THE ROYAL SOCIETY OF CHEMISTRY

1. A visible activated complex

Topic

Reaction rates/catalysis.

Timing

About 5 min.

Level

Pre-16 as a simple demonstration of catalysis, post-16 to introduce the idea of an activated complex and to allow discussion of the mechanism of catalysis.

Description

Hydrogen peroxide oxidises potassium sodium tartrate (Rochelle salt) to carbon dioxide. The reaction is catalysed by cobalt(II) chloride. When solutions of hydrogen peroxide and Rochelle salt are mixed, carbon dioxide is slowly evolved. The addition of cobalt(II) chloride causes the reaction to froth, indicating a large increase in the reaction rate. At the same time the colour of the cobalt(II) chloride turns from pink to green (an activated complex), returning to pink again within a few seconds as the reaction dies down. This indicates that catalysts actually take part in the reaction and are returned unchanged when the reaction is complete.

Apparatus

- Bunsen burner, tripod, gauze and heat-proof mat.
- One 250 cm^3 beaker.
- One 0 –100 °C thermometer.
- One 25 cm^3 measuring cylinder.
- One dropping pipette.
- Access to overhead projector (optional).

Chemicals

The quantities given are for one demonstration.

- 5 g of potassium sodium tartrate-4-water (Rochelle salt, potassium sodium 2,3-dihydroxybutanedioate, $KNaC_4H_4O_6.4H_2O$).
- 0.2 g of **cobalt(II) chloride-6-water** ($CoCl_2.6H_2O$).
- 20 cm^3 of 20 volume (*ie* approximately 6 %) hydrogen peroxide solution ($H_2O_2(aq)$).
- 65 cm^3 of deionised water.
- About 200 cm^3 of crushed ice (optional).

Method

Before the demonstration

Make a solution of 0.2 g of cobalt chloride-6-water in 5 cm^3 of deionised water.

Make a solution of 5 g of Rochelle salt in 60 cm^3 of deionised water in a 250 cm^3 beaker.

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The demonstration

Add 20 cm^3 of 20 volume hydrogen peroxide to the solution of Rochelle salt and heat the mixture to about 75 °C over a Bunsen burner. There will be a slow evolution of gas showing that the reaction is proceeding. Stirring the solution makes the evolution of gas more obvious. Now add the cobalt chloride solution to the mixture. Almost immediately the pink solution will turn green and after a few seconds vigorous evolution of gas starts and the froth will rise almost to the top of the beaker. Within about 30 seconds, the frothing subsides and the pink colour returns.

Visual tips

Stand the beaker on a overhead projector to make the evolution of gas before the addition of the catalyst more easily visible.

Teaching tips

The green activated complex can be trapped if a sample of the green solution is withdrawn with a dropping pipette and then transferred to a test-tube that is cooled in crushed ice. The solution remains green for some time.

If the reaction is considered to be going too fast for easy observation, carry it out at a lower temperature (although this will make it less easy to see the evolution of CO_2 before adding the catalyst).

Theory

The basic reaction appears to be:

$$5H_2O_2(aq) + C_4H_4O_6^{2-}(aq) \rightarrow 4CO_2(g) + 2OH^-(aq) + 6H_2O(l)$$

The equation may also be written in two parts:

$$3H_2O_2(aq) + C_4H_4O_6^{2-}(aq) \rightarrow 2CO_2(g) + 2HCOO^-(aq) + 4H_2O(l)$$

$$2HCOO^-(aq) + 2H_2O_2(aq) \rightarrow 2CO_2(g) + 2H_2O(l) + 2OH^-(aq)$$

The reaction is catalysed by pink Co^{2+} ions which are first oxidised to green Co^{3+} ions (complexed by tartrate ions) and then reduced back to Co^{2+}.

While the majority of the gas evolved is carbon dioxide, oxygen will also be produced from the decomposition of some of the hydrogen peroxide. The gas mixture will turn limewater milky, but does not extinguish a glowing splint.

Extensions

Cobalt(II) bromide also catalyses the reaction and students could be asked to try other cobalt salts. The reaction is easy to time and could form the basis of an investigation into the factors affecting reaction rates.

Further details

There are more details of the mechanism in Inner London Education Authority, *Independent Learning Project for Advanced Chemistry (ILPAC),* Unit I5, p 57– 61. London: John Murray, 1984. For note, however, that the procedure given in this book for the experiment does not appear to work satisfactorily.

Safety

Wear eye protection.

Take care when placing the solution on the OHP.

It is the responsibility of teachers doing this demonstration to carry out an appropriate risk assessment.