statistical physics → reaction kinetics ★★★

Oceanic CO_2

One of the major concerns about a "positive feedback" loop in global warming caused by CO_2 is that rising temperatures push more of the Earth's CO_2 into the atmosphere, which further causes warming.

In this problem, we will explore, in a quantitative sense, this effect, in a simplified model. The following reactions are of interest. CO_2 can exist in both a gaseous phase, or in an aqueous phase dissolved in water. However, dissolved CO_2 can disassociate into carbonic acid:

$$CO_2 + H_2O \rightleftharpoons 2H^+ + CO_3^{--}$$

Let us denote $s = [CO_2(g)]$, $t = [CO_2(aq)]$, $x = [CO_3^{--}]$, $a = [H^+]$. Henry's law tells us that

$$s = k(T)t$$

with $k'(T) > 0$, and T the temperature. Similarly, we denote with α the equilibrium coefficient for the CO_2 dissolution reaction (absorb into α the concentration of H_2O).

(a) Using charge conservation, the equations of chemical equilibrium, and conservation of carbon (assume total concentration c), find the solution to the equations, and show that the solution is unique.

(b) Show that x, a and s increase when T increases, and that t decreases.[1] Thus, this would cause a feedback loop with increases in CO_2 increasing T.

[1] I would recommend doing this graphically. Please do not simply show this result numerically.