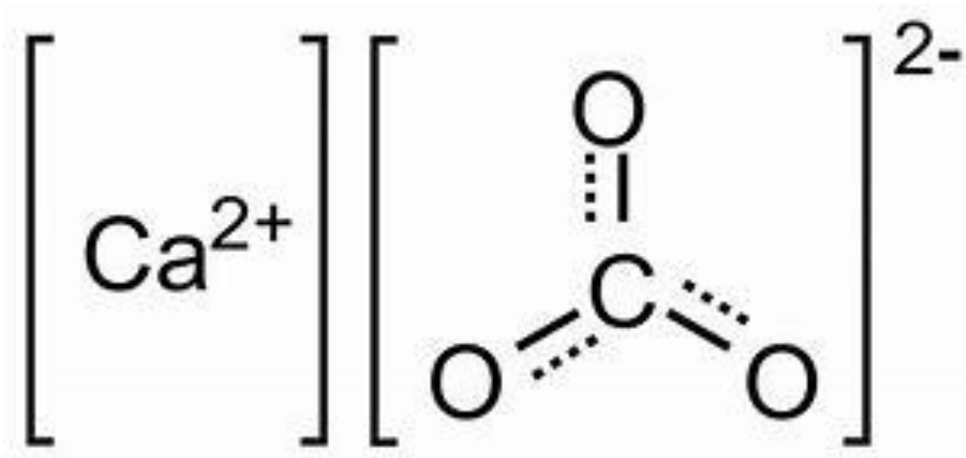
Determination Of Calcium Carbonate Content Of Various Eggshells Using Back Titration



Contents

Abstract

The aim of this investigation was measure the percentage purity of calcium carbonate in three different types of eggshell; caged, free range, and duck egg.

The Calcium Carbonate % Puirity of Caged Hen Eggshell was found to be 92.4%. Free Range Eggshell had a % Purity of 96.6% and Duck Eggshell was found to contain 99.5% Calcium Carbonate.

Introduction

The aim of this investigation was measure the percentage purity of calcium carbonate in three different types of eggshell; caged, free range, and duck egg.

Calcium Carbonate, $CaCO_3$, is a mineral, white in colour, and is the main component of different shells. It is made up of a calcium ion (Ca^{2+}) and a carbonate ion (CO_3^{2-}). It has a molar mass of 100.1 g/mol. It has a melting point of 1339°C and reacts readily with acids, making it a base.

The Ca^{2+} ion can be expressed in box notation:

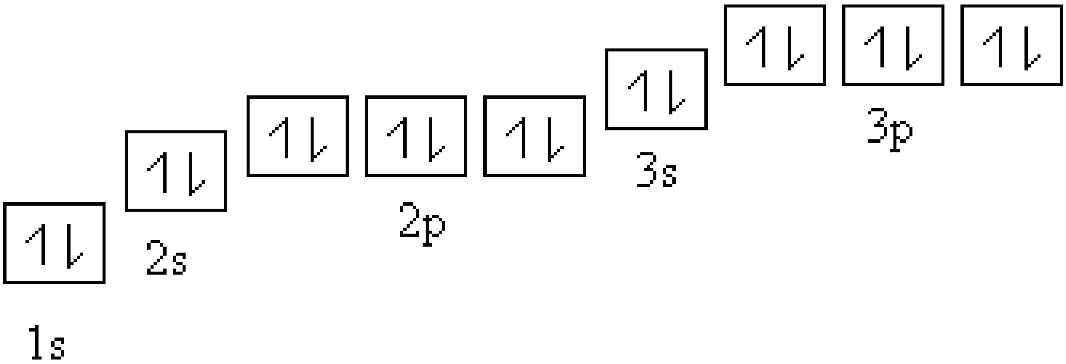


Diagram 1- Box notation of Ca^{2+} ion
(https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=22&cad=rja&uact=8&ved=2ahUKEwievZ285LjgAhVVBUIHcPyAVIQFjAVegQIARAB&url=https%3A%2F%2Fwww.quora.com%2FWhat-is-the-orbital-diagram-of-calcium-How-was-it-originallydetermined&usg=AOvVaw3zmZiI-BF5wFWGPJf8If4X)

The box notation follows the Aufbau Principle and Hunds Rule of Maximum Multiplicity. The Aufbau principle states that electrons in an atom fill up atomic orbitals in order of increasing energy:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^6\ 7s^2\ 5f^{14}$

The electrons follow Hunds Rule as they fill the orbitals singly then pair up when they have to.

