Rates and rhubarb

Rhubarb contains oxalic acid, which has the formula $C_2H_2O_4$:

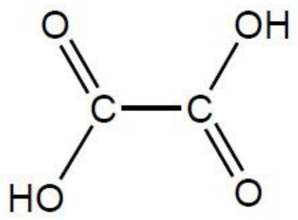

Figure 1 Structural formula of oxalic acid

Oxalic acid reacts with acidified potassium manganate(VII) and is oxidised to carbon dioxide and water:

$2\ MnO_4^- + 5\ C_2H_2O_4 + 6\ H_3O^+ \rightarrow 2\ Mn^{2+} + 10\ CO_2 + 14\ H_2O$

The potassium manganate(VII) decolourises, which provides a convenient and easy to measure end point for the reaction.

This experiment is probably most suited to less able students who do not need to be given the details of the reaction or to try to relate the rate back to the equation.

The reaction is autocatalysed (catalysed by a product of the reaction) by the Mn2+ ions. This could lead to some confusion if students analyse the results too closely.

More able students could be expected to plan their own experiment.

It is also possible to use this reaction to look at how a change in temperature affects the rate of reaction.

Timing

The practical work can easily be completed in a one hour session.

Equipment required

- Rhubarb – fresh if possible (frozen also works if the pieces are long enough and should be fine whatever the size for the concentration experiment)
- 100 cm^3 beakers (at least 2 per pair of students)
- 50 cm3 measuring cylinders
- Dilute acidified potassium manganate(VII) solution (**Irritant**) – see note below
- Timer (1 per pair)
- White tile (1 per pair)
- Knives (4–6 per class should be fine)
- 250 cm^3 beaker
- Bunsen burners, heatproof mats, tripods and gauzes
- Filter funnels and filter paper or tea strainers
- Eye protection.

Potassium manganate(VII) solution

Put 2 or 3 crystals of potassium manganate(VII) into a beaker with about 500 cm^3 distilled water and stir until the crystals dissolve. Add about 500 cm^3 2 mol dm^{-3} sulfuric acid (**Corrosive**) and stir to mix. The solution should be a light purple colour. If necessary, dilute further with a little more water. The exact concentration is not critical.

Health and safety

The sulfuric acid used for making the potassium manganate(VII) solution is 2 mol dm^{-3} and is corrosive. Once it is diluted with potassium manganate(VII) it is approximately 1 mol dm^{-3} and the resulting solution is an irritant. Wear eye protection when making and using the solution.

Warn students not to consume anything in the laboratory – they may be tempted to taste the rhubarb.

If you use home-grown rhubarb, ensure that the leaves are removed before it is given to students as they contain far more oxalic acid than the stalk and are toxic.

Answers

Surface area

1. This question could either be answered simply by saying that the surface area increases or students could measure the surface area of the rhubarb using graph paper or another method.
2. This could be answered simply by saying that the rate of reaction increases as the surface area increases. However, if students have calculated the total surface area of each sample then they could look for a mathematical relationship, *eg* as the surface area doubles, the rate of reaction doubles – or whatever is appropriate for their results.
3. There are a number of possibilities here. The stick of rhubarb may not be the same width along its length, so the length of the rhubarb pieces may vary. Measuring length is not an accurate way of ensuring that you have the same quantity of rhubarb. The outside of the rhubarb is red and the inside white – they may have different amounts of oxalic acid near them. It can be hard to tell exactly when the potassium manganate(VII) has decolourised. Students' plans for improving the experiment will vary depending on what problems they have identified.

Concentration

1. As the number of drops increases, the concentration of rhubarb in the reaction mixture increases.
2. This is not a fair test because the volume of rhubarb juice is not the same each time.
3. It is probably not a big problem in this experiment because the volume of rhubarb juice is always very small compared to the overall volume of liquid.

References and acknowledgements

This experiment is based on an idea of Don Sutherland at DUSC (Development to Update School Chemistry) in Scotland.

