

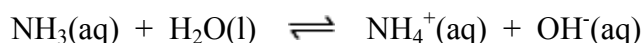
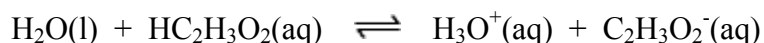
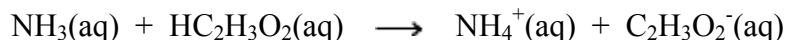
Brønsted-Lowry Acids and Bases

Although the Arrhenius definitions of acid, base, and acid-base reaction are very useful, an alternate set of definitions is also commonly employed. In this alternate system, called the Brønsted-Lowry system, an **acid** is a proton (H^+) donor, a **base** is a proton acceptor, and an **acid-base reaction** is a proton transfer. The table below summarizes the definitions of acid and base in the Arrhenius and Brønsted-Lowry systems.

Acid and Base Definitions

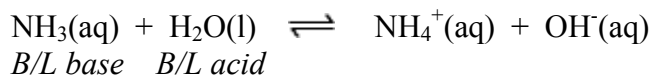
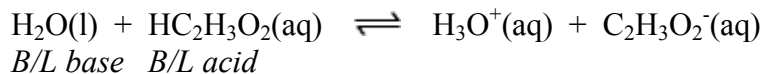
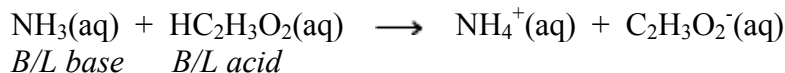
System	Acid Definition	Base Definition
Arrhenius	Generates H_3O^+ when added to water	Generates OH^- when added to water
Brønsted-Lowry	Proton (H^+) Donor in Reaction	Proton (H^+) Acceptor in Reaction

To better understand the differences and to understand why new definitions were suggested, consider the following reactions.

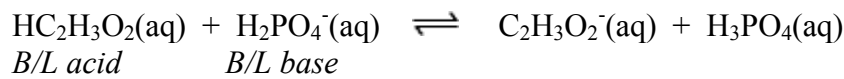


These reactions are very similar, but only the first reaction would be considered an acid-base reaction in the Arrhenius system. In each of the reactions, an H^+ is transferred from one reactant to another, but only the first is a reaction between an Arrhenius acid and an Arrhenius base. In the first reaction, an H^+ is transferred from the Arrhenius weak acid acetic acid, $\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$, to the Arrhenius weak base ammonia, $\text{NH}_3(\text{aq})$. In the second reaction, an H^+ is transferred from the Arrhenius weak acid acetic acid, $\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$, to water, which is not considered an acid or a base in the Arrhenius sense. In the third reaction, an H^+ is transferred from water, which is not considered an acid or base in the Arrhenius sense, to the Arrhenius weak base ammonia, $\text{NH}_3(\text{aq})$.

The Brønsted-Lowry system allows us to describe all of these reactions as acid-base reactions. They are repeated below, with the Brønsted-Lowry acids and bases labeled. Note that in each case the acid loses an H^+ ion as it reacts, and the base gains an H^+ ion.



Acetic acid reacts with the dihydrogen phosphate polyatomic ion, H_2PO_4^- , in a reversible reaction. In the forward reaction, acetic acid acts as the Brønsted-Lowry acid and dihydrogen phosphate acts as the Brønsted-Lowry base



The reverse reaction, too, is a Brønsted-Lowry acid-base reaction: an H^+ ion is transferred from H_3PO_4 (the acid) to a $\text{C}_2\text{H}_3\text{O}_2^-$ ion (the base). The Brønsted-Lowry base for the forward reaction (H_2PO_4^-) gains an H^+ ion to form H_3PO_4 , which then acts as a Brønsted-Lowry acid in the reverse reaction and returns the H^+ ion to $\text{C}_2\text{H}_3\text{O}_2^-$. Chemists say that H_3PO_4 is the conjugate acid of H_2PO_4^- . The **conjugate acid** of a molecule or ion is the molecule or ion that forms when one H^+ ion is added. The formulas H_3PO_4 and H_2PO_4^- represent a **conjugate acid-base pair**, which are molecules or ions that differ by one H^+ ion.

Likewise, the Brønsted-Lowry acid for the forward reaction ($\text{HC}_2\text{H}_3\text{O}_2$) loses an H^+ ion to form $\text{C}_2\text{H}_3\text{O}_2^-$, which acts as a Brønsted-Lowry base in the reverse reaction and regains the H^+ ion. Chemists say that $\text{C}_2\text{H}_3\text{O}_2^-$ is the conjugate base of $\text{HC}_2\text{H}_3\text{O}_2$. The **conjugate base** of a molecule or ion is the molecule or ion that forms when one H^+ ion is removed. The formulas $\text{HC}_2\text{H}_3\text{O}_2$ and $\text{C}_2\text{H}_3\text{O}_2^-$ represent a conjugate acid-base pair.

