# Iodine Clock Challenge

Demonstration and Inquiry

## 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

## Background

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.

## Inquiry Approach

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.

## Demonstration Questions

The iodine clock demonstration involves mixing two colorless solutions and measuring the time required for the blue color to suddenly appear. Solution A contains different amounts of 0.1 M $KIO_3$ and water, while Solution B is a standard solution containing 10 mL of 0.2 M $Na_2S_2O_5$, 30 mL of starch solution, and 40 mL water.

1. Pay close attention to the procedure used by the teacher in the iodine clock demonstration. Start timing as soon as Solutions A and B are mixed and stop when the blue color appears. Observe the reactions and record the reaction times.

| **Experiment** | **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 | |

2. Calculate the concentration of potassium iodate ($KIO_3$) in Solution A for each Experiment 1–3.
3. (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?
4. Write a general statement describing the effect of reactant concentration on the rate of a reaction.

## Inquiry Design and Procedure

1. Form a working group with two other students and brainstorm the following questions.
   - Why was the total volume of Solution A kept constant in the iodine clock demonstration?
   - In order to investigate the effect of $KIO_3$ concentration on the rate of the iodine clock reaction, the composition and



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amount of Solution B was not changed. Explain why.

- 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.
- Which graph would probably give a more accurate prediction of the amount of $KIO_3$ solution needed to make the iodine clock "ring" in 25 seconds? Explain.

2. Read the list of *Materials* that may be provided along with the *Safety Precautions* for their use. Each group will have enough materials to run three trials of the iodine clock reaction—two trial runs to gather additional data for the graph(s) and a final "challenge" run that must ring in 25 seconds. Write a detailed step-by-step procedure for the group challenge.
3. Carry out the trial runs, record data, and graph the results. Ask the teacher to measure the reaction time for the final test run.

## Materials

Potassium iodate solution, $KIO_3$, 0.1 M, 200 mL

Sodium meta-bisulfite solution, $Na_2S_2O_5$, 0.2 M, 30 mL

Starch solution, 90 mL

Water, distilled or deionized, 600 mL

Beakers, 100- and 500-mL, 3 each

Graduated cylinders, 10-mL, 50-mL (2), 100-mL, and 250-mL

Stirring rods

## *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.*

## Post-Lab Questions

1. For the final test run, how close did the actual reaction time come to the predicted time of 25 seconds? Discuss possible sources of error in the experiment and whether they would have led to longer or shorter reaction times.
2. Based on the results of the demonstration and your trial runs, predict the reaction time in seconds if 125 mL of $KIO_3$ solution were used in Solution A.
3. Explain the effect of concentration on reaction rate in terms of collisions between molecules: When the concentration of reactants increases, the reaction time _______________, because increasing the _______________ of molecules or ions in solution increases the rate of _______________ between them.
4. The overall formation of the starch–iodine complex in the iodine clock reaction occurs in a series of steps. Balance Equations 1–3 and identify the oxidizing and reducing agents in each reaction.

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

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

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

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

# Teacher's Notes for Guided Inquiry

Iodine Clock Challenge

## Materials for Demonstration

Potassium iodate solution, $KIO_3$, 0.1 M, 175 mL

Sodium meta-bisulfite solution, $Na_2S_2O_5$, 0.2 M, 30 mL

Starch solution, 90 mL

Water, distilled or deionized, 600 mL

Beakers, 100- and 500-mL, 3 each

Graduated cylinders, 10-mL, 50-mL (2), 100-mL, and 250-mL

Stirring rods, 3

## *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 within 1–2 days of use. To prepare 500 mL of 0.2 M sodium meta-bisulfite solution (enough for a class of 30 students working in pairs), add 19 grams of $Na_2S_2O_5$ to 400 mL of distilled or deionized water and stir to dissolve. Dilute the solution to 500 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 experiment.

| Experiment | 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 solution.
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.

## 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.

## 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

## Teaching Tips

- Student preparation is essential for success in a student-directed inquiry activity. In this inquiry "challenge," the students should follow the procedure used by the teacher in the demonstration. To ensure a safe lab environment, the teacher should review the students' understanding of the procedure and the safety precautions before students work in the lab.
- 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 *Post-Lab Question* #3.) 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.

