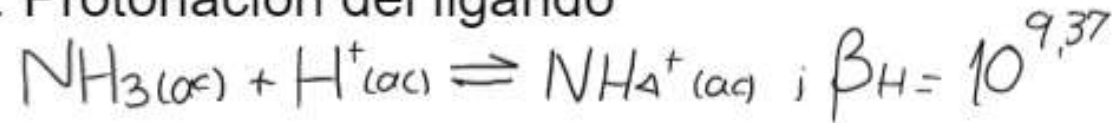
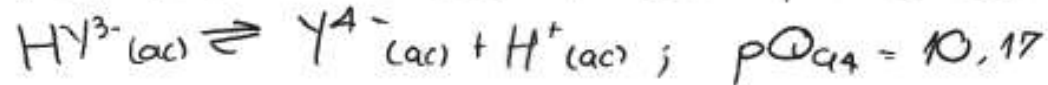
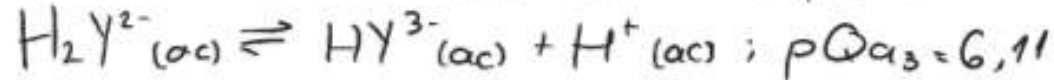
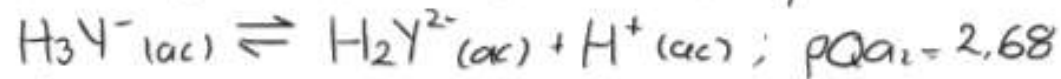
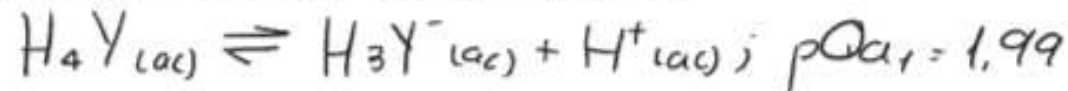


1. Equilibrios presentes

a. Protonación del ligando



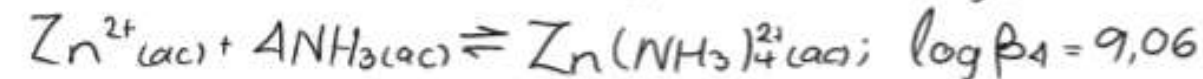
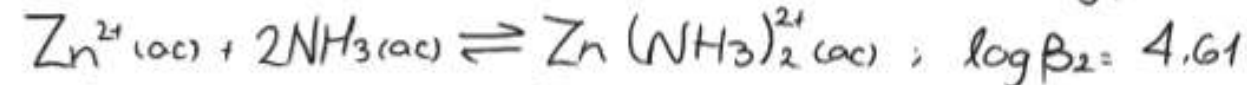
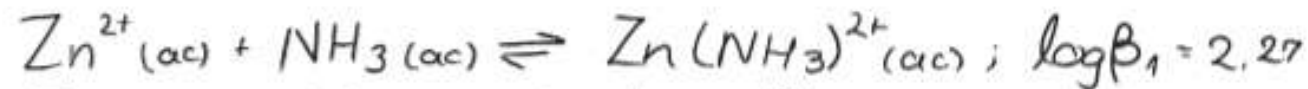
b. Desprotonación del quelón



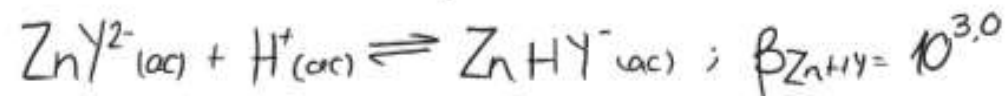
c. Formación del quelato



d. Formación de complejos ligando - metal



e. Protonación del quelato



2. Identificación de especies

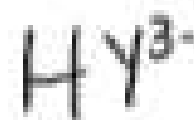
Cationes



Moléculas



Aniones



3. Planteamiento de balances

a. Para el ligando

$$C'_L = [\text{NH}_3] + [\text{NH}_4^+] = \frac{3.0 \text{ mL} \cdot 3.20 \text{ M}}{78 \text{ mL}} = 0.123 \text{ M}$$



$$\beta_H = \frac{[\text{NH}_4^+]}{[\text{NH}_3][\text{H}^+]} \therefore [\text{NH}_4^+] = \beta_H \cdot [\text{NH}_3] \cdot [\text{H}^+]$$

$$C'_L = [\text{NH}_3] + \beta_H \cdot [\text{NH}_3] \cdot [\text{H}^+]$$

$$C'_L = [\text{NH}_3](1 + \beta_H \cdot [\text{H}^+]) \therefore [\text{NH}_3] = \frac{C'_L}{(1 + \beta_H \cdot [\text{H}^+])}$$

$$[\text{NH}_3] = \frac{0.123 \text{ M}}{1 + 10^{9.37 - \text{pH}}} = 0.100 \text{ M}$$

