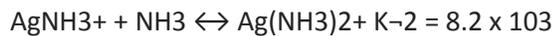


Answer on Question #56945 - Chemistry - General Chemistry

Question:

A solution is made by mixing 500.0 mL of 4.0 M NH₃ and 500.0 mL of 0.50 M AgNO₃. Ag⁺ reacts with NH₃ to form AgNH₃⁺ and Ag(NH₃)₂⁺ according to the equilibrium reactions:



Assuming no change in volume on mixing calculate the concentrations of all species in solution: [Ag⁺], [NO₃⁻], [NH₃], [AgNH₃⁺] and [Ag(NH₃)₂⁺].

Answer:

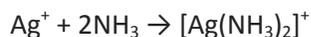
After mixing the initial concentrations of AgNO₃ and NH₃ are of 0.5 and 4 mol/L. Since AgNO₃ dissociates completely, the concentration of NO₃⁻ is 0.5 mol/L too.

The equilibrium constants are connected with concentrations of the components as follows:

$$K_1 = \frac{[\text{AgNH}_3^+]}{[\text{Ag}^+][\text{NH}_3]}$$

$$K_2 = \frac{[\text{Ag}(\text{NH}_3)_2^+]}{[\text{AgNH}_3^+][\text{NH}_3]}$$

The common equilibrium constant for the formation of [Ag(NH₃)₂]⁺:



$$K = K_1 K_2 = \frac{[\text{Ag}(\text{NH}_3)_2^+]}{[\text{Ag}^+][\text{NH}_3]^2} = 1.722 \times 10^7$$

Assuming that [Ag(NH₃)₂⁺] = z, we get [Ag⁺] = 0.5 - z and [NH₃] = 4 - 2z.

Substituting the parameters into the equilibrium constant expression, it is obtained:

$$K = \frac{z}{[(0.5-z)(4-2z)^2]} = 1.722 \times 10^7$$

$$z = 4K(0.5-z)(2-z)^2$$

$$z = 4K(0.5-z)(4 - 4z + z^2)$$

$$z = 4K(2 - 2z + 0.5z^2 - 4z + 4z^2 - z^3)$$

$$z = 8K - 24Kz + 18Kz^2 - 4Kz^3$$

$$2Kz^3 - 9Kz^2 + (12K+0.5)z - 4K = 0$$

$$3.444z^3 - 15.498z^2 + 20.664z - 6.888 = 0$$

The solution of the cubic equation gives:

$$z_1 = 0.4999999999999998$$

$$\text{Thus, } [\text{Ag}(\text{NH}_3)_2^+] = z = 0.4999999999999998 \text{ mol/L}$$

then

$$[\text{Ag}^+] = 0.5 - 0.4999999999999998 = 2 \times 10^{-16} \text{ mol/L}$$

and

$$[\text{NH}_3] = 4 - 2z \approx 3 \text{ mol/L}$$

Using the expression for K_1 the concentration of AgNH_3^+ is found:

$$[\text{AgNH}_3^+] = K_1 [\text{Ag}^+] [\text{NH}_3] = 2.1 \times 10^3 \times 2 \times 10^{-16} \times 3 = 1.26 \times 10^{-12} \text{ mol/L}$$

Finally, the concentrations of all components are:

$$[\text{NO}_3^-] = 0.5 \text{ mol/L}$$

$$[\text{Ag}^+] = 2 \times 10^{-16} \text{ mol/L}$$

$$[\text{NH}_3] \approx 3 \text{ mol/L}$$

$$[\text{AgNH}_3^+] = 1.26 \times 10^{-12} \text{ mol/L}$$

$$[\text{Ag}(\text{NH}_3)_2^+] = 0.4999999999999998 \text{ mol/L}$$