BRAC UNIVERSITY

Inspiring Excellence

Acid-Base Concept

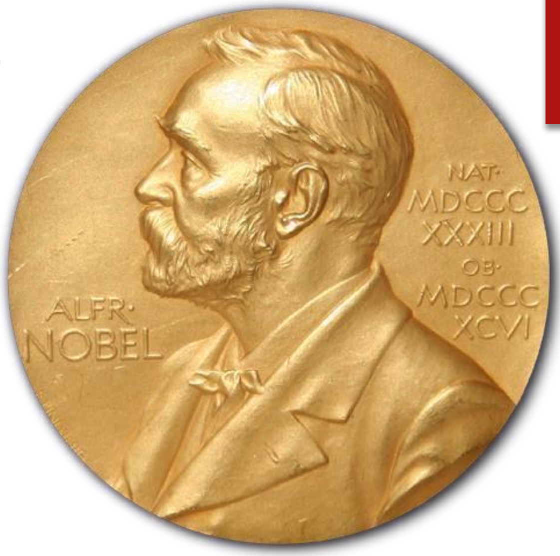
Part-01

Course: CHE101: Introduction To Chemistry

Presented By-Muhammad Mahfuz Hasan

Svante Arrhenius (1859-1927)

Swedish scientist



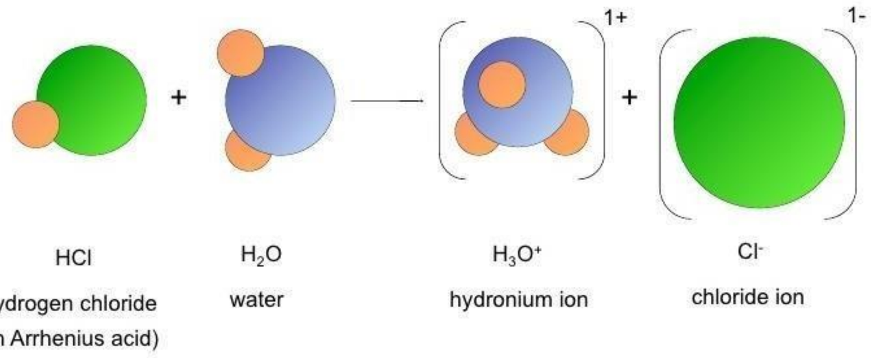
The Nobel Prize in Chemistry 1903 was awarded to Svante August Arrhenius "in recognition of the extraordinary services he has rendered to the advancement of chemistry by his electrolytic theory of dissociation."

ARRHENIUS concept of acids and bases

Savante Arrhenius (1884) proposed his concept of acids and bases. According to this concept, an acid is a compound that releases H+ ions in water; and a base is a compound that releases OH– ions in water. For example, HCl is an Arrhenius acid and NaOH is an Arrhenius base.

$$HCl(aq) \longrightarrow H^{+}(aq) + Cl^{-}(aq)$$

$$NaOH(aq) \qquad OH^{-}(aq) + Na^{+}(aq)$$



Limitations of Arrhenius concept

- It is only applicable in aqueous solutions. Arrhenius defined acids and bases as compounds producing H+ and OH– ions in water only. But a truly general concept of acids and bases should be appropriate to other solvents as well.

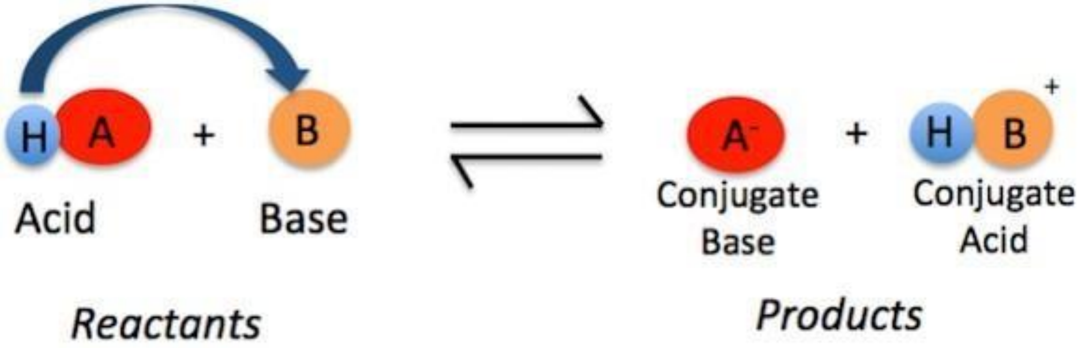
- Some bases do not contain OH– Arrhenius base is one that produces OH– ions in water. Yet there are compounds like ammonia (NH3) and calcium oxide (CaO) that are bases but contain no OH– ions in their original formulation.

