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Chemistry Lab

Experiment

Booklet

April 2nd, 2016

State Tournament

University of Wisconsin - Stout

Instructions: This exam consists of a gas law experiment worth 100 points, a chemical kinetics experiment worth 100 points, and a multiple choice exam worth 100 points (300 points total). Students may NOT write on the Experiment or Exam Booklet. Students may **only mark on their answer sheets.**

Be strategic, figure out the way that you and your team can bank as many points as possible in the time given. Place the answers to the lab experiments and multiple choice exam on the provided answer sheets. Answers not placed on the answer sheet will not be scored.

Ties will be broken by first the quality and accuracy of the kinetics experimental data, followed by the quality and accuracy of the gas law experimental data.

YOU WILL HAVE 30 MINUTES TO COMPLETE EACH EXPERIMENT

Half of the teams present will start with the gases experiment and half will start with kinetics experiment. **After 30 minutes**, we will switch stations. You will need to perform the experiment and have your station completely cleaned up **and reset to their original positions** or a penalty of up to 10 % will be assessed against your score.

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Potentially Useful Information

1 atm = 760 mm Hg = 101.325 kPa = 1.01325 bar = 14.7 psi

STP: T = 0 °C = 273.15 K; P = 1 atm

P · V = n · R · T

$$R = 0.082057 \frac{L \cdot atm}{K \cdot mol}$$

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

$$\rho_{gas} = \frac{P \cdot MW}{R \cdot T}$$

$$T(°C) = [T(°F) - 32°F] \times \frac{5(°C)}{9(°F)}$$

$$T(°F) = \left[T(°C) \times \frac{9(°F)}{5(°C)}\right] + 32°F$$

$$T(K) = [T(°C) + 273.15(°C)] \times \frac{1(K)}{1(°C)}$$

$$T(°C) = [T(K) - 273.15(K)] \times \frac{1(°C)}{1(K)}$$

There are two kinds of rate laws: the differential rate law (or just rate law) and the integrated rate law. The rate law for a reaction of the type

$$aA \longrightarrow \text{products}$$

describes the dependence of the rate on the concentration of A:

$$\text{Rate} = -\frac{\Delta[A]}{\Delta t} = k[A]^n$$

where k is called the rate constant and n is the order of the reaction in A. The rate is defined as the negative of $\Delta[A]/\Delta t$ because [A] is decreasing (as the reactants are used up in the reaction). The value for n (the order) cannot be determined from the balanced equation for the reaction but must be found experimentally. For a first-order reaction n is 1 and the rate = k[A]. For a second-order reaction n is 2 and the rate = $k[A]^2$. For a zero-order reaction n is 0 and the rate = k.

A common experimental method for determining the rate law is the method of initial rates in which several runs are carried out with different initial concentrations, and the rate is measured for each at a value of t close to $t = 0$.

An integrated rate law expresses reactant concentrations as a function of time. The integrated rate law for a first-order reaction is

$$\ln[A] = -kt + \ln[A]_0$$

where $[A]_0$ is the initial concentration of A. Thus we can calculate [A] at any time, given $[A]_0$ and k. For a reaction that shows first-order kinetics, a plot of ln[A] versus time is a straight line.

Table 12.6 Summary of the Kinetics for Reactions of the Type aA → Products That Are Zero, First, or Second Order in [A]

	Order		
	Zero	*First*	*Second*
Rate law:	Rate = k	Rate = k[A]	Rate = $k[A]^2$
Integrated rate law:	$[A] = -kt + [A]_0$	$\ln[A] = -kt + \ln[A]_0$	$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$
Plot needed to give a straight line:	[A] versus t	ln[A] versus t	$\frac{1}{[A]}$ versus t
Relationship of rate constant to the slope of straight line:	Slope = $-k$	Slope = $-k$	Slope = k
Half-life:	$t_{1/2} = \frac{[A]_0}{2k}$	$t_{1/2} = \frac{0.693}{k}$	$t_{1/2} = \frac{1}{k[A]_0}$

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EXPERIMENT 1: GASES

Introduction

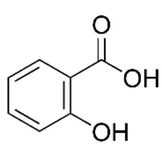
The purpose of this experiment is to study the reaction between sodium bicarbonate and the two organic acids; salicylic acid and citric acid. For convenience, we will be using Alka-Seltzer tablets as the source for these three materials. We will perform the gas forming reaction, collect the product over water, characterize the mass, volume, and density of the gas that was produced, and use the ideal gas law to study the stoichiometry and percent yield of the reaction.