4. Factores de formación

a. FHY

Reemplazando datos, se obtiene:

$$F_{HY} = 1 + 10^{pK_{a1} - pH} + 10^{pK_{a1} + pK_{a2} - 2pH} + 10^{pK_{a1} + pK_{a2} + pK_{a3} - 3pH} + 10^{pK_{a1} + pK_{a2} + pK_{a3} + pK_{a4} - 4pH}$$

$$F_{HY} = 2,48$$

b. FLM

Reemplazando datos, se obtiene:

$$F_{LM} = 1 + \beta_1 [NH_3] + \beta_2 [NH_3]^2 + \beta_3 [NH_3]^3 + \beta_4 [NH_3]^4 = 5,09$$

c. FMHY

Reemplazando datos, se obtiene:

$$F_{MHY} = 1 + \beta_{Z_{MHY}} * [H^+] = 1,00$$

b. Para el ión metálico

$$C_M = [Zn^{2+}] + [Zn(NH_3)^{2+}] + [Zn(NH_3)_2^{2+}] + [Zn(NH_3)_3^{2+}] + [Zn(NH_3)_4^{2+}]$$

$$\beta_1 = \frac{[Zn(NH_3)^{2+}]}{[NH_3] \cdot [Zn^{2+}]} \therefore [Zn(NH_3)^{2+}] = \beta_1 \cdot [NH_3] \cdot [Zn^{2+}]$$

$$\beta_2 = \frac{[Zn(NH_3)_2^{2+}]}{[NH_3]^2 \cdot [Zn^{2+}]} \therefore [Zn(NH_3)_2^{2+}] = \beta_2 \cdot [NH_3]^2 \cdot [Zn^{2+}]$$

$$\beta_3 = \frac{[Zn(NH_3)_3^{2+}]}{[NH_3]^3 \cdot [Zn^{2+}]} \therefore [Zn(NH_3)_3^{2+}] = \beta_3 \cdot [NH_3]^3 \cdot [Zn^{2+}]$$

$$\beta_4 = \frac{[Zn(NH_3)_4^{2+}]}{[NH_3]^4 \cdot [Zn^{2+}]} \therefore [Zn(NH_3)_4^{2+}] = \beta_4 \cdot [NH_3]^4 \cdot [Zn^{2+}]$$

$$C_M = [Zn^{2+}] + \beta_1 \cdot [NH_3][Zn^{2+}] + \beta_2 [NH_3]^2 [Zn^{2+}] + \beta_3 [NH_3]^3 [Zn^{2+}] + \beta_4 [NH_3]^4 [Zn^{2+}]$$

$$C_M = [Zn^{2+}] (1 + \beta_1 [NH_3] + \beta_2 [NH_3]^2 + \beta_3 [NH_3]^3 + \beta_4 [NH_3]^4)$$

factor ligando-metal

c. Para el quelón

$$C_Y = [Y^{4-}] + [HY^{3-}] + [H_2Y^{2-}] + [H_3Y^{-}] + [H_4Y]$$

$$Q_{a1} = \frac{[Y^{4-}] \cdot [H^+]}{[HY^{3-}]} \therefore [HY^{3-}] = \frac{[Y^{4-}][H^+]}{Q_{a1}}$$

$$Q_{a3} = \frac{[HY^{3-}][H^+]}{[H_2Y^{2-}]} \therefore [H_2Y^{2-}] = \frac{\frac{[Y^{4-}][H^+]}{Q_{a1}} \cdot [H^+]}{Q_{a3}} \therefore [H_2Y^{2-}] = \frac{[Y^{4-}] \cdot [H^+]^2}{Q_{a1} \cdot Q_{a3}}$$