BRONSTED–LOWRY CONCEPT

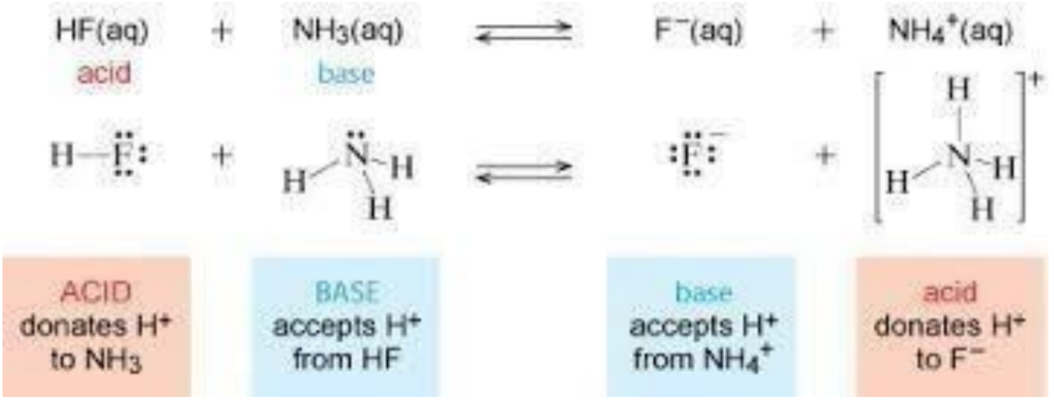
In 1923 J.N. Bronsted and J.M. Lowry independently proposed a broader concept of acids and bases. According to this theory,

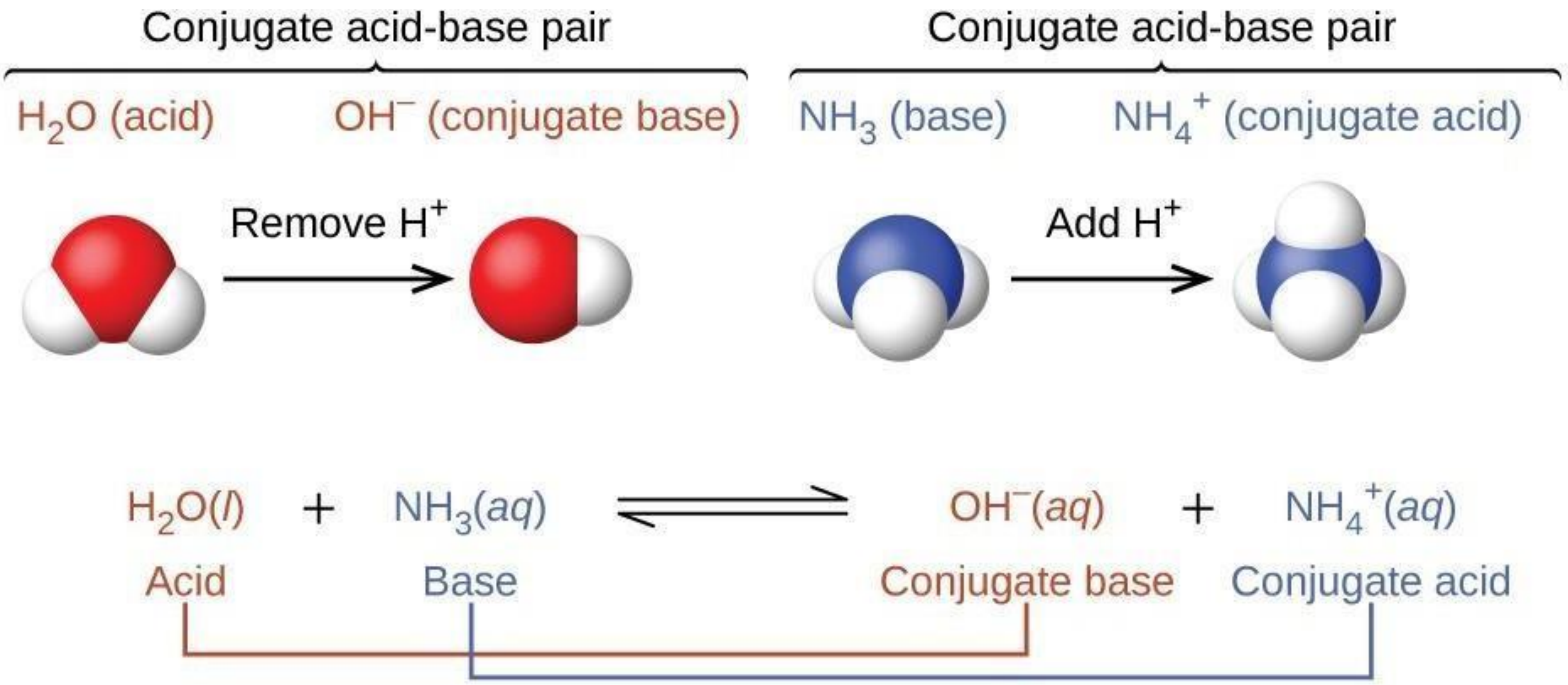
an acid is any molecule or ion that can donate a proton (H+)
a base is any molecule or ion that can accept a proton

For brevity we can say that an acid is a proton donor while a base is a proton acceptor.