Discussion

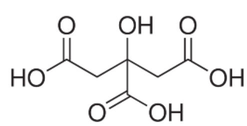
Sodium bicarbonate reacts with salicylic acid and citric acid to form carbon dioxide gas, sodium salicylate, sodium citrate, and water. (Equation 1 below). The structure of several reactants and products are shown below the chemical equation.

$$\mathbf{4\ NaHCO_3(s) + HC_9H_7O_4(s) + H_3C_6H_5O_7(s) \rightarrow 4\ CO_2(g) + NaC_9H_7O_4(aq) + Na_3C_6H_5O_7(aq) + 4\ H_2O(l)}$$

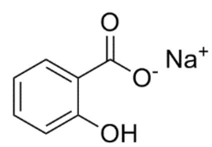
Sodium Bicarbonate + Salicylic Acid + Citric Acid → Carbon Dioxide + Sodium Salicylate + Sodium Citrate + Water



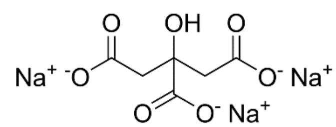
Salicylic Acid
138.12 g/mol



Citric Acid
192.12 g/mol



Sodium Salicylate
160.10 g/mol



Sodium Citrate
258.06 g/mol

The amount of gas released by the reaction will be quantified and used to calculate the percent yield of the reaction.

Materials

One Packet of 2 Alka-Seltzer Tablets

100 mL of Deionized Water

One 100-mL Graduated Cyllinder

One 125-mL Erlenmeyer Flask

One 500-mL Erlenmeyer Flask

Small Glass Plate or Watch Glass

Gas Hose Assembly

Water Basin

Analytical Balance

Take careful notice of the layout of your station.

Points will be deducted (up to 10%) from your score if you do not clean and replace all of the items back to their original positions!

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Safety Precautions

There are no particular chemical hazards associated with this experiment. However, glassware could potentially be put under gas pressure, or be inadvertently broken resulting in a broken glass of splash hazard. Wear chemical splash goggles to perform this experiment.

OPTIONAL: Gloves and a chemical-resistant apron or lab coat will be required for Experiment 2 and of course can be worn for this experient as well if desired.

Procedure

1. Obtain a packet containing two **Alka-Seltzer tablets**
2. Be careful not to destroy the label when opening the packet, you will need to use the information recorded on the label for calculations.
3. Using the analytical balance, measure the mass of one of the Alka-Seltzer tablets and record the value on your answer sheet. (Be sure to record all digits from the balance)
4. Using the analytical balance, measure the mass of the 125-mL Erlenmeyer flask and record the value on your answer sheet. (Be sure to record all digits from the balance)
5. Use the 100-mL graduated cyllinder to add **50 mL** of **deionized water** to the 125-mL Erlenmeyer flask.
6. Using the analytical balance, measure the mass of the flask plus the water added and record the value on your answer sheet. (Be sure to record all digits from the balance)
7. Add water to the basin to a depth of about 3 inches.
8. Fill the 500-mL Erlenmeyer flask to overflowing over the sink.
9. Place the glass plate or watch glass over the mouth of the flask
10. Invert the flask and hold the mouth under the water in the basin
11. Remove the glass plate or watch glass and keep the mouth of the flask under the surface of the water.
12. Prepare the gas hose assembly so that the stoppered and and the angled tube are positioned as shown in the diagram below. Slip the angled tube into the submerger mouth of the water filled and inverted 500-mL Erlenmeyer flask.

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13. This part is best accomplished as a two person operation
14. Carefully break the Alka-Seltzer tablet in half and add both pieces to the water in the 125-ml flask and ***immediately*** place the gas tube assembly stopper stopper over the mouth of the flask before any gas has a chance to escape.
15. ***Do not allow any gas to escape, this will introduce error into the volume measurement and result in inaccuracies in your reported values and lost points.***
16. After the reaction has completed and the tablet has completely dissolved, remove the hose assembly tube from the mouth of the inverted 500-mL Erlenmeyer flask, cap the mouth under water with the glass plate or watch glass, remove the flask from the basin, carefully invert the flask and set it on the benchtop.
17. Carefully remove the stopper end of the hose assembly from the 125-mL Erlenmeyer flask.
18. ***Be careful not to splash any water from the flask into the hose or onto the stopper. We will be weighing the flask to determine the mass of the gas that was produced and any lost water from the flask will be incorrectly included in the mass of the gas produced.***
19. Using the analytical balance, measure the mass of the 125-mL Erlenmeyer flask and remaining contents from the reaction and record the value on your answer sheet.
20. *If you perform the experiment carefully*, this mass is equal to the flask, water, and tablet *minus* the mass of the gas produced.
21. The volume of gas produced can be determined by removing the glass plate of watch glass and then carefully adding amounts of water to the 500-mL Erlenmeyer flask with the 100-mL graduated cyllinder until the flask is level full. Be careful to keep track of each amount added so they can be summed at the end and recorded on your answer sheet.
22. If you have time, you can reset the apparatus and repeat the experiemt with the second Alka-Seltzer tablet to verify your result or increase the statistical significance of your values by averaging your two trials.

