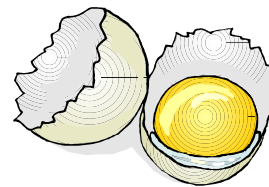


Inquiry Lab Activity:



Calcium Carbonate Content of Eggshells

Adapted from: Lechtanski, V. L. *Inquiry-Based Experiments in Chemistry*; Oxford: New York, 2000; pp 159-165.

Objectives

Students will be able to:

- design an experiment that quantifies the amount of calcium carbonate present in a natural substance.
 - relate the amount of a reactant or product of a chemical reaction to another reactant or product.
 - work collaboratively with their peers to solve a given problem in the laboratory in a way that models the scientific method.
 - apply a common acid reaction between hydrochloric acid and the carbonate ion.
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Safety

This lab uses a 3 M HCl solution. Goggles and aprons are required for the duration of this lab. Students must be reminded that excess hydrochloric acid may be present at the end of the reaction. Students may NOT heat solutions containing hydrochloric acid. All students must have their procedures approved by the teacher prior to beginning work.

Background

Calcium carbonate, CaCO_3 , is found in nature giving hardness and strength to things such as seashells, rocks, and eggshells. As hard as this substance is, it will react readily with hydrochloric acid to yield carbon dioxide gas (and two **other** products). In this experiment students will design an experiment by reacting eggshells with 3 M HCl to compare the calcium carbonate composition of white (chicken) eggshells to brown eggshells.

A good quality eggshell will contain, on average, 2.2 grams of calcium in the form of calcium carbonate. Approximately 94% of a dry eggshell is calcium carbonate and has a typical mass of 5.5 grams,¹ although these values can differ depending on sources. Amounts as low as 78% have been published. The remaining mass is composed largely of phosphorus and magnesium, and trace amounts of sodium, potassium, zinc, manganese, iron, and copper. In the case of brown versus white eggs, a definitive difference in calcium carbonate amounts may be hard to uncover. However, consider this. The color of the eggs is nothing more than a result of a different breed. The quality, nutritional value, and taste are identical between white and brown eggs, though two notable differences are size and price. Brown eggs are usually larger and slightly more expensive. The reason for the price increase is because brown eggs come from larger hens, which need to be fed more food daily. With a larger intake of calcium each day, one might expect the produced egg to have a higher calcium carbonate content. However, since the eggs are larger, it must be kept in mind that the calcium is spread over a larger surface area during egg formation. A brown eggshell's increased tendency to break, when compared to white, is often attributed to this "thinning out" of calcium during deposition.

¹ Butcher, G. D. & Miles, R. D. *Concepts of Eggshell Quality*, URL <http://www.afn.org/~poultry/flkman4.htm>

Procedure

Using the available lab equipment, design an experiment to determine what percentage of an eggshell's mass is calcium carbonate. Find the percent mass of calcium carbonate in white and brown eggshells. Keep in mind that there are several ways to execute this lab. You may not need all of the apparatus that has been provided. When preparing the eggshell, remove the membrane as it will interfere with the reaction. Assume that anything that doesn't react with the acid remains solid. PRIOR TO BEGINNING WORK, SUBMIT IN WRITING TO THE TEACHER:

1. A balanced equation for the reaction between calcium carbonate and hydrochloric acid.
 2. An outline of the procedure that you intend to use. (A significant portion of your grade will be determined by how close you are to the accepted value.)
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Materials

Consumables (per group)

- 2 different eggs (i.e. 1-white & 1-brown)
- 50 mL of 3 M HCl
- Filter paper

Lab equipment

- Mortar & pestle
 - Standard vacuum filter apparatus (side arm flask, rubber hose, funnel...)
 - Gas collection apparatus (one-holed stoppers with glass tubes & compatible flasks, rubber tubing, gas collection tubes/bottles, pneumatic troughs...)
 - Standard lab balances
 - Beakers (250 mL)
 - Graduated cylinders
 - Hot plates
 - Thermometers
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Questions

1. Calcium carbonate decomposes upon heating. Write a balanced equation for this reaction.
2. How were you sure that you added sufficient acid to completely react with all of the calcium carbonate? If you failed to add sufficient HCl, how would this affect your data?
3. If you had the opportunity to repeat this experiment, what would you do differently?
4. Based on your collected data, calculate the percent composition of calcium carbonate of both the white and brown eggshells.

