* 0019656615801 *

Cambridge Assessment International Education

# Cambridge International AS & A Level

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

Paper 3 Advanced Practical Skills 1 **May/June 2024**

**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 **12** pages.

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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** When ammonium compounds are heated with sodium hydroxide or calcium hydroxide, ammonia is liberated. The ionic equation for the reaction is shown.

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$$

**FA 1** is prepared by heating 10.0 $cm^3$ of aqueous ammonium chloride, $NH_4Cl(aq)$, with 25.0 $cm^3$ of 2.00 mol $dm^{-3}$ sodium hydroxide, NaOH. The sodium hydroxide is in excess. The reaction mixture is cooled and diluted to 250 $cm^3$ with distilled water.

You will determine the concentration of the aqueous solution of ammonium chloride by titrating the remaining sodium hydroxide from the preparation of **FA 1** with a known concentration of sulfuric acid.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

**FA 2** is 0.0520 mol $dm^{-3}$ sulfuric acid, $H_2SO_4$.
**FA 3** is bromophenol blue indicator.

**(a) Method**

- Fill the burette with **FA 2**.
- Pipette 25.0 $cm^3$ of **FA 1** into a conical flask.
- Add a few drops of **FA 3** to the conical flask.
- Perform 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 precision of your practical work.
- Record, in a suitable form in the space below, all your burette readings and the volume of **FA 2** added in each accurate titration.

**Results**

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

[7]



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**(b)** From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 $cm^3$ of **FA 1** required ..... $cm^3$ of **FA 2**. [1]

**(c) Calculations**

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

**(ii)** Calculate the amount, in mol, of sulfuric acid present in the volume of **FA 2** in **(b)**.

amount of $H_2SO_4$ = ..... mol [1]

**(iii)** Use your answer to **(c)(ii)** to calculate the amount, in mol, of sodium hydroxide in 25.0 $cm^3$ of **FA 1**.

amount of NaOH = ..... mol [1]

**(iv)** Use your answer to **(c)(iii)** and the information given to calculate the amount, in mol, of sodium hydroxide that reacted with the ammonium chloride when **FA 1** was prepared.

amount of NaOH that reacted with $NH_4Cl$ = ..... mol [2]

**(v)** Use your answer to **(c)(iv)** and the information given to calculate the concentration, in mol $dm^{-3}$, of the ammonium chloride solution used to prepare **FA 1**.

concentration of $NH_4Cl$ = ..... mol $dm^{-3}$ [1]

**(d)** When ammonia gas is prepared by heating one of its salts with calcium hydroxide, it can be dried by passing it through a drying agent.
Drying agents for gases include calcium oxide, calcium sulfate, concentrated sulfuric acid and phosphorus(V) oxide.

Select **one** of these drying agents and suggest why it is **not** suitable for drying ammonia gas.

..... is **not** suitable because .....

..... [1]

[Total: 15]



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**2** A sample of ammonium bromide has been accidentally mixed with another salt.

A student suggests that the percentage purity of the ammonium bromide can be determined by measuring the change in temperature when a solution is prepared. The enthalpy change when the sample dissolves in water, $\Delta H$, can then be calculated and compared with the literature value for ammonium bromide. You will carry out the student's experiment.

**FA 4** is ammonium bromide, $NH_4Br$, mixed with another salt.

**(a) Method**

- Support the cup in the 250 $cm^3$ beaker.
- Use the 25 $cm^3$ measuring cylinder to transfer 25.0 $cm^3$ of distilled water into the cup.
- Place the thermometer in the water and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of the water in the space for results.
- Weigh the container with **FA 4**. Record the mass.
- Add all of **FA 4** to the water in the cup.
- Stir the mixture gently so that **FA 4** dissolves.
- Measure and record the minimum temperature reached.
- Calculate and record the change in temperature.
- Weigh the container with any residual **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** added to the cup.

**Results**

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

[4]

**(b) (i)** Calculate the energy change, in J, for the reaction.

energy change = ..... J [1]

**(ii)** When one mole of ammonium bromide dissolves in water the enthalpy change, $\Delta H$, is $+16.8\,kJ\,mol^{-1}$.

Use this value to calculate the amount, in mol, of ammonium bromide in the 25.0 $cm^3$ of solution **FA 4** used in your experiment.

Assume that the enthalpy change when the other salt dissolves in water is $0\,kJ\,mol^{-1}$.

amount of $NH_4Br$ in 25.0 $cm^3$ = ..... mol [1]



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**(iii)** Calculate the mass, in g, of ammonium bromide in your sample.

