for the following test and tests in **(b)**.

To a 1 cm depth of **FA 6** in a test-tube add a 1 cm depth of dilute hydrochloric acid.
Record your observations.

.....

..... [1]

**(b) (i)** **FA 7** and **FA 8** are solutions each containing one cation and one anion, all of which are listed in the Qualitative Analysis Notes.

Carry out the following tests in separate test-tubes. Use a 1 cm depth of each solution unless otherwise specified.

| | *observations* | | |
|---|---|---|---|
| *solution* | **FA 6** | **FA 7** | **FA 8** |
| Add a few drops of aqueous silver nitrate. | | | |
| **FA 6** | | | |
| **FA 7** | | | |

[4]

**(ii)** Carry out tests using aqueous sodium hydroxide and dilute sulfuric acid to identify or confirm the identity of the ions in **FA 6**, **FA 7** and **FA 8**.
Record your tests and observations in a table in the space below.

[5]

**(c)** **(i)** From your observations in **(a)** and **(b)** identify the cation and the anion present in each of **FA 6**, **FA 7** and **FA 8** by giving their formulae.

| | *cation* | *anion* |
|---|---|---|
| **FA 6** | | |
| **FA 7** | | |
| **FA 8** | | |

[3]

**(ii)** Give an ionic equation for a precipitation reaction observed in **(b)(i)**. Include state symbols.

..... [1]

[Total: 16]

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## Qualitative Analysis Notes

### 1 Reactions of aqueous cations

| *ion* | *reaction with* | |
|---|---|---|
| | NaOH(aq) | $NH_3$(aq) |
| aluminium,<br>$Al^{3+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>insoluble in excess |
| ammonium,<br>$NH_4^+$(aq) | no ppt.<br>ammonia produced on heating | – |
| barium,<br>$Ba^{2+}$(aq) | faint white ppt. is nearly always observed unless reagents are pure | no ppt. |
| calcium,<br>$Ca^{2+}$(aq) | white ppt. with high [$Ca^{2+}$(aq)] | no ppt. |
| chromium(III),<br>$Cr^{3+}$(aq) | grey-green ppt.<br>soluble in excess | grey-green ppt.<br>insoluble in excess |
| copper(II),<br>$Cu^{2+}$(aq) | pale blue ppt.<br>insoluble in excess | pale blue ppt. soluble in excess giving dark blue solution |
| iron(II),<br>$Fe^{2+}$(aq) | green ppt. turning brown on contact with air<br>insoluble in excess | green ppt. turning brown on contact with air<br>insoluble in excess |
| iron(III),<br>$Fe^{3+}$(aq) | red-brown ppt.<br>insoluble in excess | red-brown ppt.<br>insoluble in excess |
| magnesium,<br>$Mg^{2+}$(aq) | white ppt.<br>insoluble in excess | white ppt.<br>insoluble in excess |
| manganese(II),<br>$Mn^{2+}$(aq) | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess |
| zinc,<br>$Zn^{2+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>soluble in excess |

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## 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 |

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## The Periodic Table of Elements

