Lab 8: KSP with Common Ion

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DATA COLLECTION:
(Copy the template below into the Data Collection section in LabArchives and complete it there. Your data collection in this section may be shared with your lab partners.)

Part 1: Ksp and Molar Solubility of Ca(OH)$_2$

Temperature of solution (° C)	23.5
Buret reading, final (mL)	20.7mL
Buret reading, initial (mL)	0.0mL
Volume HCl used (mL)	20.7mL
Concentration of standard HCl solution (M)	0.1049M

Part 2: Solubility of Ca(OH)$_2$ in presence of Ca^{+2}

Temperature of solution (° C)	23.0
Buret reading, final (mL)	17.5mL
Buret reading, initial (mL)	0.0mL
Volume HCl used (mL)	17.5mL
Concentration of standard HCl solution (M)	0.1049M

CALCULATIONS AND ANALYSIS:

Part 1: Ksp and Molar Solubility of Ca(OH)$_2$

Use the data you collected in the lab to calculate the following values.

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Mole HCl added	$2.17 \cdot 10^{-3} mol$
Mole OH$^-$ in saturated Ca(OH)$_2$ solution	$2.17 \cdot 10^{-3} mol$
Volume of saturated Ca(OH)$_2$ solution pipetted (L)	50.00mL
[OH^{-1}] at equilibrium (mol/L)	0.0434M
[Ca^{2+}] at equilibrium (mol/L)	0.0217M
Molar solubility of Ca(OH)$_2$	0.0217M
K$_{sp}$ of Ca(OH)$_2$	$4.09 \cdot 10^{-5}$

Show your calculations:

To find the number moles of HCl, we rearrange M = n/V and solve for n, resulting in

$n = MV = 0.1049M \cdot (20.7 \cdot 10^{-3})L = 2.17 \cdot 10^{-3} mol$. Since the indicator changes color at the point when all of the OH- in the solution has been neutralized, we may claim that the moles of OH- in the solution is equal to the moles of H+

provided by HCl. Since HCl is a strong acid, moles H+ should be equal to the moles of HCl added.

To find the concentration of [OH-], we use $M = n/V = (2.17 \cdot 10^{-3mol})/(50.00 \cdot 10^{-3}L) = 0.0434M$. To solve for [Ca2+] and the molar solubility of Ca(OH)2, we set up a RICE table as follows. Given the reaction
$Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$,
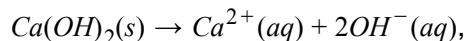
	Ca(OH)2	Ca2+	OH-
Initial	--	0	0
Change	-x	+x	+2x
Equilibrium	--	0.0217	0.0434

Observe that since 0+2x = 0.0434M, we solve for the unknown and find x = 0.0217M, giving us the concentration of Ca2+. To calculate the molar solubility, we seek to find the moles per liter of Ca(OH)2 dissolved, which is equal to x = 0.0217M.

Recall that we define $K_{sp} = [Ca^{2+}][OH^-]^2 = (0.0434M)^2(0.0217M) = 4.09 \cdot 10^{-5}$

Part 2: Solubility of Ca(OH)₂ in presence of Ca⁺²
Use the data you collected in the lab to calculate the following values.

Mole HCl added	$1.83 \cdot 10^{-3}mol$
Mole OH⁻ in saturated Ca(OH)₂ solution	$1.83 \cdot 10^{-3}mol$
Volume of saturated Ca(OH)₂ solution pipetted (L)	50.00mL
[OH⁻] at equilibrium (mol/L)	0.0366M
Molar solubility of Ca(OH)₂	0.0183M.

Show your calculations:

We approach these calculations using a process similar to that used in Part 1. To find the moles of HCl added, we use $n = MV = 0.1049M \cdot (17.5 \cdot 10^{-3}L) = 1.83 \cdot 10^{-3}mol$. Since the solution has been neutralized by the HCl titrated, we set the moles of OH- equal to the H+ ions from the dissociated HCl, equivalent to the number of moles HCl added. To find [OH-] at equilibrium, we use $M = n/V = (1.83 \cdot 10^{-3}mol)/(50.00 \cdot 10^{-3}L) = 0.0366M$. We observe from the reaction $Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$ that for every mole OH- dissolved in a solution, 0.5mole Ca(OH)2 was added. Using this ratio, we find the molar solubility of Ca(OH)2 to be 0.0366 * 0.5 = 0.0183M.

Post-Lab Questions:
1. How does the addition of CaCl$_2$ affect the molar solubility of Ca(OH)$_2$? Why?