(If you were unable to calculate the amount of ammonium bromide in **(b)(ii)**, then assume it is $2.06 \times 10^{-2}$ mol. This may **not** be the correct answer.)

mass of $NH_4Br$ in sample = ..... g [1]

**(iv)** Hence calculate the percentage by mass of ammonium bromide in your sample.

% by mass of $NH_4Br$ = ..... % [1]

**(c)** Another student states that this method is **not** accurate as the enthalpy change when the other salt dissolves in water could be exothermic.

Suggest how the calculated value in **(b)(iv)** would change if the other salt dissolves in water exothermically. Explain your answer.

.....

.....

..... [1]

**(d)** The maximum uncertainty in a single thermometer reading is ±0.5 °C.

Calculate the maximum percentage error in your temperature change recorded in **(a)**. Show your working.

maximum percentage error = ..... % [1]

[Total: 10]



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**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. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

**3** **(a)** **FA 5** is a mixture containing two cations and two anions. Three of the ions are listed in the Qualitative analysis notes.

**(i)** Carry out the following tests and record your observations in Table 3.1.

**Table 3.1**

| *test* | *observations* |
|---|---|
| **Test 1**<br>Heat a spatula measure of **FA 5** in a hard-glass test-tube. | |
| **Test 2**<br>Put a 2 cm depth of dilute nitric acid in a boiling tube. Add a spatula measure of **FA 5**. | |
| Dilute the solution from Test 2 with an equal volume of distilled water.<br>**Keep the resulting solution for use in (a)(ii)**. This solution is **FA 6.** | |

[3]



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**(ii)** Carry out the following tests using a 1 cm depth of **FA 6** in a test-tube for each test. Record your observations in Table 3.2.

**Table 3.2**

| *test* | *observations* |
|---|---|
| **Test 1**<br>Add a 1 cm depth of sodium chlorate(I),<br>then | |
| add aqueous sodium thiosulfate dropwise. | |
| **Test 2**<br>Add aqueous sodium hydroxide. | |
| **Test 3**<br>Add aqueous ammonia. | |
| **Test 4**<br>Add a 1 cm depth of aqueous copper(II) sulfate,<br>then | |
| add aqueous sodium thiosulfate dropwise until no further change occurs. | |
| **Test 5**<br>Add a few drops of aqueous silver nitrate,<br>then | |
| add aqueous ammonia until no further change occurs. | |

[4]

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**(iii)** **FA 5** reacts with nitric acid to make **FA 6** in Test 2 in Table 3.1.

State a change you would see in one of the observations in Table 3.2 if hydrochloric acid had been used to prepare **FA 6**.

.....

..... [1]

**(iv)** Use your observations in **(a)(i)** and **(a)(ii)** to identify the formulae of three of the ions present in **FA 5**.

Formulae of ions present are ..... and ..... and ..... .
[2]

**(b)** **FA 7**, **FA 8** and **FA 9** are each known to be propan-1-ol, propanal, propanoic acid or propanone. No two liquids are identical.

**(i)** You will carry out tests to identify samples of **FA 7**, **FA 8** and **FA 9**.

Test 1 has been carried out for you.

Carry out Test 2 and record your observations in Table 3.3.

**Table 3.3**

| *test* | *observations* | | |
|---|---|---|---|
| | **FA 7** | **FA 8** | **FA 9** |
| **Test 1**<br>Put a 1 cm depth in a test-tube. Add a few drops of 2,4-dinitrophenylhydrazine (2,4-DNPH reagent). | orange precipitate | orange precipitate | no change |
| **Test 2**<br>Put a 1 cm depth in a test-tube. Add a small spatula measure of solid sodium carbonate. | | | |

[1]

**(ii)** State what you can deduce from Tests 1 and 2 in Table 3.3 about the functional group present in each of **FA 7**, **FA 8** and **FA 9**.

.....

.....

..... [2]



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**(iii)** Describe a test to identify **FA 7** and **FA 8** using the reagents provided.

Carry out your test. Record your observations and conclusions.

test .....

.....

observations .....

.....

**FA 7** is ..... .

**FA 8** is ..... .

[2]

[Total: 15]

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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 $H^+$ |



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**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 | $c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$) |



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## The Periodic Table of Elements

**Key**

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

| Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 | Group 8 | Group 9 | Group 10 | Group 11 | Group 12 | Group 13 | Group 14 | Group 15 | Group 16 | Group 17 | Group 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 | | | | | | | | | | | 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>– | 113<br>**Nh**<br>nihonium<br>– | 114<br>**Fl**<br>flerovium<br>– | 115<br>**Mc**<br>moscovium<br>– | 116<br>**Lv**<br>livermorium<br>– | 117<br>**Ts**<br>tennessine<br>– | 118<br>**Og**<br>oganesson<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>144.2 | 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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