Question:

My wife hunts dead people – specifically, her ancestors (she's a genealogist). Gravestones are an excellent source of information, but historically they have been made of limestone because of its ease of cutting and carving. Unfortunately limestone dissolves in rain because of the acidity of the rain (slowly ... but over a couple hundred years it does wear away).a) A major component of rain acidity is nitric acid formed from lightning discharges. What is the reaction of the limestone with the acidic rain that eats away at the stone?b) If the pH of rain from a thunderstorm is 2.5, and 10 L of rain fall on a stone in a storm, how much limestone can be dissolved for each storm? (Assume all of the acid reacts with all of the limestone.)c) If a gravestone has dimensions of 18 inches wide, 30 inches tall, and 2.0 inches thick, how many rainstorms would it take to wear away enough to make the carving unreadable if they were 0.20 inches deep?

Solution:

Limestone is a sedimentary rock of organic, less often chemogenic origin, consisting predominantly of calcium carbonate ($CaCO_3$) in the form of calcite crystals of various sizes.

a) $CaCO_3 + 2HNO_3 = Ca(NO_3)_2 + H_2O + CO_2$;

   $CaCO_3 + 2H^+ = Ca^{2+} + H_2O + CO_2$.

b) pH = 2.5;

c (H^+) = [H^+] = $10^{-2.5}$ M = 0.00316 M;

n(H^+) = [H^+] * V = 0.00316*10 = 0.0316 mol;

n($CaCO_3$) = ½ * n(H^+) = 0.0158 mol;

m($CaCO_3$) = n($CaCO_3$) * M($CaCO_3$) = 0.0158 * 100 = 1.58 g.

c) V ($CaCO_3$) = 18 * 30 * 0,2 = 108 inches^3 = 274 sm^3;

d ($CaCO_3$) = 2,71 g/ sm^3;

m ($CaCO_3$) = d ($CaCO_3$) * V ($CaCO_3$) = 274 * 2.71 = 743.54 g;

n ($CaCO_3$) = m/M = 743.54/100 = 7.4254 mol;

n (H^+) = 2 * n($CaCO_3$) = 14.851 mol;

V (H^+) = n (H^+)/ c (H^+) = 14.851/0.00316 = 4700 L or 470 rains of 10 liters.

Answer:
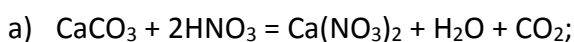
   a) $CaCO_3 + 2HNO_3 = Ca(NO_3)_2 + H_2O + CO_2$;
       $CaCO_3 + 2H^+ = Ca^{2+} + H_2O + CO_2$;
   b) 1.58 g;
   c) 4700 L or 470 rains of 10 liters.