

# Cambridge International AS & A Level

CANDIDATE  
NAME

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CENTRE  
NUMBER

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NUMBER

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## CHEMISTRY

9701/51

Paper 5 Planning, Analysis and Evaluation

May/June 2021

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

## INSTRUCTIONS

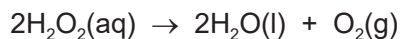
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction 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.

## INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **8** pages. Any blank pages are indicated.

- 1 Hydrogen peroxide decomposes slowly at room temperature to give water and oxygen.



The **initial** rate of this reaction can be increased by the addition of a metal oxide catalyst.

A student is asked to investigate which metal oxide catalyst is best at increasing the **initial** rate of this reaction by using a method which involves the collection of oxygen.

The student is provided with the following metal oxides: copper(II) oxide, iron(III) oxide, manganese(IV) oxide, nickel(II) oxide and titanium(IV) oxide.

The student is also provided with an excess volume, of a known concentration, of aqueous hydrogen peroxide and any laboratory equipment needed.

- (a) (i) State the independent variable.

..... [1]

- (ii) State the dependent variable.

..... [1]

- (b) State two variables that would need to be controlled.

1 .....

2 .....

[2]

- (c) Draw a labelled diagram of the assembled apparatus that could be used to carry out these experiments. The apparatus should allow the accurate recording of the oxygen produced.

[3]

- (d) (i) What measurements need to be recorded during the course of each experiment to allow the **initial** rate to be determined?

..... [1]

- (ii) How is the **initial** rate determined using these measurements?

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

- (e) How can the student ensure that the results are reliable?

..... [1]

- (f) Suggest an alternative method to investigate these reactions which does not include the collection of gas.

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

- (g) Once the reaction has finished, how can the student demonstrate that the metal oxide has not been affected by the reaction?

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

- (h) When aqueous hydrogen peroxide is stored there is a small hole in the lid of the bottle.

Suggest why this is necessary.

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

[Total: 14]

- 2 A student is given 250.0 cm<sup>3</sup> of solution containing a mixture of Fe<sup>2+</sup> and Fe<sup>3+</sup> ions. The student is asked to find the total mass of iron ions and the percentage by mass of Fe<sup>3+</sup> in the solution by performing titrations with aqueous potassium manganate(VII), KMnO<sub>4</sub>.

The student is told that the Fe<sup>3+</sup>(aq) ions can be reduced to Fe<sup>2+</sup>(aq) ions by reaction with zinc.

The student is given the following instructions.

- Calculate the mass of KMnO<sub>4</sub> needed to make 500.0 cm<sup>3</sup> of 0.0200 mol dm<sup>-3</sup> KMnO<sub>4</sub>(aq).
- Record the mass of an empty plastic weighing boat (a small container used to hold solid samples).
- Add the calculated mass of KMnO<sub>4</sub> to the weighing boat.
- Transfer the KMnO<sub>4</sub> from the weighing boat into a 100 cm<sup>3</sup> beaker.
- Add 50 cm<sup>3</sup> of distilled water to the beaker.
- Transfer the mixture from the beaker into a 500.0 cm<sup>3</sup> volumetric flask.
- Make up to the graduation mark, dropwise, with distilled water.

- (a) (i) Calculate the mass of KMnO<sub>4</sub> needed to make 500.0 cm<sup>3</sup> of 0.0200 mol dm<sup>-3</sup> KMnO<sub>4</sub>(aq).

[A<sub>r</sub>: K, 39.1; Mn, 54.9; O, 16.0]

mass of KMnO<sub>4</sub> needed = ..... g [1]

- (ii) The student used a balance accurate to two decimal places.

Calculate the percentage error in weighing the mass of the KMnO<sub>4</sub> by difference.

If you were unable to calculate a value for **2(a)(i)** use the mass 1.75 g. This is **not** the correct answer to **2(a)(i)**. Show your working.

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

- (iii) The student noticed that some crystals of KMnO<sub>4</sub> were stuck to the weighing boat after adding the KMnO<sub>4</sub> solid to the beaker.

State how the student should modify the instructions to ensure that the measured mass of KMnO<sub>4</sub> was accurate.

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

- (iv) Give two additional instructions that should be given to the student to ensure that the solution is prepared as accurately as possible.

1 .....

