

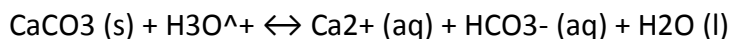
Answer on Question #63482, Chemistry / General Chemistry

The chief compound in marble is CaCO_3 . However, marble is readily attacked by acids.

$[\text{Ca}^{2+}]$ in normal rainwater of pH 5.0 = 0.024 M

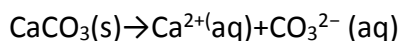
a) Determine the molar solubility of marble (that is, $[\text{Ca}^{2+}]$ in a saturated solution).

b) Determine the equilibrium constant for the overall reaction that occurs when marble reacts with acid



Solution:

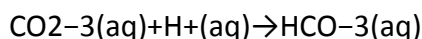
a)



For which:

$$K = [\text{Ca}^{2+}][\text{CO}_3^{2-}] = K_{sp}(\text{CaCO}_3) = 4.8 \times 10^{-9}$$

The problem here is that you have an additional reaction that takes CO_3^{2-} out of solution as soon as it's formed, and that is the acid-base reaction between CO_3^{2-} (a good base) and H^+ in the water:



For which

$$K = [\text{HCO}_3^-]/[\text{H}^+][\text{CO}_3^{2-}] = 1/K_a(\text{HCO}_3^-) = 1/5.0 \times 10^{-11} = 2.0 \times 10^{10}$$

To solve the combined equilibrium problems, you need to solve both K equations simultaneously. If you let $x = [\text{Ca}^{2+}]$ at equilibrium, and $y = [\text{HCO}_3^-]$ at equilibrium, then $[\text{CO}_3^{2-}]$ will be $x - y$. Now you have two equations in two unknowns:

$$x(x-y) = K_{sp}$$

and

$$y/(10^{-\text{pH}})(x-y) = 1/K_a$$

I was able to write $[\text{H}^+]$ as $10^{-\text{pH}}$.

$$r = 10^{-\text{pH}}/K_a$$

and

$$s = K_{sp}$$

Then our two equations are

$$x(x-y) = s$$

and

$$y/x - y = r$$

Solving the second equation for y I get

$$y = r + rx$$

Substituting that into the first equation I get

$$x^2 = s(1+r)$$

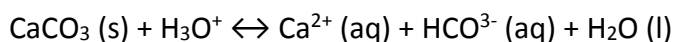
Taking the square root and remembering what everything stands for we have:

$$[\text{Ca}^{2+}] = \sqrt{K_{sp}(1 + (10^{-\text{pH}}/K_a))}$$

When I plug in the numbers I get:

$$[\text{Ca}^{2+}] = 0.0489\text{M}$$

b)



$$K_c = [\text{Ca}^{2+}][\text{HCO}_3^-][\text{H}_2\text{O}]/[\text{CaCO}_3][\text{H}_3\text{O}^+]$$