Blue Bottle Experiment

Introduction to Reaction Rates

Introduction

The "blue bottle" reaction is a classic chemistry demonstration. It is often used in general science classes to introduce the roles of observation and hypothesis in the scientific method. The demonstration is used in chemistry classes to illustrate oxidation and reduction reactions, and also to study the rates of chemical reactions.

Concepts

- Kinetics
- Rate of reaction
- Oxidation–reduction

Materials

Dextrose, $C_6H_{12}O_6$, 8 g

Methylene blue solution, 1% aqueous

Potassium hydroxide, KOH, 8 g

Water, distilled or deionized

Flask, 500-mL, with cap or stopper to fit

Graduated cylinder, 500-mL

Weighing dishes, 2

Safety Precautions

Potassium hydroxide is a corrosive solid; it is especially dangerous to eyes and may blister and burn skin. Avoid contact with eyes and skin and clean up all spills immediately. Methylene blue solution is slightly toxic by ingestion. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

To prepare the "blue bottle" solution, add 8 g of potassium hydroxide to 300 mL of water in a 500-mL flask. Stir until the solid is dissolved. Add 10 g of dextrose and a few drops of methylene blue indicator solution. Fill to the 500-mL mark, stopper or cap the flask, and mix thoroughly.

Procedure

1. Allow the "blue bottle" solution to stand undisturbed in the stoppered flask until the solution is colorless. This may take a few minutes.
2. Show students the colorless solution, then *gently* shake the flask to obtain the blue color.
3. Wait patiently as the solution turns colorless again. See the *Tips* section for the effect of shaking on the time required for the blue color to disappear.
4. Repeat steps 2 and 3 and ask students to record observations and propose possible tests to explain the colorless–blue–colorless sequence of color changes. The process can be repeated several times over a 10–15 minute period. Periodically remove the stopper to introduce more air (oxygen) into the reaction flask.
5. Discuss factors that might affect the time needed for the blue color to fade. This demonstration can be used as the basis of student-designed kinetics experiments to study the effect of temperature or concentration on the rate of the reaction.

Disposal

Consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The waste solutions from Parts A and B may be flushed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

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Tips

- Students usually think that the blue–colorless and colorless–blue reactions of the indicator are the reverse of each other. This is not the case. There are two separate reactions going on—oxidation of the colorless MB_{red} to the blue MB_{ox} form by reaction with oxygen, and reduction of the blue MB_{ox} back to the colorless MB_{red} by reaction with dextrose.
- Reaction of dextrose with methylene blue in the presence of base results in oxidation of the sugar molecule. The aldehyde or hemiacetal functional group in dextrose is oxidized to a carboxylic acid derivative (gluconic acid or gluconolactone). Oxidation of dextrose in this reaction represents an application of the concept of "reducing sugars" that students may be familiar with from prior biology classes. Dextrose is called a reducing sugar because it acts as a reducing agent in reactions with Cu^{2+} or Ag^{+} ions (recall the Benedict's test and Tollen's test from carbohydrate chemistry).
- The reaction times for the "blue bottle" reaction depend on the number of times the bottle is shaken. Try the demonstration out ahead of time to obtain convenient reaction times (shorter is better).
- One of the main misconceptions students have when they start to study kinetics involves the inverse relationship between the time they measure for a reaction to occur and the rate or speed of the reaction. Using car travel as an analogy usually clears up the confusion pretty easily.

Discussion

Kinetics is the study of the rates of chemical reactions. As reactants are transformed into products in a chemical reaction, the amount of reactants will decrease and the amount of products will increase. The rate of the reaction can be determined by measuring the concentration of reactants or products as a function of time. In some cases, it is possible to use a simple visual clue to determine a reaction rate. Thus, if one of the reactants is colored but the products are colorless, the rate of the reaction can be followed by measuring the time it takes for the color to disappear. Reactions involving the organic dye methylene blue provide a convenient example to study reaction rates. Methylene blue (abbreviated MB) exists in two forms, a reduced form and an oxidized form, that have different colors. The reduced form of methylene blue (MB_{red}) is colorless, while the oxidized form (MB_{ox}) is blue. The reduced form can be converted to the oxidized form by simply shaking it with oxygen in air (Equation 1). The oxidized form, in turn, can be converted back to the reduced form by treatment with a reducing agent, such as dextrose. Reactions involving the two forms of methylene blue are sometimes called clock reactions, because they involve a very sudden color change that is easy to time.

