Acid Base Lab : Determination of CaCO3 in toothpaste

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Introduction:

In order to know a concentration of an unknown solution, we can use the method of titration to find the concentration of that solution. Titration is a chemical method used to determine the end point of a reaction between acid and base that, therefore, can be analyzed to determine the concentration of the unknown solution. During the titration, one solution of a known-concentration titrant will be slowly added to a known volume of another solution of unknown concentration until the reaction is neutralized.[3] There are several ways of titration; strong acid-strong base titration, weak acid-strong base titration, weak base-strong acid titration, redox titration, etc. However, the titration we did in our experiment is not the direct, instead it is a back titration of a weak base, a toothpaste, with a strong acid, Hydrochloric acid.

Based on our experiment, we used two reagents: HCl and NaOH. HCl reacted with our original sample, and NaOH reacted with the first reagent. The precise measured amount of HCl was added to the sample, so when the reaction between HCl and our sample ended, we added NaOH to titrate the excess HCl.[2] Therefore, we could calculate the amount of HCl reacted with our sample, $CaCO_3$, by using the initial amount of HCl and the amount of HCl left after the reaction. This is called the back titration.[2] We will use this type of titration when the reaction between solution and titrant is occurred very slow or when we can't determine the exact end point of the reaction in some case.

Toothpaste is a daily-life product, also called dentrifrice, which is used essentially to clean our teeth in daily routine by helping to remove dentral plaque or a film of bacteria on our teeth. Toothpaste is usually found in gel-like or pastes.[1] Its major ingredients are silica, calcium carbonate and fluorine. Therefore, one of the most essential substances found in Toothpaste's ingredients is Calcium Carbonate, which helps to clean the dirty stains on our teeth, reducing the chance of them to form plaque. Calcium carbonate or $CaCO_3$ is a chemical substance normally found in rocks, shells, egg shell, etc.[5] Moreover, it can react with acid to produce salt, water and carbon dioxide. The average particle size of precipitated calcium carbonate in toothpaste is around 3-5 μm and the pH is about 9, which is basic.[6]

Purpose:

- To determine the average Calcium Carbonate in the toothpaste by using back titration
- To learn and practice back titrating a sample

Hypothesis:

- The average calcium carbonate found in the toothpaste is around 100 mg/g.

Materials:

- 3x 125 mL Erlenmeyer Flasks
- 1x spatula
- 1x stand with double burette holder
- 1x burette
- 1x stirring rod
- 1x pH meter
- 1x graduated cylinder
- 1x tube of Colgate Salt Whitening

Procedure:

1. Weigh about 0.5 g of toothpaste directly into Erlenmeyer flask
2. Add about 10 mL of H_2O into the flask and crush toothpaste using the stirring rod.
3. Add exactly 10.00 mL of 0.10 M HCL using pipette
4. Heat up at about 95 – 105 degree Celsius for about 5 minutes to dissolve toothpaste and allow it to react.
5. Take the flask off to cool it down.
6. Add an indicator
7. After cooling down, check its initial pH with pH meter
8. Check initial volume of NaOH in the burette
9. Titrate with 0.10 M NaOH until the color of the solution starting to change
10. When reaching the end point, check final pH of the solution and the volume of NaOH left in butette
11. Repeat step 1-10 with Sample 2
12. Repeat step 1-8 with Sample 3, then titrate the solution with NaOH and check the pH and the volume every 1 mL.
13. Dispose the waste in large beaker provided.

Data Results:

