Calcium Carbonate Decomposition
AP Inquiry Big Idea 4

Calcium is the fifth most abundant element in the earth's crust. Typically, calcium does not occur as the metal in nature, but is found in various natural minerals. Constituting more than 4% of the calcium in the earth's crust, whole mountain chains are made from calcium carbonate in the form of chalk, limestone, marble and dolomite. Calcium carbonate dissolves in rivers and oceans where plants and animals absorb it and use it to build skeletons and shells. It serves to harden and strengthen bones and the semipermeable outer layer of shells. As an industrial mineral it is used as a common building material for many of our worldly structures and statues. Erosion of the marble in these structures and statues is enhanced with exposure to mild acidic solutions such as acid rain.

The purpose of this lab activity is to investigate the stoichiometric relationships between the reactants and products in the decomposition reaction of calcium carbonate and learn how reaction rates are measured. The procedure provides a model for inquiry that will assist in the design of a kinetics experiment to determine the influence of concentration on the rate of reaction.

Essential Question
How are rates of chemical reactions determined by details of the molecular collisions?

Materials

Eggshell (membrane removed)	Marble chips, $CaCO_3$	3.0 M HCl (dropper bottles)
Mortar and pestle	10 mL graduated cylinder	2.0 M HCl (0.5 L bottle)
Filter paper	125 mL Erlenmeyer flask	1.0 M HCl (0.5 L bottle)
Glass stirring rod	50 mL beaker	small plastic cups or beakers
10 mL syringe with stopcock/stopper	Balloons	LabQuest
Balance	Funnel	Pressure sensor/stopper assembly

Part 1
The decomposition reaction of calcium carbonate can be observed by treating eggshells with acid. Eggshells are typically 77% to 95% calcium carbonate by mass. The range in calcium carbonate is dependent on the dietary intake of the animal. Treating the eggshell with excess acid, 100% of the calcium carbonate will react leaving the portion of the eggshell that is not calcium carbonate. The resulting solid can be filtered from the solution, dried, and massed. Subtraction of the mass of residual solid from the initial mass of the eggshell will give the amount of calcium carbonate in the eggshell.

1. Obtain and wear personal safety equipment such as googles, apron, etc. as instructed by your teacher.
2. Record the average room temperature and barometric pressure of the laboratory.
3. Grind about one-fourth of an eggshell into very small pieces using the mortar and pestle.
4. Measure the mass of a piece of filter paper. Record the mass in a data table.
5. Add approximately 0.5 g of eggshell to the filter paper on the balance. Measure the exact mass of the paper and the eggshell. Record this mass in your data table.
6. Carefully transfer the eggshell from the filter paper to the inside of a balloon. Be sure all eggshell is transferred.
7. Measure 10.0 mL of 3.0 M HCl in the graduated cylinder; add the acid to the 125 mL Erlenmeyer flask.

8. Stretch the mouth of the balloon over the mouth of the Erlenmeyer flask.
9. Raise the balloon over the flask allowing the eggshells to drop in the acid.
10. Gently swirl the flask containing the eggshell and acid mixture periodically. Record on the data sheet your observations at 1 minute intervals for a total of ten minutes or until there are no more signs of the reaction.
11. Remove the balloon from the Erlenmeyer flash and poor the contents of the flask into a 50 mL beaker. Rinse the flask with a small amount of water into the beaker.
12. Place a funnel in the mouth of the Erlenmeyer flask.
13. Fold the filter paper and place it into a funnel.
14. Carefully pour the contents of the beaker through the filter paper and funnel taking care to transfer all of the remaining shell onto the paper.
15. Rinse the eggshell and filter paper with water.
16. Allow the filter paper and shell to dry overnight. Can use heat lamps or drying oven if available.
17. Record the final mass of the unreacted eggshell and filter paper in your data table.

Part 1 Questions

1. Write a chemical equation for the reaction between calcium carbonate and hydrochloric acid.

2. Calculate the number of moles of calcium carbonate and hydrochloric acid used in the reaction.

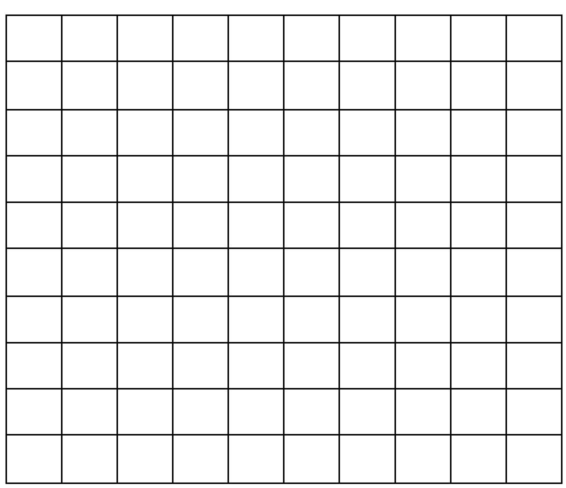
3. From the moles of each reactant, determine the limiting reactant.

4. What fraction of the eggshell was calcium carbonate?

5. Use the Ideal Gas Law to determine the approximate volume of the gas produced. Use the average room temperature and barometric pressure in the calculations.

