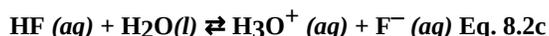


8.2: Ionization of Acids in Solution

In general, acids can be thought of as molecular compounds containing at least one hydrogen which is covalently bonded to a more electronegative atom. As an example, consider the compound hydrogen fluoride (HF). As we discussed in [Chapter 7](#), the electronegativities of hydrogen and fluorine are 2.1 and 4.0, respectively, and the hydrogen-fluoride covalent bond is very highly polarized.

Because of this, when hydrogen fluoride is dissolved in water, water molecules orient themselves around HF so that the water dipoles interact with, and stabilize, the highly polarized H—F bond. Important to this stabilization is the hydrogen bond that is formed between the hydrogen of HF and the oxygen of an adjacent water. This hydrogen bond not only stabilizes the HF molecular dipole, but it also *weakens* the H—F covalent bond. As a result of this weakening, the H—F bond stretches (the bond length increases) and then fully breaks. The hydrogen that was hydrogen-bonded to the water molecule now becomes *fully* bonded to the oxygen, forming the species H_3O^+ (the **hydronium ion**) and the fluorine now exists as a fluoride anion. This is known as the process of **acid dissociation**.

The chemical equation describing the acid dissociation reaction of HF is given in Equation 8.2a. The products of the reaction, fluoride anion and the hydronium ion, are oppositely charged ions, and it is reasonable to assume that they will be attracted to each other. If they *do* come in contact, it is also reasonable to suggest that the process of hydrogen transfer that we described above can also happen *in reverse*. That is, H_3O^+ can hydrogen bond to the fluoride ion and the hydrogen can be transferred back, to form HF and water. The chemical equation describing this process is shown in Equation 8.2b. In fact, these two reactions do occur simultaneously (and very rapidly) in solution. When we speak of a set of forward- and back-reactions that occur together on a *very fast* time-scale, we describe the set of reactions as an **equilibrium** and we use a special double arrow in the chemical reaction to show this (Equation 8.2c). Equation 8.2c can be said to represent the *equilibrium dissociation of HF in water*.



For any equilibrium, an **equilibrium constant** can be written that describes whether the *products* or the *reactants* will be the predominant species in solution. We will address this fully in [Chapter 10](#), but according to the *Law of Mass Action*, the equilibrium constant, K for this reaction, is simply given by the ratio of the activities of the products and reactants. To simplify the calculations, the activities of the **solutes** are approximated by the concentration in units of molarity. Note that **any solid or liquid reactants or products, or solvents** (such as water) are considered to be pure substances, and so have an activity that is equal to 1. Thus for the ionization of HF

$$K_a = \frac{a_{\text{H}_3\text{O}^+} \cdot a_{\text{OH}^-}}{a_{\text{HF}} \cdot a_{\text{H}_2\text{O}}} \approx \frac{[\text{H}_3\text{O}^+][\text{F}^-]}{[\text{HF}](1)} = \frac{[\text{H}_3\text{O}^+][\text{F}^-]}{[\text{HF}]}$$

When you are dealing with acids, the equilibrium constant is generally called an **acid dissociation constant**, and is written as K_a . The larger the value of K_a , the greater the extent of ionization and the higher the resulting concentration of the hydronium ion. Because the concentration of the hydronium ion is directly correlated with acidity, acids with a large value of K_a are termed **strong acids**. We will introduce “weak acids” in Chapter 10, but for now the important thing to remember is that strong acids are virtually 100% ionized in solution. That doesn’t mean that the back-reaction does not occur, it simply means that much more favorable and that 99.999999999% of the acid is present in its ionized form. Because this exceeds the number of significant figures that we typically work with, strong acids are generally described as 100% ionized in solution. Table 8.1 lists the common strong acids that we will study in this text.

Table 8.1. Common Strong Acids

Table 8.1 Common Strong Acids

HCl	hydrochloric acid
HNO ₃	nitric acid
H ₂ SO ₄	sulfuric acid
HBr	hydrobromic acid

HCl	hydrochloric acid
HI	hydroiodic acid
HClO ₄	perchloric acid

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