Teacher Stuff

Where Does This Experiment Fit into the Curriculum?

Several aspects of a chemistry curriculum can be addressed by this lab, including:

- Studying reactions of acids
- Percent composition
- Stoichiometry of chemical equations

Depending on which topic you are covering, you may need to give the students more information so that they can perform the experiment.

Why is this an Inquiry Laboratory Activity?

- The exact outcome of the experiment is unknown to both the teacher and the student (although the teacher has some idea of acceptable values.)
- There are multiple ways to solve the problem, and it is up to the student to derive a procedure.
- It is problem based.
- It involves real-life items.
- It can be extended to other calcium carbonate containing items, such as seashells, rocks, etc. Other types of eggs (if available) could also be used.

Time Frame:

This can be up to the teacher's discretion depending on the ability level and creativity of the students. This will also depend on the length of the laboratory period – it may be necessary to break the activity into multiple parts.

- Logical stopping points: post-experimental design -or- after each egg type.
- Each eggshell should take approximately 45 minutes to one hour to process.

Preparation:

1. To prepare the 3.0 M HCl, add 250 mL of concentrated HCl to 650 mL of distilled water. Then dilute to 1.0 L using distilled water.
2. To prepare the eggshells, make sure that the inner membrane is completely removed. You may want to do this as pre-lab, or students can do it if time permits.

Full Equation of Reaction:



Note that the CaCl_2 product is water soluble.

Sample Procedures:

These are four procedures that students are likely to develop. Some may take longer than others; so depending on time, you might want to steer the students to a quicker method.

1. Add acid to eggshell (this can be whole or crushed), and stir. Wait until the bubbling stops and the foam disappears. Then the mixture can be filtered, and the remaining substance can be dried overnight. The leftover can be massed once it is completely dried. The leftover substance is eggshell that is NOT calcium carbonate. Therefore, the mass of calcium carbonate can be calculated, and from that, the percent composition.
2. Follow the above procedure, but throw away the remaining eggshell. Allow the filtrate to evaporate, which will leave calcium chloride behind. Do not boil, due to excess HCl. The calcium chloride can be used as the calcium carbonate is above, although a mole ratio is required. This method takes the longest.
3. Begin as above, then use water displacement to measure the volume of carbon dioxide produced. Again, a mole ratio will be necessary to calculate the amount of calcium carbonate that was present. The ideal gas law will be necessary to determine the moles of carbon dioxide, using temperature, barometric pressure, and the vapor pressure of water.
4. Measure the mass of the eggshell and acid before the reaction, then proceed as above. Then measure the final mass of the mixture of acid and eggshell. The difference in masses is equal to the mass of carbon dioxide released. Using a balanced equation and mole ratio, the mass of calcium carbonate that reacted can be calculated.

Sample Calculations:

Sample calculations have been included for procedures 1 and 4. Note that the calculations are much simpler when following procedure 1. However, this procedure will also take more time. Procedure 4 can be completed quicker, but the calculations are more involved. These variables should be taken into account when considering the group's ability level and allotted time. The calculations can be seen on the following pages.

Procedure 1:

Sample Data:

	White Eggshell	Brown Eggshell
Mass of eggshell	2.788g	3.560g
Mass of filter paper	1.010g	1.012g
Mass of filter paper & unreacted eggshell	1.651g	2.151g

Calculations:

White Eggshell

1. Mass of unreacted eggshell = mass of filter paper & unreacted eggshell – mass of filter paper
Mass of unreacted eggshell = 1.651 – 1.010 = 0.641g

2. Mass of CaCO_3 in eggshell = mass of eggshell – mass of unreacted eggshell
Mass of CaCO_3 in eggshell = 2.788 – 0.641 = 2.147g

3. $\% \text{CaCO}_3 \text{ in eggshell} = \frac{\text{mass CaCO}_3}{\text{mass eggshell}} \times 100$

$$\% \text{CaCO}_3 = \frac{2.147\text{g}}{2.788\text{g}} \times 100 = 77\%$$

Brown Eggshell

1. Mass of unreacted eggshell = mass of filter paper & unreacted eggshell – mass of filter paper
Mass of unreacted eggshell = 2.151 – 1.012 = 1.139g

2. Mass of CaCO_3 in eggshell = mass of eggshell – mass of unreacted eggshell
Mass of CaCO_3 in eggshell = 3.560 – 1.139 = 2.421g

3. $\% \text{CaCO}_3 \text{ in eggshell} = \frac{\text{mass CaCO}_3}{\text{mass eggshell}} \times 100$

$$\% \text{CaCO}_3 = \frac{2.421\text{g}}{3.560\text{g}} \times 100 = 68\%$$

Turn page for calculations for Procedure 4...