Bronsted-Lowry Acid-Base Reaction

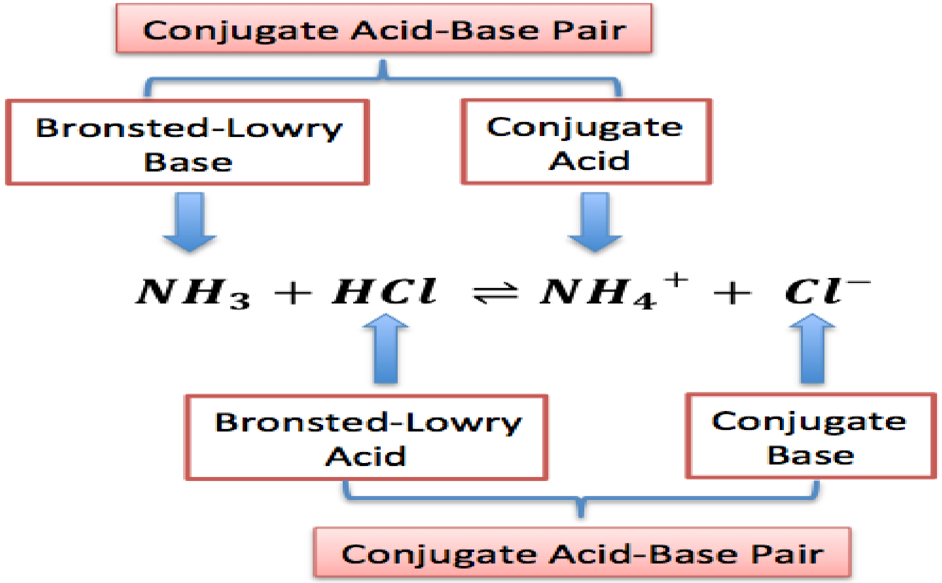



Conjugate acid-base pair
H_2O (acid)
OH^- (conjugate base)
Remove H^+
Conjugate acid-base pair
NH_3 (base)
NH_4^+ (conjugate acid)
Add H^+
$H_2O(l) + NH_3(aq) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$
Acid
Base
Conjugate base
Conjugate acid

Bronsted-Lowry concept is superior to Arrhenius concept

(1)Much wider scope. Arrhenius concept of acids and bases is restricted to the study of substances which can release **H+ or OH– ions** in water. Bronsted-Lowry concept embraces all molecules and ions that can donate a **proton** (acids) and those which can accept a proton (bases).

(2)Not limited to aqueous solutions. The Bronsted-Lowry model is not limited to aqueous solutions as is the case with Arrhenius model. It can be extended even to the gas phase. For example, gaseous ammonia (a Bronsted base) can react with hydrogen chloride gas (a Bronsted acid) to give ammonium chloride.



Lewis concept of acids and bases

LEWIS CONCEPT OF ACIDS AND BASES

In the early 1930s, G.N. Lewis proposed even a more general model of acids and bases. According to Lewis theory,

an acid is an electron-pair acceptor

a base is an electron-pair donor

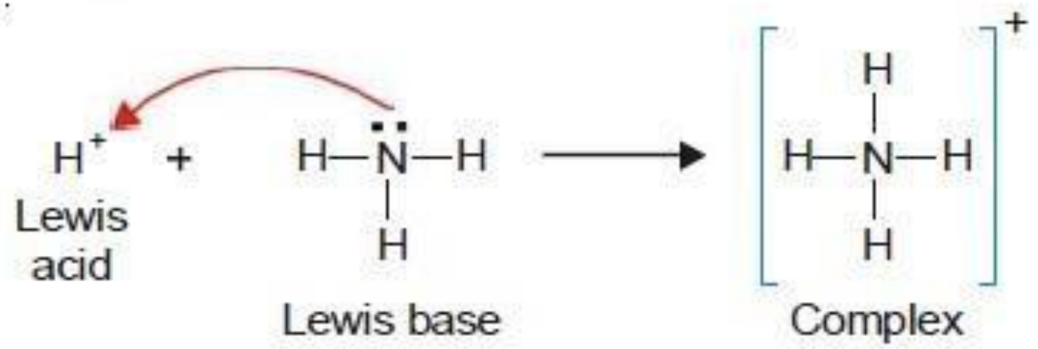
Lewis pictured an acid and base as sharing the electron pair provided by the base. This creates a covalent bond (or coordinate bond) between the **Lewis acid** and the **Lewis base.** The resulting combination is called a **Complex**. If the Lewis acid be denoted by A and the Lewis base by B, then the fundamental equation of the Lewis theory can be written as :

$$\underset{\text{Lewis acid}}{A} + \underset{\text{Lewis base}}{:B} \longrightarrow \underset{\text{Complex}}{A - B}$$

