Answer on Question #63482, Chemistry / General Chemistry

The chief compound in marble is CaCO3. However, marble is readily attacked by acids.
[Ca^2+] in normal rainwater of pH 5.0 = 0.024 M
a) Determine the molar solubility of marble (that is, [Ca^2+] in a saturated solution).
b) Determine the equilibrium constant for the overall reaction that occurs when marble reacts with acid
CaCO3 (s) + H3O^+ ↔ Ca2+ (aq) + HCO3- (aq) + H2O (l)

Solution:

a)

$CaCO_3(s) \rightarrow Ca^{2+}(aq) + CO_3^{2-}(aq)$
For which:
$K=[Ca^{2+}][CO_3^{2-}]=Ksp(CaCO_3)=4.8\times10^{-9.}$

The problem here is that you have an additional reaction that takes CO3-2 out of solution as soon as it's formed, and that is the acid-base reaction between CO3-2 (a good base) and H+ in the water:
$CO2{-}3(aq)+H+(aq) \rightarrow HCO{-}3(aq)$
For which
$K=[HCO_3^-]/[H^+][CO_3^{2-}]=1/Ka(HCO_3^-)=1/5.0\times10^{-11}=2.0\times10^{10}$

To solve the combined equilibrium problems, you need to solve both K equations simultaneously. If you let x = $[Ca^{+2}]$ at equilibrium, and y = $[HCO_3^-]$ at equilibrium, then $[CO_3^{2-}]$ will be x - y. Now you have two equations in two unknowns:
$x(x-y)=Ksp$
and
$y/(10^{-pH})(x-y)=1/Ka$
I was able to write [H+] as 10^{-pH}.
$r=10^-pH/Ka$
and
$s=Ksp$
Then our two equations are
$x(x-y)=s$
and
$y/x-y=r$
Solving the second equation for y I get
$y=r1+rx$
Substituting that into the first equation I get
$x^2=s(1+r)$
Taking the square root and remembering what everything stands for we have:
$[Ca2+]=\sqrt{(Ksp(1+(10^{-pH}/Ka))}$

When I plug in the numbers I get:
[Ca2+]=0.0489M

b)

$CaCO_3(s) + H_3O^+ \leftrightarrow Ca^{2+}(aq) + HCO^{3-}(aq) + H_2O(l)$
$Kc= [Ca^{2+}][HCO^{3-}][H_2O]/[CaCO_3][H_3O^+]$