Solubility and Complexation Chemistry

One possible treatment for oxalic acid poisoning is to give the patient an oral dose of EDTA, which we abbreviate as Y^{4-}. Because EDTA forms a strong complex with Ca^{2+} ($K_1 = 4.90\times10^{10}$) it may be capable of dissolving CaC_2O_4 crystals. As a test of the efficacy of this method, 1.00 g of CaC_2O_4 is placed in a beaker with exactly 100 mL of 0.050 M Y^{4-}. What percentage of the CaC_2O_4 dissolves and what is the equilibrium concentration of CaY^{2-}? You may assume that the pH is greater than 7.

In the presence of EDTA, the solubility reaction for CaC_2O_4 is

$$CaC_2O_4(s) + Y^{4-}(aq) \leftrightarrows CaY^{2-}(aq) + C_2O_4^{2-}(aq)$$

The equilibrium constant for this reaction, K_{eq}, is found by combining the K_{sp} reaction for CaC_2O_4 and the K_1 reaction for the formation of the calcium-EDTA complex; thus

$$CaC_2O_4(s) \leftrightarrows Ca^{2+}(aq) + C_2O_4^{2-}(aq)$$

$$Ca^{2+}(aq) + Y^{4-}(aq) \leftrightarrows CaY^{2-}(aq)$$

$$K_{eq} = K_{sp} \times K_1 = (1.38\times10^{-8}) \times (4.90\times10^{10}) = 637$$

Now we can solve for the molar solubility using an ICE table to organize information. Because the equilibrium constant is larger than 1, we first let the reaction proceed to completion and then let it relax back to equilibrium; thus

	$CaC_2O_4(s)$	+	$Y^{4-}(aq)$	$\leftrightarrows$	$CaY^{2-}(aq)$	+	$C_2O_4^{2-}(aq)$
I	-		0.05		0		0
C	-		–0.05		+0.05		+0.05
I	-		0		0.05		0.05
C	-		$+X$		X		X
E	-		X		$0.05 - X$		$0.05 - X$

Substituting into the K_{eq} expression gives

$$K_{eq} = \frac{[CaY^{2-}][C_2O_4^{2-}]}{[Y^{4-}]} = \frac{(0.05 - X)(0.05 - X)}{X} = 637$$

To simplify the problem, let's assume that $0.05 - X \approx 0.05$

$$\frac{(0.05)(0.05)}{X} = 637$$

$$X = 3.92\times10^{-6}$$

Clearly the assumption is okay (the error is less than 0.01%). The molar solubility of CaC_2O_4 is equal to the concentration of dissolved calcium, which in this case is the concentration of CaY^{2-}; thus, the molar solubility is $0.05 - X$, or 0.05 M. Given a total solution volume of 100 mL, this represents 0.005 mol or 0.64 g. This is 64% of the initial 1.00 g of CaC_2O_4.