15.5: Strong and Weak Acids and Bases

Learning Objectives

- Define a strong and a weak acid and base.
- Recognize an acid or a base as strong or weak.

Electrolytes were previously described as substances that yield ions when dissolved in water, which means that aqueous solutions of electrolytes are able to conduct electricity. It should be clear that soluble ionic compounds are electrolytes. While it may seem that molecular compounds should all be nonelectrolytes, it turns out that this isn't always the case. Molecular compounds that are classified as acids or bases are electrolytes – some are strong electrolytes; most, however, are weak electrolytes.

An acid that is a strong electrolyte is called a **strong acid**, while an acid that is a weak electrolyte is a **weak acid**. A base that is a strong electrolyte is called a **strong base**, while a base that is a weak electrolyte is called a **weak base**. Classifying acids or bases as strong or weak has nothing to do with their concentration. It is possible to have a dilute solution of a strong acid or base and it is also possible to have a concentrated solution of a weak acid or base.

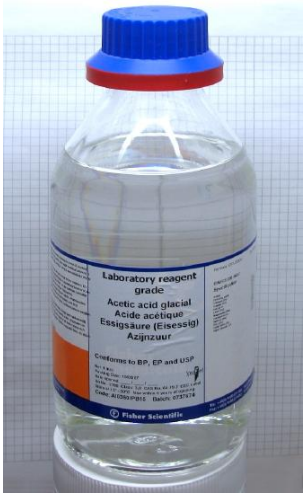

Figure 15.5.1: A bottle of 100% acetic acid, also called glacial acetic acid. The term "glacial" refers to the fact that it would often solidify in many old, poorly heated chemical stockrooms. Pure acetic acid has a freezing point of 17°C (62°F). (W. Oelen via Wikimedia Commons)

Weak acids and bases may be just as dangerous as their stronger counterparts when concentrated. For example, vinegar is an aqueous solution of acetic acid, $HC_2H_3O_2$, usually with a concentration of 5%. Vinegar is used to provide flavor and preserve foods. One might think of acetic acid as being quite harmless due to its widespread presence in foods. However, acetic acid in its pure form, called glacial acetic acid (see Figure 15.5.1), can cause severe skin burns in its concentrated form. One of the authors of this section has had such an experience back in his days in college when working with glacial acetic acid as a student in lab.

Strong Acids and Strong Bases

The terms **strong acid** and **strong base** are used to indicate that these substances are strong electrolytes when dissolved in water. The hydroxides of elements in Group IA and Group IIA on the periodic table are all strong electrolytes [except for $Mg(OH)_2$ and $Be(OH)_2$ since they are mostly insoluble in water]. As soluble ionic compounds, they dissociate completely to yield the metal ion and the hydroxide ion. Consider an aqueous solution of NaOH:

$$\mathrm{NaOH}\ (aq) \xrightarrow{100\%} \mathrm{Na^+}\ (aq) + \mathrm{OH^-}\ (aq) \tag{15.5.1}$$

NaOH is a base, due to the formation of OH^- in water and it is a strong electrolyte, since it dissociates completely in water. We say it **dissociates**, because NaOH is already an ionic compound and the ions simply dissociate, or separate, from each other when NaOH is dissolved in water. Because NaOH is a base and a strong electrolyte, NaOH is classified as a **strong base**.

When HCl is dissolved in water, it yields a solution that is strongly conducting. This is an indication that it is completely converted into ions. Since HCl is a molecular compound, we can't say it dissociates into its ions, but rather, we say that it **ionizes** completely in the presence of water. The term ionize means that ions are formed from something that was not originally ionic. To explain the existence of ions, we can show that HCl reacts with water to yield H_3O^+ (*aq*) and Cl^- (*aq*) ions:

$$\mathrm{HCl}\,(aq) + \mathrm{H_2O}\,(l) \xrightarrow{100\%} \mathrm{H_3O^+}\,(aq) + \mathrm{Cl^-}\,(aq) \tag{15.5.2}$$

Since HCl ionizes completely to form ions, it is a strong electrolyte. HCl is classified as an acid due to the formation of H_3O^+ ions in water. Consequently, HCl is classified as a **strong acid**.

Weak Acids and Weak Bases

The terms **weak acid** and **weak base** are used to indicate that these substances are weak electrolytes when dissolved in water. Most acids and bases are weak electrolytes and are also molecular compounds. As molecular compounds, this means they must ionize (react with water) to be an electrolyte, but that they do not ionize completely.

