



CANDIDATE
NAME

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CENTRE
NUMBER

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NUMBER

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9701/51

May/June 2021

1 hour 15 minutes

You must answer on the question paper.

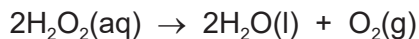
No additional materials are needed.

- 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.

- 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 cm³ of solution containing a mixture of Fe²⁺ and Fe³⁺ ions. The student is asked to find the total mass of iron ions and the percentage by mass of Fe³⁺ in the solution by performing titrations with aqueous potassium manganate(VII), KMnO₄.

The student is told that the Fe³⁺(aq) ions can be reduced to Fe²⁺(aq) ions by reaction with zinc.

The student is given the following instructions.

- Calculate the mass of KMnO₄ needed to make 500.0 cm³ of 0.0200 mol dm⁻³ KMnO₄(aq).
- Record the mass of an empty plastic weighing boat (a small container used to hold solid samples).
- Add the calculated mass of KMnO₄ to the weighing boat.
- Transfer the KMnO₄ from the weighing boat into a 100 cm³ beaker.
- Add 50 cm³ of distilled water to the beaker.
- Transfer the mixture from the beaker into a 500.0 cm³ volumetric flask.
- Make up to the graduation mark, dropwise, with distilled water.

- (a) (i) Calculate the mass of KMnO₄ needed to make 500.0 cm³ of 0.0200 mol dm⁻³ KMnO₄(aq).

[A_r: K, 39.1; Mn, 54.9; O, 16.0]

mass of KMnO₄ needed = g [1]

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

Calculate the percentage error in weighing the mass of the KMnO₄ 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 KMnO₄ were stuck to the weighing boat after adding the KMnO₄ solid to the beaker.

State how the student should modify the instructions to ensure that the measured mass of KMnO₄ 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 cm^3 of $\text{Fe}^{2+}(\text{aq})/\text{Fe}^{3+}(\text{aq})$ solution into a conical flask.

step 3 Add 10 cm^3 of 1.0 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 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 cm^3 of the filtrate into a conical flask and add 10 cm^3 of 1.0 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 ³	18.40	17.25	34.55	18.00
initial volume / cm ³	0.65	0.15	17.25	0.95
titre / cm ³				

set B

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

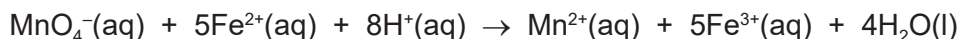
- (i) Complete both tables and calculate an appropriate average titre for each set of results. The student could **not** carry out titration 3 in **set B**.

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

set A average titre = cm³

set B average titre = cm³
 [2]

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



Calculate the mass of Fe^{2+} ions in 100 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_r : Fe, 55.8]

mass of Fe^{2+} ions = g [2]

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

mass of Fe^{2+} ions = g [1]

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

percentage by mass of 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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