Iodine Clock Challenge Demonstration

Introduction

The demonstration of an "iodine clock" involves a chemical reaction that suddenly turns blue due to the formation of the familiar iodine–starch complex. The color change occurs abruptly, like an alarm clock ringing! Can you predict the time it will take for the iodine clock to ring?

Concepts

- Kinetics
- Concentration
- Rate of reaction
- Collision theory

Inquiry Challenge

The purpose of this guided-inquiry activity is to observe the iodine clock reaction, determine how the concentration of potassium iodate influences the rate of the reaction, and predict the amount of potassium iodate needed to make the clock "ring" in 25 seconds.

Materials*

Potassium iodate solution, KIO_3, 0.1 *M*, 250 mL
Sodium meta-bisulfite solution, $Na_2S_2O_5$, 0.2 *M*, 50 mL
Starch solution, 150 mL
Water, distilled or deionized, 800 mL
Beakers, 100- and 500-mL, 5 each
Graduated cylinders, 10-mL, 50-mL (2), 100-mL, and 250-mL
Stirring rods
Timer or Stopwatch

*Enough for five trials, three given in the Demonstration Procedure, followed by one practice and one challenge trial.

Safety Precautions

Potassium iodate solution is moderately toxic by ingestion and a body tissue irritant. Sodium meta-bisulfite is also irritating to skin, eyes, and other body tissues. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Safety Data Sheets for additional safety handling, and disposal information.

Demonstration Procedure

1. Sodium meta-bisulfite solution must be freshly prepared before use. To prepare 50 mL of 0.2 *M* sodium meta-bisulfite solution, add 1.9 grams of $Na_2S_2O_5$ to 40 mL of distilled or deionized water and stir to dissolve. Dilute the solution to 50 mL with DI water and mix well before dispensing.
2. Label three 500-mL beakers 1, 2, and 3. Using a 100- and 250-mL graduated cylinder, respectively, measure and add the following amounts of 0.1 *M* potassium iodate solution and distilled water to each beaker. These are Solution A for each trial.

Trial	Solution A		Reaction Time
	0.1 M KIO_3	Water	
1	50 mL	150 mL	
2	100 mL	100 mL	
3	25 mL	175 mL	

3. Obtain three 100-mL beakers. Using a separate graduated cylinder for each solution, measure and add 10 mL of 0.2 *M* sodium meta-bisulfite solution, 30 mL of starch solution, and 40 mL of distilled water to each 100-mL beaker. These are Solution B for each experiment. Stir each combined solution.

Publication No. 11242
061616

4. Pour Solution B into Solution A in Beaker #1 and immediately start timing. Measure and record the time from when the two solutions are mixed until the appearance of the blue color.
5. Repeat step 4 two more times with Beakers #2 and 3.

The Challenge

1. Calculate the concentration of potassium iodate (KIO_3) in Solution A for each trial.
2. *(a)* How did the reaction time change as the KIO_3 concentration was changed? *(b)* How is the rate of the reaction related to the reaction time?
3. Prepare graphs of *(a)* reaction time and *(b)* 1/time versus the volume of KIO_3 solution in Solution A. Explain the shape of each graph.
4. Using the graphs, predict the amount of KIO_3 solution needed to make the iodine clock "ring" in 25 seconds.
5. Carry out the challenge!

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The final solutions may be reduced with sodium thiosulfate solution according to Flinn Suggested Disposal Method #12a. Add just enough reducing agent to decolorize the blue color of the starch–iodine complex.

