

## Arrhenius Concept of Acidity & Basicity

### Historical Background

Acids and bases have been known for a long time. When **Robert Boyle** characterized them in **1680**, he noted that acids dissolve many substances, change the color of certain natural dyes (for example, they change litmus from blue to red), and lose these characteristic properties after coming into contact with alkalis (bases).

In **18<sup>th</sup> century**, it was recognized that acids have a sour taste, react with limestone to liberate a gaseous substance (now known to be  $\text{CO}_2$ ), and interact with alkalis to form neutral substances. In **1815**, **Humphry Davy** contributed greatly to the development of the modern acid-base concept by demonstrating that hydrogen is the essential constituent of acids. Around that same time, **Joseph Louis Gay-Lussac** concluded that acids are substances that can neutralize bases and that these two classes of substances can be defined only in terms of each other.

The significance of hydrogen was reemphasized in **1887** by the Swedish scientist **Svante Arrhenius**, that acids are substances that dissociate in water to yield electrically charged atoms or molecules, called ions or hydrogen cations (now recognized to be hydronium ions  $\text{H}_3\text{O}^+$ ) and a base as a compound that dissolves in water to yield hydroxide anions ( $\text{OH}^-$ ) as;

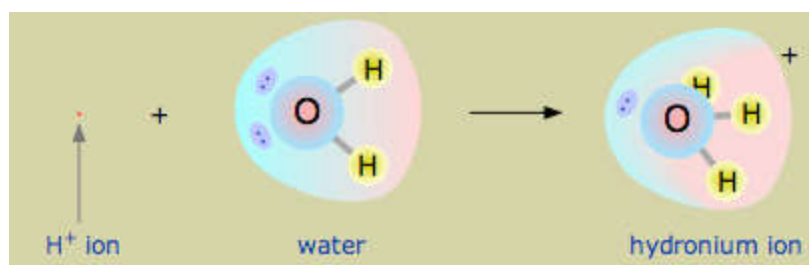
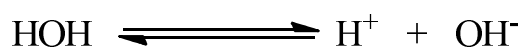
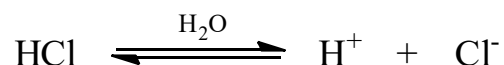


Fig 1. Acid dissociation in water

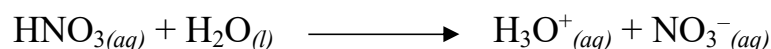
### Arrhenius acid

According to this concept, an acid is any hydrogen containing compounds which gives  $\text{H}^+$  ions in aqueous solution and a base which gives  $\text{OH}^-$  ions aqueous solution. The concentration of the  $\text{H}^+$  ions (*proton*) is increased by forming

hydronium ion. For example, hydrochloric acid in the water where HCl undergoes dissociation reaction to produce  $H^+$  ion and  $Cl^-$  ion, as explained below.



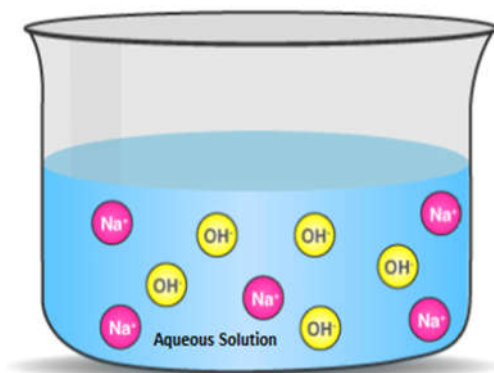
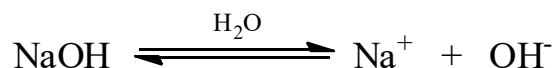
Another example of Arrhenius acid in which nitric acid dissolves in aqueous water to give hydrogen and nitrate ions is listed below;



Other examples of Arrhenius acid includes Hydrochloric acid (HCl), Nitric acid ( $HNO_3$ ), Sulfuric acid ( $H_2SO_4$ ), Phosphoric acid ( $H_3PO_4$ ), Carbonic acid ( $H_2CO_3$ ) and Acetic acid ( $CH_3COOH$ ).

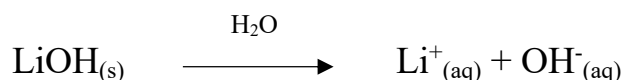
### Arrhenius Base

An Arrhenius base is a substrate that increases the concentration of hydroxide ions in the aqueous solution. The example for Arrhenius base is highly soluble sodium hydroxide compound in water, which dissociates to give sodium ion and hydroxide ion. In aqueous solution, NaOH completely dissolves to give hydroxide ion and sodium ion, to increase the concentration of hydroxide ions.



**Fig 2.** Base dissociation in water

Another example of Arrhenius base are 1st and 2nd group hydroxides, such as LiOH and Ba(OH)<sub>2</sub>.



In the above reaction, lithium hydroxide dissolves in water to give lithium-ion and hydroxide ion. Some Arrhenius bases are Sodium hydroxide (NaOH), Potassium hydroxide (KOH), Calcium hydroxide Ca(OH)<sub>2</sub>, Magnesium hydroxide Mg(OH)<sub>2</sub>.

*In American practice, OH<sup>-</sup> is frequently called the hydroxide ion. The International Union of Pure and Applied Chemistry (IUPAC) now recommends hydroxide for this species. In many equations, the shorthand H<sup>+</sup> notation is used, for which the IUPAC recommends the terms hydron or hydrogen ion, rather than proton.*

## Utility of the Concept

- (i) Since the reaction representing neutralization process involving the combination H<sup>+</sup> and OH<sup>-</sup> ions, the approximately constant molar heat neutralization would be expected. *Thus the constant heat of neutralization of strong acid by a strong base is readily understandable in terms of this concept.*
- (ii) This *concept has offered a means* of correlating catalytic behaviour with the concentration of the H<sup>+</sup> ion.

## Limitations

- (i) According to this concept, HCl is regarded as an acid only when *dissolved in H<sub>2</sub>O* and not in some other solvent such as C<sub>6</sub>H<sub>6</sub> or when it exists in the gaseous form.
- (ii) *It cannot account for the acidic and basic character of the material in non-aqueous solvents, e.g., NH<sub>4</sub>NO<sub>3</sub> in liq. NH<sub>3</sub> acts as an acid, though it does not give H<sup>+</sup> ions.*  
Similarly *many organic materials and NH<sub>3</sub>*, which *do not have OH<sup>-</sup> ions* at all, are actually known to *show basic character*.

- (iii) The neutralization process is *limited to those reactions* which can occur *in aqueous solutions only*, although reactions involving salt formation do occur in many other solvents and even in the absence of solvents.
- (iv) It *cannot explain the acidic character of certain salts* such as  $\text{AlCl}_3$  aqueous solution.