# Cambridge International AS & A Level

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

| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | | |
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* 5 5 2 6 7 5 2 9 1 6 *

**CHEMISTRY** **9701/34**

Paper 3 Advanced Practical Skills 2 **May/June 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.

**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** You will carry out a titration to determine the concentration of a solution of potassium manganate(VII). You will react potassium manganate(VII) with excess acidified potassium iodide to produce iodine. You will then titrate the iodine with sodium thiosulfate.

**FB 1** is hydrated sodium thiosulfate, $Na_2S_2O_3{\bullet}5H_2O$.
**FB 3** is aqueous potassium manganate(VII), $KMnO_4$.
**FB 4** is 0.50 mol dm$^{-3}$ potassium iodide, KI.
**FB 5** is dilute sulfuric acid, $H_2SO_4$.
starch indicator

**(a) Method**

**Preparing a solution of FB 1**

- Weigh the stoppered container of **FB 1**. Record the mass in the space below.
- Tip all the **FB 1** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FB 1** used.
- Add approximately 100 cm$^3$ of distilled water to the **FB 1** in the beaker.
- Stir the mixture with a glass rod until all the **FB 1** has dissolved.
- Transfer this solution into the 250 cm$^3$ volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make the solution in the volumetric flask up to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of sodium thiosulfate is **FB 2**. Label the flask **FB 2**.

**Titration**

- Fill the burette with **FB 2**.
- Pipette 25.0 cm$^3$ of **FB 3** into a conical flask.
- Use the 25 cm$^3$ measuring cylinder to add 15 cm$^3$ of **FB 5** to the conical flask.
- Use the same measuring cylinder to add 10 cm$^3$ of **FB 4** to the conical flask.
- Perform a rough titration by adding **FB 2** from the burette to the conical flask until the solution is yellow. Then add several drops of starch indicator and continue the titration until the mixture in the flask becomes colourless. This is the end-point.

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 below all of your burette readings and the volume of **FB 2** added in each accurate titration.

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

[8]

**(b)** From your accurate titration results, obtain a suitable value for the volume of **FB 2** to be used in your calculations.
Show clearly how you obtained this value.

The iodine produced by **FB 3** required .............................. $cm^3$ of **FB 2**. [1]

**(c) Calculations**

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

**(ii)** Calculate the number of moles of hydrated sodium thiosulfate, **FB 1**, that you weighed.

moles of $Na_2S_2O_3{\bullet}5H_2O$ = .............................. mol [1]

**(iii)** Calculate the number of moles of sodium thiosulfate in the volume of **FB 2** calculated in **(b)**.

moles of $Na_2S_2O_3$ = .............................. mol [1]

**(iv)** The reaction by which iodine is produced is shown.

$$2KMnO_4(aq) + 10KI(aq) + 8H_2SO_4(aq) \rightarrow 6K_2SO_4(aq) + 2MnSO_4(aq) + 5I_2(aq) + 8H_2O(l)$$

During the titration, sodium thiosulfate reacts with the iodine produced.

$$2Na_2S_2O_3(aq) + I_2(aq) \rightarrow 2NaI(aq) + Na_2S_4O_6(aq)$$

Use your answer to **(c)(iii)** to calculate the concentration of $KMnO_4$, in mol dm$^{-3}$, in **FB 3**.

concentration of $KMnO_4$ = .............................. mol dm$^{-3}$ [1]

**(v)** Calculate the mass of $KMnO_4$ needed to prepare 1.00 dm$^3$ of **FB 3**. Show your working.

mass of $KMnO_4$ = .............................. g [1]

**(d) (i)** Solution **FB 3** was actually prepared by dissolving 3.16 g of $KMnO_4$ in 1.00 dm$^3$ of solution.

Show how you would use your answer to **(c)(v)** to calculate the overall percentage error in your experiment.

[1]

**(ii)** A student suggested that the percentage error in the experiment would be reduced by using a 10 cm$^3$ pipette to measure **FB 4**.

State whether the student is correct. Explain your answer.

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

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

[Total: 16]

**2** You will determine the enthalpy change for the reaction of ammonia with hydrogen chloride.

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

The procedure will involve two experiments.

**FB 6** is 2.0 mol dm$^{-3}$ aqueous ammonia, $NH_3$.
**FB 7** is 3.0 mol dm$^{-3}$ hydrochloric acid, $HCl$.
**FB 8** is ammonium chloride, $NH_4Cl$.

**(a) Experiment 1: Determination of the enthalpy change of neutralisation of aqueous ammonia with hydrochloric acid**

$$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$$

**(i)**

- Support a cup in the beaker.
- Use the 50 cm$^3$ measuring cylinder to transfer 30.0 cm$^3$ of **FB 6** into the cup.
- Measure and record the temperature of the solution in the cup.
- Rinse the 25 cm$^3$ measuring cylinder with water and then with a little **FB 7**.
- Use the 25 cm$^3$ measuring cylinder to add 25.0 cm$^3$ of **FB 7** to the **FB 6** in the cup.
- Stir the mixture.
- Measure and record the maximum temperature.
- Calculate and record the temperature rise.

