

# Theory of acids and bases

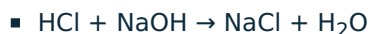
**Acids** and **bases** can be viewed from different angles. In any case, these are substances which, when they react with each other, give rise to compounds with which they form so-called "conjugated pairs".

## Arrhenius theory

It is a rather outdated theory that an acid is a compound that splits off a **proton** (hydrogen cation)<sup>[1]</sup>, and a base by a substance that cleaves the OH<sup>-</sup> anion. They react together to form water. Acid and base residues in turn form a salt.

A general scheme with acid **HA** and base **BOH** can be written as follows:  $\text{HA} + \text{BOH} \rightarrow \text{BA} + \text{H}_2\text{O}$

### Example of theory application



HCl acid cleaves H<sup>+</sup> while NaOH base cleaves OH<sup>-</sup>.

Disadvantages: the only possible solvent is water

## Brønsted-Lowry theory

Brønsted-Lowry theory<sup>[2]</sup> considers an acid as a proton-releasing substance, a base as a proton-accepting compound. An acid becomes a conjugate base (eg a salt of a given acid) and a base becomes a conjugate acid (eg water).

If the acid-base reaction (as an equilibrium reaction) reacts in the indicated direction, it is possible to assume, according to thermodynamic considerations, that the conjugated acid and base will be weaker than the original. This can be used to determine the predominant direction of the reaction.

The general scheme with the acid **HA** and the base **B** can be written as:  $\text{HA} + \text{B} \rightarrow \text{A}^- + \text{BH}^+$ .

Water can both accept protons ( $\text{H}_2\text{O} + \text{HA} \rightarrow \text{H}_3\text{O}^+ + \text{A}^-$ ) and give off ( $\text{H}_2\text{O} + \text{B} \rightarrow \text{OH}^- + \text{BH}^+$ ), depending on the environment, it can therefore be both an acid and a base and ranks so among substances **amphoteric**.

The dissociation constant determining the strength of an acid where water appears as a base for comparison is then defined as

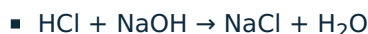
$$K_a = K_{eq} \cdot [\text{H}_2\text{O}] = \frac{[\text{H}_3\text{O}^+] \cdot [\text{A}^-]}{[\text{HA}]}$$

and her **pK<sub>a</sub>** as

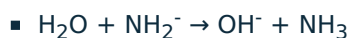
$$\text{p}K_a = -\log K_a$$

Stronger acids (higher  $K_a$ ) have lower pK<sub>a</sub> and weaker acids (lower  $K_a$ ) have higher pK<sub>a</sub>.

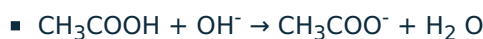
### Examples of theory application



Here, as in the previous theory, HCl acid gives up H<sup>+</sup>, however, NaOH does not formally cleave OH<sup>-</sup>, but on the contrary accepts H<sup>+</sup> (with simultaneous splitting OH<sup>-</sup>), which allows expansion even for bases without a hydroxide group.



The acid H<sub>2</sub>O splits off a proton and the base NH<sub>2</sub><sup>-</sup> (although it does not have OH<sup>-</sup>) accepts it. The conjugate base OH<sup>-</sup> and the conjugate acid NH<sub>3</sub> are formed. Although NH<sub>3</sub> normally behaves as a base, it is worth mentioning that in a large excess of OH<sup>-</sup> it can also behave as an acid.



The acid CH<sub>3</sub>COOH donates a proton and becomes the conjugate base CH<sub>3</sub>COO<sup>-</sup> and the base OH<sup>-</sup> accepts a proton and becomes the conjugate acid H<sub>2</sub>O.

## Examples of Brønsted acids and bases

**Acids:** methanol ( $pK_a = 15.54$ ), acetic acid ( $pK_a = 4.76$ ), acetone ( $pK_a = 19.3$ )

**Base:** methylamine, methanol, acetone

## Lewisian theory

According to the Lewis theory<sup>[2]</sup>, an acid is a compound accepting a free electron pair (it provides its vacant orbital), while a base is its donor (or acceptor of a vacant orbital). This theory is therefore an even greater generalization of the terms *acid* and *base*. As a particle accepting a free electron pair (and providing a free electron orbital), not only a proton (it has a free 1s orbital) but also other compounds (metal ions, metal compounds, etc.) need to serve.

Whether the compound will react as an acid or as a base depends very much on the conditions and on which part of the molecule is involved in the reaction ("acetic acid" will react with sulfuric acid as a "base" because the carbonyl or hydroxyl is protonated oxygen, as it has free electron pairs).

## Examples of Lewis acids and bases

**Acids:** HCl, HBr, HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, CH<sub>3</sub> COOH, PhOH, CH<sub>3</sub>CH<sub>2</sub>OH, **Li<sup>+</sup>**, **Mg<sup>2+</sup>**, **Br<sup>+</sup>**, **AlCl<sub>3</sub>**, **BF<sub>3</sub>**, **TiCl<sub>4</sub>**, **FeCl<sub>3</sub>**, **ZnCl<sub>2</sub>**

**Base:** alcohols, ethers, aldehydes, ketones, carboxylic acid chlorides, carboxylic acids, esters, amides, amines, sulfides

## Links

### Related Articles

- pH

### References

1. International Union of Pure and Applied Chemistry. *IUPAC Gold Book* [online]. [cit. 2010-05-08]. <<http://goldbook.iupac.org/html/H/H02904.html>>.
2. MCMURRY, John. *Organic Chemistry*. 6e, International Student Edition edition. Brooks/Coel, Thomson Learning, 2004. 1176 pp. pp. 43–55. ISBN 0-534-42005-2.