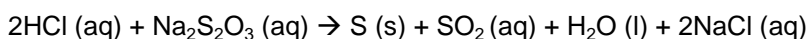**AP Chemistry Lab – Kinetics**

Experimental Overview:
In this laboratory experiment, experimental data will be used to determine the rate law for the reaction between hydrochloric acid, HCl, and sodium thiosulfate, $Na_2S_2O_3$.

$$2HCl \text{ (aq)} + Na_2S_2O_3 \text{ (aq)} \rightarrow S \text{ (s)} + SO_2 \text{ (aq)} + H_2O \text{ (l)} + 2NaCl \text{ (aq)}$$

To determine a rate law for this reaction, the following outline will be followed. First, the HCl concentration is held constant while the $Na_2S_2O_3$ concentration is varied. For each reaction, the reaction time is measured and recorded. Then, the HCl concentration is varied while the $Na_2S_2O_3$ concentration is held constant. Again, the reaction time for each reaction is measured and recorded. The reaction is timed by monitoring the appearance of the solid product, solid sulfur. As solid sulfur is formed, the reaction mixture will become opaque, clouded with precipitate. The reaction time will be measured by noting the time at which there is enough solid precipitate present to obscure a black mark on the bottom of the test tube.

From the general form for a rate law given: Rate = $k[A]^n[B]^m$, the general rate law for the reaction between HCl and $Na_2S_2O_3$ is written as:

$$\text{Rate} = k[HCl]^n[Na_2S_2O_3]^m$$

By determining how the reaction rate varies as the concentration of each reactant is varied, the orders n and m, and hence the rate law, will be determined.

Materials:
HCl, 1.0M, 30mL; $Na_2S_2O_3$, 0.30M, 30 mL;   Distilled water;   Beakers, 100 ml or other small size, 3;   Black marker; White paper;   Timer;   Small test tubes;   Syringe.

Safety Precautions:
Hydrochloric acid solution is moderately toxic by ingestion and inhalation. It is corrosive to eyes and skin. Sodium thiosulfate is a body tissue irritant. The sulfur produced in this reaction has low toxicity, but may be a skin and mucous membrane irritant. Aqueous sulfur dioxide is generated in this reaction (which is a skin and eye irritant).

Procedure:

1. Label one small beaker "HCl". Add 30 mL of 1.0 M hydrochloric acid, HCl, solution to this beaker.
2. Label another small beaker "$Na_2S_2O_3$". Pour 30 mL of 0.30 M sodium thiosulfate, $Na_2S_2O_3$, solution into this beaker
3. Label a third small beaker "water". Pour 30 mL of distilled or deionized water into this beaker.
4. Place a piece of white paper on the table where you can hold a test tube over it. Across the bottom of the tube, draw a black X covering the bottom of the tube. Hold the tube over the white paper, looking down into the bottom, and verify that your black X can be seen from the top. Repeat this X marking procedure for 3 small test tubes.
    Part A: varying the Concentration of HCl
5. Fill a syringe up to the 2 mL mark with distilled water by submerging the syringe in the "water" beaker and drawing water into the syringe until the plunger is at the 2 mL mark. Make sure that there are no air bubbles in the syringe.
6. Now submerge the syringe in the "HCl" beaker and draw 1 mL of HCl solution into the syringe so that the plunger sits at the 3 mL mark.
7. Empty the syringe into the X marked test tube 3.

8. Follow the same filling and emptying procedure as outlined in Steps 5-7, but use the amounts of water and HCl solution indicated below for the other test tubes. Fill the tubes in reverse order (tube 3, then tube 2, then tube 1). By filling the syringe with the most dilute mixture first and working up to the most concentrated, the syringe does not need to be rinsed between fillings.

Tube Number	mL HCl	mL H_2O
1	3.0 mL	0.0 mL
2	1.5 mL	1.5 mL
3	1.0 mL	2.0 mL

9. Rinse the syringe thoroughly with water. Fill the syringe to the 2 mL mark with the $Na_2S_2O_3$ solution. Prepare to start the timer. Empty the syringe into tube 1. Time the reaction with a timer by measuring the time from which the solution was added until the black X can no longer be seen through the solution. Record the exact time in seconds in Data Table 1.
10. Repeat step 9 for tubes 2 and 3, adding 2 mL of the $Na_2S_2O_3$ solution to each tube. Carefully time each reaction with a stopwatch or timer by measuring the time from which the solution was added until the black X can no longer be seen through the solution. Record the exact time in seconds in Data Table 1.

11. Repeat 5-10 in new, clean test tubes to obtain a second set of data (trial 2).
12. Empty the solutions into the waste collection beaker. Rinse each of the test tubes with soap and water, and leave to dry.

   Part B: Varying the Concentration of Na$_2$S$_2$O$_3$
13. Repeat the X marking procedure from step 4 for three more small test tubes. Fill the syringe up to the 2 mL mark with distilled water by submerging the syringe in the "water" beaker and drawing water into the syringe until the bottom of the plunger is at the 2mL mark. Make sure there are no air bubbles in the syringe.
14. Now submerge the syringe in the "Na$_2$S$_2$O$_3$" beaker and draw 1 mL of the Na$_2$S$_2$O$_3$ solution into the syringe so that the plunger sits at the 3 mL mark.
15. Empty the syringe into a clean, X marked test tube (tube 3).

