Estimating the Amount of $\underset{\text{calcium carbonate}}{\mathrm{CaCO_3}}$ in Eggshells

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1 Aim

The aim is to estimate the mass of $\underset{\text{calcium carbonate}}{\mathrm{CaCO_3}}$ containing in eggshell.

2 Introduction

General eggshell contains a large amount of $\underset{\text{calcium carbonate}}{\mathrm{CaCO_3}}$. By titrating $\underset{\text{hydrogen chloride}}{\mathrm{HCl}}$ into $\underset{\text{calcium carbonate solution}}{\mathrm{NaOH(aq)}}$ which contains $\underset{\text{calcium carbonate}}{\mathrm{CaCO_3}}$ from eggshell, we will be able to neutralize the solution and thus use the amount of $\underset{\text{hydrogen chloride}}{\mathrm{HCl}}$ used to estimate $\underset{\text{calcium carbonate}}{\mathrm{CaCO_3}}$ containing in the eggshell.

3 Materials

1. $\underset{\text{hydrogen chloride solution}}{\mathrm{HCl(aq)}}$ $(1\,\mathrm{mol\,dm^{-3}})$
2. Standard $\underset{\text{sodium hydroxide solution}}{\mathrm{NaOH(aq)}}$ $(0.1\,\mathrm{mol\,dm^{-3}})$
3. Phenolphthalein Indicator
4. Distilled Water

4 Apparatus

1. $20\mathrm{cm^3} \pm 0.05\mathrm{cm^3}$ Burette
2. $20\mathrm{cm^3} \pm 0.05\mathrm{cm^3}$ Volumetric Pipette
3. $250\mathrm{cm^3}$ Conical Flask
4. $250\mathrm{cm^3} \pm 0.12\mathrm{cm^3}$ Volumetric Flask

5. $250cm^3$ Beaker
6. Pipet
7. Filter Papers
8. Mortar
9. Pestle
10. Electronic scale
11. Weighting plate

5 Safety Measures

1. $\underset{\text{Hydrogen chloride}}{HCl}$ is flammable and may causes severe skin burns and eye damage [1]. Avoid inhaling the substance and contact with the skin.
2. $\underset{\text{Sodium hydroxide}}{NaOH}$ may causes severe skin burns and eye damage [2]. Avoid contact with the skin.

Under the safety issues may bring from the hazards listed above, lab goggles, gloves, and lab coat are required to be wearing during the whole lab session; and the one may not take any of those off if there's still anyone not done the cleaning of the lab.

6 Procedure

1. Put the dried eggshell into the mortar, use the pestle to smash the eggshells into smallest powders possible
2. Put the weighting plate and reset the electronic scale with the plate
3. Measure out 2g eggshell powder using the electronic scale, and transfer it into a conical flask
4. Measure out 60ml $\underset{\text{hydrogen chloride solution}}{HCl(aq)}$ using the graduated cylinder
5. Pour the measured $\underset{\text{hydrogen chloride solution}}{HCl(aq)}$ into the conical flask in Step 3
6. Wait for 24 hours for the $\underset{\text{hydrogen chloride solution}}{HCl(aq)}$ to mix completely with the eggshell powder
7. Fold the filter paper and filter the mixture got from Step 6
8. Pour $10cm^3$ solution got from Step 7 to the $250cm^3$ volumetric flask

9. Fill the burette with $\underset{\text{sodium hydroxide solution}}{\text{NaOH(aq)}}$
10. Record the burette reading as the "Initial Volume"
11. Add 2 drops of phenolphthalein indicator into the conical flask in Step 8
12. Hold the conical flask under the burette and,
13. Slowly add the $\underset{\text{sodium hydroxide solution}}{\text{NaOH(aq)}}$ to the eggshell powder liquid
14. Shake the conical flask continuously
15. When the reacting mixture in the conical flask turns pink, stop the burette tap
16. Record the burette reading as the "Final Volume".
17. Clean and rinse the apparatuses thoroughly, and use a tissue paper to wipe out the water remains on the apparatuses to reduce error
18. Repeat from Step 8 at least 5 times in order to reduce error

7 Data Collection

Table 1: Data

Trial	Final Volume ($\pm 0.05 cm^3$)	Initial Volume ($\pm 0.05 cm^3$)	NaOH(aq) used ($\pm 0.10 cm^3$)
1	43.4	0.0	43.4
2	42.6	0.0	42.6
3	42.6	0.6	42.0
4	42.3	0.4	41.9
5	42.5	0.4	42.1