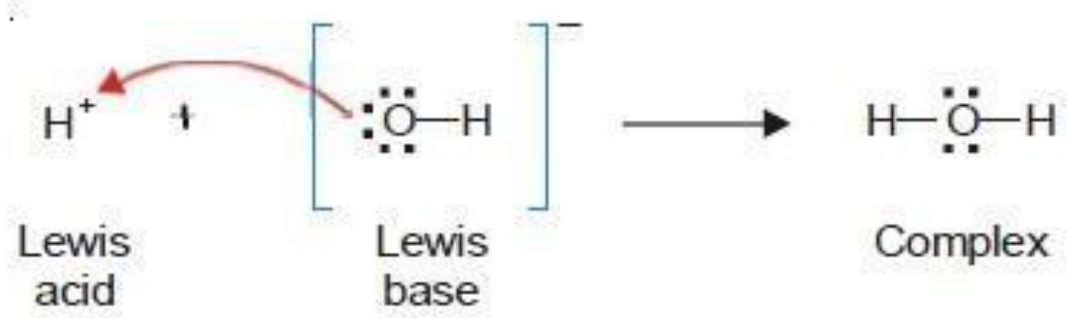
It may be noted that : (1) all cations or molecules short of an electron-pair act as Lewis acids; and (2) all anions or molecules having a lone electron-pair act as Lewis bases.

Examples of Lewis reactions

(1) **Between H^+ and NH_3.** Proton (H^+) is a Lewis acid as it can accept an electron-pair. Ammonia molecule ($:NH_3$) has an electron-pair which it can donate and is a Lewis base. Thus the Lewis reaction between H^+ and NH_3 can be written as :



(2) **Between H^+ and OH^-.** A proton (H^+) is an electron-pair acceptor and, therefore, a Lewis acid. The OH^- is an electron-pair donor and hence a Lewis base. Thus Lewis reaction between H^+ and OH^- can be written as :



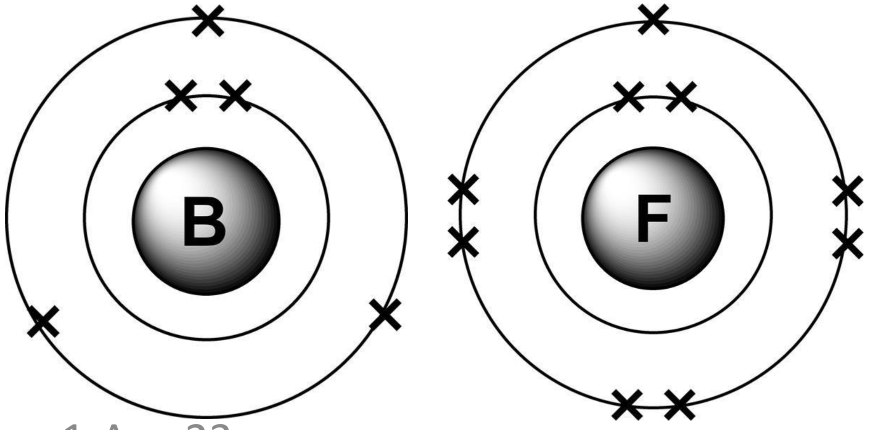
Superiority of Lewis model of acids and bases

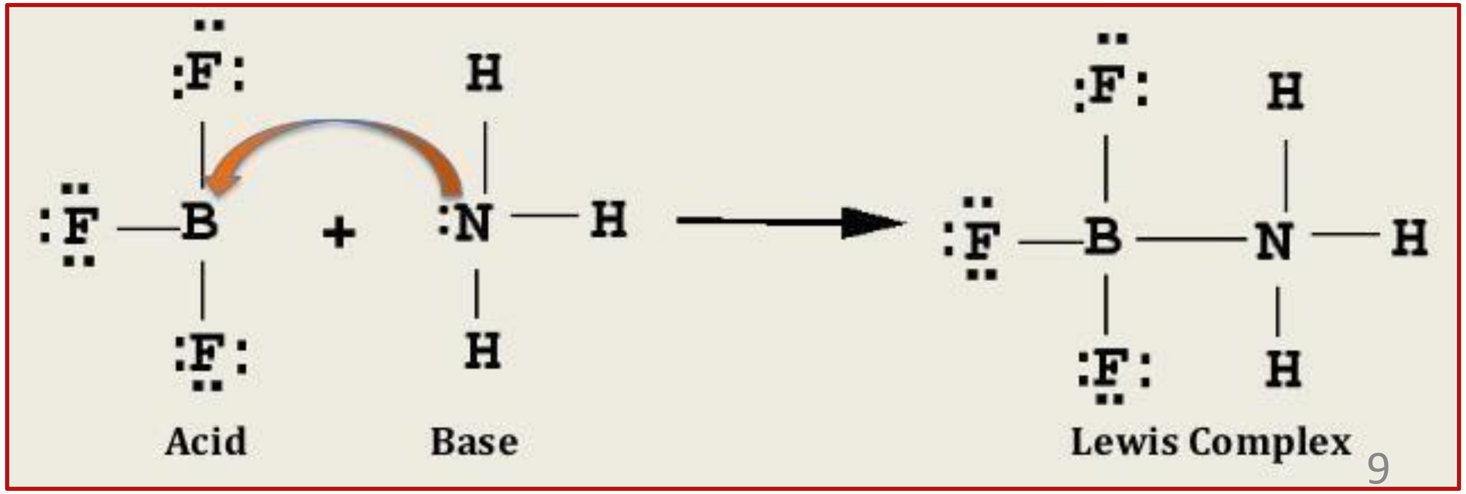
The advantages of the Lewis acid-base model are :

(1) All the Bronsted-Lowry acid base reactions are covered by the Lewis model. It is so because the transfer or gain of a proton is accompanied by the loss or donation of an electron-pair in both types of reactions.

