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Contents in Brief

CHAPTER 15

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.

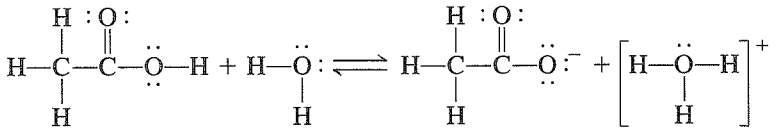
15.1 BRØNSTED ACIDS AND BASES

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.

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.

Conjugate means "joined together."

Every Brønsted acid has a conjugate base, and every Brønsted base has a conjugate acid. For example, the chloride ion (Cl^-) is the conjugate base formed from the acid HCl, and H_2O is the conjugate base of the acid H_3O^+ (hydronium ion). Similarly, the ionization of acetic acid can be represented as

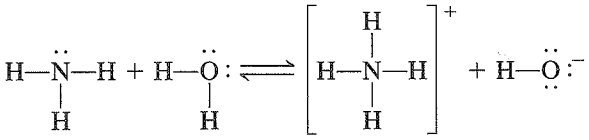


$$\underset{\text{acid}_1}{CH_3COOH(aq)} + \underset{\text{base}_2}{H_2O(l)} \rightleftharpoons \underset{\text{base}_1}{CH_3COO^-(aq)} + \underset{\text{acid}_2}{H_3O^+(aq)}$$

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 (CH_3COO^-) is the conjugate base of CH_3COOH. Both the ionization of HCl (see Section 4.3) and the ionization of CH_3COOH 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:



$$\underset{\text{base}_1}{NH_3(aq)} + \underset{\text{acid}_2}{H_2O(l)} \rightleftharpoons \underset{\text{acid}_1}{NH_4^+(aq)} + \underset{\text{base}_2}{OH^-(aq)}$$

In this case, NH_4^+ is the conjugate acid of the base NH_3, and the hydroxide ion OH^- is the conjugate base of the acid H_2O. Note that the atom in the Brønsted base that accepts a 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

$$NH_3(aq) + HF(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)$$

Answer The conjugate acid-base pairs are (1) HF (acid) and F^- (base) and (2) NH_4^+ (acid) and NH_3 (base).

Similar problem: 15.5.

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