More information on rhubarb and the acids it contains may be found at:
http://www.rhubarbinfo.com/rhubarb-poison.html (accessed December 2005)
Details of the autocatalysis of the reaction carried out in this experiment, together with a possible demonstration and video clip are available from the Journal of Chemical Education:
http://jchemed.chem.wisc.edu/JCESoft/CCA/CCA3/MAIN/AUTOCAT/PAGE1.HTM
(accessed December 2005)

Rates and rhubarb

Rhubarb contains a number of acids which give it a sour taste (this is why sugar is almost always added to it when it is cooked). One of these acids is called oxalic acid. It is toxic in large quantities, but rhubarb stalks are safe to eat because they only contain a small amount. It is enough, however, to react with potassium manganate(VII) and decolourise it. You are going to investigate how the rate of this reaction changes when two factors are changed:

- surface area
- concentration.

1. Surface area

You will need

- 1 stick of rhubarb
- 4 x 100 cm^3 beakers (or 2 if you wash and re-use them)
- 50 cm^3 measuring cylinder
- Dilute acidified potassium manganate(VII) solution
- Timer
- White tile
- Knife
- Eye protection.

Health and safety

- Read our standard health and safety guidance at https://rsc.li/3Nicn9l
- Potassium manganate(VII) solution is low hazard but avoid getting it on your hands. If you do, wash it off straight away.
- Wear eye protection when using the potassium manganate(VII) solution.
- Do not eat or taste anything in the lab.

What to do

1. Cut 3 x 5 cm lengths of rhubarb. Leave one piece as it is, cut one in half lengthways and the other into four even sized pieces (again, cut lengthways).
2. Measure 30 cm^3 acidified potassium manganate(VII) into a beaker. Pour the same quantity of water into another beaker.
3. Place the beakers on a white tile, put the 5 cm long piece of rhubarb into the potassium manganate and start the timer. Stir the solution with the rhubarb until it goes colourless. If you are not sure whether all the colour has disappeared, briefly remove the rhubarb and compare the solution to the beaker of water. When they look the same, stop the stop clock.
4. Repeat using the piece of rhubarb cut into two (use both halves) and then the piece cut into four (use all four pieces).
5. Record all your results in a results table.

Questions

1. How does the total surface area change as you cut up the rhubarb?

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2. What effect does the change in surface area have on the rate of the reaction?

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3. What are the problems with the design of this experiment and how could you improve it?

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2. Concentration

You will need

- Approx 15 cm stick of rhubarb
- 250 cm^3 beaker
- Distilled water
- Bunsen burner, heatproof mat, tripod and gauze
- Filter funnel and filter paper or a tea strainer
- 2 x 100 cm^3 beakers
- 50 cm3 measuring cylinder
- Dilute acidified potassium manganate(VII) solution
- Timer
- White tile
- Knife
- Eye protection.

Health and safety

- Wear eye protection when using a Bunsen burner or potassium manganate(VII) solution.
- Do not taste anything in the laboratory.

What to do

1. Cut the stick of rhubarb into thin (about 0.5 cm) slices and put them into the 250 cm^3 beaker. Cover the rhubarb with distilled water and heat gently using a Bunsen burner.
2. Bring the rhubarb to the boil and continue to boil it gently until it falls to pieces, which will take about 5 minutes. Turn off the Bunsen burner and leave the mixture to cool.
3. When the beaker is cool enough to pick up easily, filter or strain the mixture. Keep the filtrate (liquid).
4. Measure 30 cm^3 acidified potassium manganate(VII) into one of the 100 cm^3 beakers and the same amount of water into another. Put both beakers on a white tile.
5. Add one drop of the rhubarb filtrate to the potassium manganate(VII) and start the timer. Stop when the colour disappears and the solution looks the same as the plain water.
6. Repeat with 2, 3, 4, 5, and 6 drops of rhubarb filtrate. Record your results in a table.
7. Plot a graph of your results.

Questions

1. As the number of drops of rhubarb filtrate increases, how does the concentration of the rhubarb in the reaction mixture change?

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2. In what way is this experiment not a fair test?

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3. Why is this probably not a big problem in this experiment?

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