CE 37200: Environmental Impact Assessment

Homework 4
Chapter 5 (chemical reactions)
Due: Mar. 13

CO_2 in the atmosphere can dissolve in the ocean, which can also affect the concentration of carbonate and bicarbonate ions in the ocean water and its acidity. Suppose that the following reactions are relevant:

$CO_2(aq) \leftrightarrow CO_2(g)$,	$K_H = 27.2$	(1)
$CO_2(aq) + H_2O(l)^* \leftrightarrow H^+(aq) + HCO_3^-(aq)$,	$K_a = 4.5*10^{-7}$	(2)
$HCO_3^-(aq) \leftrightarrow H^+(aq) + CO_3^{-2}(aq)$,	$K_a = 4.7*10^{-11}$	(3)
$H_2O(l)^* \leftrightarrow H^+(aq) + OH^-(aq)$,	$K_w = 1.0*10^{-14}$	(4)

*Note: in the chemical equilibrium expressions, take $[H_2O(l)] = 1$ (unit activity)

Suppose also that
$2[CO_3^{-2}] + [HCO_3^-] + [OH^-] - [H^+] = 2.5*10^{-3}$ M (5)
(Oceanographers call this quantity *alkalinity*. It's defined so that reactions 1-4 don't change it.)

(a) Suppose that air at the ocean surface has a pressure of 1 atm and contains 280 ppmv CO_2. Find the equilibrium concentration in the ocean of all the carbon species ($CO_2(aq)$, HCO_3^- (aq), CO_3^{-2} (aq)) and the water pH.

(b) Repeat your calculations if the atmosphere CO_2 concentration increases to 400 pmv.

(c) Give the percentage difference in the equilibrium concentration of each species between (a) and (b).

(d) Consider the reaction
$CaCO_3(s) \leftrightarrow Ca^{+2}(aq) + CO_3^{-2}(aq)$, $K_{sp} = 5*10^{-9}$ (6)

Suppose that $[Ca^{+2}]$ in the ocean is 0.0105 M. How much $CaCO_3$ can precipitate per L ocean water under the CO_3^{-2} concentration you found in (a)? What about for (b)? Based on your results, explain why increasing the amount of CO_2 in the atmosphere threatens ocean organisms such as coral. (For more information, look up "ocean acidification").