(2) Many reactions which do not involve transfer of a proton are also covered by the Lewis theory. *e.g.*,

$$\mathbf{BF3 + NH3 \longrightarrow BF3 - NH3}$$

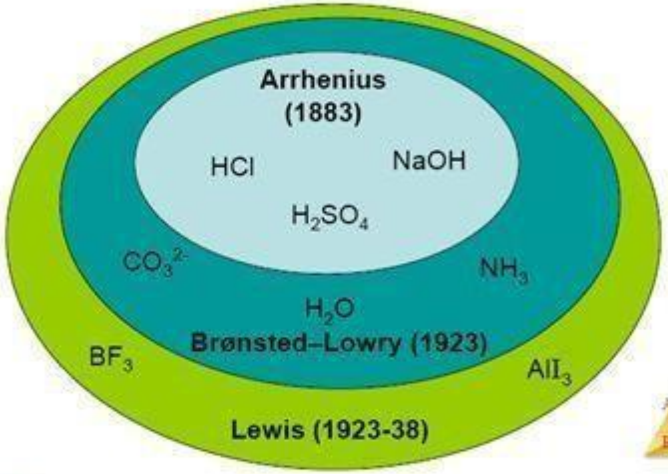


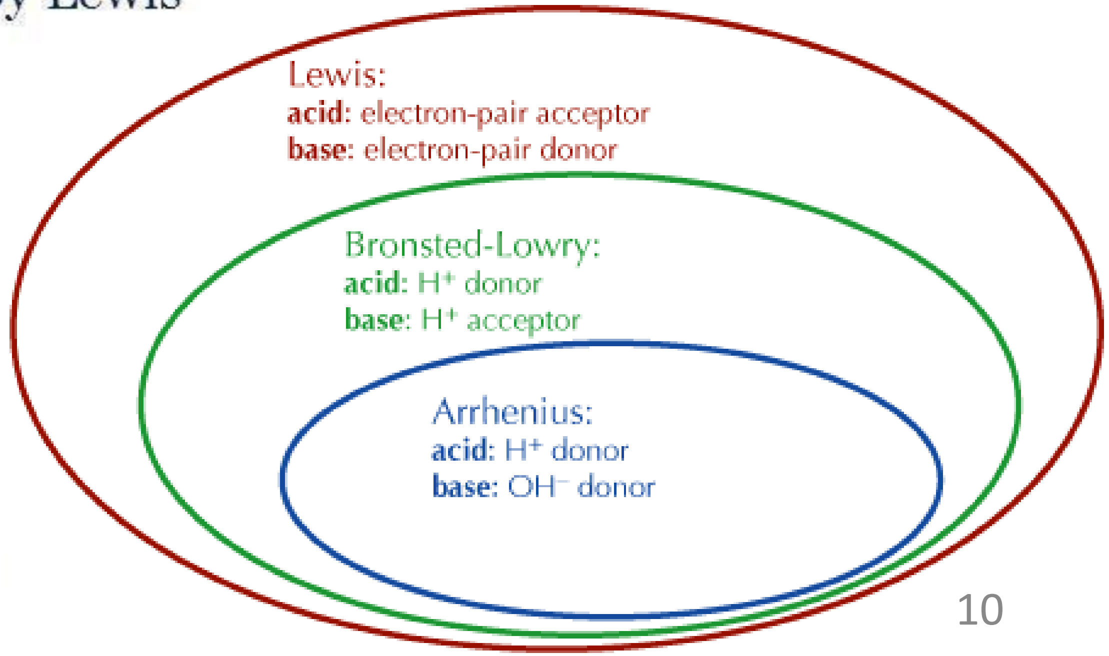


Comparison of Bronsted–Lowry an Lewis Theories of Acids and Bases

Theory	Definition of acid	Definition of base
Bronsted–Lowry	Proton donor	Proton acceptor
Lewis	Electron pair acceptor	Electron pair donor

Although all Bronsted-Lowry acids are Lewis acids, not all Lewis acids are Bronsted-Lowry acids, so the term Lewis acids are usually reserved for those species which can only be described by Lewis theory (that is those that do not release H^+).





Acid–base indicators

- When the amount of the base added equals the amount of the acid in the flask, the **equivalence point** or the **end-point** is reached.
- The end-point of a titration is shown by colour change of an indicator previously added to the acid solution in the receiver flask.
- **An acid-base indicator is an organic dye that signals the end-point by a visual change in colour.**
- **Phenolphthalein and methyl orange are two common examples of acid-base indicators.**
- Phenolphthalein is pink in base solution and colourless in acid solution.
- When added to the acid solution in the receiver flask, it shows no colour. As the added base is in slight excess, it becomes pink. Thus phenolphthalein signals the end-point by a colour change from colourless to pink.
- Similarly methyl orange indicates the end-point by a colour change from red (in acid) to yellow (in base).

