Oscillating Clock Reaction

Purpose

To demonstrate the classic Belousov-Zhabotinsky Reaction illustrating an oscillating reaction mechanism.

Materials

2 liter beaker	potassium bromate
3 500 mL Erlenmeyer flasks	Potassium bromide
magnetic stirrer / bar	malonic acid
0.1% ferroin indicator	cerium (IV) ammonium nitrate

Procedure

Preparation

1. Solution A. In a 500 mL flask, dissolve 19 grams of potassium bromate in 500 mL of distilled water. This solution is 0.23 M.
2. Solution B. In a 500 mL flask, dissolve 16 grams of malonic acid and 3.5 grams of potassium bromide in 500 mL of distilled water. This solution is 0.31 M malonic acid and 0.059 M KBr.
3. Solution C. In a 500 mL flask, dissolve 5.3 grams of cerium (IV) ammonium nitrate in 500 mL of 2.7 M sulfuric acid. This solution is 0.019 M.
4. Set the 2 liter beaker on the magnetic stirrer.

Presentation

1. Pour Solution A and Solution B into the beaker and adjust the stirrer to produce a vortex in the solution.
3. Add Solution C and 30-35 mL of ferroin. The solution will become amber.
4. After about one minute, the color of the solution will change from amber to yellow, then green, and finally red. The color will return to amber and repeat itself many times (20+).

Additional Information

1. 2.7 M sulfuric acid (pour 75 mL of 18 M sulfuric acid into 250 mL of distilled water and dilute the resulting solution to 500 mL with distilled water).
2. The overall reaction occurring in this demonstration is the cerium-catalyzed oxidation of malonic acid by bromate ions in diluted sulfuric acid. The bromate ions are

reduced to bromide ions, while the malonic acid is oxidized to carbon dioxide and water. The reaction can be represented by the equation:

$$3\ CH_2(CO_2H)_2 + 4\ BrO_3^- \rightarrow 4\ Br^- + 9\ CO_2 + 6\ H_2O$$

3. The reaction mechanism involves two different processes. Process A involves ions, and the steps are two-electron transfers. Process B involves radicals and one-electron transfers. Which process is dominant at a particular time is determined by the bromide ion concentration.

4. Process A occurs when the bromide ion concentration rises above a certain critical level, while Process B dominates when the bromide ion concentration falls below a certain level.

5. Oscillations occur because Process A consumes bromide ions and thus leads to the conditions which favor Process B. Process B liberates bromide ions, which return the reaction to control by Process A.

6. It is apparent that much is to be learned to fully understand the activities within the solution. Many oscillations infer much competition for the available ions.

Disposal

Solutions should be placed in properly labeled waste container.

Reference

Shakharshiri, Bassam; Chemical Demonstrations, Volume II, 1985.