The electrons in Ca^{2+} are held in atomic orbitals, which can be located using quantum numbers. An atomic orbital is an area of the atom where it is likely an electron will be found. There are four different types of atomic orbital with various and distinctive shapes. S, P, D and F orbitals:

There are four Quantum numbers that collectively dictate the precise location of an electron in an atom these can be classified as the principle (n), angular momentum (l), magnetic (m_l) and spin (m_s) quantum numbers.

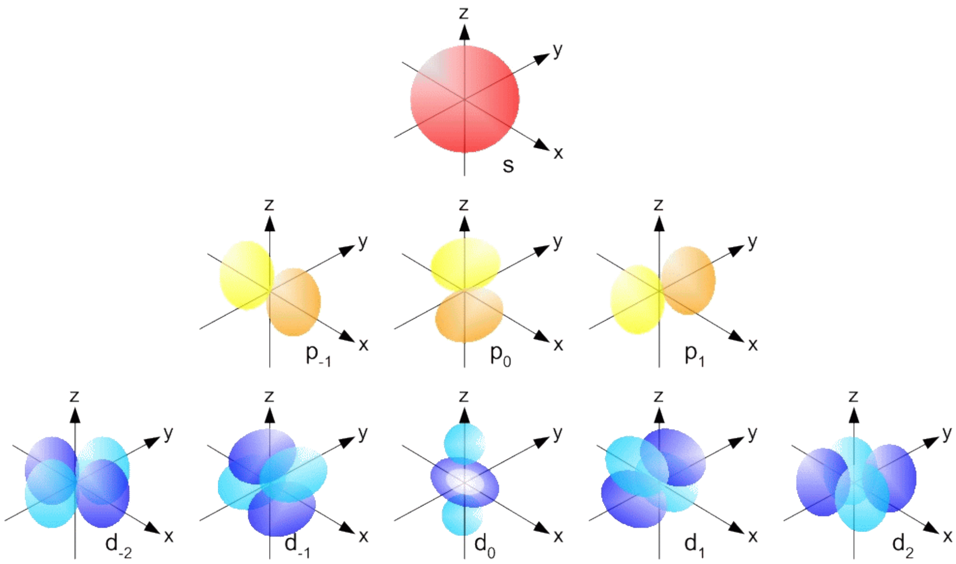
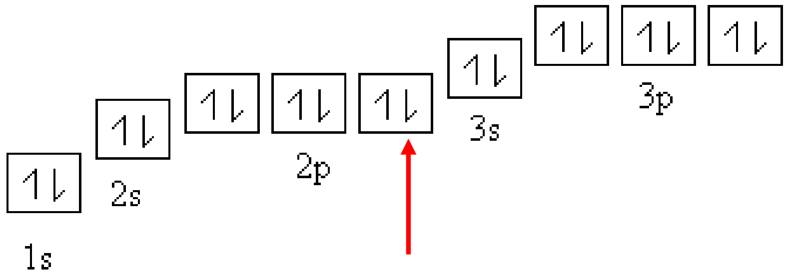


Diagram 2 - S, P and D orbitals
(https://www.compoundchem.com/2014/03/05/colours-of-transition-metal-ions-in-aqueous-solution/)

If we use the eighth electron as an example for quantum numbers. This electron has quantum numbers of: 2, 1, 1, -1/2.



The principle quantum number is given the symbol n. This electron is located in 2p so n = 2. This relates to the size of the atomic orbital. The sub shell the electron is located in is given l, the angular momentum number which tells us the shape of the orbital. For this electron it is given a value of 1 as S=0, P=1, D=2 and F=3. As some orbitals (P, D and F) have different lobes in each orbital, a 3rd quantum number, the magnetic quantum number, ml, is also required to pin point further where the electron is likely to be located. Values of ml depend on l. If a value of l=1, then ml can be -1, 0, +1. As this electron is in the third box it is given then value +1. The final quantum number is spin quantum number. This is either +1/2 or -1/2 - representing whether an electron is spin up or spin down.

This 4th quantum number also allows the electrons to follow the pauli exclusion principle which says that no two electrons will have the same 4 quantum numbers.

