**DETERMINATION OF CALCIUM CARBONATE IN EGGSHELLS BY ACID/BASE TITRATION**

## OBJECTIVE

To determine the mass percent of calcium carbonate ($CaCO_3$) in an eggshell.

## INTRODUCTION

During this lab, the percentage of $CaCO_3$ in an eggshell is determined by reacting the eggshell with hydrochloric acid. The equation for this reaction is:

$$2HCl\ (aq) + CaCO_3(s) \rightarrow Ca^{2+}\ (aq) + CO_2(g) + H_2O(l) + 2Cl^-\ (aq)$$

This reaction cannot be used directly to titrate the $CaCO_3$. Instead, an excess of hydrochloric acid is added to dissolve the eggshell, and the remaining acid is titrated with NaOH solution to determine the amount of acid that did not react with the eggshell. The equation used to determine the amount of leftover acid is:

$$HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-\ (aq)$$

In order to help the hydrochloric acid dissolve the $CaCO_{3,}$ ethyl alcohol is added to the eggshell as a wetting agent. Wetting agents are chemicals that increase the spreading and penetrating properties of a liquid by lowering its surface tension—that is, the tendency of its molecules to adhere to each other.

Although it is now banned in the United States, the pesticide DDT has caused significant damage to the environment and its wildlife. Birds are especially affected because the DDT weakens the shells of their eggs, which would break before hatching. This caused certain bird species to become endangered (i.e. the American bald eagle). One method of monitoring the strength of the egg is by determining the percent calcium carbonate in the eggshell.[1]

The percentages calculated from the experiment will be compared against a **reported value of 95% $CaCO_3$** in a dry eggshell.[2]

## MATERIALS and PROCEDURE

*Please refer to handout sheet.*

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[1] Brewer, Warren B. http://chem.lapeer.org/Chem1Docs/EggshellTitration.html

[2] Butcher, Dr. Gary D. and Miles, Dr. Richard D. Concepts of Eggshell Quality. http://www.afn.org/~poultry/flkman4.htm

## SAFETY

| CHEMICAL NAME | RISK AND SAFETY DATA |
|---|---|
| **Reactants** | |
| **Calcium carbonate** | Dust may cause irritation to eyes, respiratory system, and skin.<br>In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. |
| **Hydrochloric acid** | Extremely corrosive.<br>Inhalation of vapor can cause serious injury.<br>Ingestion may be fatal.<br>Liquid can cause severe damage to skin and eyes. |
| **Sodium hydroxide** | Very corrosive. Causes severe burns.<br>May cause serious permanent eye damage.<br>Very harmful by ingestion.<br>Harmful by skin contact or by inhalation of dust.<br>Wear suitable gloves (Neoprene or PVC). |
| **Products** | |
| **Calcium chloride (anhydrous)** | Irritating to eyes.<br>Do not breathe dust and avoid contact with skin. |
| **Carbon dioxide** | In high concentration acts as an asphyxiant.<br>Respiratory stimulant.<br>If working with carbon dioxide in confined spaces where the concentration of gas may build up, ensure adequate ventilation. |
| **Sodium chloride** | May cause skin, eye or respiratory irritation.<br>Not believed to present a significant hazard to health. |
| **Others** | |
| **Ethyl alcohol** | Causes skin, eye and respiratory system irritation.<br>Ingestion can cause nausea, vomiting and inebriation; chronic use can cause serious liver damage.<br>Highly flammable. Keep container tightly closed. |
| **Phenolphthalein** | Irritating to eyes, respiratory system and skin. |

## DATA

| | FLASK ONE | FLASK TWO | FLASK THREE |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Mass of Eggshell in Flask (g) | 0.50 g | 0.54 g | 0.47 g |
| Volume of 1.0 M HCl added to Eggshell (mL) | 9.89 mL | 9.79 g | 9.89 mL |
| Initial Volume Reading of 0.1 M NaOH titrant in buret (mL) | 0.15 mL | 12.79 mL | 14.69 mL |
| Final Volume Reading of 0.1 M NaOH titrant in buret (mL) | 22.38 mL | 39.01 mL | 45.29 mL |
| Volume of 0.1 M NaOH titrant used (mL)<br>(Volume of Titrant Used = Final Volume – Initial Volume) | 22.23 mL | 26.22 mL | 30.60 mL |

**CALCULATIONS**

1) **Calculate the number of moles of hydrochloric acid added to the eggshell in each flask.**

***Flask One***

$$9.89 \text{ mL HCl} \times \frac{1.0 \text{ mol HCl}}{1000 \text{ mL HCl}} = 0.00989 \text{ moles HCl}$$

***Flask Two***

$$9.79 \text{ mL HCl} \times \frac{1.0 \text{ mol HCl}}{1000 \text{ mL HCl}} = 0.00979 \text{ moles HCl}$$

***Flask Three***

$$9.89 \text{ mL HCl} \times \frac{1.0 \text{ mol HCl}}{1000 \text{ mL HCl}} = 0.00989 \text{ moles HCl}$$