[2]

**(ii)** Calculate the energy released in your experiment.
(Assume that 4.2 J change the temperature of 1.0 cm$^3$ of solution by 1.0 °C.)

energy released = .............................. J [1]

**(iii)** Calculate the enthalpy change of reaction, $\Delta H_1$, in kJ mol$^{-1}$, for the neutralisation of $NH_3$(aq) with $HCl$(aq).
Show your working.

$\Delta H_1$ = ...... .............................. kJ mol$^{-1}$
*sign* *value*

[2]

**(b) Experiment 2: Determination of the enthalpy change of solution of ammonium chloride**

$$NH_4Cl(s) + aq \rightarrow NH_4Cl(aq)$$

**(i)**

- Support a cup in the beaker.
- Rinse the 50 $cm^3$ measuring cylinder with distilled water.
- Use the 50 $cm^3$ measuring cylinder to transfer 30.0 $cm^3$ of distilled water into the second cup.
- Measure and record the temperature of the water in the cup.
- Weigh the container with **FB 8**. Record the mass.
- Tip all of the **FB 8** into the water in the cup.
- Stir until all **FB 8** dissolves and record the minimum temperature observed.
- Calculate and record the temperature change.
- Weigh and record the mass of the container with any residual **FB 8**.
- Calculate and record the mass of **FB 8** used.

[3]

**(ii)** Calculate the enthalpy change of solution, $\Delta H_2$, in $kJ\,mol^{-1}$, for **FB 8**, ammonium chloride. (Assume that 4.2 J change the temperature of 1.0 $cm^3$ of solution by 1.0 °C.)

$\Delta H_2$ = ...... ............................. $kJ\,mol^{-1}$
*sign* *value*

[2]

**(c)** The values for the enthalpy changes of solution of ammonia and hydrogen chloride are given.

$$NH_3(g) + aq \rightarrow NH_3(aq) \qquad \Delta H = -30.5\,kJ\,mol^{-1}$$

$$HCl(g) + aq \rightarrow HCl(aq) \qquad \Delta H = -74.8\,kJ\,mol^{-1}$$

From your answers to **(a)(iii)**, **(b)(ii)** and the data above, use Hess' Law to calculate the enthalpy change, $\Delta H_r$, in kJ mol$^{-1}$, for the reaction below.

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

$\Delta H_r$ = ...... ............................ kJ mol$^{-1}$
*sign* *value*

[1]

[Total: 11]

**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)** **FB 9** contains one anion and one cation both of which are listed in the Qualitative Analysis Notes.

**(i)** Heat a small spatula measure of **FB 9** strongly in a hard-glass test-tube.
Allow the test-tube and contents to cool.
Record all your observations.

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

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

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

**(ii)** Add a small spatula measure of **FB 9** to a 3 cm depth of dilute sulfuric acid in a test-tube.
Record all your observations.

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

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

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

**(iii)** If necessary, pour off the solution obtained in **(a)(ii)** in order to separate it from any remaining solid.
Divide this solution into two equal portions in boiling tubes.
Carry out the following tests and record your observations.

To the first boiling tube add aqueous sodium hydroxide.

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

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

To the second boiling tube add aqueous ammonia.

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

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

**(iv)** Suggest the identity of **FB 9**.

**FB 9** is ..................................................... . [1]

**(b)** **FB 10** contains one anion and one cation.

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

| *test* | *observations* |
|---|---|
| **Test 1**<br>To a 1 cm depth of aqueous copper(II) nitrate in a boiling tube, add an equal volume of **FB 10**, then | |
| warm the mixture gently and carefully. Then | |
| add one piece of aluminium foil. | |
| **Test 2**<br>Warm a 1 cm depth of **FB 10** gently in a boiling tube. Add one piece of aluminium foil. Allow the reaction to continue for one minute, then | |
| decant the solution into a boiling tube and add dilute hydrochloric acid until in excess. | |
| **Test 3**<br>To a 1 cm depth of aqueous chromium(III) sulfate in a test-tube, add **FB 10** dropwise. | |

[5]

**(ii)** Deduce the identity of the ions in **FB 10**.
If you were unable to deduce the identity of an ion, write 'unknown'.

| cation | anion |
|---|---|
| | |

[1]

[Total: 13]

**Qualitative analysis notes**

## 1 Reactions of aqueous cations

| *ion* | *reaction with* | |
|---|---|---|
| | NaOH(aq) | $NH_3$(aq) |
| aluminium, $Al^{3+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>insoluble in excess |
| ammonium, $NH_4^+$(aq) | no ppt.<br>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.<br>soluble in excess | grey-green ppt.<br>insoluble in excess |
| copper(II), $Cu^{2+}$(aq) | pale blue ppt.<br>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.<br>insoluble in excess | red-brown ppt.<br>insoluble in excess |
| magnesium, $Mg^{2+}$(aq) | white ppt.<br>insoluble in excess | white ppt.<br>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.<br>soluble in excess | white ppt.<br>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 A$l$ foil |
| nitrite, $NO_2^-$(aq) | $NH_3$ liberated on heating with $OH^-$(aq) and A$l$ 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 A*l* aluminium 27.0 | 14 Si silicon 28.1 | 15 P phosphorus 31.0 | 16 S sulfur 32.1 | 17 C*l* 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 T*l* 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 F*l* 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 – |