$$Q_{a2} = \frac{[H_2Y^{2-}][H^+]}{[H_3Y^{-}]} \therefore [H_3Y^{-}] = \frac{\frac{[Y^{4-}] \cdot [H^+]^2}{Q_{a1} \cdot Q_{a3}} \cdot [H^+]}{Q_{a2}} \therefore [H_3Y^{-}] = \frac{[Y^{4-}][H^+]^3}{Q_{a1} \cdot Q_{a3} \cdot Q_{a2}}$$

$$Q_{a1} = \frac{[H_3Y^{-}][H^+]}{[H_4Y]} \therefore [H_4Y] = \frac{\frac{[Y^{4-}][H^+]^3}{Q_{a1} \cdot Q_{a3} \cdot Q_{a2}} \cdot [H^+]}{Q_{a1}} \therefore [H_4Y] = \frac{[Y^{4-}][H^+]^4}{Q_{a1} \cdot Q_{a3} \cdot Q_{a2} \cdot Q_{a1}}$$

$$C_Y = [Y^{4-}] + \frac{[Y^{4-}][H^+]}{Q_{a1}} + \frac{[Y^{4-}][H^+]^2}{Q_{a1} \cdot Q_{a3}} + \frac{[Y^{4-}][H^+]^3}{Q_{a1} \cdot Q_{a3} \cdot Q_{a2}} + \frac{[Y^{4-}][H^+]^4}{Q_{a1} \cdot Q_{a3} \cdot Q_{a2} \cdot Q_{a1}}$$

$$C_Y = [Y^{4-}] \left(1 + \frac{[H^+]}{Q_{a1}} + \frac{[H^+]^2}{Q_{a1} \cdot Q_{a3}} + \frac{[H^+]^3}{Q_{a1} \cdot Q_{a3} \cdot Q_{a2}} + \frac{[H^+]^4}{Q_{a1} \cdot Q_{a3} \cdot Q_{a2} \cdot Q_{a1}} \right)$$

$$C_Y = [Y^{4-}] \left(1 + \frac{10^{-pH}}{10^{-pQ_{a1}}} + \frac{10^{-2pH}}{10^{-(pQ_{a1} + pQ_{a3})}} + \frac{10^{-3pH}}{10^{-(pQ_{a1} + pQ_{a3} + pQ_{a2})}} + \frac{10^{-4pH}}{10^{-(pQ_{a1} + pQ_{a3} + pQ_{a2} + pQ_{a1})}} \right)$$

$$C_Y = [Y^{4-}] \left(1 + 10^{pQ_{a1} - pH} + 10^{pQ_{a1} + pQ_{a3} - 2pH} + 10^{pQ_{a1} + pQ_{a3} + pQ_{a2} - 3pH} + 10^{pQ_{a1} + pQ_{a3} + pQ_{a2} + pQ_{a1} - 4pH} \right)$$

factor del quelón fuy

d. Para los quelatos

$$C_{MYL} = [ZnY^{2-}] + [ZnHY^{-}]$$

$$\beta_{ZnHY} = \frac{[ZnHY^{-}]}{[ZnY^{2-}] \cdot [H^{+}]} \therefore [ZnHY^{-}] = \beta_{ZnHY} \cdot [ZnY^{2-}] \cdot [H^{+}]$$

$$C_{MYL} = [ZnY^{2-}] + \beta_{ZnHY} \cdot [ZnY^{2-}] \cdot [H^{+}]$$

$$C_{MYL} = [ZnY^{2-}] (1 + \beta_{ZnHY} \cdot [H^{+}])$$

factor de quelato
 f_{MYL}

5. Constante condicional de estabilidad

$$Q'_{MY} = \frac{Q_{MY} \cdot F_{MHY}}{F_{LM} \cdot F_{HY}} \therefore Q'_{MY} = \frac{10^{16,50} \cdot 1,00}{5,09 \cdot 2,48} = 10^{9,11} > 10^{8,0}$$