The carbonate ion has three resonance structures:

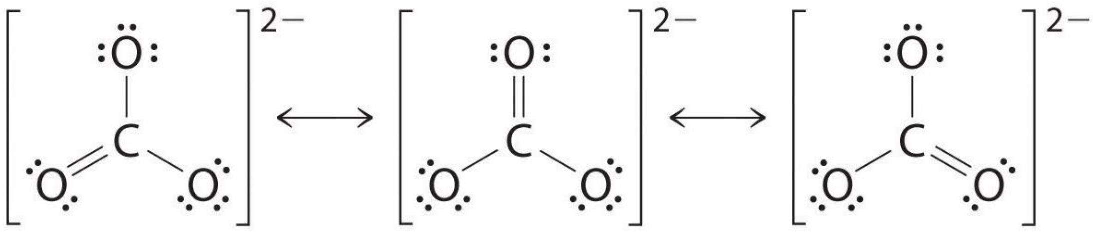


Diagram 3 - Resonance structures of Carbonate
(https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwihroru8LjgAhX7SxUIHa1OBLQQFjACegQIBhAL&url=https%3A%2F%2Fchem.libretexts.org%2FBookshelves%2FGeneral_Chemistry%2FMap%253A_Chemistry_-_The_Central_Science_(Brown_et_al.)%2F08._Basic_Concepts_of_Chemical_Bonding%2F8.6%253A_Resonance_Structures&usg=AOvVaw3EFlcZED_TUqM-r6ZKosT8)

The pi electrons are shared over the three oxygen's using three sigma bonds and one pi bond. A sigma bond is created due to end on overlap of atomic orbital whereas a pi bond is side on overlap of unused p orbitals.

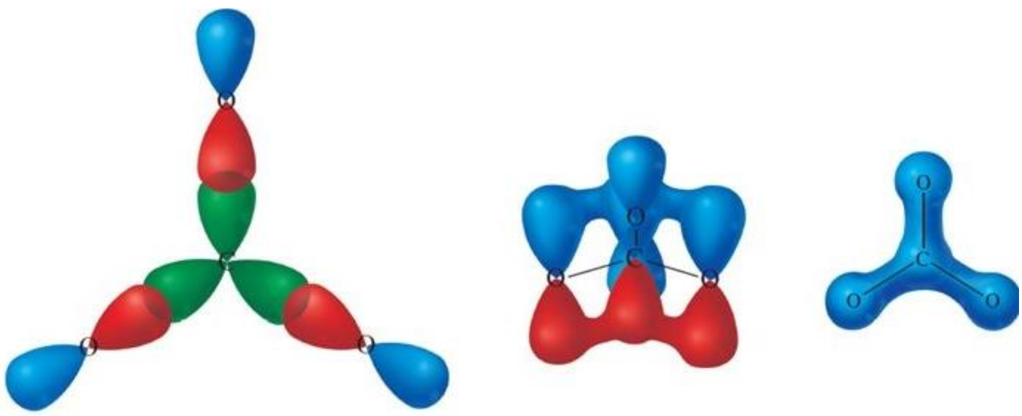


Diagram 4 - sigma and pi bonds formed from atomic orbitals

Calcium Carbonate is not soluble in water. This meant that analysing the carbonate content of eggshells required a back titration. This technique is used when the primary standard is not soluble in water and therefore a direct titration is not suitable.

A back titration is carried out in two parts. The first part involves reacting the unknown sample (1g of eggshell in this experiment) with an excess of known volume and concentration of an acid. In this experiment, HCl was used. The solution is allowed to react before the resulting solution is made into a standard solution and titrated directly with a known concentration solution of alkali. Using the results from the titration it is possible to calculate the moles of acid reacted. It is possible to calculate the original number of moles of acid as both volume and concentration was known.

A simple calculation is then carried out: original moles of acid - titrated moles of acid = moles of acid reacted with egg shell. An example calculation is shown:

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 10.3mL
Concentration of NaOH = 0.05 mol/l

n(NaOH) = c x v
n = 0.05 x 0.0103
n = 5.15 x 10^{-4} moles

1:1 NaOH: HCl
n = 5.15 x 10^{-4} moles : n = 5.15 x 10^{-4} moles
x10 (scaling up for volumetric flask)
n = 5.15 x 10^{-3} moles

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - 5.15x10^{-3} moles = **0.01985 moles**

1:2 $CaCO_3$: HCl

0.01985 / 2 = **9.925 x 10^{-3} moles of $CaCO_3$**

M = n x GFM
M = 9.925x10^{-3} moles x 100.1 g/mol
M = 0.993g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 0.993 / 1.00 x 100 = **99.3%**

Calcium Carbonate is a good primary standard as it has a relatively high molecular mass, is stable in air and water, and does not absorb water from the air, and has a high level of purity. Calcium Carbonate was used as a primary standard in a control experiment to determine if back titration was a suitable technique. This required a standard solution of Calcium Carbonate to be made. A standard solution is a solution of accurately known concentration.

