In the presence of excess hydroxide ion, Mg^{2+} can be precipitated as $Mg(OH)_2(s)$. What amount (in mol) of solid sodium hydroxide must be added to a 0.10 M solution of $Mg(NO_3)_2$ to just cause precipitation of $Mg(OH)_2(s)$. The solubility product constant of $Mg(OH)_2$ is 7.1×10^{-12} M^3.

The solubility equilibrium and product for $Mg(OH)_2(s)$ are:

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq) \qquad K_{sp} = [Mg^{2+}(aq)][OH^-(aq)]^2$$

With $[Mg^{2+}(aq)] = 0.10$ M, precipitation will occur when:

$$[OH^-(aq)]^2 \geq \frac{K_{sp}}{[Mg^{2+}(aq)]} = \frac{(7.1\times10^{-12})}{(0.10)} \text{ so } [OH^-(aq)] \geq 8.4 \times 10^{-6} \text{ M}$$

(As the volume of the solution is not specified, the number of moles of NaOH(s) cannot be given. A 1 L solution would require 8.4×10^{-6} mol.)

ANSWER: **8.4×10^{-6} M**

In a separate experiment, the $Mg(OH)_2$ is precipitated by adding 0.10 mol of $Mg(NO_3)_2$ to 1.0 L of a 0.10 M NH_3 solution. What amount (in mol) of NH_4Cl must be added to this solution to just dissolve the precipitate? The pK_a of NH_4Cl is 9.24.

With $[Mg^{2+}(aq)] = 0.10$ M, dissolution will start to occur when:

$$[OH^-(aq)]^2 \leq \frac{K_{sp}}{[Mg^{2+}(aq)]} = \frac{(7.1\times10^{-12})}{(0.10)} \text{ so } [OH^-(aq)] \leq 8.4 \times 10^{-6} \text{ M}$$

This $[OH^-(aq)]$ corresponds to pOH = $-\log_{10}([OH^-(aq)]) = -\log_{10}(8.4 \times 10^{-6}) = 5.1$. Using pH = 14.0 – pOH, pH = (14.0 – 5.1) = 8.9.

When NH_4Cl is added, the solution contains an acid (NH_4Cl) and its conjugate base (NH_3). The solution contains an acid (NH_4Cl) and its conjugate base (NH_3). The Henderson-Hasselbalch equation can be used to work out the required $[NH_4Cl]$ with $[NH_3] = 0.10$ M and pH = 8.9:

$$\text{pH} = \text{p}K_a + \log_{10}\left(\frac{[\text{base}]}{[\text{acid}]}\right) = 9.24 + \log_{10}\left(\frac{0.10}{[NH_4Cl]}\right) = 8.9$$

$$\left(\frac{0.10}{[NH_4Cl]}\right) = 10^{(8.9-9.24)} \text{ so } [NH_4Cl] = 0.2 \text{ M}$$

This molarity is for a 1.0 L solution so that 0.2 mol of NH_4Cl are required.

ANSWER: **0.2 mol**