Amfolyt + svag enprotonig syra

$$NaHCO_3 \xrightarrow{H_2O} Na^+ + {HCO_3}^-$$

$$[NaHCO_3] = [Na^+] = [{HCO_3}^-]_1$$

$$HCO_3^- + H_2O \rightleftarrows H_2CO_3 + OH^-$$

$$HCO_3^- + H_2O \rightleftarrows {CO_3}^{2-} + H_3O^+$$

$$K_{b_1} = \frac{[H_2CO_3][OH^-]}{[{HCO_3}^-]_2} \Leftrightarrow [H_2CO_3] = \frac{K_{b_1}[{HCO_3}^-]_2}{[OH^-]}$$

$$K_{a_2} = \frac{[{CO_3}^{2-}][H_3O^+]}{[{HCO_3}^-]_2} \Leftrightarrow [{CO_3}^{2-}] = \frac{K_{a_2}[{HCO_3}^-]_2}{[H_3O^+]}$$

$$K_w = [OH^-][H_3O^+] \Leftrightarrow [OH^-] = \frac{K_w}{[H_3O^+]}$$

$$K_w = K_a K_b \Rightarrow K_{b_1} = \frac{K_w}{K_{a_1}}$$

$$[{HCO_3}^-]_1 = [{HCO_3}^-]_2 + [H_2CO_3] + [{CO_3}^{2-}]$$

$$[{HCO_3}^-]_1 = [{HCO_3}^-]_2 + \frac{K_{b_1}[{HCO_3}^-]_2}{[OH^-]} + \frac{K_{a_2}[{HCO_3}^-]_2}{[H_3O^+]} = [{HCO_3}^-]_2\left(1 + \frac{K_{b_1}}{[OH^-]} + \frac{K_{a_2}}{[H_3O^+]}\right) = [{HCO_3}^-]_2\left(1 + \frac{\frac{K_w}{K_{a_1}}}{\frac{K_w}{[H_3O^+]}} + \frac{K_{a_2}}{[H_3O^+]}\right)$$

$$[{HCO_3}^-]_1 = [{HCO_3}^-]_2\left(1 + \frac{K_w[H_3O^+]}{K_{a_1}K_w} + \frac{K_{a_2}}{[H_3O^+]}\right) = [{HCO_3}^-]_2\left(1 + \frac{[H_3O^+]}{K_{a_1}} + \frac{K_{a_2}}{[H_3O^+]}\right) = [{HCO_3}^-]_2\left(\frac{K_{a_1}[H_3O^+] + [H_3O^+]^2 + K_{a_2}K_{a_1}}{K_{a_1}[H_3O^+]}\right)$$

$$\Leftrightarrow [HCO_3^-]_2 = \frac{[HCO_3^-]_1}{\left(\frac{K_{a_1}[H_3O^+] + [H_3O^+]^2 + K_{a_2}K_{a_1}}{K_{a_1}[H_3O^+]}\right)} = \frac{[HCO_3^-]_1 K_{a_1}[H_3O^+]}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}}$$

$$HA + H_2O \rightleftarrows A^- + H_3O^+$$

$$K_a = \frac{[A^-][H_3O^+]}{[HA]_2} \Leftrightarrow [A^-] = \frac{K_a[HA]_2}{[H_3O^+]}$$

$$[HA]_1 = [HA]_2 + [A^-] = [HA]_2 + \frac{K_a[HA]_2}{[H_3O^+]} = [HA]_2\left(1 + \frac{K_a}{[H_3O^+]}\right) = [HA]_2\left(\frac{[H_3O^+] + K_a}{[H_3O^+]}\right) \Leftrightarrow$$

$$[HA]_2 = \frac{[HA]_1}{\left(\frac{[H_3O^+] + K_a}{[H_3O^+]}\right)} = \frac{[HA]_1[H_3O^+]}{[H_3O^+] + K_a}$$

$$[Na^+] + [H_3O^+] = [OH^-] + [A^-] + [HCO_3^-]_2 + 2\left[{CO_3}^{2-}\right]$$

$$[Na^+] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a[HA]_2}{[H_3O^+]} + \frac{[HCO_3^-]_1 K_{a_1}[H_3O^+]}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}} + 2\frac{K_{a_2}[HCO_3^-]_2}{[H_3O^+]}$$

$$[Na^+] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a\frac{[HA]_1[H_3O^+]}{[H_3O^+] + K_a}}{[H_3O^+]} + \frac{[HCO_3^-]_1 K_{a_1}[H_3O^+]}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}} + \frac{2K_{a_2}\frac{[HCO_3^-]_1 K_{a_1}[H_3O^+]}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}}}{[H_3O^+]}$$