## Answers to Demonstration Questions

1. Observe the clock reactions and record the reaction times.

| Experiment | Solution A | | Reaction Time |
|---|---|---|---|
| | 0.1 M $KIO_3$ | Water | |
| 1 | 50 mL | 150 mL | *17 sec* |
| 2 | 100 mL | 100 mL | *8 sec* |
| 3 | 25 mL | 175 mL | *33 sec* |

2. Calculate the concentration of potassium iodate ($KIO_3$) in Solution A for each Experiment 1–3.

   *Use the dilution equation, $M_1V_1 = M_2V_2$. The concentrations are 0.025 M, 0.05 M, and 0.013 M in Experiments 1–3, respectively.*

3. (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?

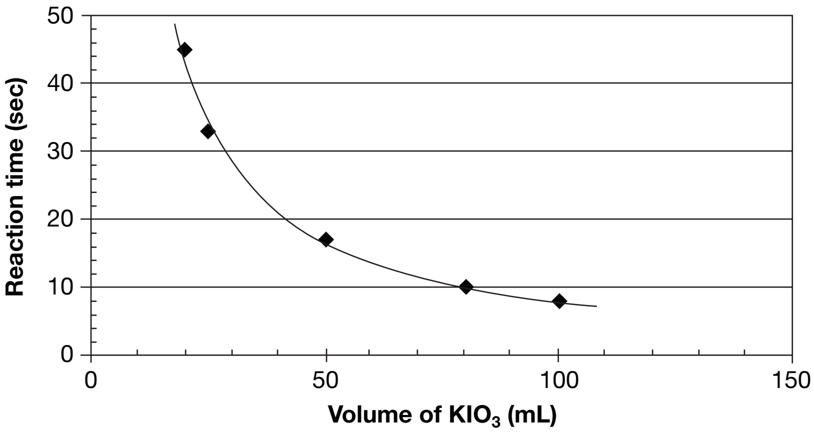
   *(a) Using Experiment 2 as a "control," the reaction time increased when the concentration was decreased (compare Experiments 1 and 2), and the reaction time decreased when the concentration was increased (compare Experiments 2 and 3). (b) The rate of a reaction is inversely proportional to the reaction time. The faster the rate of a reaction, the less time is needed for reactants to be converted to products.* **Note to teachers:** *This is a frequent source of student misconceptions.*

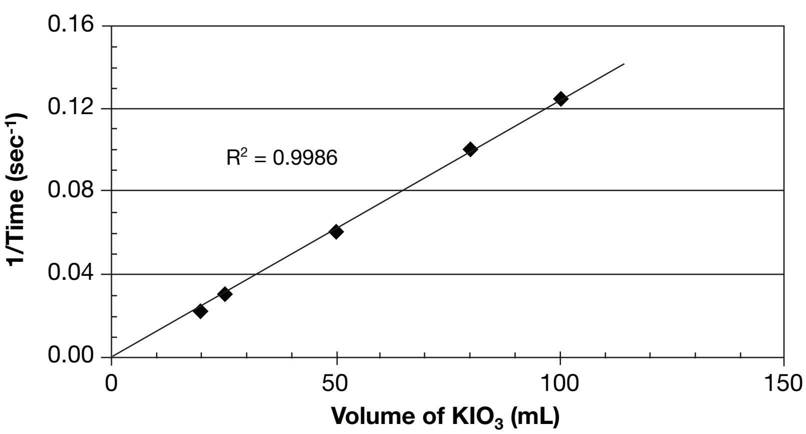
4. Write a general statement describing the effect of reactant concentration on the rate of a reaction.

   *In general, the rate of a reaction increases when the concentration of reactant(s) increases.*

## Sample Data and Graphs

| Experiment | 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)<br>26 sec (actual) | |




## 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 Chemical Demonstration Kit from Flinn Scientific Inc.

| Catalog No. | Description |
|---|---|
| AP4601 | Iodine Clock Reaction—Chemical Demonstration Kit |

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