Average NaOH(aq) used: 42.4 cm^3

8 Calculation

$$\frac{M_{(\text{HCl})} \times V_{(\text{HCl})}}{M_{(\text{NaOH})} \times V_{(\text{NaOH})}} = \frac{1}{1} \tag{1}$$

where

$$\begin{aligned} M_{(\text{HCl})} &= 1 \text{mol}\,\text{dm}^{-3} \\ M_{(\text{NaOH})} &= 0.1 \text{mol}\,\text{dm}^{-3} \\ V_{(\text{NaOH})} &= 42.4 \text{cm}^3 = 4.24 \times 10^{-2} \text{dm}^3 \end{aligned}$$

thus, we can calculate the volume of $\underset{\text{hydrogen chloride solution}}{\text{HCl(aq)}}$ (denoted as $M_{(\text{HCl(aq)})}$) as:

$$\begin{aligned} M_{(\text{HCl})} &= \frac{M_{(\text{NaOH})} \times V_{(\text{NaOH})}}{V_{(\text{HCl})}} \\ &= \frac{1.0 \times 10^{-1}\text{mol dm}^{-3} \times 4.24 \times 10^{-2}\text{dm}^3}{1.0 \times 10^{-2}\text{dm}^3} \\ &= 4.24 \times 10^{-1}\text{mol dm}^{-3} \end{aligned}$$

Now we have already calculated the mass of HCl, after that we can then use

$$\text{CaCO}_3 + 2\,\text{HCl(aq)} \rightarrow \text{CaCl}_2\text{(aq)} + \text{H}_2\text{O} + \text{CO}_2 \quad (2)$$

to calculate how many exactly does the $\underset{\text{calcium carbonate}}{\text{CaCO}_3}$ being reacted with $\underset{\text{hydrogen chloride solution}}{\text{HCl(aq)}}$ by using:

$$\begin{aligned} \frac{M_{(\text{HCl})} \times V_{(\text{HCl})}}{n_{(\text{CaCO}_3)}} &= \frac{2}{1} \\ n_{(\text{CaCO}_3)} &= \frac{4.24 \times 10^{-1}\text{mol dm}^{-3} \times 6.00 \times 10^{-2}\text{dm}^3}{2} \\ n_{(\text{CaCO}_3)} &\approx 1.27 \times 10^{-2}\text{mol} \end{aligned}$$

Thus we can calculate the mass of $\underset{\text{calcium carbonate}}{\text{CaCO}_3}$ by simply using the molar mass of it:

$$\begin{aligned} m_{(\text{CaCO}_3)} &= n_{(\text{CaCO}_3)} \times M_{(\text{CaCO}_3)} \\ m_{(\text{CaCO}_3)} &= 1.27 \times 10^{-2}\text{mol} \times (40.078 + 12.011 + 15.999 \times 3)\text{g mol}^{-1} \\ m_{(\text{CaCO}_3)} &= 1.27 \times 10^{-2}\text{mol} \times 100.086\text{g mol}^{-1} \\ m_{(\text{CaCO}_3)} &\approx 1.3\text{g} \end{aligned}$$

8.1 Error Analysis

- *Error in Volumetric Pipette* $20 \pm 0.05\text{cm}^3 \rightarrow 100 \times \frac{0.05\text{cm}^3}{42.4\text{cm}^3} = 0.12\%$
- *Error in Burette* $20 \pm 0.1\text{cm}^3 \rightarrow 100 \times \frac{0.05\text{cm}^3}{42.4\text{cm}^3} = 0.12\%$
- *Total Percentage Error* $0.12\% + 0.12\% = 0.24\%$

Total Absolute Error: $1.3\text{g} \times 0.24\% = 0.00312\text{g}$

The mass of $\underset{\textbf{calcium carbonate}}{\text{CaCO}_3}$ **in the eggshell is** $1.3 \pm 0.00312\text{g}$

9 Conclusion

By titrating using the $\underset{\text{hydrogen chloride solution}}{\mathrm{HCl(aq)}}$ into the given solution we found that the mass of $\underset{\text{calcium carbonate}}{\mathrm{CaCO_3}}$ in the eggshell is 1.3 ± 0.00312g.

References

[1] National Center for Biotechnology Information. PubChem Database. Hydrochloric acid, CID=313, `https://pubchem.ncbi.nlm.nih.gov/compound/Hydrochloric-acid` (accessed on Feb. 5, 2020)

[2] National Center for Biotechnology Information. PubChem Database. Sodium hydroxide, CID=14798, `https://pubchem.ncbi.nlm.nih.gov/compound/Sodium-hydroxide` (accessed on Feb. 5, 2020)