BRONSTED LOWRY: CONJUGATE ACID BASE PAIR

PREREQUISITES

- Arrhenius concept of acids and bases.
- Hydrogen donor and acceptor species

LEARNING OUTCOMES

- Knowledge of Lowry concept of acids and bases
- Conjugated acid base pair concept

Brønsted-Lowry Acids and Bases

What distinguishes an acid from a base in the Brønsted-Lowry theory?

Brønsted-Lowry Acids and Bases

Sodium carbonate (Na_2CO_3) and ammonia (NH_3) act as bases when they form aqueous solutions.

- Neither of these compounds is a hydroxide-containing compound, so neither would be classified as a base by the Arrhenius definition.

Brønsted-Lowry Acids and Bases

In 1923, the Danish chemist Johannes Brønsted and the English chemist Thomas Lowry were working independently.

- Each chemist proposed the same definition of acids and bases.

Brønsted-Lowry Acids and Bases

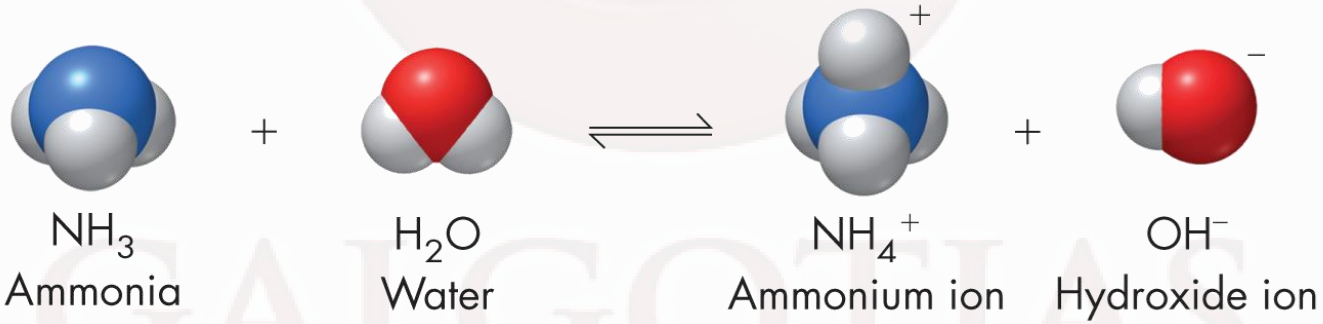
According to the Brønsted-Lowry theory, an acid is a hydrogen-ion donor and a base is a hydrogen-ion acceptor.

- This theory includes all the acids and bases that Arrhenius defined.
- It also includes some compounds that Arrhenius did not classify as bases.

Brønsted-Lowry Acids and Bases

You can use the Brønsted-Lowry theory to understand why ammonia is a base.

- When ammonia dissolves in water, hydrogen ions are transferred from water to ammonia to form ammonium ions and hydroxide ions.



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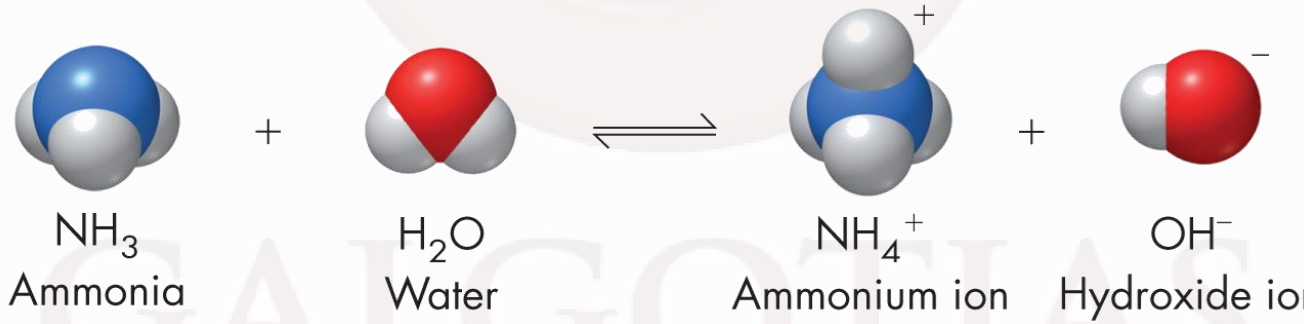


  - Ammonia is a Brønsted-Lowry base because it accepts hydrogen ions.
  - Water is a Brønsted-Lowry acid because it donates hydrogen ions.

