Working together, calculate the relative abundances of carbon species in the surface ocean

Assume pCO_2 = 400 ppm (don't need), pH = 8.1, DIC = 2.1 mmol/kg

$K_1 = e^{-13.4847}$

$K_2 = e^{-20.5504}$

$[CO_2] \approx 0.5\%$

$[HCO_3^-] \approx 96.5\%$ (bicarbonate)

$[CO_3^{2-}] \approx 13\%$ (carbonate)

$$DIC = [CO_2] + [HCO_3^-] + [CO_3^{2-}]$$

$$DIC = \frac{[HCO_3^-][H^+]}{K_1} + [HCO_3^-] + \frac{[HCO_3^-]K_2}{[H^+]}$$

same algebra →

$$[CO_2] = \frac{DIC}{\left(1 + \frac{K_1}{[H^+]} + \frac{K_1K_2}{[H^+]}\right)}$$

$$DIC = [HCO_3^-]\left(\frac{[H^+]}{K_1} + 1 + \frac{K_2}{[H^+]}\right)$$

$$[HCO_3^-] = \frac{DIC}{\left(\frac{[H^+]}{K_1} + 1 + \frac{K_2}{[H^+]}\right)}$$

$$[CO_3^{2-}] = \frac{DIC}{\left(1 + \frac{[H^+]}{K_2} + \frac{[H^+]^2}{K_1K_2}\right)}$$

<Look at Bjerrum plot>

$pCO_2 \cdot K_0 = [CO_2]$ ← pCO_2 a function of $[CO_2]$ in ocean

$pCO_2 \cdot K_0 = 10.37\ \mu mol\ [CO_2]/kg$ $\quad K_0 = e^{-3.5617}$

$pCO_2 = 365$ ppm atm

What happens if you double DIC? At first glance it seems that pCO_2 doubles... However, only true if you can double DIC while fixing pH. A closer look...

$DIC = [CO_2] + [HCO_3^-] + [CO_3^{2-}] \approx [HCO_3^-] + [CO_3^{2-}]$ ← low

Alkalinity ≈ Carbonate Alkalinity $= [HCO_3^-] + 2[CO_3^{2-}]$

With these approximations...

$[HCO_3^-] \approx 2DIC - ALK$

$[CO_3^{2-}] \approx ALK - DIC$