.....

2 .....

.....

[2]

- (b) When the  $\text{KMnO}_4(\text{aq})$  is ready for use, the student is given additional instructions.

**step 1** Fill a burette with  $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4(\text{aq})$ .

**step 2** Using a measuring cylinder, transfer  $25.00 \text{ cm}^3$  of  $\text{Fe}^{2+}(\text{aq})/\text{Fe}^{3+}(\text{aq})$  solution into a conical flask.

**step 3** Add  $10 \text{ cm}^3$  of  $1.0 \text{ mol dm}^{-3}$  sulfuric acid to the conical flask.

**step 4** Titrate this acidified solution of  $\text{Fe}^{2+}(\text{aq})/\text{Fe}^{3+}(\text{aq})$  with  $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4(\text{aq})$  until the end-point.

**step 5** Repeat titrations until the titres are concordant.  
This set of results is **set A**.

**step 6** Using a measuring cylinder, add  $100 \text{ cm}^3$  of the  $\text{Fe}^{2+}(\text{aq})/\text{Fe}^{3+}(\text{aq})$  solution into a beaker then add excess zinc. Allow time for reduction to  $\text{Fe}^{2+}(\text{aq})$  to take place.

**step 7** Filter the mixture into a beaker.

**step 8** Transfer  $25.00 \text{ cm}^3$  of the filtrate into a conical flask and add  $10 \text{ cm}^3$  of  $1.0 \text{ mol dm}^{-3}$  sulfuric acid.

**step 9** Titrate this acidified solution of the filtrate with  $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4(\text{aq})$  until the end-point.

**step 10** Repeat **steps 8** and **9** twice.  
This set of results is **set B**.

- (i) How should the burette be prepared for use before it is filled in **step 1**?

.....

..... [1]

- (ii) What must be done to ensure as accurate an end-point as possible?

.....

..... [1]

- (c) (i) Identify an experimental weakness in **step 2**. Explain how this would affect the results.

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

- (ii) How could this weakness be overcome?

..... [1]

- (d) The results for each set of titrations are shown.

**set A**

	rough	titration 1	titration 2	titration 3
final volume / cm <sup>3</sup>	18.40	17.25	34.55	18.00
initial volume / cm <sup>3</sup>	0.65	0.15	17.25	0.95
titre / cm <sup>3</sup>				

**set B**

	rough	titration 1	titration 2	titration 3
final volume / cm <sup>3</sup>	45.05	43.60	43.70	
initial volume / cm <sup>3</sup>	0.20	0.15	0.10	
titre / cm <sup>3</sup>				

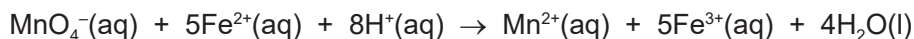
- (i) Complete both tables and calculate an appropriate average titre for each set of results. The student could **not** carry out titration 3 in **set B**.

Record the average titre to **one decimal place**.

**set A** average titre = ..... cm<sup>3</sup>

**set B** average titre = ..... cm<sup>3</sup>  
 [2]

- (ii) The reaction taking place during the titrations is shown by the equation.



Calculate the mass of  $\text{Fe}^{2+}$  ions in  $100\text{ cm}^3$  of the reduced solution, produced in **step 6**, by using the appropriate average titre from **(d)(i)**.

Give your answer to **three significant figures**.

[A<sub>r</sub>: Fe, 55.8]

mass of  $\text{Fe}^{2+}$  ions = ..... g [2]

- (iii) Calculate the mass of  $\text{Fe}^{2+}$  ions in the original  $250.0\text{ cm}^3$   $\text{Fe}^{2+}(\text{aq})/\text{Fe}^{3+}(\text{aq})$  solution, using the appropriate average titre from **2(d)(i)**.

mass of  $\text{Fe}^{2+}$  ions = ..... g [1]

- (iv) Calculate the percentage by mass of  $\text{Fe}^{3+}$  ions in the original  $250.0\text{ cm}^3$   $\text{Fe}^{2+}(\text{aq})/\text{Fe}^{3+}(\text{aq})$  solution.

percentage by mass of  $\text{Fe}^{3+}$  ions = ..... % [1]

- (v) State what change could be made to the procedure to enable titration 3 to be carried out in **set B**.

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

[Total: 16]

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