**Key**

| atomic number |
|---|
| atomic symbol |
| name |
| relative atomic mass |

| Group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | | | 1<br>H<br>hydrogen<br>1.0 | | | | | | | | | | 2<br>He<br>helium<br>4.0 |
| 3<br>Li<br>lithium<br>6.9 | 4<br>Be<br>beryllium<br>9.0 | | | | | | | | | | | 5<br>B<br>boron<br>10.8 | 6<br>C<br>carbon<br>12.0 | 7<br>N<br>nitrogen<br>14.0 | 8<br>O<br>oxygen<br>16.0 | 9<br>F<br>fluorine<br>19.0 | 10<br>Ne<br>neon<br>20.2 |
| 11<br>Na<br>sodium<br>23.0 | 12<br>Mg<br>magnesium<br>24.3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13<br>Al<br>aluminium<br>27.0 | 14<br>Si<br>silicon<br>28.1 | 15<br>P<br>phosphorus<br>31.0 | 16<br>S<br>sulfur<br>32.1 | 17<br>Cl<br>chlorine<br>35.5 | 18<br>Ar<br>argon<br>39.9 |
| 19<br>K<br>potassium<br>39.1 | 20<br>Ca<br>calcium<br>40.1 | 21<br>Sc<br>scandium<br>45.0 | 22<br>Ti<br>titanium<br>47.9 | 23<br>V<br>vanadium<br>50.9 | 24<br>Cr<br>chromium<br>52.0 | 25<br>Mn<br>manganese<br>54.9 | 26<br>Fe<br>iron<br>55.8 | 27<br>Co<br>cobalt<br>58.9 | 28<br>Ni<br>nickel<br>58.7 | 29<br>Cu<br>copper<br>63.5 | 30<br>Zn<br>zinc<br>65.4 | 31<br>Ga<br>gallium<br>69.7 | 32<br>Ge<br>germanium<br>72.6 | 33<br>As<br>arsenic<br>74.9 | 34<br>Se<br>selenium<br>79.0 | 35<br>Br<br>bromine<br>79.9 | 36<br>Kr<br>krypton<br>83.8 |
| 37<br>Rb<br>rubidium<br>85.5 | 38<br>Sr<br>strontium<br>87.6 | 39<br>Y<br>yttrium<br>88.9 | 40<br>Zr<br>zirconium<br>91.2 | 41<br>Nb<br>niobium<br>92.9 | 42<br>Mo<br>molybdenum<br>95.9 | 43<br>Tc<br>technetium<br>– | 44<br>Ru<br>ruthenium<br>101.1 | 45<br>Rh<br>rhodium<br>102.9 | 46<br>Pd<br>palladium<br>106.4 | 47<br>Ag<br>silver<br>107.9 | 48<br>Cd<br>cadmium<br>112.4 | 49<br>In<br>indium<br>114.8 | 50<br>Sn<br>tin<br>118.7 | 51<br>Sb<br>antimony<br>121.8 | 52<br>Te<br>tellurium<br>127.6 | 53<br>I<br>iodine<br>126.9 | 54<br>Xe<br>xenon<br>131.3 |
| 55<br>Cs<br>caesium<br>132.9 | 56<br>Ba<br>barium<br>137.3 | 57–71<br>lanthanoids | 72<br>Hf<br>hafnium<br>178.5 | 73<br>Ta<br>tantalum<br>180.9 | 74<br>W<br>tungsten<br>183.8 | 75<br>Re<br>rhenium<br>186.2 | 76<br>Os<br>osmium<br>190.2 | 77<br>Ir<br>iridium<br>192.2 | 78<br>Pt<br>platinum<br>195.1 | 79<br>Au<br>gold<br>197.0 | 80<br>Hg<br>mercury<br>200.6 | 81<br>Tl<br>thallium<br>204.4 | 82<br>Pb<br>lead<br>207.2 | 83<br>Bi<br>bismuth<br>209.0 | 84<br>Po<br>polonium<br>– | 85<br>At<br>astatine<br>– | 86<br>Rn<br>radon<br>– |
| 87<br>Fr<br>francium<br>– | 88<br>Ra<br>radium<br>– | 89–103<br>actinoids | 104<br>Rf<br>rutherfordium<br>– | 105<br>Db<br>dubnium<br>– | 106<br>Sg<br>seaborgium<br>– | 107<br>Bh<br>bohrium<br>– | 108<br>Hs<br>hassium<br>– | 109<br>Mt<br>meitnerium<br>– | 110<br>Ds<br>darmstadtium<br>– | 111<br>Rg<br>roentgenium<br>– | 112<br>Cn<br>copernicium<br>– | | 114<br>Fl<br>flerovium<br>– | | 116<br>Lv<br>livermorium<br>– | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lanthanoids | 57<br>La<br>lanthanum<br>138.9 | 58<br>Ce<br>cerium<br>140.1 | 59<br>Pr<br>praseodymium<br>140.9 | 60<br>Nd<br>neodymium<br>144.4 | 61<br>Pm<br>promethium<br>– | 62<br>Sm<br>samarium<br>150.4 | 63<br>Eu<br>europium<br>152.0 | 64<br>Gd<br>gadolinium<br>157.3 | 65<br>Tb<br>terbium<br>158.9 | 66<br>Dy<br>dysprosium<br>162.5 | 67<br>Ho<br>holmium<br>164.9 | 68<br>Er<br>erbium<br>167.3 | 69<br>Tm<br>thulium<br>168.9 | 70<br>Yb<br>ytterbium<br>173.1 | 71<br>Lu<br>lutetium<br>175.0 |
| actinoids | 89<br>Ac<br>actinium<br>– | 90<br>Th<br>thorium<br>232.0 | 91<br>Pa<br>protactinium<br>231.0 | 92<br>U<br>uranium<br>238.0 | 93<br>Np<br>neptunium<br>– | 94<br>Pu<br>plutonium<br>– | 95<br>Am<br>americium<br>– | 96<br>Cm<br>curium<br>– | 97<br>Bk<br>berkelium<br>– | 98<br>Cf<br>californium<br>– | 99<br>Es<br>einsteinium<br>– | 100<br>Fm<br>fermium<br>– | 101<br>Md<br>mendelevium<br>– | 102<br>No<br>nobelium<br>– | 103<br>Lr<br>lawrencium<br>– |

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