Determination of a Chemical Formula by Titration: Ca with H_2O

I. Introduction. *For background on this experiment you should read section 9.4 of your textbook, Atoms First.*

In this experiment you will do the following laboratory activities.

1. Observe the reaction of metals with hydrochloric acid and water.
2. Use titration to determine the chemical formula of the product that results from the reaction of calcium with water.

Many metals readily react in aqueous solutions. They can react with other metals, with acids and with water itself. Alkali and alkaline earth metals are particularly reactive. Lithium, sodium or potassium metals all react vigorously with water according to the following reaction.

$$2\ Na(s) + 2H_2O \rightarrow 2Na^+(aq) + 2\ OH^-(aq) + H_2(g)$$

The first three alkali metals all react vigorously and are exothermic. **The reactions can produce enough heat to ignite the evolving hydrogen gas, making the reaction hazardous.**

The reactivity of Group I metals increases with atomic number (down the group). For the alkaline earth metals (Group II), the heavier elements, starting with calcium will also react with water. The reaction of calcium with water is much slower than that of the alkali metals, but does produce hydrogen gas, calcium cations and hydroxide anions.

After the reaction of calcium with water is complete and the water is evaporated, the salt of calcium hydroxide could be collected and weighed. Alternatively, the hydroxide can be titrated with a strong acid and the amount of hydroxide can be determined. If a known amount of calcium was used to produce the hydroxide, either the evaporation or the titration method could be used to determine the chemical formula of the calcium hydroxide salt. In this lab, you will use a titration to determine this chemical formula. Most students will realize what the formula should be since they know that calcium forms a divalent cation and hydroxide ions have a charge of negative one, but this exercise demonstrates how the formula can be confirmed.

II. Method

Required Equipment	
1) Weigh paper	
2) Tweezers for handling calcium metal	
3) Test tubes	
4) Burette	

A) Reaction of zinc and calcium with HCl and water.

In this portion of the experiment you will make qualitative observations of the reactivity of zinc and calcium with water and hydrochloric acid. You will use two chemical tests to evaluate the products of these reactions. The pop test is used to detect the production of hydrogen gas and phenolphthalein is used to detect the production of hydroxide anions.

1) To a small test tube, add 5 mL of 6 M HCl.
2) Using weigh paper, weigh out one or two pieces of zinc (about 0.5 g) and add these to the test tube.
3) Observe and record what happens when the zinc is added to the acid.
4) While the reaction is proceeding rapidly, cap your test tube by holding a second test tube with your test tube holder so that it covers the top of the first test tube. This will allow you to collect the gas that is evolving during the reaction. **Be sure that you hold the two test tubes so that they form a seal between their openings, to ensure that the gas is trapped in the top test tube.**
5) Capture the evolving gas in the upper test tube for about 30 seconds. (you might want to place the test tube upside down in a burette clamp)
6) After 30 seconds, ask your lab partner to strike a match.
7) Carefully move the inverted test tube over the burning match. Record your observation. **You should hear a sharp pop if hydrogen gas was captured.**

8) Repeat steps 1 through 7, but this time use a similar amount of calcium in place of zinc. Record your observations.

In the following steps you will observe the reactions of zinc and calcium with water

9) On weighing paper, weight out similar amounts of zinc and calcium to what you used above.
10) Record the weights and add the calcium and the zinc to separate test tubes that are half-filled with water.
11) Record your observations. Make notes if you observe gas evolution or precipitation.
12) Add two drops of phenolphthalein to the test tube containing the calcium and water. Record your observations. Does the indicator show that the solution is acidic or basic?
13) Next, transfer the contents of the tube with calcium to a 250 mL beaker. Add 6 M HCl drop-wise to the beaker until the indicator turns from pink to colorless. At this point you have neutralized the mixture and it may be discarded down the drain.

B) Determination of the chemical formula of the product from the reaction of calcium metal with water.

In this portion of the experiment you will quantitatively determine the amount of hydroxide that is produced by a known mass of calcium metal reacting with water.

NOTE: You must accurately weigh your calcium that is reacted with water and you must conduct your titration carefully in order to achieve good results.

1) Accurately weigh out one piece of calcium (~0.5 g is ideal) and record the mass with milligram precision. Do this by first taring a piece of weighing paper and then adding your calcium pieces.
2) Add the calcium to a 250 mL Erlenmeyer flask
3) Add about 150 mL of water to the flask and swirl the flask until all calcium has reacted.
4) Add three drops of phenolphthalein indicator.
5) Rinse your burette with 0.300 M HCl and then fill it with 0.300 M HCl being careful not to fill above the 0 mL line.
6) Record the initial volume to the nearest 0.05 mL.
7) Begin your titration and carefully titrate just to the point where the pink color disappears. Be sure to go slowly and swirl the beaker to ensure mixing.
8) Record your final burette reading.
9) Repeat this procedure for a second trial.

Name _____ TA _____ Time _____

Data and Observations Sheet

Part A – record your part A observations here.

1) Describe your observations when zinc or calcium is added to 6 M HCl.

A) What did you observe when zinc is added to HCl?

B) What was the result of the "pop test"?

C) What was observed when you added calcium to HCl?

D) Compare the results of the two pop-tests for zinc and for calcium.

2) Describe your observation when zinc or calcium is added to water.

A) Describe what you observe when these two metals are added to water.

B) What gas is produced in these reactions?

C) Describe the color change when phenolphthalein is added to the reaction product of calcium with water.

B) Titration of the calcium-water product and determination of the chemical formula of calcium hydroxide.

Precise concentration of 0.3 M HCl from T.A. _____

		Trial 1	Trial 2
Step 1 of Section II.B	**Mass of calcium (g)**		
Step 2 of Section II.B	**Initial burette reading (mL)**		
Step 8 of Section II.B	**Final burette reading (mL)**		
Step 8 of Section II.B	**Volume of HCl used**		
Moles of calcium consumed			
Moles of HCl used			
Ratio of moles of HCl to moles of calcium			

<u>Calculations</u> Show your calculations below and record your answers in the table above.

A) Using the molar mass for calcium, find the number of moles of calcium used in each trial and record in the table above.

B) Calculate the moles of HCl that were used to complete the titration.

C) Calculate the ratio of moles of HCl used to moles of calcium consumed $\frac{\text{Moles of HCl used}}{\text{Moles of calcium consumed}}$

D) Round your ratio in part C to the nearest integer.

E) Knowing that one mole of HCl reacts with one mole of OH^- during the titration find the ratio of hydroxide to calcium. Use this value to write your measured chemical formula for calcium hydroxide.