5.3 Blue Bottle-Oxidation of dextrose by O_2 catalyzed by methylene blue

Subjects: Oxidation/reduction, stoichiometry, equilibrium, kinetics, catalysts

Description: A flask containing a colorless solution is shaken and the solution turns blue. Upon standing the solution becomes colorless again. More shaking regenerates the color.

Materials:
Note: Solution needs to be prepared immediately before the demonstration. The solution is not stable over time.

300 mL distilled water
8 g potassium or sodium hydroxide‡
10 g dextrose
methylene blue stock solution (0.2 g methylene blue in 100 mL H_2O) ‡
indigo carmine stock solution (optional)‡
500 mL Erlenmeyer flask
rubber stopper
500 mL graduated cylinder*
disposable transfer pipets
spatula
weigh boats (located next to balance)

‡Sodium hydroxide is located in the cabinet under the hood. The dextrose can be found in the chemical storage cabinets. The indicator stock solutions are in the solutions storage cabinets
*Shared item. Found on the prep shelf.

Pre-class Preparation:
1. Pour 300 mL of distilled water into the 500 mL flask and add 8 g of KOH (or NaOH).
2. Swirl the flask to dissolve the KOH (or NaOH).
3. Add 10 g of dextrose and allow it to dissolve completely.
4. Add 6-8 drops methylene blue indicator solution and swirl. Allow to rest until solution becomes colorless.

Procedure:
1. Present the flask with the clear solution.
2. Shake the flask to regenerate the blue color, which will slowly fade.
3. Repeat several times to regenerate the blue.
4. It may be necessary to remove the stopper.
5. Ask the students to explain what is happening.

Alternate: Indigo-carmine traffic light

Use 20 drops indigo carmine solution (0.25 g in 25 mL distilled water) instead of methylene blue. The solution changes from yellow-green to orange and upon more vigorous shaking, to green again.

Discussion:
In this demonstration, dextrose is oxidized by O_2 in the air in the presence of methylene blue dye. Oxidation products include glucuronic acid, gluconic acid, and δ-gluonolactone. The role of methylene blue is not well understood, but is believed to act as a catalyst in the reaction, possible being reduced by dextrose to methylene white. Methylene blue is blue in is oxidized form and colorless in its reduced form. Shaking the flask dissolves oxygen back into the solution and oxidizes the dye back to its blue form. Allowing the solution to stand allows the dextrose to reduce the methylene blue to its colorless state. This cycle can be repeated until all the dextrose is oxidized or all of the oxygen in the flask has been consumed.

This demonstration illustrates a reversible redox reaction between oxygen and methylene blue. It can also be used to introduce students to kinetics and reaction order. The reaction rate is first order in OH-, in methylene blue and in dextrose. The rate is independent of the concentration of gaseous O_2.

Safety: Potassium and sodium hydroxide are caustic and can cause severe burns. Prevent eye and skin contact by wearing proper protective equipment.

Disposal: The solution can be flushed down the drain with water.

References:
1. B.Z. Shakhashiri; *Chemical Demonstrations: A Handbook for Teachers of Chemistry*; Wisconsin; 1985; Volume 2; p. 142-146
2. L. Summerlin, and J. Ealy; *Chemical Demonstrations: A sourcebook for Teachers;* 1985; Volume 1; p. 90-91
3. J.A. Campbell, *J. Chem Educ*. 40:578(1963)
4. P.S. Chen, *Entertaining and Educational Chemical Demonstrations*, Chemical Elements Publishing Co.: Camarillo, CA (1974)