EXAMPLE - Conjugate Acids: Write the formula for the conjugate acid of (a) F^- , (b) NH_3 , (c) HSO_4^- , and (d) CrO_4^{2-} .

Solution:

In each case, the formula for the conjugate acid is derived by adding one H^+ ion to the formulas above.

- a. **HF** b. **NH_4^+** c. **H_2SO_4** d. **HCrO_4^-**

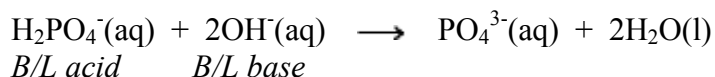
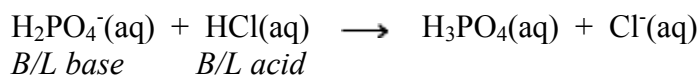
EXAMPLE - Conjugate Bases: Write the formula for the conjugate base of (a) HClO_3 , (b) H_2SO_3 , (c) H_2O , and (d) HCO_3^- .

Solution:

In each case, the formula for the conjugate base is derived by removing one H^+ ion from the formulas above.

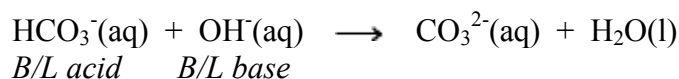
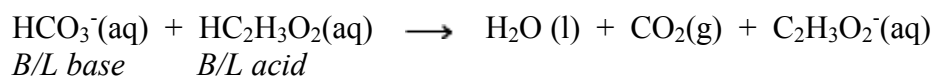
- a. **ClO_3^-** b. **HSO_3^-** c. **OH^-** d. **CO_3^{2-}**

Some substances can act as a Brønsted-Lowry acid in one reaction and a Brønsted-Lowry base in another. Consider the following net ionic equations for the reaction of dihydrogen phosphate ion with either the acid hydrochloric acid or the strong base hydroxide.

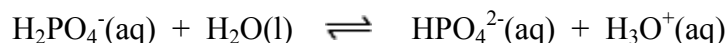
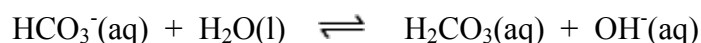


In the first reaction, the dihydrogen phosphate acts as a Brønsted-Lowry base, and in the second reaction, it acts as a Brønsted-Lowry acid. A substance that can act as either a Brønsted-Lowry acid or a Brønsted-Lowry base, depending on the circumstances, is called **amphoteric**.

The hydrogen carbonate ion is another example of an amphoteric substance. In the first reaction below, it acts as a Brønsted-Lowry base, and in the second reaction, it acts as a Brønsted-Lowry acid.



Because both dihydrogen phosphate and hydrogen carbonate can be either Brønsted-Lowry acids or bases, neither can be described as a Brønsted-Lowry acid or base except with reference to a specific acid-base reaction. For this reason, the Arrhenius definitions of acids and bases are the ones used to categorize isolated substances on the stockroom shelf. A substance generates either hydronium ions, hydroxide ions, or neither when added to water, so it is always either an acid, a base, or neutral in the Arrhenius sense. Hydrogen carbonate is an Arrhenius base because it yields hydroxide ions when added to water. Dihydrogen phosphate is an Arrhenius acid because it generates hydronium ions when added to water.



Thus, we have two systems for describing acids, bases, and acid-base reactions. The Brønsted-Lowry system is often used to describe specific acid-base reactions, but the Arrhenius system is used to describe whether isolated substances are acids, bases, or neither.

EXAMPLE - Brønsted-Lowry Acids and Bases: Identify the Brønsted-Lowry acid and base for the forward reaction in each of the following equations..

- a. $\text{HClO}_2(\text{aq}) + \text{NaIO}(\text{aq}) \longrightarrow \text{HIO}(\text{aq}) + \text{NaClO}_2(\text{aq})$
- b. $\text{HS}^-(\text{aq}) + \text{HF}(\text{aq}) \longrightarrow \text{H}_2\text{S}(\text{aq}) + \text{F}^-(\text{aq})$
- c. $\text{HS}^-(\text{aq}) + \text{OH}^-(\text{aq}) \longrightarrow \text{S}^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- d. $\text{H}_3\text{AsO}_4(\text{aq}) + 3\text{NaOH}(\text{aq}) \longrightarrow \text{Na}_3\text{AsO}_4(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$

Solution:

- a. The HClO_2 loses an H^+ ion, so it is the Brønsted-Lowry acid. The IO^- in the NaIO gains the H^+ ion, so the NaIO is the Brønsted-Lowry base.
- b. The HF loses an H^+ ion, so it is the Brønsted-Lowry acid. The HS^- gains the H^+ ion, so it is the Brønsted-Lowry base.
- c. The HS^- loses an H^+ ion, so it is the Brønsted-Lowry acid. The OH^- gains the H^+ ion, so it is the Brønsted-Lowry base.
- d. The H_3AsO_4 loses three H^+ ions, so it is the Brønsted-Lowry acid. Each OH^- in NaOH gains an H^+ ion, so the NaOH is the Brønsted-Lowry base.