overhead projector demonstrations

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Oscillating Reactions

There is probably no chemical phenomenon more fascinating than chemical oscillation. The periodic sequence of color changes an oscillating system can produce seems almost magical. An excellent review article by Irving Epstein[1] appeared last year in *Chemical & Engineering News*. It included a historical summary as well as some proposed mechanisms for these complicated multistep reactions. For an easily readable discussion of these complex reaction systems, see that article[1] or the one that appeared four years earlier in *Scientific American*[2].

Oscillating reactions can be demonstrated very effectively on the overhead projector. Two examples are given below.

Briggs–Raucher Reaction

Place a 250-mL beaker on the overhead projector stage, and pour into it equal volumes (about 10 mL) of each of the following solutions:

A 6% H_2O_2 (25 mL 30% H_2O_2 + 100 mL H_2O)
B 4.3 g KIO_3 dissolved in 100 mL H_2O + 1.5 mL 6 M H_2SO_4
C 1.56 g malonic acid + 0.34 g $MnSO_4 \cdot H_2O$ dissolved in 100 mL H_2O + 3 mL of freshly prepared 1% soluble starch solution

The beaker can be swirled gently to get thorough mixing. Several seconds after the last ingredient is added the colorless mixture turns yellow, then dark blue, then colorless again, back to yellow, dark blue, etc. There may be half a dozen or more repeating cycles before the solution finally becomes permanently black. The solutions can usually be stored for at least several months.

BZ Reaction

This is a variation of the Belousov–Zhabotinskii reaction. The colors produced are red and blue, and the system can oscillate both in time and in space, generating a pattern of ever widening concentric circles. The reaction is extremely sensitive to chloride ion, so all chloride must be excluded. The reaction is carried out in a 9-cm Petri dish, using the following solutions:

A 5 g $NaBrO_3$ dissolved in 100 mL H_2O
B 10 g NaBr dissolved in 100 mL H_2O
C 10 g malonic acid dissolved in 100 mL H_2O
D 6 M H_2SO_4
E Ferroin solution: 1.35 g 1, 10-phenanthroline (*not* the hydrochloride) + 0.7 g $FeSO_4$ dissolved in 100 mL H_2O

Solutions B, C, D, and E are most conveniently kept in small dropper bottles. To carry out the demonstration place about 5 mL of A in a beaker and add 1 dropper each of B, C, and D. The mixture will be yellow because of bromine production. Swirl the beaker until the yellow color completely disappears. Then add 1 or 2 droppers of E (the ferroin indicator solution), and swirl to mix. Pour the mixture into a Petri dish, and set the dish on an overhead projector stage. Initially red in color, the solution may shift to blue and then back to red. Swirl the dish to make sure the mixture is homogeneous, and then let it stand. After a while, tiny blue spots will start to appear. Each spot will slowly expand, eventually producing a series of concentric rings. The reaction may continue for half an hour, or even longer. In order to restart the process at any time, simply swirl the dish until the color is homogeneous. (Potassium bromate or bromide can be used in place of the sodium salt.)

[1] Epstein, Irving R. *Chem. Eng. News* **1987,** *65*(13), 24–36.
[2] Epstein, I. R., et al. *Sci. Am.* **1983,** *248*(3), 112–123.

Oxidation States of Manganese

In its compounds manganese exhibits oxidation states from +2 to +7. The common oxidation states are +2, +4, and +7, but the less common +3, +5, and +6 states are easily prepared. Since the colors of the six oxidation states are all different, showing them on an overhead projector makes for a colorful display.

Prepare the following solutions, and place them in small (2–4-oz) dropper bottles.

$MnSO_4$	2 g per 100 mL
$KMnO_4$	0.1 g per 100 mL
Na_2SO_3	2 g per 100 mL
6 M H_2SO_4	33 mL conc. H_2SO_4 per 100 mL (**Caution:** Add the acid very slowly to the water.)
6 M NaOH	24 g per 100 mL
50% NaOH	50 g NaOH dissolved in 50 mL water

These solutions can be used one drop at a time or they can be dispensed by dropperfuls. (A "dropper" refers to the amount of liquid that is easily picked up into the dropper when the bulb is squeezed and then released. It is about 0.6 mL in the case of most dropper bottles.)

Procedure

On the stage of an overhead projector line up six small (25–50-mL) beakers labelled +2, +3, +4, +5, +6, and +7 (using a marking pen on an underlying transparency sheet).

(1) In the +2 beaker place several milliliters of $MnSO_4$ solution. Although the color is pale pink, it will appear to be essentially colorless.

(2) In the +7 beaker place several milliliters of $KMnO_4$ solution. The color is the familiar purple color of permanganate.

(3) In the +4 beaker place several millilters of $MnSO_4$ solution, and then, *without mixing*, add 2 or 3 drops of $KMnO_4$. Brown spots of MnO_2 will form wherever the drops of permanganate fall.

(4) In the +3 beaker place several milliliters of $MnSO_4$ solution, and add several droppers of 6 M H_2SO_4. Then add $KMnO_4$ a few drops at a time, swirling the beaker after each addition, until the solution takes on a reddish color.

(5) In the +6 beaker place several milliliters of $KMnO_4$ solution, and add several droppers of 6 M NaOH. Then add several droppers of Na_2SO_3 solution. The color changes from purple to green as the MnO_4^- ion (permanganate) is reduced to MnO_4^{2-} (manganate).

(6) In the +5 beaker place several milliliters of $KMnO_4$ solution, and add about the same amount of 50% NaOH. Swirl the beaker rapidly until the solution turns blue, the color of MnO_4^{3-}.

Some of these oxidation states are rather unstable, but for a while the six beakers will appear as follows:

+2	colorless (or *very* pale pink), Mn^{2+} (manganous, or manganese(II))
+3	rose colored, Mn^{3+} (manganic, or manganese(III))
+4	brown, MnO_2 (manganese(IV)oxide)
+5	blue, MnO_4^{3-} (manganate(V))
+6	green, MnO_4^{2-} (manganate(VI))
+7	purple, MnO_4^- (permanganate)

General Reference

Aurora, C. L. *J. Chem. Educ.* **1977,** *54,* 302–303.