# Cambridge Assessment International Education

## Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

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

Paper 3 Advanced Practical Skills 1 **February/March 2020**

**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.

**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.

| Session |
| --- |
|  |

| Laboratory |
| --- |
|  |

| For Examiner's Use | |
| --- | --- |
| 1 | |
| 2 | |
| 3 | |
| Total | |

This document has **12** pages. Blank pages are indicated.

**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 The concentrations of solutions of hydrogen peroxide are often represented in terms of 'volume strength'. In this experiment you will determine the 'volume strength' of a solution of hydrogen peroxide by titration with acidified potassium manganate(VII).

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$
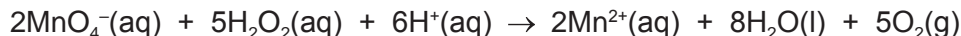
**FA 1** is 0.0300 mol dm$^{-3}$ potassium manganate(VII), $KMnO_4$.
**FA 2** is dilute sulfuric acid, $H_2SO_4$.
**FA 3** is aqueous hydrogen peroxide, $H_2O_2$.

**(a) Method**

**Dilution of FA 3**

● Pipette 25.0 cm$^3$ of **FA 3** into the 250 cm$^3$ volumetric flask.
● Make the solution up to the mark using distilled water.
● Shake the flask thoroughly.
● Label this diluted solution of hydrogen peroxide **FA 4**.

**Titration**

● Fill the burette with **FA 1**.
● Rinse the pipette thoroughly with distilled water and then with a little **FA 4**.
● Pipette 25.0 cm$^3$ of **FA 4** into a conical flask.
● Use the 25 cm$^3$ measuring cylinder to add 20 cm$^3$ of **FA 2** into the same 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 all of your burette readings and the volume of **FA 1** added in each accurate titration.

**Keep FA 1, FA 2 and FA 3 for use in Questions 2 and 3.**

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

[7]

**(b)** From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm³ of **FA 4** required .............................. cm³ of **FA 1**.  [1]

**(c) Calculations**

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

    **(ii)** Calculate the number of moles of potassium manganate(VII) present in the volume calculated in **(b)**.

moles of $KMnO_4$ = .............................. mol  [1]

    **(iii)** The equation for the reaction of potassium manganate(VII) with hydrogen peroxide is shown.

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$
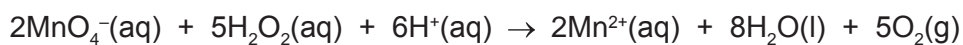
Use your answer to **(c)(ii)** to calculate the number of moles of hydrogen peroxide used in each titration.

moles of $H_2O_2$ = .............................. mol

Hence calculate the concentration of $H_2O_2$ in **FA 4**, in mol dm⁻³.

concentration of $H_2O_2$ in **FA 4** = .............................. mol dm⁻³
[1]

**(iv)** Calculate the concentration of $H_2O_2$ in **FA 3**, in $mol\,dm^{-3}$.

concentration of $H_2O_2$ in **FA 3** = ............................. $mol\,dm^{-3}$ [1]

**(v)** When hydrogen peroxide decomposes in the presence of a catalyst, oxygen is produced.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$
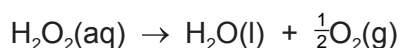
The 'volume strength' of hydrogen peroxide is equal to the volume of oxygen, in $dm^3$, produced under room conditions, when $1.00\,dm^3$ of the solution decomposes.

Use your answer to **(c)(iv)** and the equation above to calculate the volume, in $dm^3$, of oxygen produced when $1.00\,dm^3$ of **FA 3** decomposes. This is the 'volume strength', in vol, of **FA 3**.

(Under room conditions $1.00\,mol$ of gas occupies a volume of $24.0\,dm^3$.
If you were unable to calculate the concentration of $H_2O_2$ in **FA 3**, assume that it is $1.02\,mol\,dm^{-3}$. This may **not** be the correct value.)

'volume strength' of **FA 3** = ............................. vol [2]

**(d)** The maximum error in reading a $25.0\,cm^3$ pipette is $\pm0.06\,cm^3$.

Show by calculation that the pipette is more accurate than a burette for measuring $25.0\,cm^3$ of solution.

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

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

[Total: 15]

5

**2** In this experiment you will determine the enthalpy change, $\Delta H$, for the catalytic decomposition of hydrogen peroxide into water and oxygen.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$
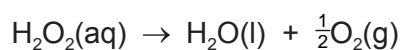
**FA 3** is aqueous hydrogen peroxide, $H_2O_2$.
**FA 5** is manganese(IV) oxide, $MnO_2$.

