Midterm Examination
March 2, 2017
Due: Beginning of Class, Tuesday, March 7, 2017

Consider a system with three anions, A, B and OH, and three cations, C, D and H. The following reactions are possible

$AH \overset{K_1}{\leftrightarrow} A^- + H^+$	reaction 1.	$BC \overset{K_5}{\leftrightarrow} B^- + C^+$	reaction 5.
$AC \overset{K_2}{\leftrightarrow} A^- + C^+$	reaction 2.	$BD \overset{K_6}{\leftrightarrow} B^- + D^+$	reaction 6.
$AD \overset{K_3}{\leftrightarrow} A^- + D^+$	reaction 3.	$COH \overset{K_7}{\leftrightarrow} OH^- + C^+$	reaction 7.
$BH \overset{K_4}{\leftrightarrow} B^- + H^+$	reaction 4.	$DOH \overset{K_8}{\leftrightarrow} OH^- + D^+$	reaction 8.

There are a total of fourteen species: *AH*, *AC*, *AD, BH*, *BC, BD*, *COH*, *DOH*, A^-, B^-, C^+, D^+, H^+, OH^-. Equilibrium coefficients govern the distribution of each of these reactions.

$$K_1 = \frac{[A^-][H^+]}{[AH]} \quad \text{or} \quad [AH] = \frac{[A^-][H^+]}{K_1} \qquad \text{equation 1.}$$

$$K_2 = \frac{[A^-][C^+]}{[AC]} \quad \text{or} \quad [AC] = \frac{[A^-][C^+]}{K_2} \qquad \text{equation 2.}$$

$$K_3 = \frac{[A^-][D^+]}{[AD]} \quad \text{or} \quad [AD] = \frac{[A^-][D^+]}{K_3} \qquad \text{equation 3.}$$

$$K_4 = \frac{[B^-][H^+]}{[BH]} \quad \text{or} \quad [BH] = \frac{[B^-][H^+]}{K_4} \qquad \text{equation 4.}$$

$$K_5 = \frac{[B^-][C^+]}{[BC]} \quad \text{or} \quad [BC] = \frac{[B^-][C^+]}{K_5} \qquad \text{equation 5.}$$

$$K_6 = \frac{[B^-][D^+]}{[BD]} \quad \text{or} \quad [BD] = \frac{[B^-][D^+]}{K_6} \qquad \text{equation 6.}$$

$$K_7 = \frac{[OH^-][C^+]}{[COH]} \quad \text{or} \quad [COH] = \frac{[OH^-][C^+]}{K_7} \qquad \text{equation 7.}$$

$$K_8 = \frac{[OH^-][D^+]}{[DOH]} \quad \text{or} \quad [DOH] = \frac{[OH^-][D^+]}{K_8} \qquad \text{equation 8.}$$

Four more equations come from molar balances on *A*, *B*, *C, D*.

$$[A_{Tot}] = [AH] + [AC] + [AD] + [A^-] \qquad \text{equation 9.}$$

$$[B_{Tot}] = [BH] + [BC] + [BD] + [B^-] \qquad \text{equation 10.}$$

$$[C_{Tot}] = [AC] + [BC] + [COH] + [C^+] \quad \text{equation 11.}$$
$$[D_{Tot}] = [AD] + [BD] + [DOH] + [D^+] \quad \text{equation 12.}$$

The pH of the solution is given, which effectively provides the values of both $[H^+]$ and $[OH^-]$.

<u>Solve for the concentration of all fourteen species as a function of pH from 1 to 13</u> for the following parameter values. Both the equilibrium coefficients and the concentrations have units of $\frac{mol}{\ell}$.

$K_1 = 10^{-1}$, $K_2 = 10^{-2}$, $K_3 = 10^{-7}$, $K_4 = 10^{-3}$, $K_5 = 10^{-4}$, $K_6 = 10^{-4}$, $K_7 = 10^{-6}$ and $K_8 = 10^{-4}$.
$[A_{Tot}] = 1.0 \cdot 10^{-3}$, $[B_{Tot}] = 0.5 \cdot 10^{-4}$, $[C_{Tot}] = 1.0 \cdot 10^{-3}$, and $[D_{Tot}] = 0.5 \cdot 10^{-4}$.