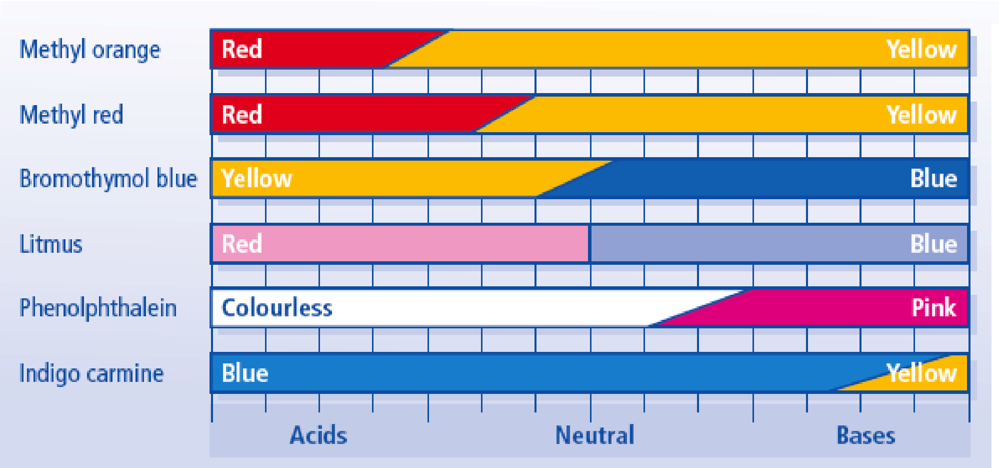
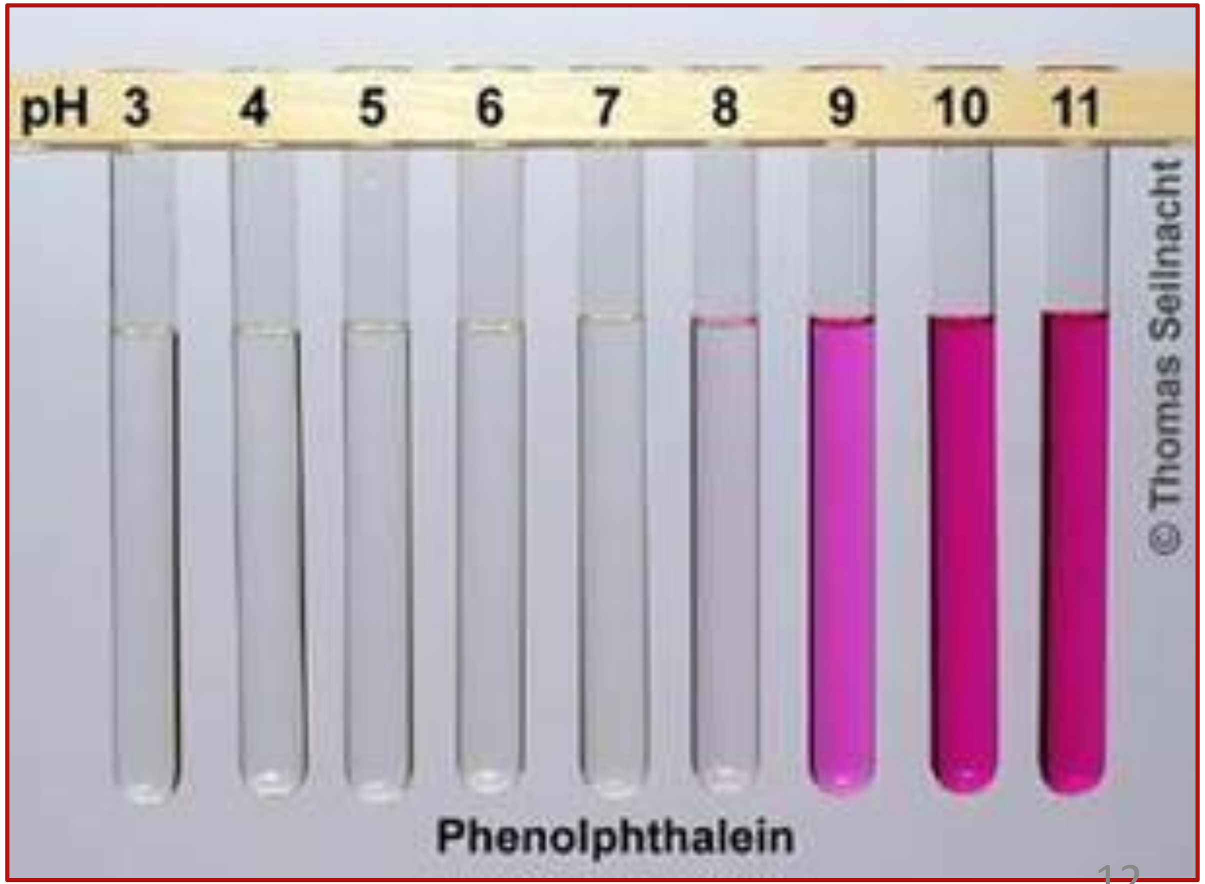