A standard solution is made by dissolving a small mass of the primary standard in a solvent in a beaker. This is then added to a volumetric flask and the beaker rinsed with deionised water, with the rinsings added to the flask also. The solution is then made up to the mark using a pipette, and inverted to ensure a thorough mixing:

This reaction is an example of an acid base titration. According to Bronsted Lowry, the definition of an acid is any substance that will donate a proton (H^+). The definition of a base is any substance that will accept a proton. In an acid base reaction the acid becomes a conjugate base and the base becomes a conjugate acid:

$$\underset{\text{Base}}{H_2O} + \underset{\text{Acid}}{H_2O} \rightleftharpoons \underset{\text{Conj Acid}}{H_3O^+} + \underset{\text{Conj Base}}{OH^-}$$

This reaction shows the amphoteric nature of water - it can behave as an acid and a base.

Acids can be categorised as either a strong acid or a weak acid. In this reaction we are using Hydrochloric Acid (HCl) which is a strong acid. This means that the molecules dissociate completely into ions in solution. Other strong acids include Sulphuric Acid, Nitric Acid and Phosphoric Acid. A weak acid is an acid which will only partially dissociate into ions. Less than 1% of molecules exist as ions in solution of a weak acid. An example of a weak acid is Ethanoic Acid and other carboxylic acids.

The way to measure pH of these acids are also different. In a strong acid we can use $pH = -\log_{10}[H^+]$. This is not suitable for weak acids as the assumption that all molecules become ions in solution does not stand. Instead, the equilibrium constant K_a of the weak acid is used as well as concentration: $pH = 1/2\ pK_a - 1/2 \log C$.

The end point of the reaction is identified by addition of an indicator. An indicator is a weak acid that is one colour in the protonated form and another colour in the deprotonated form. This reaction used Phenolphthalein:

$$\underset{\text{Colourless}}{\text{H-Phth}} \rightleftharpoons H^+ + \underset{\text{Pink}}{\text{Phth}^-}$$

As the titration between Acid and Base proceeds, the OH^- ions shift equilibrium to the right as they use up H^+. However, as the reaction proceeds this continues until no more H^+ are left and the pale pink colour prevails. This happens around pH 9.3
(https://www.chemguide.co.uk/physical/acidbaseeqia/indicators.html)

Procedures

Apparatus

- Beaker
- Stirrer
- Mortar and Pestle
- 50cm^3 Burette
- 25cm^3 Pipette
- 250cm^3 Volumetric Flask
- Clamp Stand
- 0.1M NaOH
- 0.05M NaOH
- 1M HCl
- Phenolphthalein Indicator
- Caged, Free Range and Duck Egg

Control

Calcium Carbonate (1.00g) was weighed accurately and added to a beaker of 1M HCl (25cm^3). The solution was stirred until all carbonate was dissolved and added to a volumetric flask (250cm^3). The beaker was rinsed with distilled water and rinsing's added to the volumetric flask. The solution was made up to the mark using distilled water. The solution was inverted before four 25cm^3 samples were removed using a pipette for titration. The samples were titrated with 0.05M NaOH until concordant results were obtained. Phenolphthalein indicator was used (3 drops).

Caged Egg

The caged egg was washed in distilled water and cracked and membranes removed. The shell was ground into a fine powder using mortar and pestle, it was then weighed accurately (1.00g) and added to a beaker of 1M HCl (25cm^3). The solution was stirred until all carbonate was dissolved and added to a volumetric flask (250cm^3).). The beaker was rinsed with distilled water and rinsings added to the volumetric flask. The solution was made up to the mark using distilled water. The solution was inverted before four 25cm^3 samples were removed using a pipette for titration. The samples were titrated with 0.1M NaOH until concordant results were obtained. Phenolphthalein indicator was used (3 drops). This was repeated for a second caged egg sample using the same procedure.

