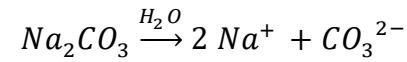
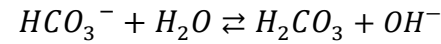
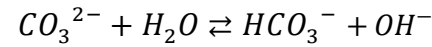


Tvåprotonig bas + svag syra



$$[Na^+] = 2[Na_2CO_3]$$

$$[CO_3^{2-}]_1 = [Na_2CO_3]$$



$$K_{b_2} = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]_2} \Leftrightarrow [HCO_3^-] = \frac{K_{b_2}[CO_3^{2-}]_2}{[OH^-]}$$

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

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

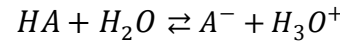
$$[CO_3^{2-}]_1 = [CO_3^{2-}]_2 + [HCO_3^-] + [H_2CO_3]$$

$$[CO_3^{2-}]_1 = [CO_3^{2-}]_2 + \frac{K_{b_2}[CO_3^{2-}]_2}{[OH^-]} + \frac{K_{b_1}[HCO_3^-]}{[OH^-]} = [CO_3^{2-}]_2 + \frac{K_{b_2}[CO_3^{2-}]_2}{[OH^-]} + \frac{K_{b_1} \frac{K_{b_2}[CO_3^{2-}]}{[OH^-]}}{[OH^-]}$$

$$[CO_3^{2-}]_1 = [CO_3^{2-}]_2 + \frac{K_{b_2}[CO_3^{2-}]_2}{[OH^-]} + \frac{K_{b_1}K_{b_2}[CO_3^{2-}]}{[OH^-]^2} = [CO_3^{2-}]_2 \left(1 + \frac{K_{b_2}}{[OH^-]} + \frac{K_{b_1}K_{b_2}}{[OH^-]^2} \right) = [CO_3^{2-}]_2 \left(\frac{[OH^-]^2 + K_{b_2}[OH^-] + K_{b_1}K_{b_2}}{[OH^-]^2} \right)$$

$$[CO_3^{2-}]_2 = \frac{[CO_3^{2-}]_1}{\left(\frac{[OH^-]^2 + K_{b_2}[OH^-] + K_{b_1}K_{b_2}}{[OH^-]^2}\right)} = \frac{[CO_3^{2-}]_1[OH^-]^2}{[OH^-]^2 + K_{b_2}[OH^-] + K_{b_1}K_{b_2}} = \frac{[CO_3^{2-}]_1 \left(\frac{K_w}{[H_3O^+]}\right)^2}{\left(\frac{K_w}{[H_3O^+]}\right)^2 + K_{b_2} \frac{K_w}{[H_3O^+]} + K_{b_1}K_{b_2}}$$

$$[CO_3^{2-}]_2 = \frac{\frac{[CO_3^{2-}]_1 K_w^2}{[H_3O^+]^2}}{\frac{K_w^2}{[H_3O^+]^2} + \frac{K_{b_2}K_w}{[H_3O^+]} + K_{b_1}K_{b_2}} = \frac{\frac{[CO_3^{2-}]_1 K_w^2}{[H_3O^+]^2}}{\frac{K_w^2 + K_{b_2}K_w[H_3O^+] + K_{b_1}K_{b_2}[H_3O^+]^2}{[H_3O^+]^2}} = \frac{[CO_3^{2-}]_1 K_w^2}{K_w^2 + K_{b_2}K_w[H_3O^+] + K_{b_1}K_{b_2}[H_3O^+]^2}$$



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

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

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

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

$$2[Na_2CO_3] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a[HA]_2}{[H_3O^+]} + \frac{K_{b_2}[CO_3^{2-}]_2}{[OH^-]} + 2 \frac{[CO_3^{2-}]_1 K_w^2}{K_w^2 + K_{b_2}K_w[H_3O^+] + K_{b_1}K_{b_2}[H_3O^+]^2}$$

$$2[Na_2CO_3] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a \frac{[HA]_1[H_3O^+]}{[H_3O^+] + K_a}}{[H_3O^+]} + \frac{K_{b_2}[CO_3^{2-}]_2}{\frac{K_w}{[H_3O^+]}} + \frac{2[CO_3^{2-}]_1 K_w^2}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2}$$

$$2[Na_2CO_3] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a[HA]_1}{[H_3O^+] + K_a} + \frac{K_{b_2}[H_3O^+][CO_3^{2-}]_2}{K_w} + \frac{2K_w^2[CO_3^{2-}]_1}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2}$$