    NOTE: *you will only be given* ***1 paket*** *of Alka-Seltzer tablets, if you are unable to produce useable data with either of them,* **you will not be given additional Alka-Seltzer tablets.**

Disposal

- *All solutions produced in this experiment are non-toxic and may be disposed of down the sink drain.*
- ***Thoroughly rinse all beakers and graduated cylinders, shake dry, and return ALL ITEMS to their original places at your station.***

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Calculations

23. Calculate the **mass** of the beaker, water, and Alka-Seltzer tablet and record the value on your answer sheet, this is the initial mass of the system at the beginning of the reaction.
24. Subtract the final mass of the 125-mL Erlenmeyer flask and reaction contents after the reaction from the initial mass and record the value on your answer sheet. ***This value is equal to the mass of gas produced.***
25. Determine the **density** of the gas produced by dividing the mass of the gas by the volume of the gas produced and record the value on your answer sheet.
26. Calculate the **theoretical density** of carbon dioxide using the periodic table to calculate molecular weight and the density equation below and record the value on your answer sheet. Assume a pressure of 1 atm and a temperature of 22 °C.

$$\rho_{gas} = \frac{P \cdot MW}{R \cdot T}$$

Analysis

Additional questions for this experiment are found on your answer sheet

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EXPERIMENT 2: KINETICS

Procedure adapted from "CHEM FAX Publication No. 91860" by FLINN Scientific, 2009.

Introduction

The purpose of this experiment is to use the **method of initial rates** to determine the form of the rate law for the reaction between sodium thiosulfate and hydrochloric acid. The reaction, which produces solid colloidal sulfur, will be followed by measuring the time needed for the reaction mixture to become **opaque**, a visual indication that a particular concentration of colloidal sulfur has been achieved. The results will be analyzed graphically to determine the individual **orders** of both reactants, the overall **reaction order**, the value of the **rate constant**, the **differential rate law**, and the **half life** of the reaction.

Discussion

Sodium thiosulfate reacts with hydrochloric acid to form sulfurous acid, aqueous sodium chloride, and a colloidal suspension of solid sulfur (Equation 2).

$$\mathbf{Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow H_2SO_3(aq) + 2NaCl(aq) + S(s)} \qquad \textit{Equation 2}$$

The kinetics of the reaction can be analyzed by varying the concentration of each reactant and then graphing reaction rate as a function of concentration for each reactant.

Materials

110 mL of 0.125 M Sodium Thiosulfate Solution

27.5 mL of 2 M Hydrochloric Acid

112.5 mL of Deionized Water

Two 100-mL Graduated Cyllinders

One 10-mL Graduated Cyllinder

Five 50-mL Beakers

Glass Stir Rod

Plastic Pipette

Copy Paper and a Black Sharpie Marker

Wall Clock, Wrist Watch, or Similar Timer

Take careful notice of the layout of your station.

Points will be deducted (up to 10 %) from your score if you do not clean and replace all of the items back to their original positions!

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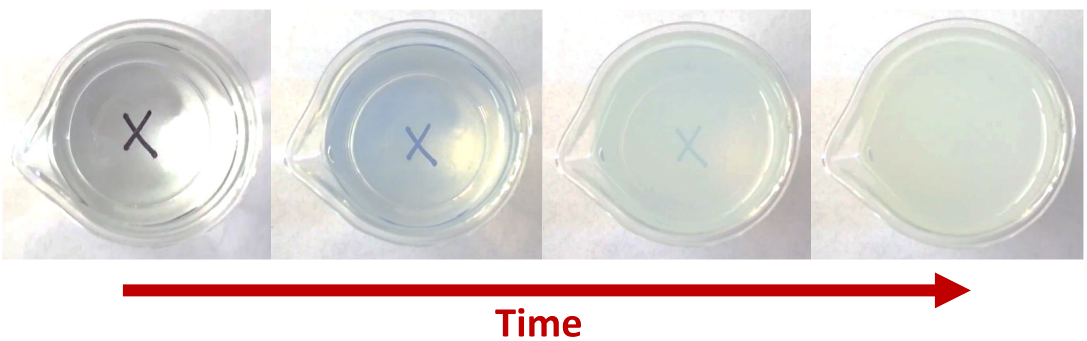
Safety Precautions