**(a) Method**

**Experiment 1**

- Support one of the plastic cups inside the $250\,cm^3$ beaker.
- Use the $50\,cm^3$ measuring cylinder to add $30\,cm^3$ of **FA 3** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the plastic cup.
- Stir constantly until the maximum temperature is reached and record this temperature.
- Calculate and record the temperature rise.
- Rinse and dry the thermometer.

**Experiment 2**

- Support the second plastic cup inside the $250\,cm^3$ beaker.
- Use the $50\,cm^3$ measuring cylinder to add $40\,cm^3$ of **FA 3** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the plastic cup.
- Stir constantly until the maximum temperature is reached and record this temperature.
- Calculate and record the temperature rise.

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

[5]

**(b) Calculation**

**(i)** Calculate the energy released in **Experiment 1**.
[Assume that 4.2 J changes the temperature of 1.0 cm³ of solution by 1.0 °C.]

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

**(ii)** Use your answer to **1(c)(iv)** to calculate the number of moles of hydrogen peroxide used in **Experiment 1**.
(If you were unable to calculate the concentration of $H_2O_2$ in **FA 3**, assume that it is 1.02 mol dm⁻³. This may **not** be the correct value.)

moles of $H_2O_2$ = .............................. mol  [1]

**(iii)** Calculate the enthalpy change, in kJ mol⁻¹, for the decomposition of 1 mole of hydrogen peroxide into water and oxygen.

enthalpy change = ......  ............................ kJ mol⁻¹  [1]
                  *sign*           *value*

**(c) (i)** A student suggested that the experiment would be more accurate if the same mass of **FA 5**, manganese(IV) oxide, had been weighed out for each experiment.

State and explain whether you agree with the student's suggestion.

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

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

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

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

**(ii)** The student also suggested that **Experiments 1** and **2** should give the same temperature rise, even though a greater volume of **FA 3** was used in **Experiment 2**.

State and explain whether you agree with the student's suggestion.

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

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

............................................................................................................................. [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)**  **FA 3** is aqueous hydrogen peroxide, $H_2O_2$.
         **FA 6** is a solution containing two cations and one anion from those listed in the Qualitative analysis notes.

    **(i)**   To a 1 cm depth of **FA 6** in a boiling tube, add aqueous sodium hydroxide until it is in excess. Then heat the tube, gently and carefully.
             Keep the mixture obtained in the boiling tube for the test in **(a)(ii)**.

             Record **all** your observations.
             Identify the cations in **FA 6**.

             observations ................................................................................................................

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

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

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

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

             **FA 6**: cations are ................................................... and ...................................................
                                                                                                                    [4]

    **(ii)**  To the mixture obtained from **(a)(i)**, carefully add a 1 cm depth of **FA 3**.
             Record your observations.

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

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

    **(iii)** One reaction taking place in **(a)(ii)** involves oxidation of one of the cations in **FA 6**.

             Give the half-equation to show this oxidation reaction. State symbols are not required.

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

(b) **FA 1** is aqueous potassium manganate(VII).
    **FA 2** is dilute sulfuric acid.
    **FA 7** and **FA 8** are solutions, each containing one cation and one anion.

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

| test | observations | |
| --- | --- | --- |
| | **FA 7** | **FA 8** |
| **Test 1**<br>To a 1 cm depth of solution in a test-tube, add a small spatula measure of solid sodium carbonate. | | |
| **Test 2**<br>To a 1 cm depth of solution in a test-tube, add an equal volume of **FA 2** and a few drops of **FA 1**, then | | |
| add a few drops of aqueous starch. | | |
| **Test 3**<br>To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate, then | | |
| add aqueous ammonia. | | |

[5]

(ii) Identify the anion in **FA 7**.

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

(iii) Identify **FA 8**.

**FA 8** is .................................................................................................................. [1]

(iv) Carry out one further test to confirm the identity of the cation in **FA 8**.
State the name of the reagent you used and record the observation(s) you made.

reagent ........................................................................................................................

observation(s) ..............................................................................................................

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

[1]

[Total: 14]

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**10**

## Qualitative analysis notes

### 1 Reactions of aqueous cations

| ion | 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 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. soluble in excess | 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 |

## 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 |

## The Periodic Table of Elements

Group

**Key**

atomic number
**atomic symbol**
name
relative atomic mass

| 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>– |