$$2[Na_2CO_3] + [H_3O^+]$$

$$= \frac{K_w}{[H_3O^+]} + \frac{K_a[HA]_1}{[H_3O^+] + K_a} + \frac{K_{b_2}[H_3O^+] \frac{[CO_3^{2-}]_1 K_w^2}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2}}{K_w} + \frac{2K_w^2[CO_3^{2-}]_1}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2}$$

$$2[Na_2CO_3] + [H_3O^+] = \frac{K_w}{[H_3O^+]} + \frac{K_a[HA]_1}{[H_3O^+] + K_a} + \frac{K_w K_{b_2}[H_3O^+][Na_2CO_3]}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2} + \frac{2K_w^2[Na_2CO_3]}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2}$$

$$2[Na_2CO_3][H_3O^+] + [H_3O^+]^2 = K_w + \frac{K_a[HA]_1[H_3O^+]}{[H_3O^+] + K_a} + \frac{K_w K_{b_2}[H_3O^+]^2[Na_2CO_3] + 2K_w^2[H_3O^+][Na_2CO_3]}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2}$$

$$\begin{aligned} & 2[Na_2CO_3][H_3O^+]^2 + [H_3O^+]^3 + 2K_a[Na_2CO_3][H_3O^+] + K_a[H_3O^+]^2 \\ &= K_w [H_3O^+] + K_w K_a + K_a[HA]_1[H_3O^+] \\ &+ \frac{K_w K_{b_2}[H_3O^+]^3[Na_2CO_3] + 2K_w^2[H_3O^+]^2[Na_2CO_3] + K_w K_a K_{b_2}[H_3O^+]^2[Na_2CO_3] + 2K_w^2 K_a[H_3O^+][Na_2CO_3]}{K_w^2 + K_{b_2} K_w [H_3O^+] + K_{b_1} K_{b_2} [H_3O^+]^2} \end{aligned}$$

$$\begin{aligned} & 2K_w^2[Na_2CO_3][H_3O^+]^2 + K_w^2[H_3O^+]^3 + 2K_w^2 K_a[Na_2CO_3][H_3O^+] + K_w^2 K_a[H_3O^+]^2 + 2K_{b_2} K_w [Na_2CO_3][H_3O^+]^3 + K_{b_2} K_w [H_3O^+]^4 \\ &+ 2K_a K_{b_2} K_w [Na_2CO_3][H_3O^+]^2 + K_a K_{b_2} K_w [H_3O^+]^3 + 2K_{b_1} K_{b_2} [Na_2CO_3][H_3O^+]^4 + K_{b_1} K_{b_2} [H_3O^+]^5 \\ &+ 2K_a K_{b_1} K_{b_2} [Na_2CO_3][H_3O^+]^3 + K_a K_{b_1} K_{b_2} [H_3O^+]^4 \\ &= K_w^3[H_3O^+] + K_w^3 K_a + K_w^2 K_a[HA]_1[H_3O^+] + K_{b_2} K_w^2[H_3O^+]^2 + K_w^2 K_{b_2} K_a[H_3O^+] + K_a K_{b_2} K_w [HA]_1[H_3O^+]^2 \\ &+ K_w K_{b_1} K_{b_2} [H_3O^+]^3 + K_w K_a K_{b_1} K_{b_2} [H_3O^+]^2 + K_a K_{b_1} K_{b_2} [HA]_1[H_3O^+]^3 + K_w K_{b_2} [H_3O^+]^3[Na_2CO_3] \\ &+ 2K_w^2[H_3O^+]^2[Na_2CO_3] + K_w K_a K_{b_2} [H_3O^+]^2[Na_2CO_3] + 2K_w^2 K_a[H_3O^+][Na_2CO_3] \end{aligned}$$