Conjugate Acids and Bases

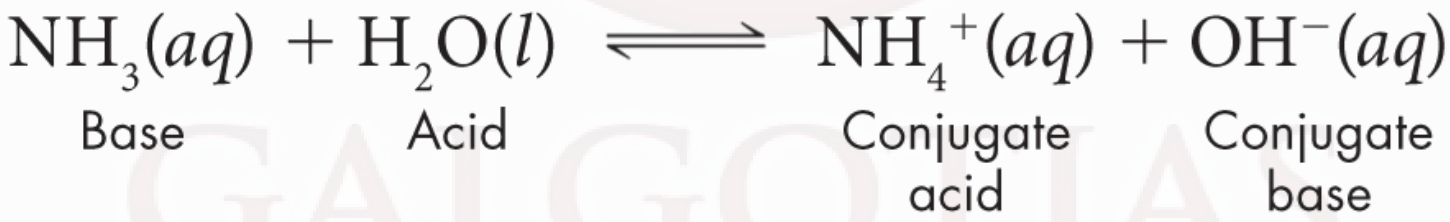
When the temperature of an aqueous solution of ammonia is increased, ammonia gas is released.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

- HNH_4^+ reacts with OH^- to form more NH_3 and H_2O.
- In the reverse reaction, ammonium ions donate hydrogen ions to hydroxide ions.
  - NH_4^+ (the donor) acts as a Brønsted-Lowry acid, and OH^- (the acceptor) acts as a Brønsted-Lowry base.

Conjugate Acids and Bases

In essence, the reversible reaction of ammonia and water has two acids and two bases.



Conjugate Acids and Bases

A **conjugate acid** is the ion or molecule formed when a base gains a hydrogen ion.

- NH_4^+ is the conjugate acid of the base NH_3.

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

Conjugate Acids and Bases

A **conjugate base** is the ion or molecule that remains after an acid loses a hydrogen ion.

- OH^- is the conjugate base of the acid H_2O.

$$\underset{\text{Base}}{NH_3(aq)} + \underset{\text{Acid}}{H_2O(l)} \rightleftharpoons \underset{\substack{\text{Conjugate}\\\text{acid}}}{NH_4^+(aq)} + \underset{\substack{\text{Conjugate}\\\text{base}}}{OH^-(aq)}$$

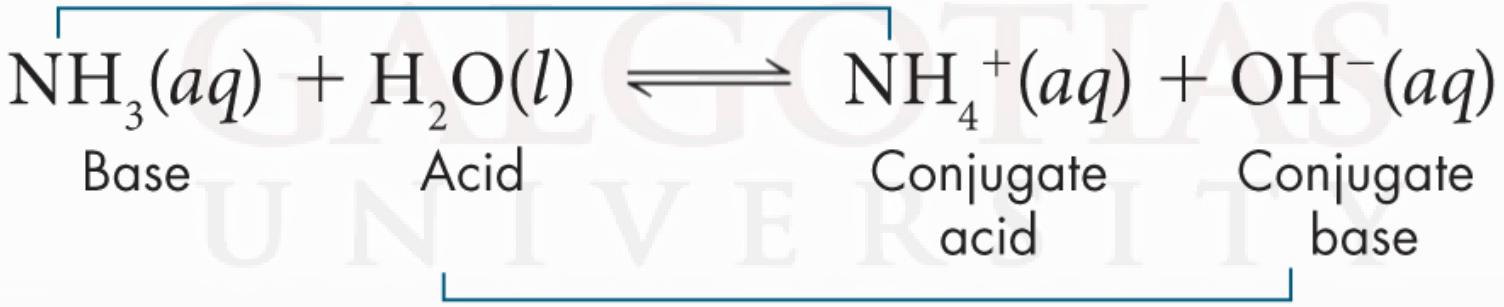
Conjugate Acids and Bases

Conjugate acids are always paired with a base, and conjugate bases are always paired with an acid.

