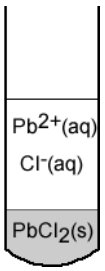
CHEM1002 Worksheet 12: The Solubility Product

Model 1: Le Châtelier's Principle and Solubility



If the concentration of a reactant is increased, the equilibrium responds by producing more products. If the concentration of a product is increased, the equilibrium responds by producing more reactant.

$$PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Cl^-(aq)$$

$PbCl_2$ is not very soluble in water. The picture shows a test tube containing a saturated solution of lead chloride in contact with a precipitate of solid.

The effect on this solubility of adding Pb^{2+}(aq) or Cl^-(aq) ions from another source is called the *common ion effect*.

Critical thinking questions

1. Write down the solubility product expression, K_{sp}, for lead chloride.

2. Sodium chloride dissolves completely to give Na^+(aq) and Cl^-(aq) ions. If sodium chloride is added to the saturated solution, what would be the effect on the solubility of lead chloride? (*Hint:* consider how the equilibrium written above would shift, according to Le Châtelier's principle, when these ions are added).

3. Sodium chloride is added so that [Cl^-(aq)] = 0.5 M. Rearrange your K_{sp} expression to give [Pb^{2+}(aq)].

4. What is the effect of adding drops of a 0.5 M solution of $Pb(NO_3)_2$ to the test tube?

5. What is the effect of adding extra $PbCl_2$(s) to the test tube?

Model 2: Solubility and pH

Metal hydroxides dissolve to give metal ions and hydroxide ions. The solubility is very sensitive to pH since this controls $[OH^-(aq)]$. For example,

$$Fe(OH)_3(s) \rightleftharpoons Fe^{3+}(aq) + 3OH^-(aq)$$

All forms of life depend on iron and the concentration of iron in the oceans and elsewhere is one of the primary factors limiting the growth rates of the most basic life forms. One reason for the low availability of iron(III) is the insolubility of $Fe(OH)_3$ which has a K_{sp} of only 1×10^{-39}.

Critical thinking questions

1. Write down the expression for the solubility product, K_{sp}, for $Fe(OH)_3$.

2. The pH of the oceans is currently 8.18. Use this to work out $[OH^-(aq)]$.

3. If x moles of $Fe(OH)_3$ dissolve in 1.00 L of water, $[Fe^{3+}(aq)] = x$ mol L^{-1}. Use your answers to Q1 and Q2 to work out x in the ocean.

4. If the amount of CO_2 in the atmospheres increases, the pH of the oceans will *decrease* due to the equilibrium below. What will happen to $[Fe^{3+}(aq)]$?

$$CO_2(g) + H_2O(l) \rightleftharpoons HCO_3^- + H_3O^+(aq)$$

5. The concentration of Fe^{3+} in our blood is about 1×10^{-6} M. Assuming a typical blood pH of 7.4, calculate the concentration of free Fe^{3+} in our blood and account for any difference with the actual concentration.