Activity: Reaction Rate

Objective

Determine how stirring and reactant concentration affect the reaction rate between acetic acid and sodium bicarbonate.

Materials and Equipment

- Data collection system
- Absolute pressure sensor
- Sampling bottle, plastic, 500-mL
- Rubber stopper, two-hole, to fit the sampling bottle and fitted with a 50-cm piece of tubing with a quick-release connector, and a stopcock
- Graduated cylinder, 100-mL
- Beaker, 100-mL
- Balance, readability: 0.01 g
- Syringe
- Magnetic stirrer with stirring bar
- Sodium bicarbonate ($NaHCO_3$), 2 g
- 0.50 M acetic acid ($HC_2H_3O_2$), 60 mL
- Waste container
- Tap water, 180 mL plus water to rinse the sampling bottle between trials

Safety

- The gas being generated causes an increase in pressure, which may expel the stopper from the bottle. Wear eye protection during this experiment to prevent injury due to flying objects or splashed chemicals.
- Do not point the sampling bottle toward yourself or anyone else.

***NOTE**: Record all work, including tables, data, diagrams, and answers, into your notebook.*

Procedure – Part 1: No stirring versus stirring

☐ 1. In the steps below, you will react 0.40 g of sodium bicarbonate ($NaHCO_3$) with 10.0 mL of 0.50 M acetic acid ($HC_2H_3O_2$) in the 500-mL sampling bottle. Before beginning the reaction, use the Ideal Gas Law to calculate the maximum pressure (kPa) you expect to obtain when the reaction is complete.

HINTS: a) Does your sampling bottle hold more than 500 mL? b) Watch the units carefully. c) Don't forget to include air pressure already in your sampling bottle. d) $R = 8.314 \frac{L \cdot kPa}{mol \cdot K}$.

☐ 2. Will the reaction between $NaHCO_3$ and $HC_2H_3O_2$ occur faster with or without stirring? Explain your prediction.

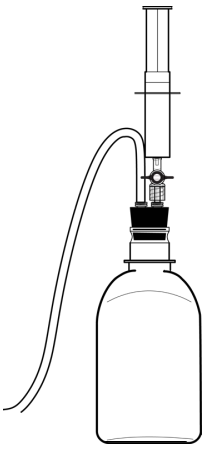
☐ 3. Copy Table 1 into your notebook.

Table 1: Reaction rate comparison: with and without stirring, collected data

Reaction Conditions	Mass of $NaHCO_3$ (g)	Volume of 0.50 M $HC_2H_3O_2$ (mL)	Initial Pressure (kPa)	Final Pressure (kPa)	Time Reaction Started (s)	Time Reaction Stopped (s)
Without stirring	RECORD THE DATA IN YOUR NOTEBOOK.					
With stirring						

☐ 4. Connect the pressure sensor to your data collection system ◆(2.1) and create a new file ◆(1.2) with a pressure (kPa) versus time (s) graph and a digits display of pressure (kPa). ◆(7.1.1)(7.3.1)

☐ 5. Determine if the reaction occurs faster with or without stirring. To do this, follow the steps listed below once while constantly swirling the sampling bottle (stirring) and once without swirling (no stirring).



a. Use a balance to obtain 0.40 g of $NaHCO_3$. Record the exact mass in Table 1.

b. Place the $NaHCO_3$ you just measured into the 500-mL sampling bottle.

c. Firmly place the stopper into the sampling bottle. Turn the stopcock to the closed position.

d. Attach the absolute pressure sensor to the sampling bottle using the quick-release connector.

e. Expel all the air from the syringe and place the syringe in a 100-mL beaker containing the 0.50 M $HC_2H_3O_2$. Pull the plunger out until the syringe contains 10.0 mL of solution (with no air bubbles). Record the exact volume in Table 1.

f. Twist the syringe onto the stopcock.

g. Start collecting data ◆(6.2) and after 10 seconds, turn the stopcock to the open position and inject the $HC_2H_3O_2$ into the sampling bottle. Immediately turn the stopcock to the closed position.

h. Collect data until the reaction is complete (the data stabilizes at the maximum pressure) or until the reaction has run for two minutes and then stop data collection. ◆(6.2)

g. Record in Table 1 the initial pressure, the time the reactants were mixed, the final pressure, and the time the reaction was stopped. ◆(9.1)

h. Remove the syringe from the stopcock and then release the pressure from the bottle by slowly removing the stopper from the bottle.

i. Pour the solution in the bottle into the waste container. Clean the bottle by rinsing it with water.

