Investigating the reaction between manganate(VII) and ethanedioate ions – student sheet

In this experiment you are going to use a continuous monitoring method to investigate how the rate of the reaction between ethanedioate ions, $C_2O_4^{2-}$(aq), and manganate(VII) ions, MnO_4^-(aq), changes with the concentration of MnO_4^- ions. You will then go on to investigate the effect of the addition of a small amount of Mn^{2+} ions on the reaction.

Pre-lab questions

1. Manganate(VII) ions, MnO_4^-, undergo a redox reaction in acidic solution with ethanedioate ions, $C_2O_4^{2-}$. During the reaction, the manganate(VII) ions are reduced to Mn^{2+} ions and the ethanedioate ions are oxidised to CO_2.

Write two half-equations for the oxidation and reduction processes respectively.

Combine to produce a full redox equation for the reaction.

2. In this reaction Mn^{2+} ions act as an **autocatalyst**.

Explain what an autocatalyst is.

Write equations to show how Mn^{2+} ions act as a catalyst in this reaction.

3. In this investigation you will measure the concentration of manganate(VII) ions at any time during the reaction using a colorimeter.

a. Draw a simple diagram of a colorimeter and use it to explain how a colorimeter works.

b. Potassium manganate(VII) is a deep purple colour. What colour filter should you select?

4. If you have a reaction involving **A**, with an order of reaction with respect to A of **n**, you can express this in a rate equation.

$$\textbf{Rate} = \textbf{k}[\textbf{A}]^{\textbf{n}} \quad \text{where k = the rate constant for the reaction}$$

If you take a log of both sides, the equation becomes:

$$\textbf{log(rate)} = \textbf{n log[A]} + \textbf{log k}$$

By comparing this equation to the equation of a straight line (y = mx + c) explain how you could determine the order of the reaction with respect to A, **n**, and the value of the rate constant, **k**, from a graph of log(rate) against log[A] for this reaction.

Procedure

Eye protection must be worn

Apparatus	Chemicals
burette (50 cm^3) 50 cm^3 volumetric flask / measuring cylinder (×5) colorimeter with cuvettes test tubes with rubber bungs 10 cm^3 measuring cylinder pipettes	potassium manganate(VII) solution, 0.002 mol dm^{-3} (no hazard) acidified ethanedioic acid solution* (CORROSIVE – causes severe skin burns and eye damage) manganese(II) sulfate solution, 0.02 mol dm^{-3} (no hazard) distilled water

Creating a calibration curve

1. Prepare the following solutions containing varying concentrations of MnO_4^- ions.

   Using a burette, carefully transfer the required amount of the $KMnO_4$ solution (0.002 mol dm^{-3}) into a 50 cm^3 volumetric flask or measuring cylinder and make up to 50 cm^3 with distilled water.

   Complete the table by calculating the concentration of MnO_4^-(aq) ions in each final solution.

Solution	Volume of 0.002 mol dm^{-3} $KMnO_4$ solution added / cm^3	Concentration of MnO_4^-(aq) ions in final solution / mol dm^{-3}
1	10.0	
2	7.5	
3	5.0	
4	2.5	
5	1.0	

2. Place a cuvette containing distilled water into a colorimeter and using a suitable filter adjust to 0% absorbance.
3. Place each of the solutions **1** to **5** into the colorimeter in turn and read off the corresponding absorbance.
4. Plot a graph of absorbance (y-axis) against concentration (x-axis) - **the calibration curve**.

The investigation

1. Place 2.0 cm^3 of a 0.002 mol dm^{-3} solution of potassium manganate(VII) in a test tube. Fit the tube with a rubber bung.
2. Zero a stop clock ready for use.
3. Using a small measuring cylinder, add 8.0 cm^3 of the acidified ethanedioic acid solution to the test tube containing the potassium manganate(VII) solution.

   Quickly stopper the tube, invert the tube to mix the contents and **start the stop clock**.
4. Using a teat pipette, quickly transfer some of the mixture from the test tube to a cuvette and place the cuvette in the colorimeter. Measure the absorbance of the mixture in the cuvette every 20 seconds until the absorbance drops to 0.01.
5. Using the calibration curve, convert the absorbance values obtained into concentrations of MnO_4^-.
6. Plot a graph of time against concentration of MnO_4^- ions.
7. Repeat steps 1 to 6, but this time add 1 drop of the 0.02 mol dm^{-3} solution of manganese(II) sulfate to the acidified ethanedioic acid solution before mixing.
8. Compare the two graphs. What effect does the addition of 1 drop of $Mn^{2+}(aq)$ have on the reaction? Explain why.

Further analysis

1. By determining the gradient of the curve at different points in the plot of the concentration of $MnO_4^-(aq)$ ions, $[MnO_4^-(aq)]$, against time for **the reaction in which $Mn^{2+}(aq)$ ions were added** from the start of the experiment, determine the rate of the reaction for 5 different concentrations of $MnO_4^-(aq)$ ions.
2. Plot a graph of log(rate) against $\log[MnO_4^-]$ and use it to determine the order of the reaction with respect to $MnO_4^-(aq)$ ions.