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It is a rather outdated theory that an acid is a compound that splits off a **proton** (hydrogen cation)[1], and a base by a substance that cleaves the OH^- anion.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: $HA + BOH \rightarrow BA + H_2O$

Example of theory application

- $HCl + NaOH \rightarrow NaCl + H_2O$

  HCl acid cleaves H^+ while NaOH base cleaves OH^-.

Disadvantages: the only possible solvent is water

Brønsted-Lowry theory

Brønsted-Lowry theory[2] 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: $\mathbf{HA + B \rightarrow A^- + BH^+}$.

Water can both accept protons ($H_2O + HA \rightarrow H_3O^+ + A^-$) and give off ($H_2O + B \rightarrow OH^- + BH^+$), 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

$$K_a = K_{eq} \cdot [\mathrm{H_2O}] = \frac{[\mathrm{H_3O^+}] \cdot [\mathrm{A^-}]}{[\mathrm{HA}]}$$

and her ***pK***

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

Stronger acids (higher K_a) have lower pK_a and weaker acids (lower K_a) have higher pK_a.

Examples of theory application

- $HCl + NaOH \rightarrow NaCl + H_2O$

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

- $H_2O + NH_2^- \rightarrow OH^- + NH_3$

  The acid H_2O splits off a proton and the base NH_2^- (although it does not have OH^-) accepts it. The conjugate base OH^- and the conjugate acid NH_3 are formed. Although NH_3 normally behaves as a base, it is worth mentioning that in a large excess of OH^- it can also behave as an acid.

- $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2 O$

  The acid CH_3COOH donates a proton and becomes the conjugate base CH_3COO^- and the base OH^- accepts a proton and becomes the conjugate acid H_2O.

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[2], 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_3, H_2SO_4, CH_3 COOH, PheOH, CH_3CH_2OH, **Li^+**, **Mg^{2+}**, **Br^+**, **$AlCl_3$**, **BF_3**, **$TiCl_4$**, **$FeCl_3$**, **$ZnCl_2$**

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

Links

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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.