The initial molar solubility of Ca(OH)2 was 0.0217M, while the molar solubility of Ca(OH)2 with CaCl2 was 0.0183M, a value lower than the initial quantity. We may write the dissolving of Ca(OH)2 as an equilibrium formula, where $Ca(OH)_2(s) \rightarrow Ca^{+2}(aq) + 2OH^-(aq)$. The addition of CaCl2 adds more of the products (Ca2+) to the solution. As Le Chatelier's Principle states, when stress is added on one side of the system, the reaction will shift towards the other side to balance this, resulting in more of the solid Ca(OH)2 to precipitate (and less of the dissolved ions to be present). This reduction in the amount of ions that may be dissolved from the initial solid Ca(OH)2 will decrease the molar solubility, which was observed in our experimental results.

2. If some solid Ca(OH)$_2$ is transferred into the titration flask in Part 1, will the calculated K$_{sp}$ value for Ca(OH)$_2$ be higher or lower than the accepted value? Explain.

When calculating the Ksp, we have assumed that the solution we used in the titration was saturated. That is, before any HCl is added into the solution, a negligible amount of the solid Ca(OH)2 will dissolve, since the solvent has dissolved the maximum amount of the solute it can hold. However, as HCl is added, pulling the Ca2+ out of the water, more of the Ca(OH)2 will be able to dissolve since Ca(OH)2 (s) --> Ca2+ (aq) + 2OH- (aq), as per Le Chatelier's principle. This implies that the total amount of HCl titrated into the solution will be more than intended, resulting in a Ksp higher than the accepted value.

3. If the endpoint of the titration is overrun in Part 1, will the calculated K$_{sp}$ value for Ca(OH)$_2$ be higher or lower than the accepted value? Explain.

If we overruns the endpoint of the titration, than the calculated mole OH- in the saturated solution will be higher than what was expected (since we assume mole HCl added is equal to the amount of OH- neutralized). Recall that the calculated [Ca2+] value is dependent on this [OH-] concentration, both of which determine the Ksp value in turn, where Ksp = [Ca2+][OH-]^2. Since there is a positive correlation between these concentrations, is follows that the calculated Ksp value will be higher than what was anticipated.

4. If the original Ca(OH)$_2$ solution is not saturated in Part 1, will the calculated K$_{sp}$ value for Ca(OH)$_2$ be higher or lower than the accepted value? Explain.

If the original Ca(OH)2 was not saturated, the Ksp value will be lower than the accepted value. Since it is assumed that the current concentration of the Ca(OH)2 dissolved in the water is the maximum concentration, it follows that this (lower) concentration is incorrectly assumed to be the maximum amount of Ca(OH)2 the solvent can dissolve, decreasing the Ksp value.

CONCLUSIONS:
Error Analysis: List two potential specific sources of experimental error that you could minimize if attempting the experiment again. Think through the steps of the procedure you performed; for each possible source of error, identify (1) how a step might have been performed poorly and (2) how error might have affected your it might have affected your final results, specifying how it would have affected a final conclusion if possible. (e.g. "We spilled a small quantity of liquid on the balance scale. This would have resulted calculations using in a smaller mass than there actually was and therefore an incorrectly low density.")

(1) During the titration process, we were uncertain of around when the amount of HCl added would alter the color of the indicator. Since we had started the lab late (we split from a funny 4-person group into two 2-person groups), we rushed the process slightly. Consequently, as we added the HCl, we only barely caught the color change in time in our rush. However, had we paused the adding of the HCl earlier to allow the solution to be mixed, I suspect we would not have needed as many milliliters of HCl, suggesting that our Ksp value may be higher than needed.

(2) We had rinsed the flask prior to use with distilled water. There was a small amount of this water left in the flask when we added the Na(OH)2, while would have further diluted the solution. This may result in an inaccurate estimate of the concentration of our solutes, which would overestimate Ksp.

Conclusion: Use 3 sentences or fewer to report your overall conclusions, answering the question: **What is the K_{sp} for $Ca(OH)_2$)?** Point to specific reasons for your conclusion, including evidence obtained in lab, and outline the reasons why this evidence supports your conclusion. Be sure to acknowledge if there is any uncertainty or ambiguity in your conclusion.

Lab 8 investigates the titration of a strong base with the strong acid, HCl, to find the molar solubility of Ca(OH)2 under two conditions: one, with only Ca(OH)2 in the solution and, two, with an added presence of Ca2+ in the solution. Based on the HCl added, we found that the Ksp of Ca(OH)2 was 4.09*10^-5, and that adding Ca2+ would reduce the solubility of the solute. However, it is worth noting that the amount of HCl added -- which determined our values in our concentration calculations -- could have been inaccurately measured, since we stopped the titration right after the indicator changed color, and there were residual substances in some of the equipment we used.