Determining the percentage mass of $CaCO_3$ in an eggshell

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Introduction

Egg shell is the outer covering of the shelled eggs. Various types include various compounds in them. They have different uses as well, such as using it as paint, or in gardens, but mostly as a cleaner. The major component of the eggshell is calcium carbonate ($CaC0_3$), that is a determinant of it strength and of that protection of developing the embryo.

The exact percentage by mass of $CaC0_3$ in an eggshell can be measured by using the method - back titration. The calcium carbonate is insoluble in water, but dissolves in different acids very readily. It is shown in the following equation:

$$2\ HCl_{(aq)} + CaC0_{3\ (s)} \longrightarrow CaCl_{2\ (aq)} + CO_{2\ (g)} + H_20_{(l)}$$

This reaction cannot be used directly to titrate the $CaC0_3$. The titration process would be or is very slow when the reaction is close to the end point. Another way, which is adding excess of acid is done in order to dissolve all the $CaC0_3$, and then titrating the remaining HCl with NaOH to determine the amount of acid which has not reacted during the first reaction.

This is the reaction:

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_20_{(l)}$$

Design

Research Question

What is the percentage by mass of $CaCO_3$ in an eggshell?

Variables

Table 1: Variables

Variables	
Independent	Mass of Eggshell
Dependent	1. Volume of NaOH used to neutralise the excess of HCL (cm^3) 2. Mass of $CaCO_3$ (g) 3. amount of HCl reacted with $CaCO_3$ from the eggshell
Controlled	1. Concentration of NaOH (mol dm^{-3}) 2. Concentration of HCl (mol dm^{-3}) 3. Mass of eggshell (g) 4. Temperature (°C) 5. Number of trials
Uncontrolled	Source of an eggshell

Apparatus

1. 30 grams of an eggshell
2. 150 cm^3 1M NaOH
3. 125 cm^3 1M HCl
4. Total of 15 drops of phenolphthalein (3 in each sample)
5. 50 cm^3 ± 0.01 cm^3 burette
6. Stand
7. 50 cm^3 beaker x7

8. 50 cm^3 measuring cylinder
9. 0.2 cm^3 ± 0.01 cm^3 Pipette x 2
10. Test Tube x1
11. Mortar and Pestle
12. Electronic Mass Balance ± 0.01 g

Risk assessment and Safety Rules

All necessary safety precautions were undertaken. No lab rule was broken, everything went as planned. The performers were wearing lab coats, rubber gloves, and protective glasses to ensure safety throughout the experiment. The only thing was to be careful with the acid.

Procedure

1. The eggshell was separate manually.
2. 30 grams of the eggshell was weighted on an electronic mass balance.
3. It was then powered by the mortar.
4. Watch glass was placed on the balance and 0.5 grams of the powdered eggshell was weighted and then placed in one beaker.
5. 30 cm^3 of 1M HCl was measured in a cylinder and poured into the beaker with the eggshell.
6. Then the whole solution was heated to a warmth degree so that the reaction could occur quickly.
7. The reaction mixture was stirred using the stirring rod.
8. The titration equipment was prepared.
   a. Burette was placed on a stand and set up properely.
   b. Burette was filled with 50 cm^3 1M NaOH using the beaker and the funell.

9. The mixture taken out from the heat, then 3 drops of phenolphthalein was put into the reaction mixture of the eggshell and the HCL using the pipette when the reaction was completed.

10. The reaction mixture was titrated by NaOH standard solution until the phenolphthalein changed its colour into pink.

11. The value from the burette was read and note down into the notebook.

12. The steps 4-11 were repeated 4 more times.

Data Collection and Processing

Table 2: Volume of NaOH used to titrate the eggshell

Number of Trial	Mass of Eggshell / 1 g ± 0.01 g	Volume of NaOH / 1 cm^3 ± 0.1 cm^3
1	0.50	24.6
2	0.50	24.7
3	0.49	24.8
4	0.50	24.9
5	0.51	24.7

Table 3: Mean and Standard Deviation of mass of the eggshell and volume of NaOH

	Mass of Eggshell / 1 g ± 0.01 g	Volume of NaOH / 1 cm^3 ± 0.1 cm^3
Mean	0.50	24.7
Standard Deviation	0.01	0.1

Mean mass of eggshell : (0.50 x 3 + 0.51 + 0.49) / 5 = 0.50 g ± 0.01 g

Mean volume of NaOH : (24.6 + 24.7 x 2 + 24.8 + 24.9) = 24.7 cm^3 ± 0.1 cm^3

The standard deviation of the results was calculated using a formula :

$$S = \sqrt{\frac{\Sigma(X - \overline{X})^2}{N}}$$

where S = the standard deviation of a sample,
Σ means "sum of,"
X = each value in the data set,
$\overline{X}$ = mean of all values in the data set,
N = number of values in the data set.

