**Greening the Clock Reaction:**

**HIGH SCHOOL**

**Green Chemistry & Sustainable Science**

**Rates of Reaction Lab**

**Teacher Background:**

The amount of each reactant present and the temperature of the reaction vessel typically influence the rate at which a chemical reaction proceeds. And, typically, this relationship between the Reaction Rate and Reagent Concentration takes a simple form known as the ***rate law***: rate = k[A]x[B]y

Clock reactions can be performed with a variety of reagents, including bisulfites, formaldehyde, mercuric ions, and thiosulfates. The traditional clock reaction involves the use of mercuric ions. And while the mercury compounds are typically not used in today’s classrooms it provides an excellent example for highlighting how experiments have evolved and the importance of green chemistry.

Traditionally the ‘Old Nassau’ clock reaction is preformed for a rates of reaction lab.Three colourless solutions containing iodate ions, hydrogen sulphite ions, mercury(II) ions and starch are mixed. After a few seconds the solution suddenly turns orange with a precipitate of mercury(II) iodide and a few seconds later suddenly turns black with the starch-iodine complex.

*The ‘Old Nassau’ clock reaction mechanism:*

Sodium metabisulfite and water react to form sodium hydrogen sulfite: Na2S2O5 + H2O 🡪 2 NaHSO3

 Iodate(V) ions are reduced to iodide ions by the hydrogen sulfite ions: IO3- + 3 HSO3- 🡪 I- + 3 SO42- + 3 H+

When the concentration of iodide ions becomes sufficient for the solubility product of the HgI2 to exceed 4.5 x 10-29 mol3 dm-9, then orange mercury(II) iodide precipitates until the Hg2+ ions are consumed (assuming an excess of I- ions): Hg2+ + 2 I- 🡪 HgI2 (orange or yellow)

 If I- and IO3- ions remain, then an iodide-iodate reaction takes place: IO3- + 5 I- + 6 H+ 🡪 3 I2 + 3 H2O

 The resulting starch-iodine complex is black to blue-black: I2 + starch 🡪 a blue/black complex

This lab is popular due to the dramatic color change of the reactions. In this lab students will investigate the hazards associated with the traditional lab and apply green chemistry principles while preforming a clock reaction lab replacement using common household safer materials.

*Greener clock reaction mechanism:*

The reaction rate being studied is for the following reaction:

H2O2 + 3 I– + 2 H+ ➞ I3– + 2 H2O

The I– is produced by adding excess vitamin C (ascorbic acid C6H6O6)to tincture of iodine

I3– + C6H8O6 ➞ 2 H+ + 3 I– + C6H6O6

When the H2O2 is added to the first reaction, it begins to produce I3. But since the ascorbic acid (C6H6O6)reacts with the I3 immediately, it prevents the I3 from reacting with the starch. The color change occurs only after all the vitamin C is used up.

Clarify for students that they are measuring time in this lab rather than rate, as the time gets smaller the rate increases and is larger.

References:

Vitamin C Clock Reaction:

“Getting Off to a Safe Start: Using safer starting materials for chemical reactions”, Introduction to Green Chemistry, ACS, 2002, p 5-11.

Nassau Reaction Background:

<http://chemistry.about.com/od/chemistrydemonstrations/a/nassaureaction.htm>

<https://www.youtube.com/watch?v=Tv6_IsdnaGg>

**Safety Information:**

* Goggles should be worn at all times.
* Gloves and aprons may be worn.
* Hand protection should be used when removing glassware from heat.

**Educational Goal:** To understand reaction rate, concentration and determine the order of a reaction and the rate constant.

**Student Objectives:** Students will …

* Apply the concepts of reaction rate to a clock reaction.
* Think critically about a process and how it might be improved using green chemistry principles

**Materials:**

* Distilled water
* 1000 mg Vitamin C tablets
* Tincture of iodine (2%)
* Hydrogen peroxide (3%)
* Liquid laundry starch
* Thermometer
* Ice bath
* Warm water bath
* Mortar and pestle
* 6 150 ml beakers
* 3 150-ml Erlenmeyer flasks (stock solutions)
* Permanent marker

**Time required:** 1 x 45 minutes lessons

**Standards Met:** **NGSS:**

**HS-PS1-5.** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

**HS-PS3-4.** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

**New York State Chemistry Standards:**

**3.4** Use kinetic molecular theory to explain rates of reactions and the relationships among temperature, pressure and volume of a substance; iv describe the concentration of particles and rates of opposing reactions in an equilibrium system; v describe the effect of stress on equilibrium; vi use collision theory to explain how various factors such as temperature, surface area and concentration influence the rate of reaction

**Rates of Reaction Student Lab**

**Purpose:** To apply green chemistry principlesas youinvestigate the variables that influence the rates of reaction.

**Background:**

Chemical kinetics is the study of the rates at which chemical reactions occur, the factors that affect the speed of reactions, and the mechanisms by which reactions proceed. The reaction rate depends on the reactants, the concentrations of the reactants, the temperature at which the reaction takes place, and any catalysts or inhibitors that affect the reaction.