6. Cálculos dependientes del punto de equivalencia

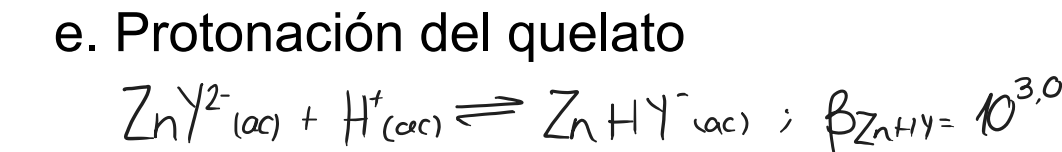
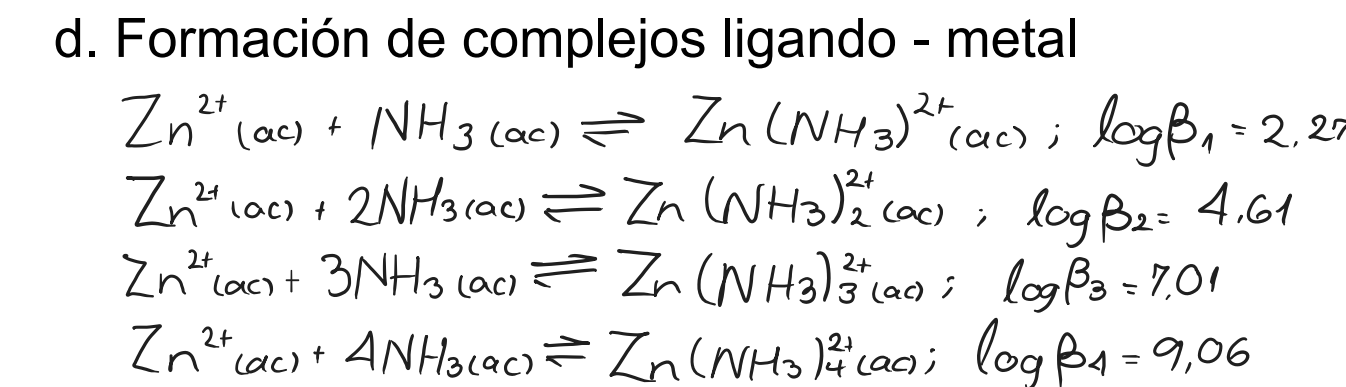
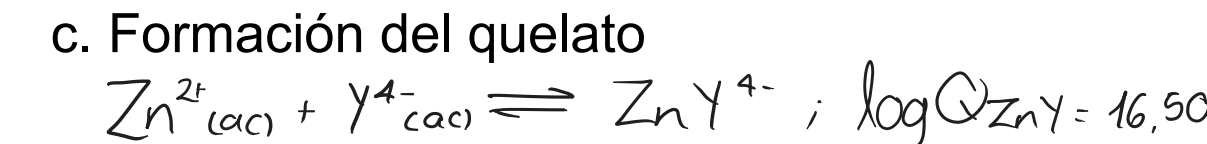
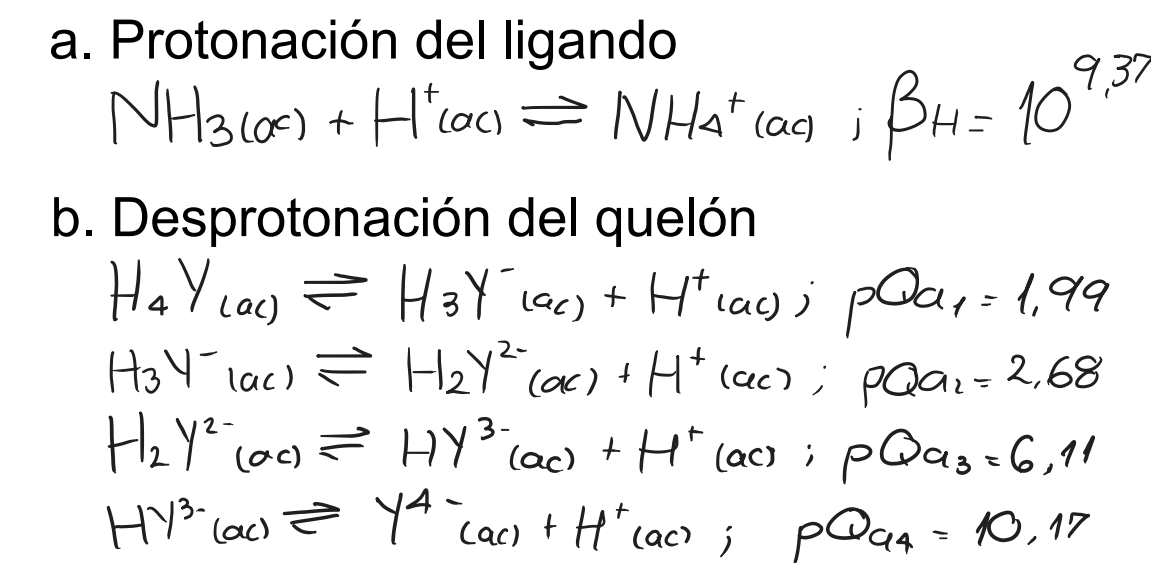
$$[]_{\text{METAL}} \cdot V_{\text{METAL}} = []_{\text{EDTA}} \cdot V_{\text{EDTA}} \therefore V_{\text{EDTA}} = \frac{[]_{\text{METAL}} \cdot V_{\text{METAL}}}{[]_{\text{EDTA}}} = 20 \text{ mL}$$