6. From your observations, write a statement explaining the reaction rate in regards to the concentrations of the reactants and products over time.

7. On the graph, draw a curve illustrating the volume of gas produced versus time according to your observation. Draw a second curve predicting the change in gas production if the experiment were to be repeated doubling the concentration of hydrochloric acid used in the reaction.



Part 1 Data Table

Average room temperature	˚C
Barometric pressure	atm
Mass of filter paper	grams
Mass of filter paper + eggshell before reaction	grams
Mass of eggshell before reaction	grams
Mass of filter paper + eggshell after the reaction	grams
Mass of eggshell after the reaction	grams
Mass of $CaCO_3$ reacted	grams

Observations

Record your observations at 1 minute intervals for a total of ten minutes or until there are no more signs of the reaction.

Part 2

In the previous activity, the amount of calcium carbonate in an eggshell was determined using the mass loss method. Another method for analyzing the amount of $CaCO_3$ in a sample is the gas collection method. This is accomplished by capturing the gas produced and measuring its volume. If the volume is fixed, then the change in pressure can be measured. Due to the proportionality of volume or pressure to the number of moles of gas, the initial rate of the reaction can be determined. Given a known mass of marble and three concentrations of hydrochloric acid, you will determine the reaction order with respect to the hydrochloric acid concentration and write the rate law for the reaction.

The general procedure is given below in order to collect the gas product of the reaction between marble and hydrochloric acid. Determine the experimental parameters prior to testing. Below are some questions to consider. Discuss your ideas with your teacher before proceeding.

- How many trials are required?
- What amounts of marble and acid are required?
- Do the amounts need to be consistent between trials?
- Are trials with different acid concentrations required?
- What data needs to be collected?
- What data is most important in determining the reaction rate?
- How can the data collected be used to determine the initial rates of reaction and the effect of reactant concentration on the rate?

Preparation of LabQuest and reaction vessel:

1. Power the LabQuest and allow approximately 1 minute for the boot process to complete.
2. Attach a pressure sensor to analog port #1.
3. The device will automatically detect the sensor. Tap the Mode box in the upper right corner of screen to set parameters for data collection. Select Time Based from the drop down menu. Set rate to 1 sample/s. Tap on the rate box and type in 1 to change. Set duration to 90 seconds. Tap on the duration box and type in 90. Be sure the unit is set to seconds using the drop down menu.
4. Obtain stopper assembly with plastic tubing to connect to the pressure sensor and stopcock. Your teacher will have these preassembled for you. The Erlenmeyer flask from the previous activity will serve as your reaction vessel.
5. Grind marble sample into a fine powder. Mass marble powder (not to exceed 0.50 grams) and place into Erlenmeyer flask.
6. Insert stopper assembly into the opening of the flask so that it has a tight fit.
7. Connect the rubber tubing to the pressure sensor.
8. Obtain sample of acid (not to exceed 10 mL) in the syringe.
9. Close the stopcock on the stopper assembly and then attach the syringe with acid onto the stopcock with a gentle twisting motion. Keep stopcock closed until instructed to open.

Procedure:

The pressure created by the production of gas will cause the stopper assembly to pop out of the top of the flask resulting in incomplete data collection. It is required that one student hold the stopper assembly in place during the data collection, while another students operates the LabQuest. Decide the roles each of each lab partner before starting data collection.

1. Open the stopcock, but do not expel acid into the flask.
2. Start data collection.

3. At the 10 second mark, quickly expel acid into the flask and close the stopcock. **AGAIN, ONE MEMBER OF THE GROUP MUST SECURELY HOLD THE STOPPER ASSEMBLY IN THE TOP OF FLASK.**
4. Data collection will stop automatically after 90 seconds.
5. Once data collect stops, carefully twist the stopper assembly from the flask to relieve the pressure from inside.
6. Dispose contents of flask in sink and rinse with water.
7. If additional trials are deemed necessary in order to compare reaction rates, obtain marble sample and acid for next trial. Place marble in flask and attach syringe with acid to stopper as previously done.
8. Once you are ready to start collecting data for next trial, open the stopcock. Do not expel any acid from the syringe.
9. Start data collection. The LabQuest will prompt you to save previous run. Select save. Data collection will not start until a selection is made.
10. At the 10 second mark, quickly expel acid into the flask and close the stopcock. **AGAIN, ONE MEMBER OF THE GROUP MUST SECURELY HOLD THE STOPPER ASSEMBLY IN THE TOP OF FLASK.**
11. Data collection will stop after 90 seconds.
12. Repeat for a third trial if deemed necessary. Data for all trials will be saved for analysis.

Analysis

1. Because the reaction rates tend to slow as the concentration of reactants is reduced, initial rates are often used to compare rates between reactions using different reactant concentrations. From your data, determine the initial rate for each trial.
2. Using the kinetic molecular theory, explain your rate observations at the molecular level.
3. How did the experimental initial rates compare to your prediction in Part 1?
4. From the balanced decomposition equation, what is the relationship between the rate of acid consumed and the rate if gas produced?
5. From your analysis of the initial rates, write a rate expression that would represent the decomposition of calcium carbonate using hydrochloric acid?
6. What would be the units for the rate constant?