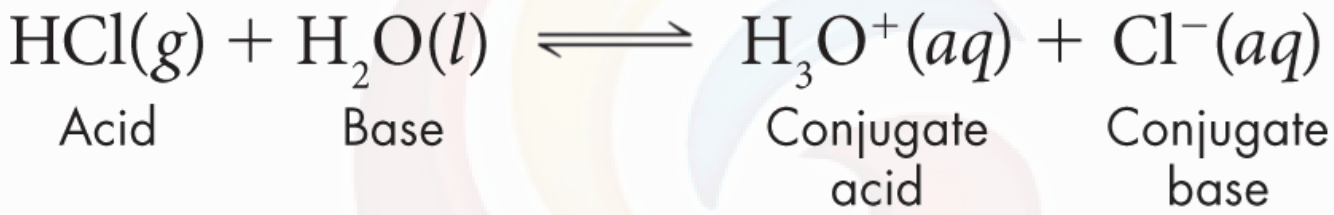
- A **conjugate acid-base pair** consists of two ions or molecules related by the loss or gain of one hydrogen ion.

Conjugate Acids and Bases

- The ammonia molecule and the ammonium ion are a conjugate acid-base pair.
- The water molecule and the hydroxide ion are also a conjugate acid-base pair.



Conjugate Acids and Bases



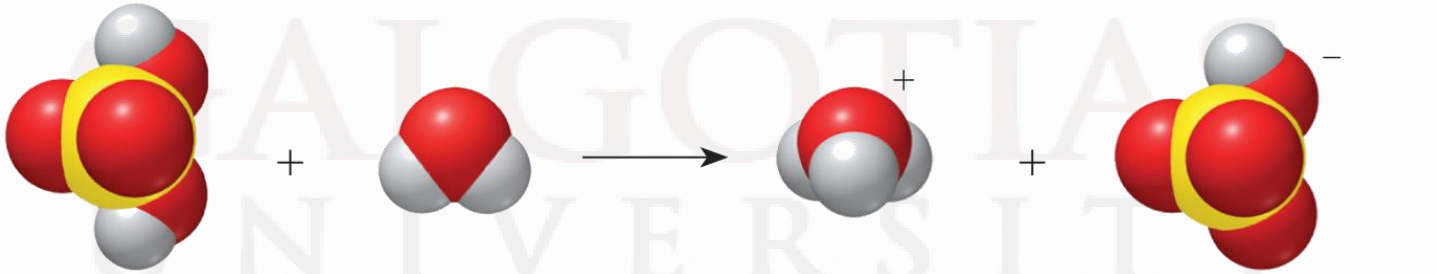
In this reaction, hydrogen chloride is the hydrogen-ion donor and is by definition a Brønsted-Lowry acid. Water is the hydrogen-ion acceptor and a Brønsted-Lowry base.

- The chloride ion is the conjugate base of the acid HCl.
- The hydronium ion is the conjugate acid of the water base.

Conjugate Acids and Bases

The figure below shows the reaction that takes place when sulfuric acid dissolves in water.

- The products are hydronium ions and hydrogen sulfate ions.
- Use the figure to identify the two conjugate acid-base pairs.



Some Conjugate Acid-Base Pairs	
Acid	**Base**
HCl	Cl^-
H_2SO_4	HSO_4^-
H_3O^+	H_2O
HSO_4^-	SO_4^{2-}
CH_3COOH	CH_3COO^-
H_2CO_3	HCO_3^-
HCO_3^-	CO_3^{2-}
NH_4^+	NH_3
H_2O	OH^-

Amphoteric Substances

Note that water appears in both the list of acids and the list of bases.

- Sometimes water accepts a hydrogen ion.
- At other times, it donates a hydrogen ion.
- How water behaves depends on the other reactant.

Some Conjugate Acid-Base Pairs

Acid	Base
HCl	Cl^-
H_2SO_4	HSO_4^-
H_3O^+	H_2O
HSO_4^-	SO_4^{2-}
CH_3COOH	CH_3COO^-
H_2CO_3	HCO_3^-
HCO_3^-	CO_3^{2-}
NH_4^+	NH_3
H_2O	OH^-

Amphoteric Substances

A substance that can act as either an acid or a base is said to be **amphoteric**.

- Water is amphoteric.
  - In the reaction with hydrochloric acid, water accepts a proton and is therefore a base.
  - In the reaction with ammonia, water donates a proton and is therefore an acid.

Checkpoint

How can one substance, such as water, be both an acid and a base, according to the Brønsted-Lowry definition?

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How can one substance, such as water, be both an acid and a base, according to the Brønsted-Lowry definition?

Because water can act as both a hydrogen-ion donator and a hydrogen-ion acceptor, it can act as both an acid and a base according to the Brønsted-Lowry definition.

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