Name ____ Date _______________ Period _____

Activity: Sulfur Clock Reaction

Objective: Students will use experimental data to determine the rate law for a reaction

Essential Vocabulary:

- Rate Law
- Molarity
- Dilution
- Rate Constant
- Reaction Order

Introduction:

The rate of a chemical reaction may depend on the concentration of one or more reactants or it may be independent of the concentration of a given reactant. Exactly how the rate depends on the reactant concentrations is expressed in an equation called the rate law. How can the rate law for reaction be determined? That is the focus for this laboratory investigation.

We know that rate laws follow the general format: **Rate = $k[A]^a[B]^b$**

k is the reaction specific rate constant and is dependent on temperature. A and B are the molarities of the reactants in the solution.

We also talk about exponents ^{a} and ^{b} as the order of the reaction. The overall order of the reaction is the sum of these exponents. For example, the Haber process is a reaction in which ammonia is produced from its constituent elements.

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

If the rate law for this reaction is **Rate = $k[H_2]^2[N_2]^1$**, we say that the reaction is 2nd order with respect to hydrogen and 1st order with respect to the nitrogen. The overall reaction order is 3.

In today's lab we will determine the rate law for the reaction between hydrochloric acid (HCl) and sodium thiosulfate, $Na_2S_2O_3$.

$$2\ HCl_{(aq)} + Na_2S_2O_{3(aq)} \rightarrow S_{(s)} + SO_{2(aq)} + H_2O_{(l)} + 2\ NaCl_{(aq)}$$

We will be able to measure reaction progression because as the reaction occurs, solid sulfur is formed and 'falls out' of solution as a precipitate.

Materials:

- 5 mL disposable pipettes
- 24-well plates
- (3) 50 mL beakers
- 6 M HCl
- 0.15 M $Na_2S_2O_3$
- sheet of graph paper
- timer

Background Knowledge: The following data was collected by performing five separate trials of the reaction between nitrogen monoxide and oxygen gas at 25°C.

$$2\ NO_{(g)} + O_{2(g)} \rightarrow 2\ NO_{2(g)}$$

Trial #	[NO]	[O_2]	Reaction Time (s)	Average Reaction Rate (1/Reaction Time) (s^{-1})
1	0.02	0.01	35.7	0.028
2	0.02	0.02	17.5	0.057
3	0.02	0.04	8.8	0.11
4	0.04	0.02	4.4	0.23
5	0.01	0.02	71.4	0.014

1. If you want to determine the reaction order with regards to the concentration of oxygen, which 2 trials should you look at?

From trial 1 to trial 2, we doubled the concentration of the oxygen gas from 0.01 M to 0.02 M. As a result of that, the reaction rate also doubled from 0.028 to 0.057 s^{-1}. We utilize another short equation to determine the reaction order with regards to oxygen gas.

Concentration Change$^{\text{Reaction Order}}$ = Reaction Rate Change

Seeing as the concentration doubled, we would indicate that in our equation with a 2. The same idea is applied to the Reaction Rate change, which is also indicated by a 2.

$$2^x = 2$$

x = 1, so the reaction order with regards to oxygen is 1

2. Using the same procedure, determine the reaction order with regards to NO.

3. Using any of the five trials, determine the k value by plugging in the reaction rate and the concentrations of each reactant raised to their reaction orders. Include the units of k in your answer.

4. Write the complete Rate Law Equation for this reaction at 25°C, including the value of k.

5. Determine the rate of the reaction and the anticipated reaction time if the [NO]=0.05 M and [O_2] =0.002 M.

Procedure:

Safety: Please let your instructor know if you have sensitivity to sulfur. Hydrochloric acid is a strong acid that may cause burns if spilled on the skin or eyes. Wear safety goggles and aprons.

Protocol:

1. The night before the lab, determine the concentrations of the reactants and record the concentration of HCl and $Na_2S_2O_3$ for each trial in the data section. You must take into account the degree of dilution that took place prior to initiating the reaction. Assume that 20 drops = 1 mL and use the dilution equation to determine the solution concentrations. $M_1V_1 = M_2V_2$

2. Obtain a 24-well plate, 3 small beakers (label them as water, HCl and $Na_2S_2O_3$), 3 pipettes, and a sheet of graph paper.

3. You will conduct each of these trials and add each of the chemicals in the order they are listed. In trials 1-3, you will be diluting the $Na_2S_2O_3$ and in Trials 4-6 you will be diluting the HCl.

Trial 1	**Trial 2**	**Trial 3**
30 drops of $Na_2S_2O_3$ 0 drops of H_2O 20 drops of HCl	15 drops of $Na_2S_2O_3$ 15 drops of H_2O 20 drops of HCl	10 drops of $Na_2S_2O_3$ 20 drops of H_2O 20 drops of HCl
Trial 4	**Trial 5**	**Trial 6**
30 drops of HCl 0 drops of H_2O 20 drops of $Na_2S_2O_3$	15 drops of HCl 15 drops of H_2O 20 drops of $Na_2S_2O_3$	10 drops of HCl 20 drops of H_2O 20 drops of $Na_2S_2O_3$

4. Place the reaction well on a sheet of graph paper. As the reaction progresses, the sulfur will precipitate of solution and eventually will be present so much that you can no longer see the lines on the graph paper. You will measure the reaction time by measuring the time from the first drop of the last solution added in each trial until you can no longer see the lines on the graph paper.

5. Complete each of the six trials and record all data in the data table.

Data:

Reactant Concentrations and Reaction Rates

Trial #	[HCl]	[$Na_2S_2O_3$]	Reaction Time (s)	Reaction Rate (s^{-1})
1				
2				
3				
4				
5				
6				

Data Analysis

1. Determine the reaction order for both HCl and $Na_2S_2O_3$. What is the overall order for this reaction?

2. Determine the value of k for the Rate Law for this particular chemical reaction under these conditions.

3. Using your newly generated rate law, calculate the reaction rate and reaction time for the reaction with [HCl] =0.5 M and [$Na_2S_2O_3$] =0.1 M.

4. Speculate why the [HCl] used in this experiment is so high.

5. Using your knowledge of collision theory, how would increasing the temperature affect the reaction rates that you measured in lab?