$$\begin{aligned}
& 2K_w^2[Na_2CO_3][H_3O^+]^2 + K_w^2[H_3O^+]^3 + 2K_w^2K_a[Na_2CO_3][H_3O^+] + K_w^2K_a[H_3O^+]^2 + 2K_{b_2}K_w[Na_2CO_3][H_3O^+]^3 + K_{b_2}K_w[H_3O^+]^4 \\
& + 2K_aK_{b_2}K_w[Na_2CO_3][H_3O^+]^2 + K_aK_{b_2}K_w[H_3O^+]^3 + 2K_{b_1}K_{b_2}[Na_2CO_3][H_3O^+]^4 + K_{b_1}K_{b_2}[H_3O^+]^5 \\
& + 2K_aK_{b_1}K_{b_2}[Na_2CO_3][H_3O^+]^3 + K_aK_{b_1}K_{b_2}[H_3O^+]^4 - K_w^3[H_3O^+] - K_w^3K_a - K_w^2K_a[HA]_1[H_3O^+] - K_{b_2}K_w^2[H_3O^+]^2 \\
& - K_w^2K_{b_2}K_a[H_3O^+] - K_aK_{b_2}K_w[HA]_1[H_3O^+]^2 - K_wK_{b_1}K_{b_2}[H_3O^+]^3 - K_wK_aK_{b_1}K_{b_2}[H_3O^+]^2 - K_aK_{b_1}K_{b_2}[HA]_1[H_3O^+]^3 \\
& - K_wK_{b_2}[H_3O^+]^3[Na_2CO_3] - 2K_w^2[H_3O^+]^2[Na_2CO_3] - K_wK_aK_{b_2}[H_3O^+]^2[Na_2CO_3] - 2K_w^2K_a[H_3O^+][Na_2CO_3] = 0
\end{aligned}$$

$$\begin{aligned}
& K_{b_1}K_{b_2}[H_3O^+]^5 + [H_3O^+]^4(K_{b_2}K_w + 2K_{b_1}K_{b_2}[Na_2CO_3] + K_aK_{b_1}K_{b_2}) \\
& + [H_3O^+]^3(K_w^2 + 2K_{b_2}K_w[Na_2CO_3] + K_aK_{b_2}K_w + 2K_aK_{b_1}K_{b_2}[Na_2CO_3] - K_wK_{b_1}K_{b_2} - K_aK_{b_1}K_{b_2}[HA]_1 \\
& - K_wK_{b_2}[Na_2CO_3]) \\
& + [H_3O^+]^2(2K_w^2[Na_2CO_3] + K_w^2K_a + 2K_aK_{b_2}K_w[Na_2CO_3] - K_{b_2}K_w^2 - K_aK_{b_2}K_w[HA]_1 - K_wK_aK_{b_1}K_{b_2} - 2K_w^2[Na_2CO_3] \\
& - K_wK_aK_{b_2}[Na_2CO_3]) + [H_3O^+](2K_w^2K_a[Na_2CO_3] - K_w^3 - K_w^2K_a[HA]_1 - K_w^2K_{b_2}K_a - 2K_w^2K_a[Na_2CO_3]) - K_w^3K_a \\
& = 0
\end{aligned}$$

$$\begin{aligned}
& K_{b_1}K_{b_2}[H_3O^+]^5 + [H_3O^+]^4(K_{b_1}K_{b_2}(2[Na_2CO_3] + K_a) + K_{b_2}K_w) \\
& + [H_3O^+]^3(K_w^2 + K_{b_2}K_w[Na_2CO_3] + K_aK_{b_2}K_w + 2K_aK_{b_1}K_{b_2}[Na_2CO_3] - K_wK_{b_1}K_{b_2} - K_aK_{b_1}K_{b_2}[HA]_1) \\
& + [H_3O^+]^2(K_w^2K_a + K_aK_{b_2}K_w[Na_2CO_3] - K_{b_2}K_w^2 - K_aK_{b_2}K_w[HA]_1 - K_wK_aK_{b_1}K_{b_2}) \\
& + [H_3O^+](K_w^3 - K_w^2K_a[HA]_1 - K_w^2K_{b_2}K_a) - K_w^3K_a = 0
\end{aligned}$$

$$\begin{aligned}
& K_{b_1}K_{b_2}[H_3O^+]^5 + [H_3O^+]^4(K_{b_1}K_{b_2}(2[Na_2CO_3] + K_a) + K_{b_2}K_w) \\
& + [H_3O^+]^3(K_{b_1}K_{b_2}(2K_a[Na_2CO_3] - K_a[HA]_1 - K_w) + K_w(K_w + K_{b_2}[Na_2CO_3] + K_aK_{b_2})) \\
& + [H_3O^+]^2(K_aK_{b_2}K_w(Na_2CO_3 - [HA]_1 - K_{b_1}) + K_w^2(K_a - K_{b_2})) - [H_3O^+](K_w^2(K_w + K_a[HA]_1 + K_{b_2}K_a)) - K_w^3K_a = 0
\end{aligned}$$