$$[Na^+] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a[HA]_1}{[H_3O^+] + K_a} + \frac{[HCO_3^-]_1 K_{a_1}[H_3O^+]}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}} + \frac{2K_{a_2}[HCO_3^-]_1 K_{a_1}}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}}$$

$$[Na^+] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a[HA]_1}{[H_3O^+] + K_a} + \frac{[HCO_3^-]_1 K_{a_1}[H_3O^+] + 2K_{a_2}[HCO_3^-]_1 K_{a_1}}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}}$$

$$[Na^+][H_3O^+] + [H_3O^+]^2 = K_w + \frac{K_a[HA]_1[H_3O^+]}{[H_3O^+] + K_a} + \frac{[HCO_3^-]_1 K_{a_1}[H_3O^+]^2 + 2K_{a_2}[HCO_3^-]_1 K_{a_1}[H_3O^+]}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}}$$

$$\begin{aligned}[Na^+][H_3O^+]^2 + [H_3O^+]^3 + K_a[Na^+][H_3O^+] + K_a[H_3O^+]^2 \\ = K_w[H_3O^+] + K_wK_a + K_a[HA]_1[H_3O^+] \\ + \frac{[HCO_3^-]_1 K_{a_1}[H_3O^+]^3 + 2K_{a_2}[HCO_3^-]_1 K_{a_1}[H_3O^+]^2 + [HCO_3^-]_1 K_{a_1}[H_3O^+]^2 K_a + 2K_{a_2}[HCO_3^-]_1 K_{a_1}[H_3O^+]K_a}{[H_3O^+]^2 + K_{a_1}[H_3O^+] + K_{a_2}K_{a_1}}\end{aligned}$$

$$\begin{aligned}&[Na^+][H_3O^+]^4 + [H_3O^+]^5 + K_a[Na^+][H_3O^+]^3 + K_a[H_3O^+]^4 + K_{a_1}[Na^+][H_3O^+]^3 + K_{a_1}[H_3O^+]^4 + K_aK_{a_1}[Na^+][H_3O^+]^2 + K_aK_{a_1}[H_3O^+]^3 \\ &+ K_{a_2}K_{a_1}[Na^+][H_3O^+]^2 + K_{a_2}K_{a_1}[H_3O^+]^3 + K_{a_2}K_{a_1}K_a[Na^+][H_3O^+] + K_{a_2}K_{a_1}K_a[H_3O^+]^2 \\ &= K_w[H_3O^+]^3 + K_wK_a[H_3O^+]^2 + K_a[HA]_1[H_3O^+]^3 + K_wK_{a_1}[H_3O^+]^2 + K_wK_aK_{a_1}[H_3O^+] + K_aK_{a_1}[HA]_1[H_3O^+]^2 \\ &+ K_wK_{a_2}K_{a_1}[H_3O^+] + K_wK_aK_{a_2}K_{a_1} + K_aK_{a_2}K_{a_1}[HA]_1[H_3O^+] + K_{a_1}[HCO_3^-]_1[H_3O^+]^3 + 2K_{a_2}K_{a_1}[HCO_3^-]_1[H_3O^+]^2 \\ &+ K_aK_{a_1}[HCO_3^-]_1[H_3O^+]^2 + 2K_aK_{a_2}K_{a_1}[HCO_3^-]_1[H_3O^+]\end{aligned}$$

$$\begin{aligned}&[Na^+][H_3O^+]^4 + [H_3O^+]^5 + K_a[Na^+][H_3O^+]^3 + K_a[H_3O^+]^4 + K_{a_1}[Na^+][H_3O^+]^3 + K_{a_1}[H_3O^+]^4 + K_aK_{a_1}[Na^+][H_3O^+]^2 + K_aK_{a_1}[H_3O^+]^3 \\ &+ K_{a_2}K_{a_1}[Na^+][H_3O^+]^2 + K_{a_2}K_{a_1}[H_3O^+]^3 + K_{a_2}K_{a_1}K_a[Na^+][H_3O^+] + K_{a_2}K_{a_1}K_a[H_3O^+]^2 - K_w[H_3O^+]^3 - K_wK_a[H_3O^+]^2 \\ &- K_a[HA]_1[H_3O^+]^3 - K_wK_{a_1}[H_3O^+]^2 - K_wK_aK_{a_1}[H_3O^+] - K_aK_{a_1}[HA]_1[H_3O^+]^2 - K_wK_{a_2}K_{a_1}[H_3O^+] - K_wK_aK_{a_2}K_{a_1} \\ &- K_aK_{a_2}K_{a_1}[HA]_1[H_3O^+] - K_{a_1}[HCO_3^-]_1[H_3O^+]^3 - 2K_{a_2}K_{a_1}[HCO_3^-]_1[H_3O^+]^2 - K_aK_{a_1}[HCO_3^-]_1[H_3O^+]^2 \\ &- 2K_aK_{a_2}K_{a_1}[HCO_3^-]_1[H_3O^+] = 0\end{aligned}$$

