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.

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. Blank pages are indicated.

[Turn over

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).

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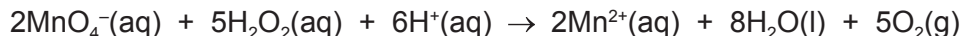
FA 1 is $0.0300\,mol\,dm^{-3}$ potassium manganate(VII), $KMnO_4$.
FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is aqueous hydrogen peroxide, H_2O_2.

(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 cm^3 of **FA 4** required .... cm^3 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.

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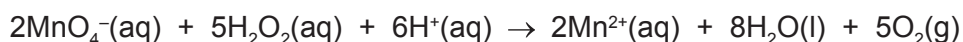
Use your answer to **(c)(ii)** to calculate the number of moles of hydrogen peroxide used in each titration.

moles of H$_2$O$_2$ = ... mol

Hence calculate the concentration of H$_2$O$_2$ in **FA 4**, in mol dm^{-3}.

concentration of H$_2$O$_2$ in **FA 4** = ... mol dm^{-3}
[1]

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

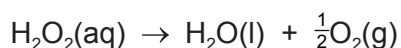concentration of H_2O_2 in **FA 3** = ... $mol\,dm^{-3}$ [1]

(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]

2 In this experiment you will determine the enthalpy change, ΔH, for the catalytic decomposition of hydrogen peroxide into water and oxygen.

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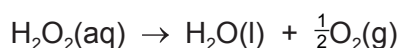
FA 3 is aqueous hydrogen peroxide, H_2O_2.
FA 5 is manganese(IV) oxide, MnO_2.

(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 To a 1 cm depth of solution in a test-tube, add a small spatula measure of solid sodium carbonate.		
Test 2 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 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]

BLANK PAGE

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		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 –	113	114 **F*l*** flerovium –	115	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 –