



PHYSICAL PHARMACY CAPSULE 4.6

Principles of pH

pH is a critical variable in pharmaceuticals, and a basic understanding of its principles and measurement is important. Let's begin with a definition of the term pH. The p comes from the word power. The H, of course, is the symbol for hydrogen. Together, the term pH means the hydrogen ion exponent.

The pH of a substance is a measure of its acidity, just as a degree is a measure of temperature. A specific pH value tells the exact acidity. Rather than stating general ideas, such as cherry syrup is acidic or the water is hot, a specific pH value gives the same relative point of reference, thus providing more exact communication. "The cherry juice has a pH of 3.5" or "the water is at 80°C" provides an exact common language.

pH is defined in terms of the hydrogen ion activity:

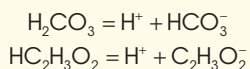
$$\text{pH} = -\log_{10} a_{\text{H}^+} \text{ or } 10^{-\text{pH}} = a_{\text{H}^+}$$

pH equals the negative logarithm of the hydrogen ion activity or the activity of the hydrogen ion is 10 raised to the exponent $-\text{pH}$. The latter expression renders the use of the p exponent more obvious. The activity is the effective concentration of the hydrogen ion in solution. The difference between effective and actual concentration decreases as one moves toward more dilute solutions, in which ionic interaction becomes progressively less important.

Normally, reference is made to the hydrogen ion when reference should be made to the hydronium ion (H_3O^+). It is a matter of convenience and brevity that only the hydrogen ion is mentioned, even though it is normally in its solvated form:



The complexing of the hydrogen ion by water affects activity and applies to other ions, which partially complex or establish an equilibrium with the hydrogen ion. In other words, equilibrium such as



complexes the hydrogen ion so that it is not sensed by the pH measuring system. This is why an acid-base titration is performed if the total concentration of acid (H^+) is needed. These effects on hydrogen ion activity are obvious, but other more subtle effects are involved in the correlation of activity and concentration.

The activity of the hydrogen ion can be defined by its relation to concentration (C_{H^+} , molality) and the activity coefficient f_{H^+} :

$$a_{\text{H}^+} = f_{\text{H}^+} + C_{\text{H}^+}$$

If the activity coefficient is unity, activity is equal to concentration. This is nearly the case in dilute solutions, whose ionic strength is low. Since the objective of most pH measurements is to find a stable and reproducible reading that can be correlated with the results of some process, it is important to know what influences the activity coefficient and therefore the pH measurement.

The factors that affect the activity coefficient are the temperature (T), the ionic strength (μ), the dielectric constant (ϵ), the ion charge (Z), the size of the ion in angstroms (\AA), and the density of the solvent (d). All of these factors are characteristics of the solution that relate the activity to the concentration by two main effects: the salt effect and the medium effect; the latter relates the influence that the solvent can have on the hydrogen ion activity. Thus, hydrogen activity is