16. Follow the same filling and emptying procedure as outlined in steps 13-15, but use the amounts of water and Na$_2$S$_2$O$_3$ solution indicated below for tubes 2 and 3. Fill the tubes in reverse order (tube 3, then tube 2, then tube 1). By filling the syringe with the most dilute mixture first and working up to the most concentrated, the syringe does not need to be rinsed between fillings.

Tube Number	mL Na$_2$S$_2$O$_3$	mL H$_2$O
1	3.0 mL	0.0 mL
2	1.5 mL	1.5 mL
3	1.0 mL	2.0 mL

17. Rinse the syringe thoroughly with water. Fill the syringe to the 2 mL mark with the HCl solution. Prepare to start the timer. Empty the syringe into the test tube. Time the reaction with a timer by measuring the time from which the solution was added until the black X can no longer be seen through the solution. Record the exact time in seconds in Data Table 2.
18. Repeat step 17 for the other tubes, adding 2 ml of the HCl solution to each.. Carefully time each reaction with a timer by measuring the time from which the solution was added until the black X can no longer be seen through the solution. Record the exact time in seconds in Data Table 2.
19. Repeat steps 13-18 to obtain a second set of data.

Data Table 1 - Varying the Concentration of HCl

Tube Number	Initial [HCl], M	Initial [Na$_2$S$_2$O$_3$], M	Final [HCl], M	Final [Na$_2$S$_2$O$_3$], M	Reaction Time (s) Trial 1	Reaction Time (s) Trial 2	Average
1							
2							
3							

Data Table 2 - Varying the Concentration of Na$_2$S$_2$O$_3$

Tube Number	Initial [HCl], M	Initial [Na$_2$S$_2$O$_3$], M	Final [HCl], M	Final [Na$_2$S$_2$O$_3$], M	Reaction Time (s) Trial 1	Reaction Time (s) Trial 2	Average
1							
2							
3							

SAMPLE DATA AND POST LAB QUESTIONS

Data Table 1 - Varying the Concentration of HCl

Tube Number	Initial [HCl], M	M1V1 with 5 mL total volume Initial [Na$_2$S$_2$O$_3$], M	Final [HCl], M	M1V1 with 5 mL total volume Final [Na$_2$S$_2$O$_3$], M	Reaction Time (s) Trial 1	Reaction Time (s) Trial 2	Average
1	1.0 M	0.3 M	0.6 M	0.12 M	16.64 s	15.19 s	15.92 s
2	0.5 M	0.3 M	0.3 M	0.12 M	14.06 s	14.80 s	14.43 s
3	0.33 M	0.3 M	0.2 M	0.12 M	15.03 s	16.52 s	15.78 s

Data Table 2 - Varying the Concentration of Na$_2$S$_2$O$_3$

Tube Number	Initial [HCl], M	Initial [Na$_2$S$_2$O$_3$], M	Final [HCl], M	Final [Na$_2$S$_2$O$_3$], M	Reaction Time (s) Trial 1	Reaction Time (s) Trial 2	Average
1	0.4 M	0.18 M	0.4 M	0.18 M	13.19 s	12.86 s	13.02 s
2	0.4 M	0.09 M	0.4 M	0.09 M	24.50 s	18.75 s	21.62 s
3	0.4 M	0.06 M	0.4 M	0.06 M	35.52 s	45.49 s	40.50 s

Post-Lab Questions: Kinetics

1. Calculate the initial concentration of the HCl solutions in Part A. Remember to calculate the concentration of the HCl solutions that will diluted by mixing water and HCl in the syringe using the equation M1V1 = M2V2. Record concentrations in the table. Show at least one sample calculation in your notebook. Record the initial concentration of Na$_2$S$_2$O$_3$ solution used in Part A in the table. Repeat for Part B and Data Table 2.
2. Calculate the final concentrations of the HCl solutions and Na$_2$S$_2$O$_3$ solutions after mixing them together for each test tube. Record these concentrations in the tables. Show at least one sample calculation below. To calculate these concentrations, remember that mixing the solutions dilutes each of them. Use M1V1 = M2V2 to calculate the final concentrations after dilution.
3. Calculate and record the reaction rate in sec^{-1} for each tube in the Data Tables. Show one sample calculation in your notebook.
4. Plot three graphs to represent the data obtained for [HCl] in Data Table 1. Each graph should represent the potential integrated equations for each order of [HCl] (plot [HCl] vs time, 1/[HCl] vs time, and ln[HCl] vs time.) With this graph determine the order of [HCl].
5. Repeat the above question for the [Na$_2$S$_2$O$_3$]. You can include this plot on the graphs of [HCl] but be sure to label each line accordingly.
6. What is the overall order of the reaction?
7. Write the rate law for this reaction.
8. Solve for the rate constant and include correct units.