Free Range Egg

The free range egg was washed in distilled water and cracked and membranes removed. The shell was ground into a fine powder using mortar and pestle, it was then weighed accurately (1.00g) and added to a beaker of 1M HCl (25cm^3). The solution was stirred until all carbonate was dissolved and added to a volumetric flask (250cm^3).). The beaker was rinsed with distilled water and rinsings added to the volumetric flask. The solution was made up to the mark using distilled water. The solution was inverted before four 25cm^3 samples were removed using a pipette for titration. The samples were titrated with 0.05M NaOH until concordant results were obtained. Phenolphthalein indicator was used (3 drops). This was repeated for a second free range egg sample using the same procedure

Duck Egg

The duck egg was washed in distilled water and cracked and membranes removed. The shell was ground into a fine powder using mortar and pestle, it was then weighed accurately (1.00g) and added to a beaker of 1M HCl (25cm^3). The solution was stirred until all carbonate was dissolved and added to a volumetric flask (250cm^3).). The beaker was rinsed with distilled water and rinsings added to the volumetric flask. The solution was made up to the mark using distilled water. The solution was inverted before four 25cm^3 samples were removed using a pipette for titration. The samples were titrated with 0.05M NaOH until concordant results were obtained. Phenolphthalein indicator was used (3 drops). This was repeated for a second duck egg sample using the same procedure.

Risk Assessment

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Chemical	Risks	Actions
Sodium Hydroxide (0.05M and 0.1M)	Irritant	• Wear gloves when handling NaOH. • Wash any spillages on skin with copious amounts of water. • Report any spillages.
Hydrochloric Acid (1M)	Low hazard	• No extra actions needed.
Phenolphthalein (low concentration)	Low hazard	• Wear gloves when handling. • Use drops of it.

Modifications

The caged egg shell solution was titrated with 0.1M NaOH. This was changed to 0.05M NaOH for Free Range and Duck Egg as the titration results were too small, they were less than 5.0 cm^3.

As the titration result of Free Range Egg Sample 1 was very close to the acceptable limit of 5mL, with some results under 5 cm^3 I carried out a calculation based on those results. The % purity was over 100%. This confirmed that to have a more acceptable titre volume (of more than 5 cm^3) and get an expected result, the concentration of NaOH would be halved to 0.05M.

<u>Raw Data</u>

The following were used in all experiments:

Hydrochloric Acid Concentration	1 $moll^{-1}$
Hydrochloric Acid Volume	25 cm^3
Volumetric Flask	250 cm^3
Sodium Hydroxide Concentration	Control & Caged - 0.1 $moll^{-1}$ Free Range & Duck - 0.05 $moll^{-1}$

Control	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	2.2	8.0	13.4	18.7
Final burette reading /cm^3	8.0	13.4	18.7	24.0
Titre volume /cm^3	5.8	5.4	5.3	5.3

Average Titre = 5.3 cm^3

Caged 1	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	0.7	7.3	13.5	19.5
Final burette reading /cm^3	7.3	13.5	19.5	25.7
Titre volume /cm^3	6.6	6.2	6.0	6.2

Average Titre = 6.1 cm^3

Caged 2	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	0.0	7.4	14.4	21.4
Final burette reading /cm^3	7.4	14.4	21.4	28.3
Titre volume /cm^3	7.4	7.0	7.0	6.9

Average Titre = 7.0 cm^3

Free Range 1 Results Discarded	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	0.0	5.3	10.2	15.2
Final burette reading /cm^3	5.3	10.2	15.2	20.2
Titre volume /cm^3	5.3	4.9	5.0	5.0

Average Titre = 5.0 cm^3

Free Range 1	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	0.1	12.7	23.2	0.0
Final burette reading /cm^3	12.7	23.2	34.5	11.3
Titre volume /cm^3	12.6	11.5	11.3	11.3

Average Titre = 11.4 cm^3

Free Range 2	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	12.5	23.9	35.3	0.4
Final burette reading /cm^3	23.9	35.3	46.8	11.8
Titre volume /cm^3	11.4	11.4	11.3	11.4

Average Titre = 11.4 cm^3

Duck Egg 1	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	0.4	11.5	21.8	31.6
Final burette reading /cm^3	11.5	21.8	31.6	41.9
Titre volume /cm^3	11.1	10.3	9.8	10.3

Average Titre = 10.3 cm^3

Duck Egg 2	Rough	Titre 1	Titre 2	Titre 3
Initial burette reading /cm^3	0.9	9.5	19.7	29.9
Final burette reading /cm^3	9.5	19.7	29.9	40.2
Titre volume /cm^3	8.6	10.2	10.2	10.3

Average Titre = 10.2 cm^3

Results

General Observations:

The end point of the reaction was observed when the colourless phenolphthalein solution turned a pale shade of pink.

