Experiment 2

Acidity of Copper(II) Sulphate(VI) Solution and Solubility Product of Copper(II) Hydroxide

Student Handout

Purposes

1. To determine the pH of $CuSO_4$ solution at various concentrations.
2. To determine the solubility product, K_{sp}, for $Cu(OH)_2$.

Background

Copper(II) sulphate(VI), $CuSO_4$, dissolves readily in water to give Cu^{2+} and SO_4^{2-} ions. On the other hand, $Cu(OH)_2$ is sparingly soluble. Therefore, Cu^{2+} ion in a $CuSO_4$ solution may precipitate out as $Cu(OH)_2$ with OH^-, which originally exists in water as a result of ionisation of water. In pure water, $[OH^-] = 1.0 \times 10^{-7}$ mol dm^{-3}. To avoid precipitation, the maximum concentration for $[Cu^{2+}]$ is equal to $K_{sp}/[OH^-]^2$ $= 1.0 \times 10^{14}$ dm^6 mol^{-2} $\times K_{sp}$. If the concentration of the $CuSO_4$ solution is higher than this value, precipitation occurs. Both values for $[Cu^{2+}]$ and $[OH^-]$ decrease until the equilibrium between Cu^{2+} and OH^- is re-established, at which $[Cu^{2+}][OH^-]^2 = K_{sp}$. The resulting $CuSO_4$ solution becomes acidic, since OH^- ion, but not H^+ ion, is consumed in precipitation. The pH values are different for different concentrations of $CuSO_4$.

In this experiment, the pH value is measured for a series of $CuSO_4$ solutions with concentrations of 0.01 to 0.2 M. As will be found out, these concentrations exceed the maximum concentration of Cu^{2+} ion to prevent precipitation of $Cu(OH)_2$. Yet, no precipitate will be observed in these solutions. It suggests that the amount of precipitate is so little for visual observation. Hence, it is reasonable to assume $[Cu^{2+}]$ $\approx [CuSO_4]_0$, where $[CuSO_4]_0$ is the concentrations for the $CuSO_4$ solutions. On the other hand, $[OH^-]$ can be determined through the pH value measured. As a result, K_{sp} can be determined as $[Cu^{2+}][OH^-]^2$.

Task

Photos of the experiment are available at http://www.chem.cuhk.edu.hk/ssc.htm.

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Prepare $CuSO_4$ solutions with concentrations of 0.2, 0.1, 0.05 and 0.01 M from the stock solution. Measure the pH for these solutions and calculate K_{sp} for each of them. Compare your results with the literature value.

Safety

Handle all chemicals with great care. Avoid direct contact of chemicals with skin. Dispose of chemical waste, broken glassware and excess materials according to your teacher's instruction.

Further information on the chemicals used in the experiment can be found in the Material Safety Data Sheet (MSDS). Consult your teacher for details.

Materials and Apparatus Available

0.2 M $CuSO_4$ solution
pH meter
Volumetric flasks
Pipettes

Questions for Further Thought

1. Verify the assumption: $[Cu^{2+}] \approx [CuSO_4]_0$. Hint: for each solution, calculate the decrease in $[OH^-]$ (for precipitation), which is equal to $[H^+] - [OH^-]$, and hence the decrease in $[Cu^{2+}]$. Then compare the latter value with $[CuSO_4]_0$.
2. The precipitation of $Cu(OH)_2$ can be treated as a hydrolysis process in which Cu^{2+} ions somehow react with water molecules. Write a chemical equation for this process.

Reference

D. A. Skoog, D. M. West and F. J. Holler, *Fundamentals of Analytical Chemistry,* 5^{th} Ed., Saunders College Publishing, New York, 1988, p. 376.

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