$$\underset{\text{Colorless}}{MB_{red}} + O_2 \rightarrow \underset{\text{Blue}}{MB_{ox}} \qquad \textit{Equation 1}$$

The rate of reaction of the blue, oxidized form MB_{ox} with dextrose and potassium hydroxide to give the colorless, reduced form MBred (Equation 2) can be studied by measuring the time needed for the blue color to disappear.

$$\underset{\text{Blue}}{MB_{ox}} + \text{dextrose} + KOH \rightarrow \underset{\text{Colorless}}{MB_{red}} \qquad \textit{Equation 2}$$

The "blue bottle" demonstration is thus a good introductory lead-in for guided-inquiry kinetics experiments. Students can design experiments to investigate how changing the temperature or changing the concentration of potassium hydroxide will affect the rate of reaction of methylene blue. The basic process is always the same—when a colorless solution containing MB_{red} is shaken, it turns blue (Equation 1). The time needed for the solution to turn colorless (Equation 2) can then be measured and used to determine the rate of reaction and the effects of concentration and temperature on the rate.

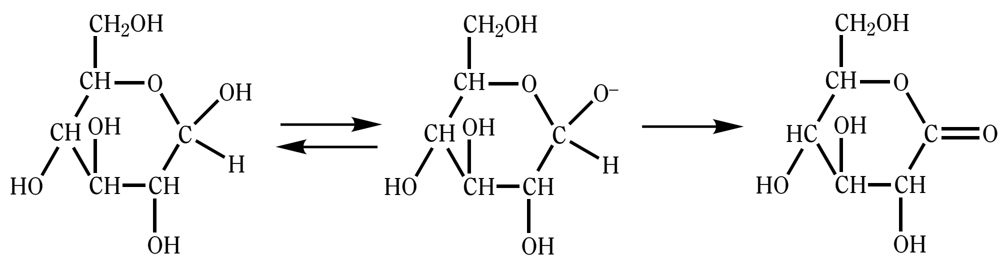
Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions
Content Standard G: History and Nature of Science, nature of scientific knowledge

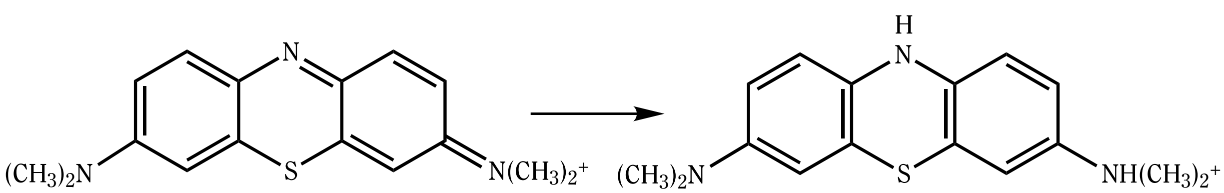
Supplementary Information

Oxidation of dextrose (glucose) in the presence of potassium hydroxide involves an initial acid–base reaction to form the glucoside anion, followed by 2*e*⁻ oxidation to gluconolactone.



D-Glucose *Glucoside Anion* *D-Gluconolactone*

The $2e^-$ oxidation of glucose is coupled with the $2e^-$ reduction of methylene blue (MB_{ox}).



Methylene Blue Oxidized Form (Blue) *Methylene Blue Reduced Form (Colorless)*

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Blue Bottle Experiment* activity, presented by Irwin Talesnick, is available in *Introduction to Reaction Rates*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Blue Bottle Experiment* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Feeling Blue—Chemical Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP8653	Feeling Blue Demonstration Kit
D0002	Dextrose, 500 g
M0074	Methylene Blue Solution, 1% Aqueous, 100 mL
P0059	Potassium Hydroxide, 100 g

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.