Activity and activity coefficients III: Ionic strength

Ionic strength (I) is a term useful to characterize collectively the solutes in a solution. With regard to the concept of activity, ionic strength is an attempt to estimate the possible interaction of an ion with other ions, presumably counterions, in the solution.

Ionic strength is defined as the sum of the products of concentration and square of the charge for each of the n solutes in the solution:

$$I = \frac{1}{2}\sum_{i=1}^{n} m_i z_i^2$$

The sum is divided then by 2. If we are interested in the interactions of a cation of interest with all the anions in the solution, or the interactions of an anion with all the cations of the solution, then we would only need to consider half the total charge – so we divide by 2.

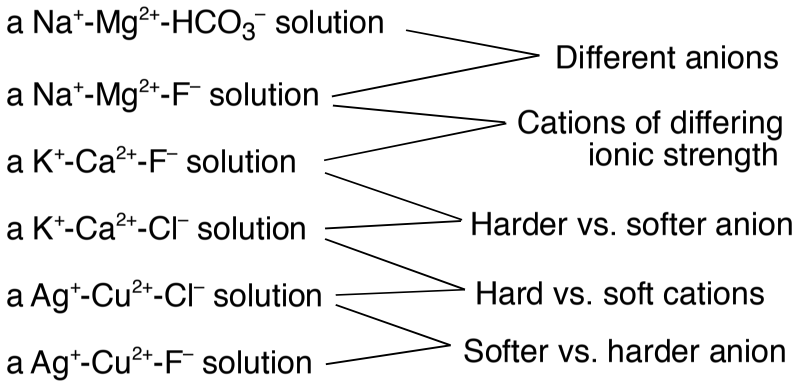
The following would be a reasonable geochemical template for calculation of ionic strength:

$[K^+]$ x 1 = _____
$[Na^+]$ x 1 = _____
$[Ca^{2+}]$ x 4 = _____
$[Mg^{2+}]$ x 4 = _____
$[F^-]$ x 1 = _____
$[Cl^-]$ x 1 = _____
$[HCO_3^-]$ x 1 = _____
$[SO_4^{2-}]$ x 4 = _____
$[PO_4^{3-}]$ x 9 = _____
$[SiO_2]$ x 0 = ____0_
\+
__sum_
÷ 2 _____
= ____I___

Some representative values of I are 0.02 for river water (a dilute solution), 0.7 for seawater, and 9 for water of the Dead Sea, which is extremely saline.

Ionic strength thus characterizes with one term the solutes of the entire solution. Compared to total dissolved solids (TDS), which is reported by weight as ppm, ionic strength provides more information because it uses the actual mole-based concentrations of solutes (not favoring heavier solutes) and because it takes into account the charge of the solutes, which has great significance in predicting formation of complexes and thus predicting activity of an ion.

With that said, one weakness of ionic strength is that considers only the charge of the various solutes. Consider the following six solutions:



The behavior of these solutions would differ considerably, and they would present very different environments for a third cation or second anion. In this respect, ionic strength provides only a crude characterization of a solution, and one sees why an understanding of activity using ion-specific terms might be more powerful. We will return to that thought in Part VI of this series.