Calculations

Amount of alkali in titration: c x V = 1.00 mol dm^{-3} x 0.0247 dm^3 = 0.0247 mol

$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

1:1 reaction therefor 0.0247 moles of HCl react with NaOH added

Amount of acid used initially

= c x V = 1.00 mol dm^{-3} x 0.030 dm^3 = 0.030 mol

Amount of acid reacting with $CaCO_3$

= 0.030 mol - 0.0247 = 0.0053 mol

$2\,HCl_{(aq)} + CaCO_{3(s)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

2:1 ratio therefore 0.0024 (0.5 x 0.0053) moles of $CaCO_3$ react with the HCl

Mass of $CaCO_3$ = n x M = 0.0024 mol x 100.9 g mol^{-3} = 0.24 g

Percentage by mass of $CaCO_3$ = 100 x (0.24 / 0.50) = 48 %

Conclusion and Evaluation

The results of the experiment show exclusive evidence that is was successful. It supports the thesis that $CaCO_3$, probably the main component of an eggshell. The percentage of mass was 48 %. Although the values of NaOH used in titration varies highly, a fairly large standard deviation, the results seem to be reliable, as natural material was taken from different eggs that probably differed in $CaCO_3$ content. The uncertainties throughout the experiment were there as well, they made only the slightest changes to the results, as the results were good enough. The accepted value for the amount of Calcium Carbonate in an eggshell is about 95%.

The percetange error = experimental value / accepted value x 100% =

= 48 / 95 x 100 = **50.5%**

The experiment involved a very low probability of random error, that is what resulted in low standard deviations. Not only standard deviation but also percentage uncertainty were all on a low level. That can be due to precise weighing and measuring devices as well as precision while doing or undertaking the titration process. We can assure ourselves that there was no systematic error from this experiment because it is certain that both the scale and the burette don't have a zero offset error.

During titration labs there is always a chance that one can over-titrate, this means that you continue to add the base even after the required actual colour change has taken place already. This can be due to the eyes of the observer as they are not 100% focused. The person can easily miss the exact moment of neutralisation. Such mistakes introduce slight error to results. However this cannot be neglected. In this practical in it was vital and done that this error was reduced to all part, because of the number of trials done. The more number of trials, is a proper way to minimise

the significance of the sources of random error. There were no sources of systematic error noticed during the whole experiment. All of these clearly show us that the result we obtained was a rather precise one.

Table 7: Improvements Table

List of Problems	Improvement
Improving Preciseness	The number of trials could be increased.
Impurities Involved	All the materials should be cleaned before the experiment. It should be rinsed thoroughly before the practical , especially the burette.
Method Improvement	Because the reaction occurs slowly, it is a good idea to heat the mixture before titrating to let all of the eggshell neutralised. Actually, we did that and that can be qualified as a positive.
Ways to reduce error of Neutralisation Moment	There are many ways in which this can be done they are listed in the paragraph above.
Random Errors	Readings from the burette as well as the weightings can be repeated several times and averaged for better results.

The main weakness of the procedure is stirring the eggshell power with the acid. The powder is very light and is drifting on the surface of the acid and sticks to the walls of the beaker. The fizzing bubbles were observed during that time, and they were intense. That is the reason the mixture was heated so the reaction could be more quicker and better results could be obtained. That is the reason why in some cases more acid was left in the beaker after the reaction, more powder rescued from the reaction mixture.

The slight amount of human error is never fully eliminated. There could be different and simple method to do the titration process. First way is having more than one person to be looking at it, because attention spans and reaction time one a person can be faster than the other person. Second way, is having a dark piece of cardboard underneath the breaker, which would allow for greater accuracy when looking at the solution at the right angle to its surface. Thirdly, the solution should be stirred during the titration to allow the based spread evenly. The third solution of stirring, which was actually applied to our experiment and it worked properly. The easiest and the most effective one is adding several drops of ethanol to the eggshell powder. This acts as a wetting agent and helps the HCl dissolve the $CaCO_3$. Overall the experiments can always be improved and this time also.

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