Control Experiment

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 5.3mL
Concentration of NaOH = 0.05 mol/l

n(NaOH) = c x v
n = 0.05 x 0.0053
n = 2.65×10^{-4} moles

1:1 NaOH: HCl
n = 2.65×10^{-4} moles: n = 2.65×10^{-4} moles
x10 (scaling up for volumetric flask)
n = 2.65×10^{-3} moles

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - 2.65×10^{-3} moles = **0.02235 moles**

1:2 $CaCO_3$: HCl

0.02235 / 2 = **0.01112 moles of $CaCO_3$**

M = n x GFM
M = 0.01112 moles x 100.1 g/mol
M = 1.12g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 1.12 / 1.00 x 100 = **112%**

This experimental result shows that this method is valid, despite giving a result of more than 100%. A titre of more than 5.0mL was obtained making the technique a valid one, and validating the concentration used.

Caged Egg Sample 1

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 6.1mL
Concentration of NaOH = 0.1 mol/l

n(NaOH) = c x v
n = 0.1 x 0.0061
n = 6.1×10^{-4} moles

1:1 NaOH: HCl
n = 6.1×10^{-4} moles: n = 6.1×10^{-4} moles
x10 (scaling up for volumetric flask)
n = 6.1×10^{-3} moles

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - 6.1×10^{-3} moles = **0.0189 moles**

1:2 $CaCO_3$: HCl

0.0189 / 2 = **9.45×10^{-3} moles of $CaCO_3$**

M = n x GFM
M = 9.45×10^{-3} moles x 100.1 g/mol
M = 0.945g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 0.945 / 1.00 x 100 = **94.6%**

Caged Egg Sample 2

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 7.0mL
Concentration of NaOH = 0.1 mol/l

n(NaOH) = c x v
n = 0.1 x 0.0070

$n = 7x10^{-4}$ moles

1:1 NaOH: HCl
$n = 7x10^{-4}$ moles: $n = 7x10^{-4}$ moles
x10 (scaling up for volumetric flask)
<u>$n = 7x10^{-3}$ moles</u>

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - $7x10^{-3}$ moles = **<u>0.018 moles</u>**

1:2 $CaCO_3$: HCl

0.018 / 2 = **<u>9×10^{-3} moles of $CaCO_3$</u>**

M = n x GFM
M = $9x10^{-3}$ moles x 100.1 g/mol
M = 0.901g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 0.901 / 1.00 x 100 = **<u>90.1%</u>**

<u>Average Caged Egg % = 94.6 + 90.1 / 2 = 92.35% = 92.4%</u>

Free Range Egg Sample 1

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 11.4mL
Concentration of NaOH = 0.05 mol/l

n(NaOH) = c x v
n = 0.05 x 0.0114
n = $5.7x10^{-4}$ moles

1:1 NaOH: HCl
n = $5.7x10^{-4}$ moles: n = $5.7x10^{-4}$ moles
x10 (scaling up for volumetric flask)
n = $5.7x10^{-3}$ moles

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - $5.7x10^{-3}$ moles = **0.0193 moles**

1:2 $CaCO_3$: HCl

0.0193 / 2 = **9.65×10^{-3} moles of $CaCO_3$**

M = n x GFM
M = $9.65x10^{-3}$ moles x 100.1 g/mol
M = 0.966g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 0.966 / 1.00 x 100 = **96.6%**

Free Range Egg Sample 2

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 11.4mL
Concentration of NaOH = 0.05 mol/l

n(NaOH) = c x v
n = 0.05 x 0.0114

$n = 5.7 \times 10^{-4}$ moles

1:1 NaOH: HCl
$n = 5.7 \times 10^{-4}$ moles: $n = 5.7 \times 10^{-4}$ moles
x10 (scaling up for volumetric flask)
<u>$n = 5.7 \times 10^{-3}$ moles</u>

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - 5.7×10^{-3} moles = **<u>0.0193 moles</u>**

1:2 $CaCO_3$: HCl

0.0193 / 2 = **<u>9.65×10^{-3} moles of $CaCO_3$</u>**

M = n x GFM
M = 9.65×10^{-3} moles x 100.1 g/mol
M = 0.966g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 0.966 / 1.00 x 100 = **<u>96.6%</u>**