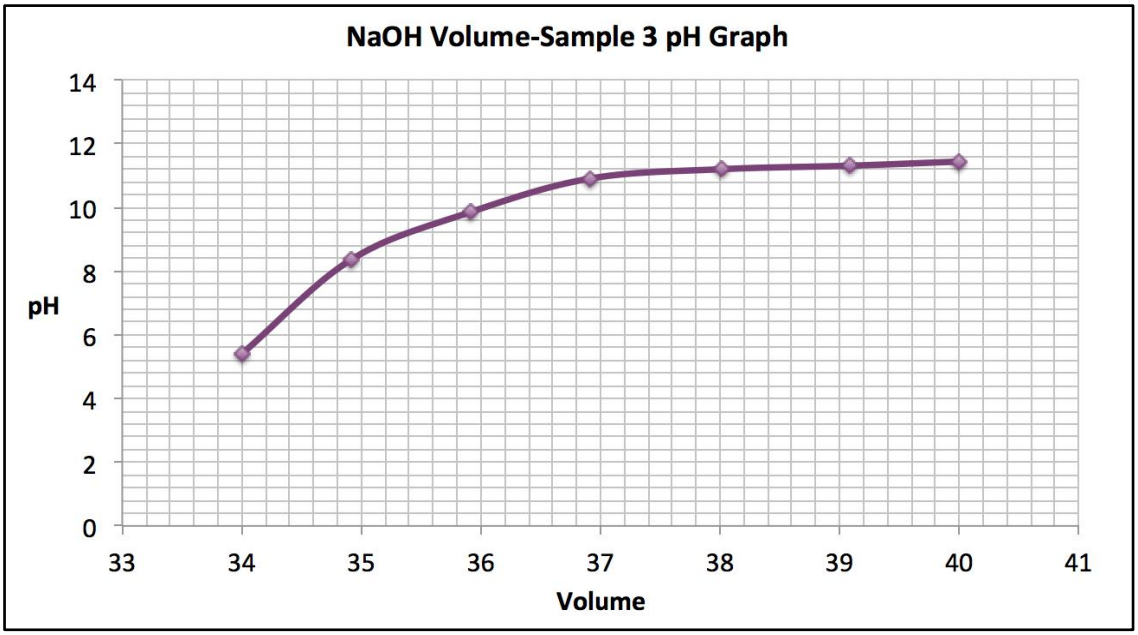
Data Table

		Sample 1	Sample 2	Sample 3
Weight toothpaste (g)		0.79	0.62	0.91
pH	Initial	7.62	5.24	5.41
	Final	9.09	8.34	8.37
Volume (mL)	Initial	32.65	32.91	34.00
	Final	32.91	34.00	34.92
	Total	0.26	1.09	0.92

	Sample 1	Sample 2	Sample 3
Total Vol of HCl added (mL)	10	20	20
Vol. HCl reacted with toothpaste (mL)	9.74	18.91	19.08
Moles HCL reacted	9.74×10^{-4}	1.891×10^{-3}	1.908×10^{-3}
Moles $CaCO_3$	4.87×10^{-4}	9.455×10^{-4}	9.54×10^{-4}
Amount $CaCO_3$ (mg)	48.7	94.55	95.4
Amount $CaCO_3$ (mg/g)*	61.65	152.5	104.84
Average $CaCO_3$ (mg/g)	106.33		
Standard Deviation	106.33 ± 45.44		
%RSD	42.73%		

*miligrams of CaCO3 per gram of toothpaste

<u>NaOH Volume- Sample3 pH Graph</u>



Discussion:

This experiment was performed to determine the average amount of calcium carbonate in the toothpaste. First of all, we mixed toothpaste with water and HCl, and heated it up. According to the equation, $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$, after calcium carbonate reacted with hydrochloric acid, calcium chloride, carbon dioxide and water were produced. As carbon dioxide can higher the acidity of the solution, it needs to be eliminated. One way to get rid of it is to heat up the solution because the high temperature made CO_2, which is in the gas state, float up to the surface of the solution and evaporate. By this method, we also speeded up the rate of the reaction to occur. After the reaction between $CaCO_3$ and HCl was done, there were some HCl left in the solution due to the excess amount of HCl we add in. In order to calculate the amount of $CaCO_3$ in the toothpaste, the excess amount of HCl was titrated with a titrant, NaOH. We did the titration until the solution got neutralized. We then know that left amount of HCl from the volume of NaOH we added into the solution with HCl because, to be neutral, a base should be added in an acidic solution with the same concentration of the acid. We then knew the amount of $CaCO_3$ since we already knew the total amount of HCl we first added and the left amount after the reaction with $CaCO_3$. The amount of $CaCO_3$ equaled to the total amount subtracted by the left amount. Also, an end point was the point that phenolphthalein, the indicator we added in the solution to indicate the pH, starting to turn pink from colorless color; an equivalence point was the point when the equivalent quantities of acid and base were mixed—in this case was HCl and NaOH. Normally, we could not see the equivalence point by our eyes, so the indicator was necessarily used. Phenolphthalein was an indicator that could indicate the pH in the same range as the equivalence point. If we choose a right indicator, the equivalence point and the end point would be very close. Usually, phenolphthalein turned pink when the pH of the solution was about 8 to 9 or when solution turned basic. It was because phenolphthalein was a weak acid with colorless and its ion was pink. To turn it to pink, base should be added to break phenolphthalein apart because when it was split, its ion showed its color, which is pink. Therefore, the basicity of the solution came from the base we added to allow the indicator turn pink to indicate the pH of that solution. After we finished the titration, we recorded the final pH and NaOH volume. And again, we had to do twice more for an accuracy of the results. We did exactly the same with the first one, but, absolutely, we did not get the same results from the two more times because the amount of the toothpaste we added each time was not the same. Thus, we performed the experiment three times in total and calculate the average value later.

Conclusion:

From the results, we finally got the average amount of $CaCO_3$ of 106.33 mg/g with the standard deviation of ±45.44. The reason was because we had made a mistake on the experiment. The instruction told to add the toothpaste about 5 g. each but we added it much higher than 5 every time. However, it was fine, yet the main thing was that we checked the initial pH and it was over 7. If it was higher than 7, we should add 10mL more of HCl, but we did not. Also, because of this reason, when we did the titration with NaOH, it changed the color very fast that we could not stop it, so we over-added the NaOH to the solution, which could make the result

inaccurate. Based on the data table, the results of the Sample 1 were much different from those of the Sample 2 and of the Sample 3. Also, to repeat the experiment many times could check whether our results were accurate or precise. That helped us a lot. The more times we did the experiment will be the more accuracy of the results. If we did the experiment just one time, we might not recognize if we had done something wrong and that would completely change the way that the results should be because there would be nothing to compare with. To evaluate the experiment and reduce the error, we should be much more careful and we should help each other to observe things.

References

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