For example, when acetic acid is placed in water, approximately 1% of the molecules *ionize*. The remaining 99% of $HC_2H_3O_2$ molecules remain intact and unreacted. Since most of the molecules do not ionize, the solution is only weakly conducting. This reaction may be visualized in equation form as:

$$\mathrm{HC_2H_3O_2}\,(aq) + \mathrm{H_2O}\,(l) \xrightarrow{\sim 1\%} \mathrm{H_3O^+}(aq) + \mathrm{C_2H_3O_2^-}\,(aq) \tag{15.5.3}$$

Since this reaction does not go 100% to completion, it is more appropriate to write it as a **reversible reaction** to indicate that most of the reaction mixture remains as reactants:

$$\mathrm{HC_2H_3O_2}\,(aq) + \mathrm{H_2O}\,(l) \rightleftharpoons \mathrm{H_3O^+}(aq) + \mathrm{C_2H_3O_2^-}\,(aq) \tag{15.5.4}$$

Since $HC_2H_3O_2$ ionizes only partially to form ions, it is a weak electrolyte. $HC_2H_3O_2$ is classified as an acid due to the formation of H_3O^+ ions in water. Consequently, $HC_2H_3O_2$ is classified as a **weak acid**.

When NH_3 is dissolved in water, it *ionizes* to yield a solution that is weakly conducting. Therefore, we show its reaction with water as a reversible reaction to indicate that most of the reaction mixture remains as reactants and not as ions:

$$\mathrm{NH_3}\,(aq) + \mathrm{H_2O}\,(l) \rightleftharpoons \mathrm{NH_4^+}(aq) + \mathrm{OH^-}\,(aq) \tag{15.5.5}$$

NH_3 is a base, due to the formation of OH^- in water and it is a weak electrolyte, since it ionizes only partially in water. Because NH_3 is a base and a weak electrolyte, NH_3 is classified as a **weak base**.

Classification of Acids and Bases as Strong or Weak

As it turns out, there are very few strong acids and very few strong bases. Those classified as strong acids and strong bases are listed in Table 15.5.1. If an acid is not listed here, it is a weak acid. If a base is not listed here, it is a weak base.

Table 15.5.1: Strong Acids and Strong Bases

Strong Acids	Strong Bases
HCl	Group IA and Group IIA hydroxides*, *including*:
HBr	LiOH
HI	NaOH
HNO_3	KOH
H_2SO_4	RbOH
$HClO_3$	CsOH
$HClO_4$	$Ca(OH)_2$

Strong Acids	Strong Bases
	$Sr(OH)_2$
	$Ba(OH)_2$

*$Mg(OH)_2$ is sometimes classified as a strong base, since it ionizes completely. However, because it is relatively insoluble, little dissolves and relatively few OH^- ions are formed in solution. Therefore, is is also sometimes classified as a weak base. It will be considered a weak base in this text.

As mentioned above, Table 15.5.1 is an all-inclusive list of strong acids and a strong bases. If an acid or base does not appear in on the list in Table 15.5.1, it is classified as weak. Table 15.5.2 below shows a few common weak acids and weak bases:

Table 15.5.2: Some Common Weak Acids and Weak Bases

Weak Acids	Weak Bases
$HC_2H_3O_2$	$Mg(OH)_2$
H_3PO_4	NH_3
HF	
H_2CO_3	

✅ Example 15.5.1: Identifying Strong and Weak Acids and Bases

Identify each acid or base as strong or weak.

A. HCl
B. $Mg(OH)_2$
C. C_5H_5N

Solution

A. Because HCl is listed in Table 15.5.1, it is a strong acid.
B. Because $Mg(OH)_2$ is listed in Table 15.5.2, it is a weak base.
C. Since it is implied this must be an acid or a base, it must be a base since it does not have H out at the front of the formula. It can be assumed that C_5H_5N would act as a proton acceptor and therefore act as a base. Since it does not contain a OH^- ion, it cannot be considered a strong base; it is a weak base.

✏️ Exercise 15.5.1

Identify each acid or base as strong or weak.

A. LiOH
B. HNO_2

Answer A

strong base

Answer B

weak acid

✅ Example 15.5.2: Characterizing Base Ionization

Write the balanced chemical equation for the dissociation of $Ba(OH)_2$ and indicate whether it proceeds 100% to products or not.

Solution

This is an ionic compound of Ba^{2+} ions and OH^- ions. When an ionic compound dissolves, it separates into its constituent ions:

$$\mathrm{Ba(OH)_2}\ (aq) \xrightarrow{100\%} \mathrm{Ba^{2+}}\ (aq) + 2\ \mathrm{OH^-}\ (aq)$$

$Ba(OH)_2$ is listed in Table 15.5.1, so this reaction proceeds 100% to products.

✏️ Exercise 15.5.2

Write the balanced chemical equation for the ionization of nitrous acid (HNO_2) and indicate whether it proceeds 100% to products or not.

Answer

The reaction is as follows:

$$\mathrm{HNO_2}\ (aq) + \mathrm{H_2O}\ (l) \rightleftharpoons \mathrm{H_3O^+}\ (aq) + \mathrm{NO_2^-}\ (aq)$$

It does not proceed 100% to products because nitrous acid is a weak acid.

Key Takeaways

- Strong acids and bases are 100% ionized in aqueous solution.
- Weak acids and bases are less than 100% ionized in aqueous solution.