<u>Average Free Range Egg % = 96.6 + 96.6 / 2 = 96.6%</u>

Duck Egg Sample 1

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 10.3mL
Concentration of NaOH = 0.05 mol/l

n(NaOH) = c x v
n = 0.05 x 0.0103
n = 5.15×10^{-4} moles

1:1 NaOH: HCl
n = 5.15×10^{-4} moles: n = 5.15×10^{-4} moles
x10 (scaling up for volumetric flask)
n = 5.15×10^{-3} moles

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - 5.15×10^{-3} moles = **0.01985 moles**

1:2 $CaCO_3$: HCl

0.01985 / 2 = **9.925×10^{-3} moles of $CaCO_3$**

M = n x GFM
M = 9.925×10^{-3} moles x 100.1 g/mol
M = 0.993g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 0.993 / 1.00 x 100 = **99.3%**

Duck Egg Sample 2

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Average Titre of NaOH = 10.2mL
Concentration of NaOH = 0.05 mol/l

n(NaOH) = c x v
n = 0.05 x 0.0102
n = 5.1×10^{-4} moles

1:1 NaOH: HCl
n = 5.1x10^{-4} moles: n = 5.1x10^{-4} moles
x10 (scaling up for volumetric flask)
<u>n = 5.1x10^{-3} moles</u>

Original moles of acid = n x c
n = 1 x 0.025
n = 0.025moles

Moles of unreacted acid = 0.025 moles - 5.1x10^{-3} moles = **<u>0.0199 moles</u>**

1:2 $CaCO_3$: HCl

0.0199 / 2 = **<u>9.95 x 10^{-3} moles of $CaCO_3$</u>**

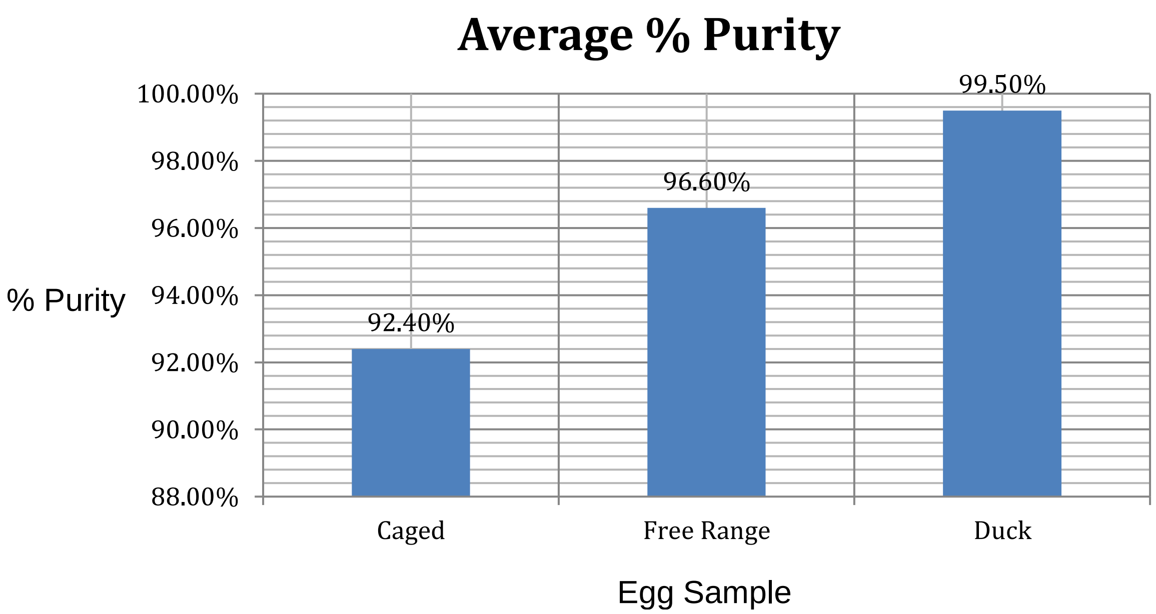
M = n x GFM
M = 9.95x10^{-3} moles x 100.1 g/mol
M = 0.996g

% Purity = Calculated Mass / Sample Mass x 100
% Purity = 0.996 / 1.00 x 100 = **<u>99.6%</u>**

<u>Average Duck Egg % = 99.3 + 99.6 / 2 = 99.45% = 99.5%</u>

Summary of Results:

Egg Sample	Average % Purity
Caged	92.4 %
Free Range	96.6 %
Duck	99.5 %



Conclusion

The Calcium Carbonate % Puirity of Caged Hen Eggshell was found to be 92.4%. Free Range Eggshell had a % Purity of 96.6% and Duck Eggshell was found to contain 99.5% Calcium Carbonate.