TABLE 27.5. pH RANGES OF SOME ACID-BASE INDICATORS

Indicator	Colour change (acid-base)	pH range
Methyl orange	red-orange	3.1 – 4.4
Methyl red	red-yellow	4.4 – 6.0
Litmus	red-blue	5.0 – 8.0
Bromothymol blue	yellow-blue	6.0 – 7.6
Phenolphthalein	colourless-pink	8.3 – 10.0

METHYL ORANGE

PHENOLPHTHALEIN



Titration

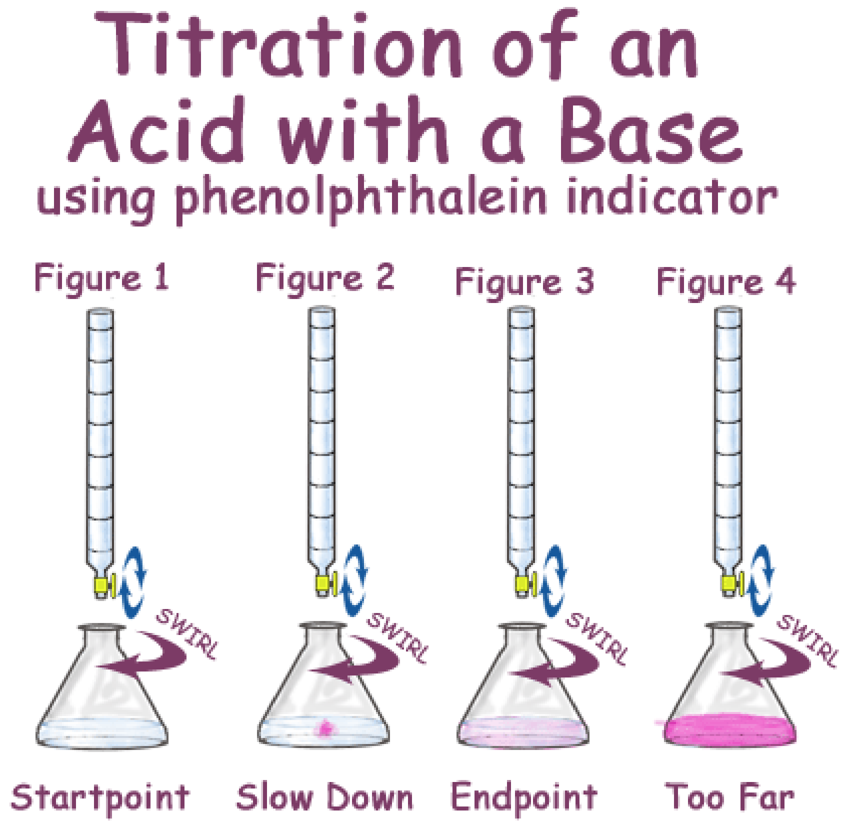
Titration is the slow **addition of one solution of a known concentration** (called a titrant) to a **known volume of another solution of unknown concentration** until the reaction reaches neutralization, which is often indicated by a color change. In titration the known concentration is used to determine the concentration of an unknown solution.

Choice of a suitable indicator

The choice of a suitable indicator for a particular acid-base titration depends on the nature of the acid and the base involved in the titration. We may have the titration of :

(a) a strong acid with a strong base
(b) a weak acid with a strong base
(c) a strong acid with a weak base
(d) a weak acid with weak base

Which indicator is suitable for a given titration, can be found by examining the titration curve of that titration.



Theories of acid-base indicators

Two theories have been put forward to explain the indicator action in acid-base titrations :

(1) The Ostwald's theory
(2) The Quinonoid theory

The Ostwald's theory:

According to this theory :

(1) an acid-base indicator is a weak organic acid (HIn) or a weak organic base (InOH), where the letter "In" stands for a complex orange group. Methyl orange and phenolphthalein are both weak acids.
(2) the un-ionised indicator, HIn, has a colour different from the In^- ions produced by the ionization of the indicator in aqueous solution.
(3) the degree of ionisation of the indicator determines the visible colour of the indicator solution.

