Answer on Question #63480 - Chemistry – General Chemistry

In the qualitative analysis scheme, magnesium and nickel precipitate from solution upon the addition of sodium hydroxide. Once separated from the remaining cations by filtration or decanting, the solid mixture is acidified and warmed to dissolve magnesium and nickel cations back into solution. Adding ammonia creates a buffer solution. (Remember, HCl and NH_3 makes for NH_4^+ cation.) The buffered solution should just be basic (say, pH = 8). Adding sodium hydrogen phosphate (Na_2HPO_4) precipitates magnesium as $MgNH_4PO_4$ ($K_{sp} = 3x10^{-13}$).
$K_{sp} = [Mg^{2+}]*[NH_3]*[HPO_4^{2-}] = 3 \times 10^{-13}$.
Molar solubility = 6.7×10^{-5} M
a) Calculate the $[NH_4^+]$ in a pH of 8.
b) Calculate the molar solubility of $MgNH_4PO_4$ in a solution with pH of 8.

Solution.
$Mg^{2+} + 2NaOH \rightarrow Mg(OH)_2\downarrow + 2Na^+$
$Mg(OH)_2 + 2H^+ \rightarrow Mg^{2+} + 2H_2O$

$Mg^{2+} + HPO_4^{2-} + NH_3 \rightarrow MgNH_4PO_4\downarrow$

a) pH = 8
$NH_3 + HCl = NH_4Cl$
V (solution) = 1 L; $n_0(NH_3)$ = 1 mol; $C_0(NH_3)$ = 1 mol/L
$C(NH_4^+)$ = x mol/L; $C(NH_3)$ = (1–x) mol/L

$$pH = pK_{a,NH_4^+} - \lg\frac{C_{NH_4^+}}{C_{NH_3}}$$

$K_{b,\,NH3} = 1.76\cdot10^{-5}$; $pK_{b,\,NH3} = -\lg K_{b,\,NH3} = -\lg(1.76\cdot10^{-5}) = 4.75$;
$pK_{a,NH4+} = pK_w - pK_{b,\,NH3} = 14 - 4.75 = 9.25$

$$pH = 9.25 - \lg\frac{x}{1-x} = 8$$

x = (1–x) × 17.78
x = 17.78 −17.78x
18.78x = 17.78
x = 0.95 mol/L
$[NH_4^+]$ = 0.95 mol/L

b) $K_{sp} = [Mg^{2+}]*[NH_4^+]*[PO_4^{3-}] = 3 \times 10^{-13}$
$K_{sp} = S \times 0.95 \times S = 3 \times 10^{-13}$

$$S = \sqrt{\frac{K_{sp}}{0.95}} = \sqrt{\frac{3\times10^{-13}}{0.95}} = 5.6\times10^{-7}\,M$$

Answer: a) $[NH_4^+]$ = 0.95 mol/L
b) $S = 5.6\times10^{-7}$ M