$$C_{MY} = [ZnY^{2-}] = \frac{V_{\text{METAL}} \cdot [Zn^{2+}]_i}{V_{\text{TOTAL}}} = \frac{25 \text{ mL} \cdot 0,020 \text{ mmol}}{98 \text{ mL}} = 5 \times 10^{-3} \text{ M}$$

$$[Zn^{2+}]_{p.E} = \sqrt{\frac{[ZnY^{2-}] \cdot f_{MY}}{Q_{ZnY} \cdot F_{LM} \cdot F_{MY}}} \therefore [Zn^{2+}]_{p.E} = \sqrt{\frac{5 \times 10^{-3} \text{ M} \cdot 2,48}{10^{16,5} \cdot 10^{5,09} \cdot 1,00}} = 1,78 \times 10^{-12} \text{ M}$$

$$pZn_{p.E} = \log\left(\frac{1}{[Zn^{2+}]_{p.E}}\right) = 11,7$$

1. Equilibrios presentes



2. Identificación de especies

Cationes	Moléculas	Aniones
NH_4^+	NH_3	H_3Y^-
H^+	H_4Y	H_2Y^{2-}
Zn^{2+}		HY^{3-}
$\text{Zn}(\text{NH}_3)^{2+}$		Y^{4-}
$\text{Zn}(\text{NH}_3)_2^{2+}$		ZnY^{2-}
$\text{Zn}(\text{NH}_3)_3^{2+}$		ZnHY^-
$\text{Zn}(\text{NH}_3)_4^{2+}$		

3. Planteamiento de balances

a. Para el ligando

$$C_L = [\text{NH}_3] + [\text{NH}_4] = \frac{3,0\text{ mL} \cdot 0,20\text{ M}}{78\text{ mL}} = 0,023\text{ M}$$
$$\text{NH}_3 + \text{H}^+ \rightleftharpoons \text{NH}_4^+ ; \beta_H = 10^{9,37}$$
$$\beta_H = \frac{[\text{NH}_4^+]}{[\text{NH}_3][\text{H}^+]} \therefore [\text{NH}_4^+] = \beta_H \cdot [\text{NH}_3] \cdot [\text{H}^+]$$
$$C_L = [\text{NH}_3] + \beta_H \cdot [\text{NH}_3] \cdot [\text{H}^+]$$
$$C_L = [\text{NH}_3](1 + \beta_H \cdot [\text{H}^+]) \therefore [\text{NH}_3] = \frac{C_L}{(1 + \beta_H \cdot [\text{H}^+])}$$
$$[\text{NH}_3] = \frac{0,023\text{ M}}{1 + 10^{9,37} \cdot 10^{-7,4}} = 0,000\text{ M}$$