In this lab you will first watch a common iodine clock reaction YouTube demo, investigate the hazards associated with the chemicals used in the lab and complete a greener clock reaction lab. The term clock reaction refers to the mixture of reacting chemicals that demonstrates a property shift (in this case color change) after a predictable amount of time.

**Pre-Lab**

1. Watch the following demo of the “Old Nassau Reaction” or the Halloween Clock Reaction.

Describe briefly what happened during the reaction.

<https://www.youtube.com/watch?v=Tv6_IsdnaGg>

1. Review the SDS’s for the chemicals found in the “Old Nassau Reaction“. List the hazards associated with the sodium metabisulfite, mercury(II) chloride and potassium iodate.
2. Does this lab align with the green chemistry principles? Why or why not please explain? (use 12 principles sheet to explain)

**Procedure:**

To complete this lab each student group should have Starch Solution, Vitamin C Stock Solution, 3% Hydrogen Peroxide, Tincture of Iodine and DI Water.

**Part 1: Preparation of Stock solutions:**

Vitamin C Stock Solution

1. Make a vitamin C solution by crushing a 1000mg vitamin C tablet and dissolving it in 60 mL of distilled water using a 150ml Erlenmeyer flask.
2. Place the flask on the hotplate over low heat (50°C to 80°C). The solution will take about 10 minutes to dissolve. Once dissolved label “Vitamin C Stock Solution”.

Starch Solution

1. Spray liquid starch to cover the bottom of the 150 ml Erlenmeyer flask. Extract with graduated pipette.

**Part 2: The effect of concentration on the clock reaction (*Trial 1, Trail 2, and Trial 3)***

* 1. There are three Trials, each with different concentrations (see the table below). Preform Step 2.2 and Step 2.3 for Trial 1a, then for Trial 2, and then again for Trial 3.
  2. Prepare “Solution A” and “Solution B” in two separate 150mL beakers. Label these beakers.
  3. Pour solution A into a 150mL beaker. Then pour solution B and mix. Begin timing immediately and continue to mix until there is a color change. Record the time it takes for the color to change.

**Solution A**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Vitamin C stock** | **Tincture of Iodine** | **DI Water** |
| **Trial 1** | 5.0mL | 5.0mL | 60.0mL |
| **Trial 2** | 5.0mL | 5.0mL | 30.0mL |
| **Trial 3a** | 5.0mL | 5.0mL | 90.0mL |

**Solution B**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **3% Hydrogen Peroxide** | **Starch Solution** | **DI Water** |
| **Trial 1** | 15.0mL | 2.0mL | 60.0mL |
| **Trial 2** | 15.0mL | 2.0mL | 30.0mL |
| **Trial 3a** | 15.0mL | 2.0mL | 90.0mL |

**Part 3: The effect of temperature on the clock reaction**

* 1. ***Trial 3b:*** Prepare the same Solutions A and B that you used for Trial 1a, but cool the solutions to 0°C before mixing by placing the containers in an ice bath. Mix and timing the reaction as before.
  2. ***Trial 3c:*** Prepare the same Solutions A and B that you used for Trial 1a, but this time using a warm water bath to heat the solutions to 40 °C. Mix and timing the reaction as before.

**Extensions:**

Graph your results.

Experiment with different concentrations of the two solutions.

**Questions:**

1. What is the relationship between the time it takes for a reaction to occur and the reaction rate?

Please explain.

1. What is the relationship between the concentration of the reactants and the rate of this reaction?

Please explain.

1. What is the relationship between the temperature and the rate of this reaction?

Please explain.

1. Explain the key differences between the pre-lab chemicals investigated and the chemicals used for the Greener Clock Reaction lab. (be sure to cite 12 principles)

**Teacher Key:**

**“Old Nassau” Clock Reaction Safety Information – Chemicals Used and Produced**

**Sodium metabisulfite Na2S2O5 (sodium pyrosulfite)**

***Potential hazards*:** Moderately toxic; releases toxic sulfur dioxide, especially on contact with acids.

**Mercury(II) chloride HgCl2 (mercuric chloride, corrosive sublimate)**

***Potential hazards:*** HIGHLY TOXIC: CUMULATIVE POISON; CORROSIVE TO SKIN.

**Potassium iodate KIO3**

***Potential hazards*:** Toxic. May ignite if mixed with combustible materials or organic compounds; toxic fumes emitted on heating. Reacts violently with aluminium, magnesium, carbon, sulfur and phosphorus. A violent reaction occurs if mixed with sodium bisulphite and a drop of water added. Toxic fumes evolved on reaction with concentrated sulfuric acid.

**Sodium hydrogensulfite (sodium bisulfite)**

***Potential hazards***: Moderately toxic; releases toxic sulfur dioxide, especially on contact with acids.

**Mercury(II) iodide solution <0.1%**

***Potential hazards:*** TOXIC. Do not ingest.

**Iodine solid mixture, <25% wt/wt**

***Potential hazards:*** Toxic; highly lung-irritant vapour evolved from the solid and from concentrated solutions. May cause an allergic reaction on skin. Do not mix with concentrated ammonia solution, since a highly explosive nitrogen triiodide complex is formed. Do not mix with acetaldehyde, or antimony metal since violently exothermic reactions may occur. Heat iodine only in a fume cupboard since the vapour is a powerful lung irritant.