2) **Calculate the number of moles of hydrochloric acid remaining after the reaction with $CaCO_3$ in each flask.**

***Flask One***

$$22.23 \text{ mL NaOH} \times \frac{0.1 \text{ mol NaOH}}{1000 \text{ mL NaOH}} \times \frac{1 \text{ mol HCl}}{1 \text{ mol NaOH}} = 0.002223 \text{ mol HCl}$$

***Flask Two***

$$26.22 \text{ mL NaOH} \times \frac{0.1 \text{ mol NaOH}}{1000 \text{ mL NaOH}} \times \frac{1 \text{ mol HCl}}{1 \text{ mol NaOH}} = 0.002622 \text{ mol HCl}$$

***Flask Three***

$$30.60 \text{ mL NaOH} \times \frac{0.1 \text{ mol NaOH}}{1000 \text{ mL NaOH}} \times \frac{1 \text{ mol HCl}}{1 \text{ mol NaOH}} = 0.003060 \text{ mol HCl}$$

**CALCULATIONS (Cont'd)**

**3) Calculate the number of moles of hydrochloric acid that reacted with $CaCO_3$. (Moles of HCl Added – Moles of HCl Remaining)**

***Flask One***

0.00989 moles HCl - 0.002223 mol HCl = 0.007667 mol HCl

***Flask Two***

0.00979 moles HCl - 0.002622 mol HCl = 0.007168 mol HCl

***Flask Three***

0.00989 moles HCl - 0.003060 mol HCl = 0.00683 mol HCl

**4) Calculate the mass in grams of $CaCO_3$ in each flask.**

***Flask One***

$$0.007667 \text{ mol HCl} \times \frac{1 \text{ mol } CaCO_3}{2 \text{ mol HCl}} \times \frac{100.09 \text{ g } CaCO_3}{1 \text{ mol } CaCO_3} = 0.3837 \text{ g } CaCO_3$$

***Flask Two***

$$0.007168 \text{ mol HCl} \times \frac{1 \text{ mol } CaCO_3}{2 \text{ mol HCl}} \times \frac{100.09 \text{ g } CaCO_3}{1 \text{ mol } CaCO_3} = 0.3587 \text{ g } CaCO_3$$

***Flask Three***

$$0.00683 \text{ mol HCl} \times \frac{1 \text{ mol } CaCO_3}{2 \text{ mol HCl}} \times \frac{100.09 \text{ g } CaCO_3}{1 \text{ mol } CaCO_3} = 0.3418 \text{ g } CaCO_3$$

**5) Calculate the mass percent of $CaCO_3$ in each flask.**

***Flask One***

$$\frac{0.3837 \text{ g } CaCO_3}{0.50 \text{ g eggshell}} \times 100 = 76.74\% = \mathbf{77\%\ CaCO_3}$$

***Flask Two***

$$\frac{0.3587 \text{ g } CaCO_3}{0.54 \text{ g eggshell}} \times 100 = 66.43\% = \mathbf{66\%\ CaCO_3}$$

***Flask Three***

$$\frac{0.3418 \text{ g } CaCO_3}{0.47 \text{ g eggshell}} \times 100 = 72.72\% = \mathbf{73\%\ CaCO_3}$$

**6) Calculate the average mass percent of $CaCO_3$ and percent error.**

$$\frac{(0.77 + 0.66 + 0.73) \times 100}{3} = \mathbf{72\%\ CaCO_3}$$

$$\text{Percent Error} = \frac{(\text{Experimental Value} - \text{Actual Value})}{\text{Actual Value}} \times 100$$

$$= \frac{(0.72 - 0.95)}{0.95} \times 100$$

$$= \mathbf{24\%\ error}$$

## CONCLUSION

The calculations reveal that there was an average mass percent of 72% $CaCO_3$ in the eggshell. Compared against the reported value of 95% $CaCO_3$, there was a 24% error in the results of this experiment.

## ERROR ANALYSIS

Certain factors that may have led to error in the results include:

- Egg membrane remaining on the shell

  Some of the membrane could have probably been found with the ground eggshells in the flasks, especially since it can be very difficult to see and remove.

  Any membrane remnants would have reacted with the NaOH titrant; therefore, not all of the titrant would have reacted directly with the hydrochloric acid. One would have to consider that the volumes of the titrant measured would also include the amount of titrant reacted with the membranes.

- Incomplete Dissolution of the Eggshell

  It is important that all of the ground eggshell dissolves because it contains the $CaCO_3$ that is being analyzed in the experiment. The reaction between the $CaCO_3$ and the hydrochloric acid might not have been completed if the flasks were removed from hotplates too early, since the higher temperature is beneficial in increasing the rate of said reaction.

  If that is the case, there would have been a greater volume of hydrochloric acid remaining in the flasks before the titrations. Therefore, the calculated mass percent $CaCO_3$ in the eggshell would be lower than it would have been had all of the $CaCO_3$ dissolved.