☐ 6. Copy Table 2 into your notebook and complete it by calculating the change in pressure, change in time, and the average rate of the reaction for each trial.

NOTE: "Average rate of reaction" equals the change in pressure (product formation) divided by the change in time.

Table 2: Reaction rate comparison: with and without stirring, calculated data

Reaction Conditions	Change in Pressure (kPa)	Change in Time (s)	Average Rate of Reaction (kPa/s)
Without stirring	RECORD THE DATA IN YOUR NOTEBOOK.		
With stirring			

☐ 7. Did the reaction occur faster with stirring or without stirring? Support your answer with data.

☐ 8. Was your prediction correct? Explain any differences.

Procedure – Part 2: Changing reactant concentration

☐ 9. In this part of the procedure you will react 10 mL of 0.50 M $HC_2H_3O_2$ with different concentrations of $NaHCO_3$. In each trial you will use 0.40 g of $NaHCO_3$ but you will dissolve it in different amounts of water (30 mL, 60 mL, and 90 mL) to create different concentrations.

a. Which solution will be the most concentrated?

b. Which solution will be the most dilute?

☐ 10. Predict how concentration will affect the rate of the chemical reaction. Explain your reasoning.

☐ 11. Copy Table 3 into your notebook.

Table 3: Reaction rate comparison: different concentrations of sodium bicarbonate, collected data

Volume of Water Added to $NaHCO_3$ (mL)	Mass of $NaHCO_3$ (g)	Volume of 0.50 M $HC_2H_3O_2$ (mL)	Initial Pressure (kPa)	Final Pressure (kPa)	Time Reaction Started (s)	Time Reaction Stopped (s)
30.0						
60.0	RECORD THE DATA IN YOUR NOTEBOOK.					
90.0						

☐ 12. Determine how concentration (with constant stirring for all trials) affects the reaction rate by performing the reaction 3 times, each with a different starting concentration of $NaHCO_3$, as follows:

a. Use a balance to obtain the mass of 0.40 g of $NaHCO_3$. Record the exact mass in Table 3.

b. Place the $NaHCO_3$ you just measured in the 500-mL sampling bottle and then add the specified amount of water.

c. Place the sampling bottle on a magnetic stirrer, add a stir bar to the bottle, and set the stirrer to medium speed. Allow the $NaHCO_3$ to dissolve before continuing with the next step. Continue stirring throughout the reaction.

d. Firmly place the stopper into the sampling bottle.

e. Attach the pressure sensor to the sampling bottle using the quick-release connector.

f. Fill the syringe with 10.0 mL of 0.50 M acetic acid ($HC_2H_3O_2$). Record the exact volume in Table 3.

g. Twist the syringe onto the stopcock.

h. Start collecting data ⓪(6.2) and after 10 seconds, turn the stopcock to the open position and inject the $HC_2H_3O_2$ into the sampling bottle, keeping the magnetic stirrer at medium speed the entire time. Immediately turn the stopcock to the closed position.

i. Collect data until the reaction is complete (the data stabilizes at the maximum pressure) or until the reaction has run for two minutes, and then stop data collection. ⓪(6.2)

j. Record in Table 3 the initial pressure, the time the reactants were mixed, the final pressure, and the time the reaction was stopped. ⓪(9.1)

h. Remove the syringe from the stopcock and then release the pressure from the bottle by slowly removing the stopper from the bottle.

i. Pour the solution in the bottle into the waste container. Clean the bottle by rinsing it with water.

☐ 13. Copy Table 4 into your notebook. Complete it by calculating the number of moles and molarity of $NaHCO_3$ in each trial as well as the change in pressure, change in time, and the average rate of the reaction for each trial.

Table 4: Reaction rate comparison: different concentrations of sodium bicarbonate, calculated data

Volume of Water Added to $NaHCO_3$ (mL)	Moles of $NaHCO_3$ (mol)	Molarity of $NaHCO_3$ (M)	Change in Pressure (kPa)	Change in Time (s)	Average Rate of Reaction (kPa/s)
30.0					
60.0	RECORD THE DATA IN YOUR NOTEBOOK.				
90.0					

☐ 14. How does the concentration affect the reaction rate? Support your answer with data.

☐ 15. Was your prediction correct? Explain any differences.

Questions

1. Sketch the data you collected on a graph of pressure (kPa) versus time (s). Label each data run.
2. Describe what is meant by the rate of a chemical reaction. Use the terms "reactants" and "products" in your answer.
3. Why does measuring the pressure measure the rate of the reaction between $NaHCO_3$ and $HC_2H_3O_2$?
4. Describe two ways you can increase the rate of a chemical reaction.