Cambridge Assessment International Education

# Cambridge International AS & A Level

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| CANDIDATE NAME | | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | | |

*8205044804*

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

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

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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 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** An iron compound can contain $Fe^{2+}$ ions, $Fe^{3+}$ ions or both ions.

In this experiment, you will determine the percentage by mass of iron in **FA 1**, an unknown compound. You will first prepare a solution of the compound and then carry out a titration using acidified potassium manganate(VII), $KMnO_4$.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

The end-point of the titration is when all the $Fe^{2+}$ ions have been oxidised and so unreacted potassium manganate(VII) causes the colour of the solution to become a permanent pale pink.

**FA 1** is a sample of the unknown compound.
**FA 2** is 0.0100 mol dm$^{-3}$ potassium manganate(VII), $KMnO_4$.
**FA 3** is dilute sulfuric acid, $H_2SO_4$.

**(a) Method**

**Weighing the compound**

- Weigh the sample of **FA 1** and its container.
- Tip the **FA 1** into the 250 cm$^3$ beaker.
- Reweigh the container including any residual **FA 1**.
- Record both your readings clearly in the space below.
- Calculate the mass of **FA 1** transferred into the beaker. Record the mass.

**Preparing the solution**

- Add approximately 200 cm$^3$ of distilled water to the beaker and stir until the **FA 1** has dissolved.
- Pour the contents carefully into the 250 cm$^3$ volumetric flask.
- Rinse the contents of the beaker with a little distilled water and add these washings to the flask.
- Fill the flask to the line with distilled water and shake thoroughly.
- Label this solution **FA 4**.

**Titration**

- Fill the burette with **FA 2**.
- Pipette 25.0 $cm^3$ of **FA 4** into a conical flask.
- Use the 25 $cm^3$ measuring cylinder to add 15 $cm^3$ of **FA 3** to the conical flask.
- Add **FA 2** from the burette until the solution in the flask turns a permanent pink.
- Carry out a rough titration and record your burette readings in the space below.

rough titre = .............................. $cm^3$

- Carry out as many accurate titrations as you think are necessary to obtain consistent results.
- Make sure that your recorded results show the precision of your practical work.
- Record in a suitable format, in the space below, all your burette readings and the volume of **FA 2** added in each accurate titration.

| | |
|---|---|
| I | |
| II | |
| III | |
| IV | |
| V | |
| VI | |
| VII | |
| VIII | |

[8]

**(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 4** required .............................. $cm^3$ of **FA 2**. [1]

**(c) Calculations**

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

**(ii)** Calculate the amount, in mol, of manganate(VII) ions in the volume recorded in **(b)**.

amount of $MnO_4^-$ = .............................. mol [1]

**(iii)** Calculate the amount, in mol, of iron(II) ions in the weighed sample of **FA 1**.

amount of $Fe^{2+}$ = .............................. mol [1]

**(iv)** Calculate the percentage by mass of iron in **FA 1**. Show your working.

percentage by mass of iron = .............................. % [2]

**(d)** A student carries out the same experiment as in **(a)**. The student receives a sample of **FA 1** in a container with a lid. The student records the initial mass of the container with its lid and the sample of **FA 1**. Then the student records the mass of the container with the residue but forgets to replace the lid.

How would this error alter the student's answer to **(c)(iv)**?
Explain your answer.

..............................................................................................................................

.............................................................................................................................. [1]

**(e)** State **two** assumptions that have been made in calculating the percentage by mass of iron in **FA 1** in **(c)(iv)**.

..............................................................................................................................

..............................................................................................................................

.............................................................................................................................. [2]

[Total: 17]

**Question 2 starts on the next page.**

**2** In this experiment you will determine the percentage by mass of magnesium in a hydrated salt, Mg**X**•7$H_2O$, where **X** represents the anion.

You will measure the loss of mass when a sample of the hydrated salt is heated to form the anhydrous salt.

**FA 5** is a pure sample of Mg**X**•7$H_2O$

**(a) Method**

- Weigh the crucible with its lid. Record the mass.
- Add all of **FA 5** to the crucible.
- Reweigh the crucible with its lid and **FA 5**. Record the mass.
- Support the crucible in the pipe-clay triangle on top of the tripod.
- Heat the crucible with the lid on **gently** for about 1 minute.
- Remove the lid and then heat strongly for a further 4 minutes.
- Replace the lid and allow the crucible to cool for at least 5 minutes.

**While the crucible is cooling you may wish to begin work on Question 3.**

- When the crucible is cool enough to handle, reweigh the crucible with its lid and its contents. Record the mass.
- Calculate and record the mass of **FA 5** used.
- Calculate and record the mass of water lost.

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

[5]

**(b) Calculations**

**(i)** Calculate the amount, in mol, of water lost.

amount of $H_2O$ lost = ............................ mol [1]

**(ii)** Calculate the percentage by mass of magnesium in **FA 5**. Show your working.

percentage by mass of Mg = .............................. % [2]

**(c)** Suggest **two** assumptions that must be made for this experiment to give an accurate value of the percentage of Mg.

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

....................................................................................................................................... [2]

[Total: 10]

**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** **(a)** **FA 6** is an acidified aqueous solution of a salt which contains two cations and one anion, all of which are listed in the Qualitative analysis notes.

**(i)** Select a reagent or reagents for use in tests to identify the two cations.
Record your observations.

[2]

**(ii)** The anion in **FA 6** is either the sulfate ion, $SO_4^{2-}$, or the sulfite ion, $SO_3^{2-}$.
Select a reagent or reagents for use in tests to identify the anion.
Record your observations.

[2]

**(iii)** Identify the ions present in **FA 6** and give their formulae.

The cations present in **FA 6** are ............................. and ............................. .

The anion present in **FA 6** is ............................. .

[2]

**(b)** Carry out the tests and record your observations.
For each test use a 1 cm depth of **FA 6** in a test-tube.

| *test* | *observations* |
|---|---|
| **Test 1**<br>Add a 1 cm depth of aqueous sodium sulfite, then | |
| add a 1 cm depth of dilute sulfuric acid.<br>**Rinse out this test-tube thoroughly.** | |
| **Test 2**<br>Add a 1 cm depth of aqueous potassium iodide, then | |
| add a few drops of starch solution. | |

[2]

**(c)** **FA 7**, **FA 8** and **FA 9** are aqueous solutions of sodium salts. Each solution contains one of the following ions: $CO_3^{2-}$, $Cl^-$, $Br^-$.

You will identify which solution contains which ion.

**(i)** Carry out the tests and record your observations.
For each test use a 1 cm depth of **FA 7**, **FA 8** or **FA 9** in a test-tube.

| *test* | *observations* | | |
|---|---|---|---|
| | **FA 7** | **FA 8** | **FA 9** |
| Add a few drops of aqueous silver nitrate, then | | | |
| add aqueous ammonia. | | | |

[3]

**(ii)** If your results are insufficient to identify which anion is present in each solution, carry out a further test. Record your test and observations.

[1]

**(iii)** Identify which solution contains which ion.

The $CO_3^{2-}$ ion is present in .............................. .

The $Cl^-$ ion is present in .............................. .

The $Br^-$ ion is present in .............................. .

[1]

[Total: 13]

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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.<br>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<br>insoluble in excess | green ppt. turning brown on contact with air<br>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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>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;<br>decolourises acidified aqueous $KMnO_4$ |
| sulfate, $SO_4^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (insoluble in excess dilute strong acids);<br>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);<br>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)<br>$V_m = 24.0\,dm^3\,mol^{-1}$ 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 | 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 – | 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 – |