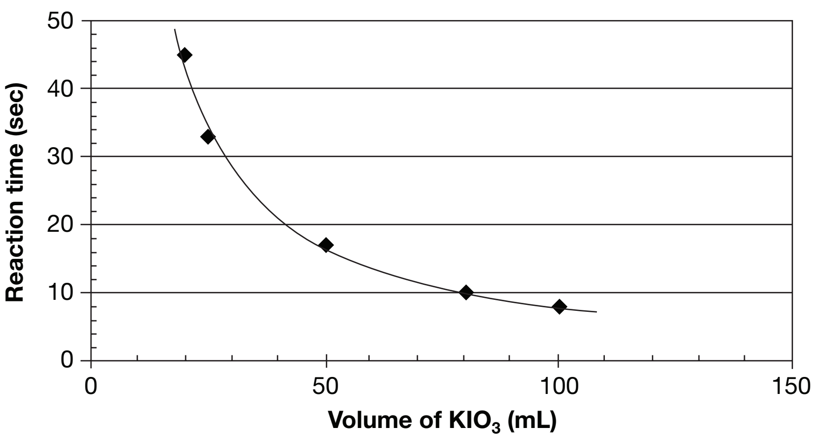
Tips

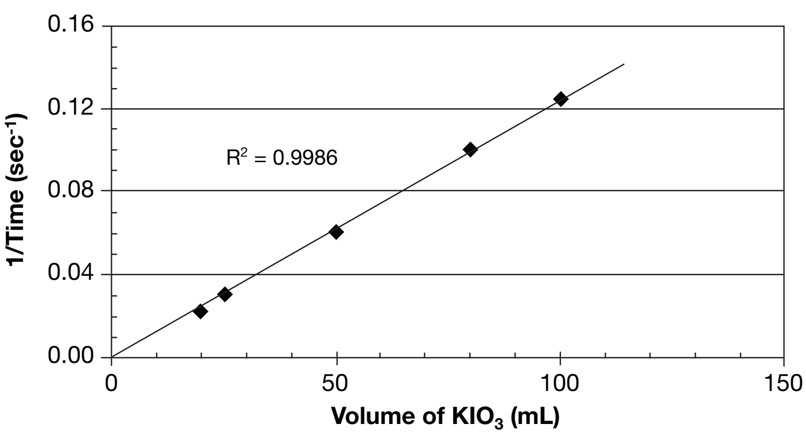
- Starch solutions have a poor shelf life. For best results, use recently purchased starch solution or prepare fresh within one week of use. Please consult the *Laboratory Solution Preparation* section in the *Reference* section of your current *Flinn Scientific Catalog/Reference Manual* for instructions.
- Sodium bisulfite and sodium meta-bisulfite are interconverted in the presence of water ($Na_2S_2O_5 + H_2O \rightarrow 2NaHSO_3$). In aqueous solution, the equilibrium overwhelmingly favors sodium bisulfite. Both sodium bisulfite and sodium meta-bisulfite thus produce a solution of bisulfite ions (HSO_3^-) when dissolved in water. Sodium meta-bisulfite, also known as anhydrous sodium bisulfite and as sodium pyrosulfite, is the preferred source of bisulfite ions for this demonstration.
- While iodine clock demonstrations are a popular and effective means of teaching kinetics concepts, the overall reaction mechanism is actually quite complicated and frequently confusing to students. (See the sequence of reactions in the *Discussion* section.) The slow steps in the overall reaction are assumed to be the formation of iodine (Equations 1 and 2). Iodine formed in the slow step is quickly consumed by a very fast reaction with bisulfite ions (Equation 3). The blue color does not appear, therefore, until all of the bisulfite ions have been consumed. Bisulfite ions are the limiting reactant and the rate of the overall reaction is first order in potassium iodate. The details of this experimental design are omitted in the student section of this write-up so that students can focus on the kinetics concepts.
- The volume of KIO_3 used in Solution A is directly proportional to its overall concentration in the reaction mixture since the total volumes of Solutions A and B are kept constant in all trials. This fact makes it possible to use the volume of KIO_3 rather than its concentration when plotting the graphs and analyzing the results.

Sample Data and Results

Trial	Solution A		Reaction Time (sec)	Reaction Rate (sec^{-1})
	0.1 M KIO_3	Water		
1	50 mL	150 mL	17	0.0606
2	100 mL	100 mL	8	0.125
3	25 mL	175 mL	33	0.0303
4*	20 mL	180 mL	45	0.0222
5*	80 mL	120 mL	10	0.100
Challenge!	33 mL	167 mL	25 sec (predicted) 26 sec (actual)	

*Included to give more accurate data for the challenge trial. Trials 1–3 are generally sufficient to make an accurate prediction for the amount of KIO_3 required to make the iodine clock "ring" in 25 seconds.





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 describes how fast the reaction occurs. The greater the rate of the reaction, the less time is needed for a specific amount of reactants to be converted to products. Some of the factors that may affect the rate of a chemical reaction include temperature, the nature of the reactants, their concentrations, and the presence of a catalyst.

The reaction time and the reaction rate depend on the KIO_3 concentration. Using Experiment 2 as a "control," the reaction time increased when the concentration was decreased (compare Experiments 1 and 2), and the reaction time decreased when the concentration was increased (compare Experiments 2 and 3). The rate of a reaction is inversely proportional to the reaction time. The rate of the iodine clock reaction is directly proportional to the amount and concentration of KIO_3. See the best-fit straight line obtained in the graph of 1/time (rate) versus volume of KIO_3. The reaction is first order with respect to the KIO_3 concentration.

The effect of concentration of the rate of reaction can be explained in terms of collisions between molecules. When the concentration of reactants increases, the reaction rate increases, because increasing the number of molecules or ions in solutions increases the probability of collisions between them.

The overall formation of the starch–iodine complex in the iodine clock reaction occurs in a series of steps.

$$IO_3^-(aq) + 3HSO_3^-(aq) \rightarrow I^-(aq) + 3H^+(aq) + 3SO_4^{2-}(aq) \qquad \textit{Equation 1}$$

$$6H^+(aq) + 5I^-(aq) + IO_3^-(aq) \rightarrow 3I_2(aq) + 3H_2O(l) \qquad \textit{Equation 2}$$

$$I_2(aq) + HSO_3^-(aq) + H_2O(l) \rightarrow 2I^-(aq) + SO_4^{2-}(aq) + 3H^+(aq) \qquad \textit{Equation 3}$$

$$I_2(aq) + \text{Starch} \rightarrow \text{Dark-blue colored complex}$$

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: Structure and properties of matter, chemical reactions

Reference

For a complete explanation of the principles of iodine clock reactions, please see "The Order of Reaction" experiment in *Kinetics*, Volume 14 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific: Batavia, IL (2003).

Materials for *Iodine Clock Challenge* are available as a Guided Inquiry Student Laboratory Kit from Flinn Scientific Inc.

Catalog No.	Description
AP7356	Iodine Clock Inquiry Challenge

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