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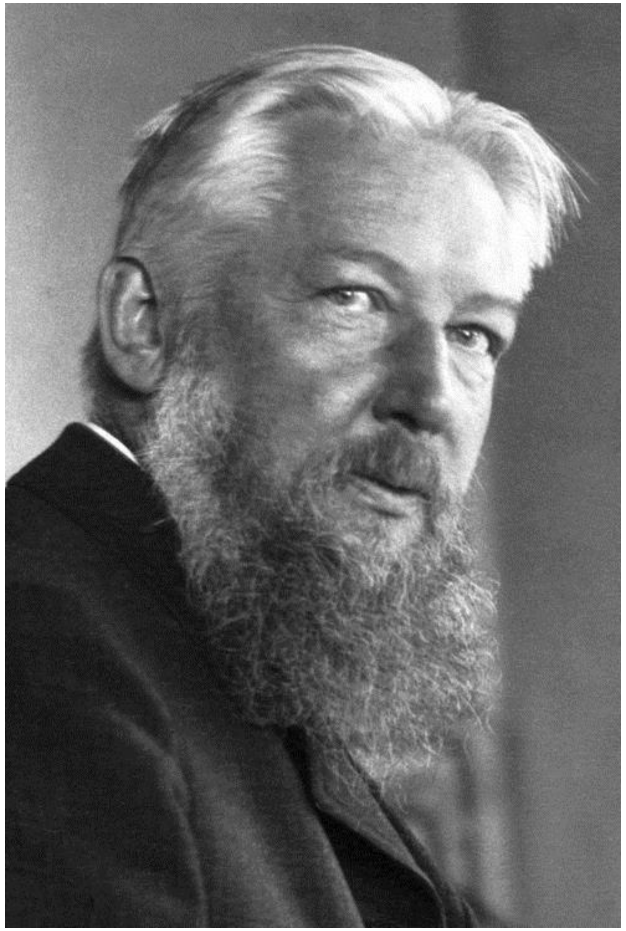
Wilhelm Ostwald 1853-1932



The Nobel Prize in Chemistry 1909 was awarded to Wilhelm Ostwald "in recognition of his work on catalysis and for his investigations into the fundamental principles governing chemical equilibria and rates of reaction."

THEORY OF INDICATORS:

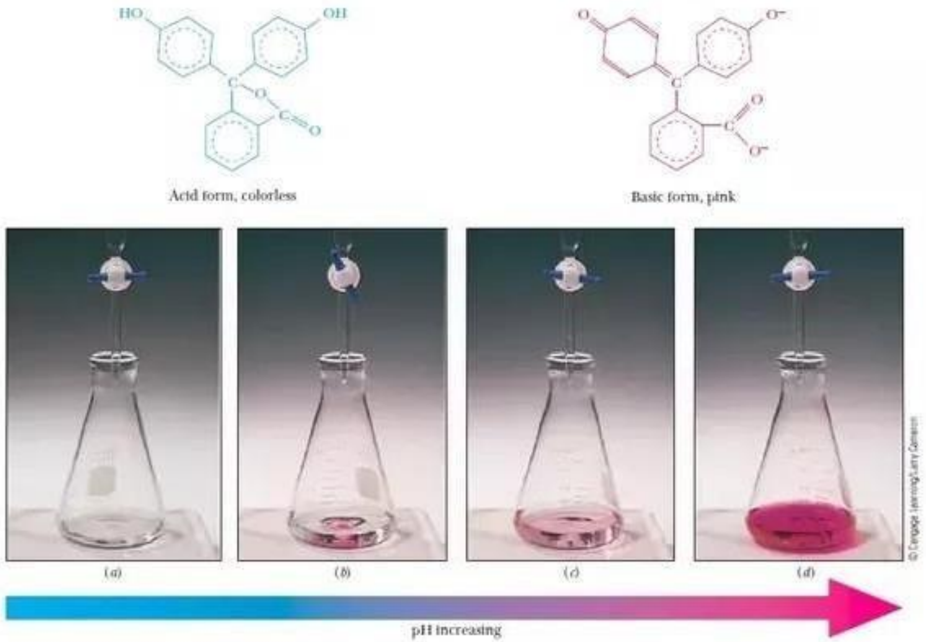
$$\underset{\text{(colorless)}}{HPh} \rightleftharpoons \underset{\text{(colorless)}}{H^+} + \underset{\text{(pink color)}}{Ph^-}$$

1. Ostwald's theory:

Phenolphthalein: It can be represented as HPh. It ionises in solution to a small extent as:

$$\underset{\text{Colourless}}{HPh} \leftrightarrow H^+ + \underset{\text{Pink}}{Ph^-}$$

The undissociated molecules of phenolphthalein are colourless while Ph^- ions are pink in colour. In presence of an acid the ionisation of HPh is practically negligible as the equilibrium shifts to left hand side due to high concentration of H^+ ions. Thus, the solution would remain colourless. On addition of alkali, hydrogen ions are removed by OH^- ions in the form of water molecules and the equilibrium shifts to right hand side. Thus, the concentration of Ph^- ions increases in solution and they impart pink colour to the solution.



Phenolphthalein. Drawings show the acid and base forms of phenolphthalein, an indicator commonly used for the titration of an acid with strong base. *(a)* The acidic solution is initially clear. *(b)* When base is added, the solution turns pink momentarily but disappears with swirling. *(c)* The first permanent pink indicates the endpoint. *(d)* The solution is vividly colored beyond the equivalence point, where base is in excess.

According to Arrhenius concept base is a compound that releases ________in water

a. H^+ ion
b. OH^- ions
c. Both

b. OH^- ions

Which concept is superior explaining the acid/base nature of molecules?

a. Arrhenius concept
b. Bronsted-Lowry
c. Lewis concept

c. Lewis concept

Ammonia can act as base according to the Bronsted-Lowry concept.

a. True
b. False

a. True

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