Unit 16 ATM401, ATM601 and CHEM601

Application, analysis, and evaluation

1. All students: Calculate the number of H^+ and OH^- ions present in $100ml$ of collected rainwater having a pH value of 5 at 25^oC.

2. All students: At 25^oC and a partial pressure of CO_2 at normal pressure, the concentration of CO_2 dissolved in water drops is $10^{-5}M$ at equilibrium with the ambient air.
   $CO_2(g) + H_2O \rightleftharpoons CO_2(aq) \rightarrow H_2CO_3$

   $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

   Assume $K = 4.2 \cdot 10^{-7}$ for the ion product and neglect the self-ionization of water. Determine the pH of CO_2 saturated drops.

3. Undergraduate students: The gas SO_2 dissolves in water as follows:

   $SO_2(g) \longleftrightarrow SO_2(g) \cdot H_2$ with $K_1 = 1.2M/atm$

   $SO_2(g) \cdot H_2O \longleftrightarrow HSO_3^- + H^+$ with $K_2 = 1.310^{-2}M$

   $HSO_3^- \longleftrightarrow SO_3^{2-} + H^+$ with $K_3 = 6.3 \cdot 10^{-8}M$

   where $K_i = 1,2,3$ are the equilibrium constants.What are the oxidation numbers in the various compounds in the equations above? At typical pH values of cloud droplets and rain drops, in which form of the above reactions is the most suphur? Explain why.

4. Graduate students: The ocean is an important sink for CO_2. The equilibrium between atmosphere and ocean reads

   $CO_2(g) \longleftrightarrow CO_2 \cdot H_2O$ with $K_H = \frac{[CO_2 \cdot H_2O]}{p_{CO_2}}$

   $CO_2 \cdot H_2O \longleftrightarrow HCO_3^- + H^+$ with $K_1 = \frac{[HCO_3^-][H^+]}{[CO_2 \cdot H_2O]}$

   $HCO_3^- \longleftrightarrow CO_3^{2-} + H^+$ with $K_2 = \frac{[CO_3^{2-}][H^+]}{[HCO_3^-]}$

   Here $K_H = 0.03M/atm$, $K_1 = 9 \cdot 10^{-7}M$, and $K_2 = 7 \cdot 10^{-10}M$. How much CO_2 is dissolved in the oceans ($V_{ocean} = 1.4 \cdot 10^{18}m^3$) when the atmosphere is at equilibrium with the entire ocean. Assume an ocean pH of 8.2 ($[H^+] = 6.3 \cdot 10^{-9}M$) and an partial pressure of CO_2 at sea level of $3.6 \cdot 10^{-4}atm$. Determine the fraction of CO_2 in the atmosphere under the assumption that the atmosphere is at equilibrium with the ocean. Use the total number of moles of CO_2 in the atmosphere and dissolved in the ocean for the latter calculation. Note that the result you obtain this way is an incorrect description of the CO_2 uptake by oceans because the equlibriums assumption overestimates the uptake. Explain why.

5. Graduate students: Hypothetically assume that the concentration of CO_2 increases to 500 ppm. What effect would this increase have on the pH of rainwater? Compare the new pH value with the pH value of current clean rainwater. Evaluate by how much the pH would increase or decrease?