Experiment 13E

FV1/21/04

THE BLUE BOTTLE REACTION[1]

Materials: Unknown solution (corrosive), unknown solid, 1% methylene blue, two 250 mL Erlenmeyer flasks, one #6 rubber stopper (with no holes), manometer assembly (rubber stoppers with glass and rubber tubing), magnetic stirrer, stir bar.

Purpose: To propose a reaction mechanism for the blue bottle reaction.

Learning Objectives: By the end of this experiment, the student should be able to demonstrate the following proficiencies:

1. Set up a crude manometer.
2. Determine relative rates of chemical reactions.
3. Apply the basic concepts of chemical kinetics to determine reaction mechanisms.

Discussion:

The rate at which a homogeneous reaction takes place depends upon the following factors: inherent properties of the reacting materials, the temperature, the concentration of the reactants, and catalysts. The order of reaction can only be determined experimentally. Likewise, experimental kinetic results are very important in determining the mechanism of a given reaction; i.e., in determining a detailed picture of how the reaction occurs. Many observed reactions occur by a sequence of elementary steps (one step reactions).

The following experiment in which you will use a solution of unknown composition will illustrate many of the important points of kinetics as well as cause one to do some original thinking in arriving at a reaction mechanism.

Procedure and Results:

1. Slowly add the following reagents to a 250 mL Erlenmeyer flask:

   Approximately 125 mL of the unknown solution **(this solution is corrosive)**
   2.5 g of the unknown solid
   2 drops of 1% methylene blue

2. Stopper the flask with the rubber stopper and shake it vigorously. What is observed?

3. After the flask has stood for a while what is observed?

[1]This experiment is adapted from: S. C. Engerer and A. G. Cook, "The Blue Bottle Reaction as a General Chemistry Experiment on Reaction Mechanisms," J. Chem. Educ. **1999**, 76, 1519.

4. Shake the flask again. What is observed now?

5. Does the coloration come from the rubber stopper? How did you show this?

6. What other possible sources of the coloration can you suggest?

7. Suggest methods for verifying or disproving these possibilities.

8. Replace the air in the flask with nitrogen gas and quickly stopper the flask again. Use the following procedure:

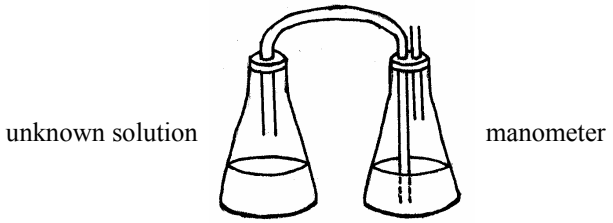
   - Take your stoppered flask to the cylinder of nitrogen.
   - Place the tube that is connected to the cylinder into your unknown solution.
   - Holding the tube in place, open the valve (that the tube is connected to) approximately ½ turn and bubble the nitrogen gas through the solution for approximately one minute.
   - Turn off the nitrogen gas, remove the tube, and quickly stopper the flask with the rubber stopper.

   Now shake the flask as was done previously. What is observed?

9. Remove the rubber stopper, swirl the solution, and let it sit for a few minutes. Stopper the flask and shake as before. What is observed now?

10. Replace the rubber stopper with a simple manometer as follows:

- Place about 125 mL of water into a 250 mL Erlenmeyer flask.
- Slide a stir bar into the unknown solution, and place the flask containing the unknown solution onto a magnetic stirrer.
- Using the manometer assembly, connect the two flasks. First, connect the flask with the unknown solution. The long glass tube should be in the flask with the water (see figure below).
- Observe the water level in the manometer.



a. Turn on the magnetic stirrer so that a large vortex is produced. What is observed in the manometer (the flask with the water)? What is observed in the other flask? Turn off the magnetic stirrer after about 2 minutes.

b. Observe the manometer and the unknown solution for about one minute after the magnetic stirrer is turned off. State your observations.

11. What conclusions can be drawn from your observations in 8, 9, and 10?

12. Is the initial reaction reversed when going from blue to colorless again? What led you to this conclusion?

13. Shake the flask. How does the rate of the coloration step compare with the rate of the decoloration step?

14. Write a tentative reaction mechanism for the reaction taking place based on what has been observed thus far. (Use the letters A, B, C, … for the reactants and products since the experimenter does not know what substances are present in the reaction mixture.) Which step in your tentative reaction mechanism is the slow step? Show the tentative mechanism to your instructor and have him or her initial it.

15. Does the length of time the flask remains blue depend on how long one shakes the flask? Does the intensity of the blue color depend on how long one shakes the flask? Complete the following experiments to assist in answering these questions.

Number of Shakes	**Duration of Blue Color (sec)**	**Intensity of Blue Color**
1		
2		
4		
6		
8		

16. Draw simple graphs of

    a. the duration of the blue color vs. the number of shakes.

    b. the intensity of the blue color vs. time for two different numbers of shakes.

17. How can these observations be explained? In this explanation, consider how they relate to the mechanism proposed in 14, and determine what modifications to the mechanism are necessary.

18. Write a final mechanism for the reaction which is consistent with all observations. Indicate which step is the slow step and identify any catalyst that may be present.

Write the net reaction.

19. Write the rate law for the reaction. It may be necessary to include in the rate law an intermediate instead of only reactants and products.

20. What is the overall order of the reaction?