b. Para el ión metálico

$$C_M = [\text{Zn}^{2+}] + [\text{Zn}(\text{NH}_3)^{2+}] + [\text{Zn}(\text{NH}_3)_2^{2+}] + [\text{Zn}(\text{NH}_3)_3^{2+}] + [\text{Zn}(\text{NH}_3)_4^{2+}]$$
$$\beta_1 = \frac{[\text{Zn}(\text{NH}_3)^{2+}]}{[\text{NH}_3] \cdot [\text{Zn}^{2+}]} \therefore [\text{Zn}(\text{NH}_3)^{2+}] = \beta_1 \cdot [\text{NH}_3] \cdot [\text{Zn}^{2+}]$$
$$\beta_2 = \frac{[\text{Zn}(\text{NH}_3)_2^{2+}]}{[\text{NH}_3]^2 \cdot [\text{Zn}^{2+}]} \therefore [\text{Zn}(\text{NH}_3)_2^{2+}] = \beta_2 \cdot [\text{NH}_3]^2 \cdot [\text{Zn}^{2+}]$$
$$\beta_3 = \frac{[\text{Zn}(\text{NH}_3)_3^{2+}]}{[\text{NH}_3]^3 \cdot [\text{Zn}^{2+}]} \therefore [\text{Zn}(\text{NH}_3)_3^{2+}] = \beta_3 \cdot [\text{NH}_3]^3 \cdot [\text{Zn}^{2+}]$$
$$\beta_4 = \frac{[\text{Zn}(\text{NH}_3)_4^{2+}]}{[\text{NH}_3]^4 \cdot [\text{Zn}^{2+}]} \therefore [\text{Zn}(\text{NH}_3)_4^{2+}] = \beta_4 \cdot [\text{NH}_3]^4 \cdot [\text{Zn}^{2+}]$$
$$C_{ML} = [\text{Zn}^{2+}] + \beta_1 \cdot [\text{NH}_3] \cdot [\text{Zn}^{2+}] + \beta_2 \cdot [\text{NH}_3]^2 \cdot [\text{Zn}^{2+}] + \beta_3 \cdot [\text{NH}_3]^3 \cdot [\text{Zn}^{2+}] + \beta_4 \cdot [\text{NH}_3]^4 \cdot [\text{Zn}^{2+}]$$
$$C_{ML} = [\text{Zn}^{2+}] \left(1 + \beta_1 \cdot [\text{NH}_3] + \beta_2 \cdot [\text{NH}_3]^2 + \beta_3 \cdot [\text{NH}_3]^3 + \beta_4 \cdot [\text{NH}_3]^4 \right)$$

(acción quelato-metal, β_{ML})

c. Para el quelón

$$C_Y = [\text{Y}^{4-}] + [\text{HY}^{3-}] + [\text{H}_2\text{Y}^{2-}] + [\text{H}_3\text{Y}^-] + [\text{H}_4\text{Y}]$$
$$\alpha_4 = \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]}{[\text{HY}^{3-}]} \therefore [\text{HY}^{3-}] = \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]}{\alpha_4}$$
$$\alpha_3 = \frac{[\text{HY}^{3-}] \cdot [\text{H}^+]}{[\text{H}_2\text{Y}^{2-}]} \therefore [\text{H}_2\text{Y}^{2-}] = \frac{[\text{HY}^{3-}] \cdot [\text{H}^+]}{\alpha_3} \therefore [\text{H}_2\text{Y}^{2-}] = \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]^2}{\alpha_4 \cdot \alpha_3}$$
$$\alpha_2 = \frac{[\text{H}_2\text{Y}^{2-}] \cdot [\text{H}^+]}{[\text{H}_3\text{Y}^-]} \therefore [\text{H}_3\text{Y}^-] = \frac{[\text{H}_2\text{Y}^{2-}] \cdot [\text{H}^+]}{\alpha_2} \therefore [\text{H}_3\text{Y}^-] = \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]^3}{\alpha_4 \cdot \alpha_3 \cdot \alpha_2}$$
$$\alpha_1 = \frac{[\text{H}_3\text{Y}^-] \cdot [\text{H}^+]}{[\text{H}_4\text{Y}]} \therefore [\text{H}_4\text{Y}] = \frac{[\text{H}_3\text{Y}^-] \cdot [\text{H}^+]}{\alpha_1} \therefore [\text{H}_4\text{Y}] = \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]^4}{\alpha_4 \cdot \alpha_3 \cdot \alpha_2 \cdot \alpha_1}$$
$$C_Y = [\text{Y}^{4-}] + \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]}{\alpha_4} + \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]^2}{\alpha_4 \cdot \alpha_3} + \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]^3}{\alpha_4 \cdot \alpha_3 \cdot \alpha_2} + \frac{[\text{Y}^{4-}] \cdot [\text{H}^+]^4}{\alpha_4 \cdot \alpha_3 \cdot \alpha_2 \cdot \alpha_1}$$
$$C_Y = [\text{Y}^{4-}] \left(1 + \frac{[\text{H}^+]}{\alpha_4} + \frac{[\text{H}^+]^2}{\alpha_4 \cdot \alpha_3} + \frac{[\text{H}^+]^3}{\alpha_4 \cdot \alpha_3 \cdot \alpha_2} + \frac{[\text{H}^+]^4}{\alpha_4 \cdot \alpha_3 \cdot \alpha_2 \cdot \alpha_1} \right)$$
$$C_Y = [\text{Y}^{4-}] \left(1 + \frac{10^{-7,4}}{10^{-10,4}} + \frac{10^{-7,4} \cdot 10^{-7,4}}{10^{-10,4} \cdot 10^{-6,1}} + \frac{10^{-7,4} \cdot 10^{-7,4} \cdot 10^{-6,1}}{10^{-10,4} \cdot 10^{-6,1} \cdot 10^{-2,68}} + \frac{10^{-7,4} \cdot 10^{-7,4} \cdot 10^{-6,1} \cdot 10^{-2,68}}{10^{-10,4} \cdot 10^{-6,1} \cdot 10^{-2,68} \cdot 10^{-1,99}} \right)$$