Evaluation

Evaluation of Procedures

This investigation used a correct and appropriate sample size. Three types of egg were chosen from a very deliberate different range of prices - from the cheapest egg (caged) to mid range (free range) to expensive eggs (duck eggs).

A control experiment was carried out in order to validate the procedure.

The titration was correctly repeated until concordant results were obtained. This is standard procedure. However, I repeated my entire experiment for each sample twice so that an average could be taken. In doing so I used a new egg for each and followed the procedure again. This made my results more accurate.

To ensure a similar end point was reached on each titration, I kept the rough titre to hand so that a direct comparison could be made. This was particularly useful as some end points were a very light shade of pink. This again made my results accurate.

During the cleaning process, it was not possible to remove all membrane from the eggshell before it was reacted with acid. This could have altered the volume of acid required to react with the base.

It is possible that not all of the eggshell dissolved in the acid in the first part of the procedure. This was crucial as it was only the leftover acid that is then titrated with base. This could mean some Calcium Carbonate went unreacted and therefore is not included in calculations, leading to inaccurate results.

It is possible that the eggshell was not completely dry before being weighed. This may have contributed to weight on the balance meaning less than 1.00g was actually reacted with the acid leading to inaccurate results.

There are intrinsic uncertainties in some of the class B glassware that was used in the experiment. A 25cm^3 pipette has an uncertainty of $\pm$ 0.06 cm^3, whilst a 50cm^3 burette has an uncertainty of $\pm$ 0.1 cm^3. A 250cm^3 Volumetric Flask has an uncertainty of $\pm$ 0.3 cm^3. A 2 decimal place balance has an uncertainty of $\pm$ 0.01 g.

Evaluation of Results

The control experiment I carried out gave a % purity value of more than 100%. My results were valid in that they were close to this value and did not go over 100%. A possible reason for gaining a value of more than 100% could be that more than one base was present in the eggshell. The Hydrochloric Acid would not discriminate between bases and would react with any bases present. This may mean that my calculation included other bases not accounted for in mass.

The general trend of my results is an expected trend. It is well documented that caged hens have less free space and a more stressful existence. This would contribute to them being unable to produce eggs containing the same % purity of Calcium Carbonate as a Free Range Hen, or a Duck, which have a better quality of life.

There are intrinsic uncertainties in some of the class B glassware that was used in the experiment. A 25cm^3 pipette has an uncertainty of ± 0.06 cm^3, whilst a 50cm^3 burette has an uncertainty of ± 0.1 cm^3. A 250cm^3 Volumetric Flask has an uncertainty of ± 0.3 cm^3. A 2 decimal place balance has an uncertainty of ± 0.01 g.

For my experiments:

Volumetric Flask Volume = 250cm^3 ± 0.3 cm^3.

% Uncertainty = 0.3 / 250 x 100 = 0.12%.

Pipette Volume = 25cm^3 ± 0.06 cm^3

% Uncertainty = 0.06 / 25 x 100 = 0.24%

Balance = 1.00g ± 0.01g

% Uncertainty = 0.01 / 1.00 x 100 = 1%

<u>Burette Error</u>

Control Titre Volume = 5.3cm^3 ± 0.1 cm^3

% Uncertainty = 0.1 / 5.3 x 100 = 1.9%

Caged Egg 1 Titre Volume = 6.1cm^3 ± 0.1 cm^3

% Uncertainty = 0.1 / 6.1 x 100 = 1.6%

Caged Egg 2 Titre Volume = 7.0cm^3 ± 0.1 cm^3

% Uncertainty = 0.1 / 7.0 x 100 = 1.4%

Free Range Egg 1 Titre Volume = 11.4cm^3 $\pm$ 0.1 cm^3

% Uncertainty = 0.1 / 11.4 x 100 = 0.9%

Free Range Egg 2 Titre Volume = 11.4cm^3 $\pm$ 0.1 cm^3

% Uncertainty = 0.1 / 11.4 x 100 = 0.9%

Duck Egg 1 Titre Volume = 10.3cm^3 $\pm$ 0.1 cm^3

% Uncertainty = 0.1 / 10.3 x 100 = 1.0%

Duck Egg 2 Titre Volume = 10.2cm^3 $\pm$ 0.1 cm^3

% Uncertainty = 0.1 / 10.2 x 100 = 1.0%

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