$$\begin{aligned}&[H_3O^+]^5 + [H_3O^+]^4\left([NaHCO_3] + K_a + K_{a_1}\right) \\ &+ [H_3O^+]^3\left(K_a[NaHCO_3] + K_{a_1}[NaHCO_3] + K_aK_{a_1} + K_{a_2}K_{a_1} - K_w - K_a[HA]_1 - K_{a_1}[NaHCO_3]\right) \\ &+ [H_3O^+]^2\left(K_aK_{a_1}[NaHCO_3] + K_{a_2}K_{a_1}[NaHCO_3] + K_{a_2}K_{a_1}K_a - K_wK_a - K_wK_{a_1} - K_aK_{a_1}[HA]_1 - 2K_{a_2}K_{a_1}[NaHCO_3]\right. \\ &\left. - K_aK_{a_1}[NaHCO_3]\right) + [H_3O^+]\left(K_{a_2}K_{a_1}K_a[NaHCO_3] - K_wK_aK_{a_1} - K_wK_{a_2}K_{a_1} - K_aK_{a_2}K_{a_1}[HA]_1 - 2K_aK_{a_2}K_{a_1}[NaHCO_3]\right) \\ &- K_wK_aK_{a_2}K_{a_1} = 0\end{aligned}$$

$$[H_3O^+]^5 + [H_3O^+]^4\left([NaHCO_3] + K_a + K_{a_1}\right) + [H_3O^+]^3\left(K_a[NaHCO_3] + K_aK_{a_1} + K_{a_2}K_{a_1} - K_w - K_a[HA]_1\right)$$
$$+ [H_3O^+]^2\left(K_{a_2}K_{a_1}K_a - K_wK_a - K_wK_{a_1} - K_aK_{a_1}[HA]_1 - K_{a_2}K_{a_1}[NaHCO_3]\right)$$
$$+ [H_3O^+]\left(-K_wK_aK_{a_1} - K_wK_{a_2}K_{a_1} - K_aK_{a_2}K_{a_1}[HA]_1 - K_aK_{a_2}K_{a_1}[NaHCO_3]\right) - K_wK_aK_{a_2}K_{a_1} = 0$$

$$[H_3O^+]^5 + [H_3O^+]^4\left([NaHCO_3] + K_a + K_{a_1}\right) + [H_3O^+]^3\left(K_a[NaHCO_3] + K_aK_{a_1} + K_{a_2}K_{a_1} - K_w - K_a[HA]_1\right)$$
$$+ [H_3O^+]^2\left(K_{a_2}K_{a_1}K_a - K_wK_a - K_wK_{a_1} - K_aK_{a_1}[HA]_1 - K_{a_2}K_{a_1}[NaHCO_3]\right)$$
$$- [H_3O^+]\left(K_wK_aK_{a_1} + K_wK_{a_2}K_{a_1} + K_aK_{a_2}K_{a_1}[HA]_1 + K_aK_{a_2}K_{a_1}[NaHCO_3]\right) - K_wK_aK_{a_2}K_{a_1} = 0$$

$$[H_3O^+]^5 + [H_3O^+]^4\left([NaHCO_3] + K_a + K_{a_1}\right) + [H_3O^+]^3\left(K_a\left([NaHCO_3] + K_{a_1} - [HA]_1\right) + K_{a_2}K_{a_1} - K_w\right)$$
$$+ [H_3O^+]^2\left(K_{a_1}\left(K_{a_2}K_a - K_w - K_a[HA]_1 - K_{a_2}[NaHCO_3]\right) - K_wK_a\right)$$
$$- [H_3O^+]\left(K_{a_1}\left(K_wK_a + K_wK_{a_2} + K_aK_{a_2}[HA]_1 + K_aK_{a_2}[NaHCO_3]\right)\right) - K_wK_aK_{a_2}K_{a_1} = 0$$