Examples of Solving Complex Ion Equilibrium

A solution has initial $[\text{Cu}^{+2}] = 0.010 \text{ M}$ and initial $[\text{NH}_3] = 1.000 \text{ M}$. The complex ion $\text{Cu(NH}_3)_4^{+2}$ forms in solution with $K_f = 5.01 \times 10^{13}$. Calculate the $[\text{Cu}^{+2}]$ when equilibrium is achieved.

$$\text{Cu}^{+2} + 4 \text{ NH}_3 \rightleftharpoons \text{Cu(NH}_3)_4^{+2} \quad \text{formation}$$

$0.010 \text{ M} \quad 1.000 \text{ M} \quad 0.0 \text{ M}$

Since the formation equilibrium constant is so large, solving the usual "ICE" table will give an equilibrium molarity of $\text{Cu}^{+2}$ equal to 0.

$$K_f = \frac{[\text{Cu(NH}_3)_4^{+2}]}{[\text{Cu}^{+2}][\text{NH}_3]^4}$$

To find the actual molarity (a very small number), one must solve this kind of problem for the reverse reaction, a dissociation. This is set up by first converting all metal ion into complex, the product of formation, and then using the reverse reaction in a "SPICE" table.

Start with Product Initially

$$\text{Cu(NH}_3)_4^{+2} \rightleftharpoons \text{Cu}^{+2} + 4 \text{ NH}_3 \quad \text{dissociation}$$

<table>
<thead>
<tr>
<th>SPI</th>
<th>0.010 M</th>
<th>0.0 M</th>
<th>0.960 M = 1.000 - 4(0.010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-x</td>
<td>+x</td>
<td>+4x</td>
</tr>
<tr>
<td>E</td>
<td>0.010 M</td>
<td>x</td>
<td>0.960 M</td>
</tr>
</tbody>
</table>

x is a very small number

Now plug into $K_d$ and solve for x

$$K_d = \frac{[\text{Cu}^{+2}][\text{NH}_3]^4}{[\text{Cu(NH}_3)_4^{+2}]}$$

A solution has initial $[\text{Fe}^{+3}] = 0.0050 \text{ M}$ and initial $[\text{C}_2\text{O}_4^{-2}] = 0.075 \text{ M}$. The complex ion $\text{Fe(C}_2\text{O}_4)_3^{-3}$ forms in solution with $K_f = 2.00 \times 10^{20}$. Calculate the $[\text{Fe}^{+3}]$ when equilibrium is achieved.

$$\text{Fe}^{+3} + 3 \text{ C}_2\text{O}_4^{-2} \rightleftharpoons \text{Fe(C}_2\text{O}_4)_3^{-3} \quad \text{formation}$$