OBJECTIVES

- To understand the solubility of slightly soluble salts.
- To calculate $K_{sp}$ values from experimental data.
- To prepare a saturated solution of a slightly soluble salt.
- To use a primary standard to determine the concentration of an acid.

IN THE LAB

- Students will work in pairs.

WASTE

- Neutral solutions may be washed down the drain with excess water.
EXPERIMENT 17:
SOLUBILITY OF CALCIUM HYDROXIDE

SAFETY

• HCl solutions should be handled with care.
• Ca(OH)₂ (as solid and in a solution) should be handled with care.

All of the reference data in textbooks comes from somewhere. At some point, someone had to do the experiments needed to determine what the values were for every solubility product constant listed in your textbook and other references. In this experiment, we will determine the $K_{sp}$ of calcium hydroxide by finding the hydroxide concentration in a saturated solution of Ca(OH)$_2$. A saturated solution is one in which the maximum amount of solute has been dissolved. Remember that solubility is dependent on temperature, so the amount of solute dissolved in a saturated solution will vary with the temperature. There are three parts to this experiment that you need to consider when writing your procedure.

Part I—Saturated Solution
Each pair of students will prepare a saturated Ca(OH)$_2$ solution. When preparing a saturated solution, you should add more solute than you think will dissolve so that the maximum amount is dissolved. Saturated solutions take time to prepare, so you’ll need to make the solution during the first lab session so that it will be ready for use in the second lab session. Some things to think about:

- Is it necessary to know the exact mass of solute added?
- What volume of the saturated solution will you need?
- How many grams of Ca(OH)$_2$ will be needed? Add no more than 4 g/L of water.

Before we actually use the saturated solution, it will have to be filtered to remove the excess solute. When titrating with HCl, hydroxide will be removed from the solution. According to Le Châtelier’s principle, if we remove OH$^-$ from an unfiltered solution, more of the Ca(OH)$_2$ will dissolve in order to restore equilibrium. Some things to think about:

- What would happen to the $K_{sp}$ value if we used the unfiltered solution?
- How does filtering the solution before titrating prevent problems?

Part II—Standardization of HCl
Just as we did in Experiment 7 with the NaOH solution, we will need to standardize the concentration of HCl. By accurately determining the concentration of HCl using a primary standard, we will get much better results for the $K_{sp}$ value. Sodium carbonate will be used to standardize the HCl solution so that we can accurately determine the amount of hydroxide present in the saturated solution.

$$\text{Na}_2\text{CO}_3 + 2 \text{HCl} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 2 \text{NaCl}$$

Some things to think about:

- How many trials should you do for the standardization?
- What volume of HCl will be needed to complete all of the trials?
- Why is it important that the sodium carbonate be dry before using it to standardize HCl?
- How many equivalence points do you expect to see in the titration curve?

Part III—Determination of [OH$^-$]
Once we have prepared the saturated Ca(OH)$_2$ and found the exact concentration of the HCl, we can then determine the concentration of hydroxide present in the solution. This will allow us to determine the value of $K_{sp}$ for Ca(OH)$_2$.

$$2 \text{HCl} + \text{Ca(OH)}_2 \rightarrow \text{CaCl}_2 + 2 \text{H}_2\text{O}$$
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Some things to think about:

- How can we find the concentration of OH\(^-\)?
- How can we find the concentration of Ca\(^{2+}\)?
- What is the \(K_{sp}\) expression for Ca(OH)\(_2\)?
- How many equivalence points do you expect to see in the titration curve?

Tips for Procedure

- Write the procedure before you come to lab.
- Use 0.2–0.3 g of Na\(_2\)CO\(_3\) for each trial in the standardization. Record the exact mass used. Na\(_2\)CO\(_3\) is located in the desiccators near the balance. Ask your TA for assistance.
- Determine the amount of HCl needed so that you have enough for the entire experiment.
- Do at least three titrations for the standardization of HCl. This should be completed on Day 1. **File names 001, 002, 003.**
- Use ~25 mL of Ca(OH)\(_2\) solution for each trial.
- Do at least three titrations of the Ca(OH)\(_2\) solution to determine the hydroxide concentration. **File names 004, 005, 006.**
- Record the exact volumes and masses used for all reagents.
- Read the data analysis questions to make sure you have all the information needed to answer the questions.

Materials

Na\(_2\)CO\(_3\)
HCl solution
Ca(OH)\(_2\)
storage bottles (2)
pH sensor
drop counter
MeasureNet
other glassware, as needed

Procedure

You must write your procedure and prepare your lab notebook to record data before coming to lab to do the experiment. Make sure that you will collect the data necessary to complete the data analysis questions. It’s better to have too much information and not need it, than to need something and not have it.

Data Analysis

1. Write the equilibrium reaction for the dissolution of Ca(OH)\(_2\).
2. What is the equilibrium expression for the dissolution of Ca(OH)\(_2\)?
3. Calculate the average HCl concentration.
4. Calculate the average OH\(^-\) concentration.
5. Using the average OH\(^-\) concentration, calculate the Ca\(^{2+}\) concentration.
6. Calculate the \(K_{sp}\) for calcium hydroxide.
7. Using a print or online resource, find the accepted value for the \(K_{sp}\) of Ca(OH)\(_2\). Look for a value that was measured at a temperature as close to that of the room when you completed the experiment. Determine the percent error in your \(K_{sp}\) value at room temperature. In your discussion section, explain how any differences in temperature would affect the percent error.
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