

## EXPERIMENT 13: THE IODINE CLOCK REACTION

(New and Improved!)

Data: Be sure to record the concentrations of the stock solutions!

[KI] = \_\_\_\_\_

[Na<sub>2</sub>S<sub>2</sub>O<sub>8</sub>] = \_\_\_\_\_

[K<sub>2</sub>S<sub>2</sub>O<sub>3</sub>] = \_\_\_\_\_

Experiment	volume of [KI]	volume of [Na <sub>2</sub> S <sub>2</sub> O <sub>8</sub> ]	volume of [K <sub>2</sub> S <sub>2</sub> O <sub>3</sub> ]	volume of water	Temperature	TIME (seconds)-1	TIME (seconds)-2
1	20.0 mL	20.0 mL	10.0 mL	0 mL	23 °C		
2	20.0 mL	20.0 mL	5.00 mL	5.00 mL	23 °C		
3	20.0 mL	20.0 mL			23 °C		
4	10.0 mL	20.0 mL	10.0 mL	10.0 mL	23 °C		
5		20.0 mL	10.0 mL	10.0 mL	23 °C		
6	20.0 mL	20.0 mL	10.0 mL	0 mL	°C		
7	20.0 mL	20.0 mL	10.0 mL	0 mL	°C		
8	20.0 mL	20.0 mL	10.0 mL	0 mL	°C		
9	20.0 mL	20.0 mL	10.0 mL	0 mL	°C		

### PART II: Temperature Effects.

Four measurements will be made over a range of temperatures between 0 °C and 50 °C. Replace the beakers for the Na<sub>2</sub>S<sub>2</sub>O<sub>8</sub> solution and KI solution with labeled test tubes. These test tubes will be immersed in a water bath (600 mL of distilled water) to obtain the different temperatures. Use the solutions as described in the first experiment.

To obtain the highest temperature heat the water bath to approximately 60 °C and then place the test tubes containing the Na<sub>2</sub>S<sub>2</sub>O<sub>8</sub> solution and KI solution into the water bath for a few minutes. Mix the solutions with the cold indicator solution. Use the thermometer to measure the temperature of the solution. Measure the time to the formation of the starch-I<sub>2</sub> complex. This is sixth experiment.

In the seventh experiment repeat the experiment with the new solutions only use a water bath temperature of between 25 °C and 40 °C.

In the eighth use a temperature slightly cooler than room temperature. Immerse the test tubes into a water bath which is near 15 °C.

In the ninth experiment immerse the test tubes into an ice bath.

**PART III: Calculations.**

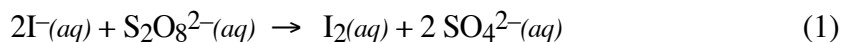
Exp. #	moles of I <sup>-</sup> added	moles of S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> added	moles of S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> consumed	moles of S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> remaining	[S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> ] remaining	Temperature	time
1							
2							
3							
	moles of I <sup>-</sup> added	moles of S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> added	moles of S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> added	[S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> ] initially	[I <sup>-</sup> ] initially	Temperature	time
1							
4							
5							
		moles of S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> added	moles of S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> consumed	Δ[S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> ]	time	Temperature	$\frac{\Delta[S_2O_8^{2-}]}{\Delta t}$
1							
6							
7							
8							
9							

Complete the above table.

Sample calculations: (Show a sample calculation for one of the experiments in the above table.)

Graphing the data:

Our goal is to arrive at the rate law for the reaction;



The general rate law for the above reaction is;

$$\text{rate} = k[\text{S}_2\text{O}_8^{2-}]^m[\text{I}^{-}]^n \quad (2)$$

We need to determine the order of the reaction with respect to both reactants, and determine the rate constant.

Several plots will have to be made to interpret the data and determine the order of the reaction with respect to  $\text{S}_2\text{O}_8^{2-}$ . To determine the order of the reaction with respect to the  $\text{S}_2\text{O}_8^{2-}$  we will assume the  $[\text{I}^{-}]$  is constant over the course of the reaction. This is not an unreasonable assumption since its concentration is fairly high and a very small amount of it reacts. By making that assumption the rate law for our reaction which is;

$$\text{rate} = k[\text{S}_2\text{O}_8^{2-}]^m[\text{I}^{-}]^n \quad (2)$$

in the general case becomes;

$$\text{rate} = (k [\text{I}^{-}]^n)[\text{S}_2\text{O}_8^{2-}]^m \quad (3)$$

or

$$\text{rate} = (k')[\text{S}_2\text{O}_8^{2-}]^m \quad (4)$$

This rate law looks like the rate law for a simple reaction (actually under the conditions of our experiment we should properly refer to the rate law as pseudo-simple). Therefore, we can apply all the knowledge we have about determining orders of simple reactions to our data.

To determine the order of the reaction with respect to  $\text{S}_2\text{O}_8^{2-}$  we can prepare two plots; one of  $\ln[\text{S}_2\text{O}_8^{2-}]$  versus time and the second of  $1/[\text{S}_2\text{O}_8^{2-}]$  versus time. The plot which is linear tells us what the order of the reaction is with respect to  $\text{S}_2\text{O}_8^{2-}$ . (Note: It may be useful to obtain all of the data collected in your particular laboratory for your plot.)

To determine the order of the reaction with respect to  $\text{I}^{-}$  we must shift gears. To start we can return to our general rate law for our reaction;

$$\text{rate} = k[\text{S}_2\text{O}_8^{2-}]^m[\text{I}^{-}]^n \quad (5)$$

At this point we know the order of the reaction with respect to  $\text{S}_2\text{O}_8^{2-}$ . To get the order of the reaction with respect to  $\text{I}^{-}$  we will use the method of initial rates. But we will apply some thought before we do any calculations. To use the method of initial rates we would like to complete the following table;

Exp. #	$[\text{I}^{-}]_0$	$[\text{S}_2\text{O}_8^{2-}]_0$	Initial Rate $\frac{\Delta[\text{S}_2\text{O}_8^{2-}]}{\Delta t}$
1			
4			
5			

We have already calculated the initial concentration of both reactants. Notice the initial concentration  $[\text{S}_2\text{O}_8^{2-}]$  is constant for all three experiments. Also since we are adding the

same amount of thiosulfate,  $S_2O_3^{2-}$  to each of the solutions the change ( $\Delta[S_2O_8^{2-}]$ ) will also be the same. Since the method of initial rates has us determining ratios of the rate of the reaction we see that something interesting happens;

$$\frac{\text{rate}_1}{\text{rate}_4} = \dots =$$

The  $[S_2O_8^{2-}]$  cancels and we just need to look at the ratios of the times for each pair of experiments. This ratio is equated to the ratio of the  $[I^-]_0$  raised to the power of  $m$  (the order). Since we know the initial concentrations we can determine the order of the reaction with respect to  $I^-$ .

Now the rate constant can be calculated because we know the order of the reaction with respect to the reactants.

Activation Energy:

To determine  $E_a$  plot  $\ln k$  versus  $\frac{1}{T}$  for the sixth through ninth experiment. We need to calculate the rate constant for each experiment 6 – 9. Since the initial concentrations of  $[S_2O_8^{2-}]$  and  $[I^-]$  are all the same as Experiment 1 we can calculate  $k$  using the specific rate law and substituting the different initial rates that are determined for Experiments 1 and 6 - 9.

The activation energy for the reaction can be obtained from such a plot. The relationship is given as,

$$\text{slope} = -\frac{E_a}{8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}}}$$