Procedure 4:

Sample Data:

	White Egg Shell	Brown Egg Shell
Mass of eggshell	1.545g	1.657g
Mass of beaker	69.607g	68.506g
Mass of HCl	10.103g	10.403g
Total Initial Mass	81.255g	80.593g
Final Mass of beaker & contents	80.739g	80.098g
Mass of CO ₂ (g) lost	0.516g	0.495g

Calculations:

White Egg Shell

- Mass of CO₂ (g) lost = Final mass of beaker & contents – total initial mass
Mass of CO₂ (g) lost = 81.255 – 80.739 = 0.516g
- Moles of CO₂ (g) lost = $\text{Mass of CO}_{2(g)} \times \frac{1 \text{ mol CO}_2}{44.0 \text{ g CO}_2} = \text{Moles of CO}_{2(g)}$
 $0.516 \text{ g} \times \frac{1 \text{ mol}}{44.0 \text{ g}} = 0.01173 \text{ mol CO}_2$
- Moles of CO₂ = Moles of CaCO₃ (1:1 mole ratio according to balanced chemical equation)
0.01173 mol CaCO₃
- Mass of CaCO₃ = $\text{Moles of CaCO}_3 \times \frac{100.1 \text{ g CaCO}_3}{1 \text{ mol CaCO}_3} = \text{Mass of CaCO}_3$
 $0.01173 \text{ mol CaCO}_3 \times \frac{100.1 \text{ g CaCO}_3}{1 \text{ mol CaCO}_3} = 1.174 \text{ g CaCO}_3$
- % CaCO₃ in eggshell = $\frac{\text{mass CaCO}_3}{\text{mass Eggshell}} \times 100 = \% \text{ CaCO}_3$
 $\frac{1.174 \text{ g}}{1.545 \text{ g}} \times 100 = 76\% \text{ CaCO}_3$

Brown Eggshell

- Mass of CO₂ (g) lost = Final mass of beaker & contents – total initial mass
Mass of CO₂ (g) lost = 80.593 – 80.098 = 0.495g
- Moles of CO₂ (g) lost = $\text{Mass of CO}_{2(g)} \times \frac{1 \text{ mol CO}_2}{44.0 \text{ g CO}_2} = \text{Moles of CO}_{2(g)}$

$$0.495\text{g} \times \frac{1\text{mol}}{44.0\text{g}} = 0.01126\text{mol CO}_2$$

3. Moles of CO_2 = Moles of CaCO_3 (1:1 mole ratio according to balanced chemical equation)
 0.01126 mol CaCO_3

4. Mass of CaCO_3 = Moles of $\text{CaCO}_3 \times \frac{100.1\text{g CaCO}_3}{1\text{mol CaCO}_3} = \text{Mass of CaCO}_3$

$$0.01125\text{mol CaCO}_3 \times \frac{100.1\text{g CaCO}_3}{1\text{mol CaCO}_3} = 1.127\text{g CaCO}_3$$

5. % CaCO_3 in eggshell = $\frac{\text{mass CaCO}_3}{\text{mass Eggshell}} \times 100 = \% \text{CaCO}_3$

$$\frac{1.127\text{g}}{1.657\text{g}} \times 100 = 68\% \text{CaCO}_3$$

Notes:

- Eggshells are about 94% calcium carbonate by mass.
- To preserve materials, groups of two or three may be organized. In addition, the groups can use about $\frac{1}{2}$ of the eggshell, allowing the eggs to stretch further.
- A larger beaker (250 mL) is recommended due to the large amount of foaming.
- The eggshells may be crushed or used whole.
- Students need to be sure to wait until all foaming has subsided before progressing.

Answers to Questions:

1. $\text{CaCO}_3 (\text{s}) \rightarrow \text{CaO} (\text{s}) + \text{CO}_2 (\text{g})$
2. Up to teacher discretion.
3. Up to teacher discretion.
4. Answers will vary depending on data collected during experimentation.