(acción del quelón β_{MY})

d. Para los quelatos

$$C_{MYL} = [\text{ZnY}^{2-}] + [\text{ZnHY}^-]$$
$$\beta_{\text{ZnHY}} = \frac{[\text{ZnHY}^-]}{[\text{ZnY}^{2-}] \cdot [\text{H}^+]} \therefore [\text{ZnHY}^-] = \beta_{\text{ZnHY}} \cdot [\text{ZnY}^{2-}] \cdot [\text{H}^+]$$
$$C_{MYL} = [\text{ZnY}^{2-}] + \beta_{\text{ZnHY}} \cdot [\text{ZnY}^{2-}] \cdot [\text{H}^+]$$
$$C_{MYL} = [\text{ZnY}^{2-}] \left(1 + \beta_{\text{ZnHY}} \cdot [\text{H}^+] \right)$$

(acción de quelato β_{MYL})

4. Factores de formación

a. FHY

Reemplazando datos, se obtiene:

$$F_{HY} = 1 + 10^{10,4-10} + 10^{10,4+10,4-1,99} + 10^{10,4+10,4+10,4-2,68} + 10^{10,4+10,4+10,4+10,4-3,67} + 10^{10,4+10,4+10,4+10,4-6,11}$$
$$F_{HY} = 2,48$$

b. FLM

Reemplazando datos, se obtiene:

$$F_{LM} = 1 + \beta_1 \cdot [\text{NH}_3] + \beta_2 \cdot [\text{NH}_3]^2 + \beta_3 \cdot [\text{NH}_3]^3 + \beta_4 \cdot [\text{NH}_3]^4 = 5,09$$

c. FMHY

Reemplazando datos, se obtiene:

$$F_{MHY} = 1 + \beta_{\text{ZnHY}} \cdot [\text{H}^+] = 1,00$$

5. Constante condicional de estabilidad

$$Q_{MY} = \frac{Q_{MY} \cdot F_{MHY}}{F_{LM} \cdot F_{HY}} \therefore Q_{MY} = \frac{10^{16,50} \cdot 1,00}{5,09 \cdot 2,48} = 10^{9,11} > 10^{8,0}$$

6. Cálculos dependientes del punto de equivalencia

$$[\text{Zn}^{2+}]_{\text{MSEAL}} \cdot V_{\text{MSEAL}} = [\text{Zn}^{2+}]_{\text{EDTA}} \cdot V_{\text{EDTA}} \therefore V_{\text{EDTA}} = \frac{[\text{Zn}^{2+}]_{\text{MSEAL}} \cdot V_{\text{MSEAL}}}{[\text{Zn}^{2+}]_{\text{EDTA}}} = 2,0\text{ mL}$$
$$C_{MY} = [\text{ZnY}^{2-}] = \frac{V_{\text{MSEAL}} \cdot [\text{Zn}^{2+}]_i}{V_{\text{total}}} = \frac{25\text{ mL} \cdot 0,020\text{ mmol/L}}{45\text{ mL}} = 5 \times 10^{-3}\text{ M}$$
$$[\text{Zn}^{2+}]_{\text{FE}} = \sqrt{\frac{[\text{ZnY}^{2-}] \cdot F_{MY}}{Q_{ZnY} \cdot F_{LM} \cdot F_{MHY}}} \therefore [\text{Zn}^{2+}]_{\text{FE}} = \sqrt{\frac{5 \cdot 10^{-3} \cdot 10^{-9,11}}{10^{8,0} \cdot 10^{5,09} \cdot 1,00}} = 1,78 \times 10^{-6}\text{ M}$$
$$pZ_{\text{FE}} = \log \left(\frac{1}{[\text{Zn}^{2+}]_{\text{FE}}} \right) = 11,7$$