Briggs-Rauscher Oscillating Reaction

Recommended for Chapter(s): 1, & 15

Demo #005

Materials NOT in box

1. Solutions A, B, and C. Make sure to e-mail Darby (feldwinn@chem.ucsb.edu) a few days in advance to make sure the solutions are ready for you.
2. Hot/stir plate (general cabinet).
3. Safety goggles.

Procedure

1. Put a stir bar in the beaker and place it on the hotplate.
2. Pour all of bottle A (50 mL) and bottle B (50 mL) into the beaker.
3. Adjust the speed of the stirring to make a vortex (solutions A and B must be mixed before solution C is added).
4. Pour all of bottle C (50 mL) into the beaker.
5. The reaction will oscillate between clear, amber, and deep blue.

Safety

1. Wear safety goggles.

Clean Up

1. Pour the used solution into the waste bottle.
2. Return the materials to the cart in the demonstration library room.

Stockroom Notes

1. In the hood add sodium thiosulfate pentahydrate to the waste until the solution becomes colorless (sometimes the solution is white that is also acceptable). The reaction with sodium thiosulfate pentahydrate is exothermic and the mixture will become very hot. After the solution is clear it can be dumped down the drain with plenty of water.
2. If new solutions have to be made use the following instructions
    a. Solution A (4 M H_2O_2): Pour 400 mL of distilled water into a 2-liter beaker. Wearing gloves pour 410 mL of 30% hydrogen peroxide into the beaker of water. Dilute the solution to 1.0 liter with distilled water.
    b. Solution B (0.20 M KIO_3 and 0.077 M H_2SO_4): Place 43 g of potassium iodate and approximately 800 mL of distilled water in a 2 L beaker. Add 4.3 mL concentrated H_2SO_4 to this mixture. Warm and stir the mixture until the potassium iodate dissolves. Dilute the solution to 1.0 liter with distilled water.

    c. Solution C (0.15 M malonic acid and 0.020 M $MnSO_4$): Dissolve 16 g of malonic acid and 3.4 g of manganese(II) sulfate monohydrate in approximately 500 mL of distilled water in a 2 L beaker. In a 100 ml beaker, heat 50 ml of distilled water to a boil. In a 50 mL beaker, mix 0.3 g of soluble starch with 5 mL of distilled water and stir the mixture to form a slurry. Pour the slurry into the boiling water and continue heating and stirring the mixture until the starch has dissolved (1-2 minutes). Pour the starch solution into the solution of malonic acid and manganese(II) sulfate. Dilute the mixture to 1.0 L with distilled water

3. Replace glassware with clean glassware.
4. The three bottles for the solutions will be empty. Do not refill them.
5. Return items to demonstration tub.
6. Return tub to the demonstration library.
    a. Return the goggles to the goggle box.
    b. Return the Stir/Hot plate to the general cabinet.

Discussion

Solution A	4 M hydrogen peroxide (H_2O_2)
Solution B	0.20 M potassium iodate (KIO_3) and 0.077 M sulfuric acid (H_2SO_4)
Solution C	0.15 M malonic acid ($CH_2(CO_2H)_2$), 0.020 M manganese sulfate monohydrate ($MnSO_4 \cdot H_2O$), and starch

The overall chemical reaction occurring is:

$IO_3^- + 2H_2O_2 + CH_2(CO_2H)_2 + H^+ \rightarrow ICH(CO_2H)_2 + 2O_2 + 3H_2O$

Note: $MnSO_4 \cdot H_2O$ is a catalyst and starch is an indicator

This reaction can be broken into two steps:

$IO_3^- + 2H_2O_2 + H^+ \rightarrow HOI + 2O_2 + 2H_2O$ (1)
$HOI + CH_2(CO_2H)_2 \rightarrow ICH(CO_2H)_2 + H_2O$ (2)

Reaction 1 can occur by two different processes: a radical process which is turned on when I^- concentration is low, or by a nonradical process when the I^- concentration is high. Both processes reduce iodate (IO_3^-) to hypoiodous acid (HOI). The radical process forms HOI at a much faster rate than the nonradical process.

The reactions in the nonradical process (when I^- concentration is high) are seen below

$IO_3^- + I^- + 2H^+ \rightarrow HIO_2 + HOI$ (a_1)
$HIO_2 + I^- + H^+ \rightarrow 2HOI$ (a_2)
$2HOI + 2H_2O_2 \rightarrow 2I^- + 2O_2 + 2H^+ + 2H_2O$ (a_3)

The reactions in the radical process (when I^- concentration is low) are seen below

$2IO_3^- + 2HIO_2 + 2H^+ \rightarrow 4IO_2\cdot + 2H_2O$ (b_1)*
$4IO_2\cdot + 4Mn^{2+} + 4H_2O \rightarrow 4HIO_2 + 4Mn(OH)^{2+}$ (b_2)
$4Mn(OH)^{2+} + 4H_2O_2 \rightarrow 4Mn^{2+} + 4H_2O + 4HOO\cdot$ (b_3)
$4HOO\cdot \rightarrow 2H_2O_2 + 2O_2$ (b_4)
$2HIO_2 \rightarrow IO_3^- + HOI + H^+$ (b_5)

* Initially IO_3^- reacts with H_2O_2 to produce a little HIO_2

Reaction 2 also occurs in two steps.

$I^- + HOI + H^+ \rightarrow I_2$ (amber colored) $+ H_2O$ (c1)

$$I_2 + CH_2(CO_2H)_2 \rightarrow ICH(CO_2H)_2 + H^+ + I^- \quad (c_2)$$

The amber color results from the production of the I_2. The I_2 forms because of the rapid production of HOI during the radical process. When the radical process is occurring, HOI is created faster than it can be consumed by reaction c_1. The excess HOI starts reacting with the H_2O_2 as seen in nonradical process in reaction a_3; this converts HOI to I^-. This increases the concentration of I^- until a critical point is reach at which time the nonradical process takes over. The nonradical process does not produce HOI nearly as fast as the radical process, so the amber color begins to clear as I_2 is consumed more quickly than it can be created (reaction c_2). Eventually the I^- concentration drops low enough for the radical process to restart so the cycle can repeat itself.

The deep blue color is the result of the I^- and I_2 binding to the starch present in the solution and is an indication that the I^- concentration is greater than the HOI concentration.

Materials in the box

1. 250 ml beaker
2. Stir bar
3. 3 bottles for solutions (these bottles will be empty)
4. Sodium thiosulfate pentahydrate Fisher S445-500
5. Waste bottle