

# Chemistry

SIXTH EDITION

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Raymond Chang

*Williams College*

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# Acids and Bases

## INTRODUCTION

SOME OF THE MOST IMPORTANT PROCESSES IN CHEMICAL AND BIOLOGICAL SYSTEMS ARE ACID-BASE REACTIONS IN AQUEOUS SOLUTIONS. IN THIS FIRST OF TWO CHAPTERS ON THE PROPERTIES OF ACIDS AND BASES, WE WILL STUDY THE DEFINITIONS OF ACIDS AND BASES, THE pH SCALE, THE IONIZATION OF WEAK ACIDS AND WEAK BASES, AND THE RELATIONSHIP BETWEEN ACID STRENGTH AND MOLECULAR STRUCTURE. WE WILL ALSO LOOK AT OXIDES THAT CAN ACT AS ACIDS OR BASES.

- 15.1** BRØNSTED ACIDS AND BASES
- 15.2** THE ACID-BASE PROPERTIES OF WATER
- 15.3** pH—A MEASURE OF ACIDITY
- 15.4** STRENGTH OF ACIDS AND BASES
- 15.5** WEAK ACIDS AND ACID IONIZATION CONSTANTS
- 15.6** WEAK BASES AND BASE IONIZATION CONSTANTS
- 15.7** THE RELATIONSHIP BETWEEN THE IONIZATION CONSTANTS OF ACIDS AND THEIR CONJUGATE BASES
- 15.8** DIPROTIC AND POLYPROTIC ACIDS
- 15.9** MOLECULAR STRUCTURE AND THE STRENGTH OF ACIDS
- 15.10** ACID-BASE PROPERTIES OF SALTS
- 15.11** ACID-BASE PROPERTIES OF OXIDES AND HYDROXIDES
- 15.12** LEWIS ACIDS AND BASES

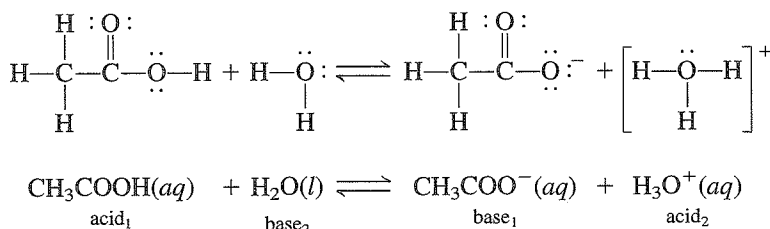
## 15.1 BRØNSTED ACIDS AND BASES

In Chapter 4 we defined a Brønsted acid as a substance capable of donating a proton, and a Brønsted base as a substance that can accept a proton. These definitions are generally suitable for a discussion of the properties and reactions of acids and bases.

Conjugate means  
"joined together."

An extension of the Brønsted definition of acids and bases is the concept of the *conjugate acid-base pair*, which can be defined as *an acid and its conjugate base or a base and its conjugate acid*. The conjugate base of a Brønsted acid is the species that remains when one proton has been removed from the acid. Conversely, a conjugate acid results from the addition of a proton to a Brønsted base.

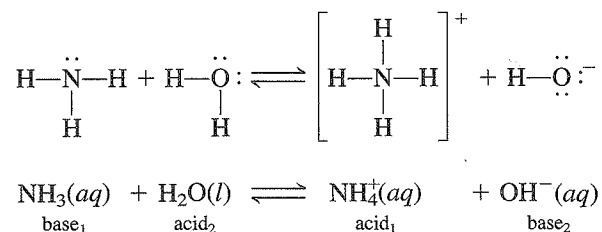
Every Brønsted acid has a conjugate base, and every Brønsted base has a conjugate acid. For example, the chloride ion ( $\text{Cl}^-$ ) is the conjugate base formed from the acid  $\text{HCl}$ , and  $\text{H}_2\text{O}$  is the conjugate base of the acid  $\text{H}_3\text{O}^+$  (hydronium ion). Similarly, the ionization of acetic acid can be represented as



The formula of a conjugate base always has one fewer hydrogen atom and one more negative charge (or one fewer positive charge) than the formula of the corresponding acid.

The subscripts 1 and 2 designate the two conjugate acid-base pairs. Thus the acetate ion ( $\text{CH}_3\text{COO}^-$ ) is the conjugate base of  $\text{CH}_3\text{COOH}$ . Both the ionization of  $\text{HCl}$  (see Section 4.3) and the ionization of  $\text{CH}_3\text{COOH}$  are examples of Brønsted acid-base reactions.

The Brønsted definition also allows us to classify ammonia as a base because of its ability to accept a proton:



In this case,  $\text{NH}_4^+$  is the conjugate acid of the base  $\text{NH}_3$ , and the hydroxide ion  $\text{OH}^-$  is the conjugate base of the acid  $\text{H}_2\text{O}$ . Note that the atom in the Brønsted base that accepts a  $\text{H}^+$  ion must have a lone pair.

In Example 15.1 we identify the conjugate pairs in an acid-base reaction.

**EXAMPLE 15.1**

Identify the conjugate acid-base pairs in the reaction between ammonia and hydrofluoric acid in aqueous solution



**Answer** The conjugate acid-base pairs are (1)  $\text{HF}$  (acid) and  $\text{F}^-$  (base) and (2)  $\text{NH}_4^+$  (acid) and  $\text{NH}_3$  (base).

Similar problem: 15.5.

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