Hydrochloric acid solution is corrosive to eyes and skin. It is moderately toxic by ingestion and inhalation. Sodium thiosulfate solution is a body tissue irritant. The reaction of sodium thiosulfate and hydrochloric acid generates sulfur dioxide gas, which is a skin and eye irritant. Perform this demonstration in a well-ventilated lab only. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, gloves, and chemical-resistant apron or lab coat.

Procedure

27. Write an X on a piece of white copy paper using a Sharpie marker
28. Place a clean 50-mL beaker on the X drawn on the paper
29. Using separate 100-mL graduated cylinders for the solution and water, measure and add the required amounts of **0.125 M sodium thiosulfate** and **deionized water** to the beaker. Be as precise as possible. A table showing the amounts that should be used is printed on your answer sheet.
30. Measure the required amount of **2 M hydrochloric acid** into a 10-mL graduated cylinder. Use the plastic pipette to add the correct amount to the graduated cylinder.
31. Carefully add the hydrochloric acid to the sodium thiosulfate solution and **immediately start timing**.
32. Quickly stir the solution for a few seconds using a glass stirring rod.
33. Carefully observe the black X while looking down through the solution.



34. **Stop timing** when the black "X" is no longer visible (see illustration above). Record the reaction time in seconds in the data table on your answer sheet.
35. **Repeat this procedure for each trial.**
36. Perform the first three trials keeping the concentration of hydrochloric acid constant and varying the sodium thiosulfate concentration.
37. The center concentration (trial 2) will be used in the second part of this experiment and **the data can simply be copied down to the second table**.
38. In trials 4 and 5, the sodium thiosulfate concentration is kept constant and the hydrochloric acid concentrtion is varied.

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Disposal

- *Pour the colloidal sulfur suspensions into the sulfur waste container in the fume hood.*
- ***Thoroughly rinse all beakers and graduated cyllinders, shake dry, and return ALL ITEMS to their original places at your station.***

Calculations

39. Calculate the **initial molar concentration** of sodium thiosulfate, **[$Na_2S_2O_3$]**, in each trial. The final volume in each case is 50 mL of solution. (**Remember $C_1V_1 = C_2V_2$**)
40. Calculate the **initial molar concentration** of hydrochloric acid, **[HCl]**, in each trial.
41. Calculate the **Inverse Time**, (1/reaction time). This value is *proportional to* the average rate of the reaction between time 0 and the time that the colloidal sulfur product concentration had increased to the point that the X on the page was no longer visible.

Graphing

42. Plot **concentration vs. reaction time** and **concentration vs. inverse time** for both reactants on your answer sheet. Shetch a best fit line or curve through your data points.
43. Because the same concentration (degree of cloudiness) was used as the endpoint for each trial, the **order of each reactant** can be determined from the plots of inverse time as a function of concentration.

Analysis

44. Write the algebraic form of the **Rate Law** equation with **variables** for each reactant order on your answer sheet
45. Determine the **Order** (0, 1, or 2) of **sodium thiosulfate** in this reaction from your data and record on your answer sheet
46. Determine the **Order** (0, 1, or 2) of **hydrochloric acid** in this reaction from your data and record on your answer sheet
47. Write the **Rate Law** for this reaction based on your data with the **actual reactant orders** written into the equation on your answer sheet
48. Determine the **Overall Reaction Order** (0, 1, 2, 3, or 4) from your data and record on your answer sheet
49. The reaction mixture becomes cloudy at an approximate sulfur concentration of **5.0×10^{-3} M**. If we assume this is the concentration of sulfur at the "cloud point" for each trial, the **actual Reaction Rate** can be calculated for each trial by multiplying the **Inverse Time** by this concentration. At the beginning of the reation, t_0, the sulfur concentration was 0. At the "cloud point" when timing was stopped, the concentration of sulfur was **5.0×10^{-3} M**.
50. Calculate the **Reaction Rate** for each trial assuming a cloud point sulfur concentration of **5.0×10^{-3} M** and record on your answer sheet.
51. Calculate the value of the **Rate Constant**, k, for this reaction using your data and record on your answer sheet. Be sure to include the **proper units** for your Rate Constant.
52. Calculate the **Half-Life** for this reaction and record on your answer sheet.