Republic of Iraq Ministry of Higher
Education & Scientific Research
University of Al-Maarif
College of Dentistry

Chimical proprites of acids and bases

Lec(2)

First stage

By
Qusay Abdulsattar

Chimical proprites of acids

(i) Reaction with Metals

Acids react explosively with metals like sodium, potassium and calcium. However, dilute acids (HCl, H2SO4) react moderately with reactive metals like: Mg, Zn, Fe and Al to form their respective salts with the evolution of hydrogen.

$$Zn_{(s)} + H_2SO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + H_{2(g)}\uparrow$$

$$2Al_{(s)} + 6HCl_{(aq)} \longrightarrow 2AlCl_{3(aq)} + 3H_{2(g)}\uparrow$$

(ii) **Reaction with Carbonates and Bicarbonates**

Acids react with carbonates and bicarbonates to form corresponding salts with the evolution of carbon dioxide gas.

$$CaCO_{3(aq)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)}\uparrow + H_2O_{(l)}$$

$$2NaHCO_{3(aq)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2CO_{2(g)}\uparrow + 2H_2O_{(l)}$$

(iii) Reaction with Bases

Acids react with bases (oxides and hydroxides of metal and ammonium hydroxide) to form salts and water. This process is called neutralization.

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

$$CuO_{(s)} + H_2SO_{4(aq)} \longrightarrow CuSO_{4(aq)} + H_2O_{(l)}$$

(iv) Reaction with Sulphites and Bisulphites

Acids react with sulphites and bisulphites to form salts with the liberation of sulphur dioxide gas.

$$CaSO_{3(aq)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + SO_{2(g)} \uparrow + H_2O_{(l)}$$

$$NaHSO_{3(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + SO_{2(g)} \uparrow + H_2O_{(l)}$$

(v) Reaction with Sulphides

Acids react with metal sulphides to liberate hydrogen sulphide gas.

$$FeS_{(s)} + H_2SO_{4(aq)} \longrightarrow FeSO_{4(aq)} + H_2S_{(g)} \uparrow$$

Following acids are called mineral acids.

Hydrochloric acid (HCl), Sulphuric acid (H2SO4), Nitric acid (HNO3)

Naturally Occurring Acids		
	Acid	Source
i	Citric acid	Citrus fruits i.e., lemon, oranges
ii	Lactic acid	sour milk
iii	Formic acid	Stings of bees and ants
iv	Butyric acid	Rancid butter
v	Tartaric acid	Tamarind, grapes, apples
vi	Malic acid	Apples
vii	Uric acid	Urine
viii	Stearic acid	Fats

Uses of Acids

1. **Sulphuric acid** is used to manufacture fertilizers, ammonium sulphate, calcium superphosphate,explosives, paints, dyes, drugs. It is also used as an electrolyte in lead storage batteries.
2. **Nitric acid** is used in manufacturing of fertilizer (ammonium nitrate), explosives, paints, drugs and etching designs on copper plates.
3. **Hydrochloric** acid is used for cleaning metals, tanning and in printing industries.
4. **Benzoic acid** is used for food preservation.
5. **Acetic acid** is used for flavouring food and food preservation. It is also used to cure the sting of wasps.

Examples of some important acids and bases

Acid

- Hydrochloric acid, HCI
- Nitric acid, HNO3
- Sulphuric acid, H2SO4
- Phosphoric acid, H3PO4

Base

- Sodium hydroxide, NaOH
- Potassium hydroxide, KOH
- Calcium hydroxide, Ca(OH)2
- Aluminium hydroxide, Al(OH)3

Limitations of Arrhenius Concept

1. This concept is applicable only in aqueous medium and does not explain nature of acids and bases in non-aqueous medium.

2. According to this concept, acids and bases are only those compounds which contain hydrogen (H+) and hydroxide (OH) ions, respectively. It can’t explain the nature of compounds like CO2, NH3, etc. which are acid and base, respectively.

Although this concept has limited scope yet, it led to the development of more general theories

of acid-base behaviour.

Bronsted-Lowry Concept

In 1923, the Danish chemist Bronsted and the English chemist Lowry independently presented their theories of acids and bases on the basis of proton-transfer. According to this concept:

An acid is a substance (molecule or ion) that can donate a proton (H+) to another substance.

A base is a substance that can accept a proton (H+)from another substance.

For example, HCl acts as an acid while NH3 acts as a base:

$$HCl_{(aq)} + NH_{3(aq)} \rightleftharpoons NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$$

Similarly, when HC1 dissolves in water; HC1 acts as an acid and H_2O as a base.

$$\underset{\text{Acid}}{HCl_{(aq)}} + \underset{\text{Base}}{H_2O_{(aq)}} \rightleftharpoons \underset{\text{Conjugate acid}}{H_3O^+{}_{(aq)}} + \underset{\text{Conjugate base}}{Cl^-{}_{(aq)}}$$

It is a reversible reaction. In the forward reaction, HCl is an acid as it donates a proton, whereas H2O is a base as it accepts a proton. In the reverse reaction, Cl- ion is a base as it accepts a proton from acid H3O+ ion. CI- ion is called a conjugate base of acid HCl and H3O+ion is called a conjugate acid of base H2O. It means every acid produces a conjugate base and every base produces a conjugate acid such that there is conjugate acid-base pair. Conjugate means joined together as a pair.

A conjugate acid is a specie formed by accepting a proton by a base.
A conjugate base is a specie formed by donating a proton by an acid.

Thus, conjugate acid-base pair differs from one another only by a single proton.

Similarly

$$\underset{\text{Acid}}{CH_3COOH_{(aq)}} + \underset{\text{Base}}{H_2O_{(aq)}} \rightleftharpoons \underset{\text{Conjugate base}}{CH_3COO^-_{(aq)}} + \underset{\text{Conjugate acid}}{H_3O^+_{(aq)}}$$

According to Bronsted-Lowry concept, an acid and a base always work together to transfer a proton. That means, a substance can act as an acid (proton donor) only when another substance simultaneously behaves as a base (proton acceptor). Hence, a substance can act as an acid as well as a base, depending upon the nature of the other substance. For example, H2O acts as a base when it reacts with HCl as stated above and as an acid when it reacts with ammonia such as:

$$H_2O_{(l)} + NH_{3(aq)} \rightleftharpoons NH_4^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$$

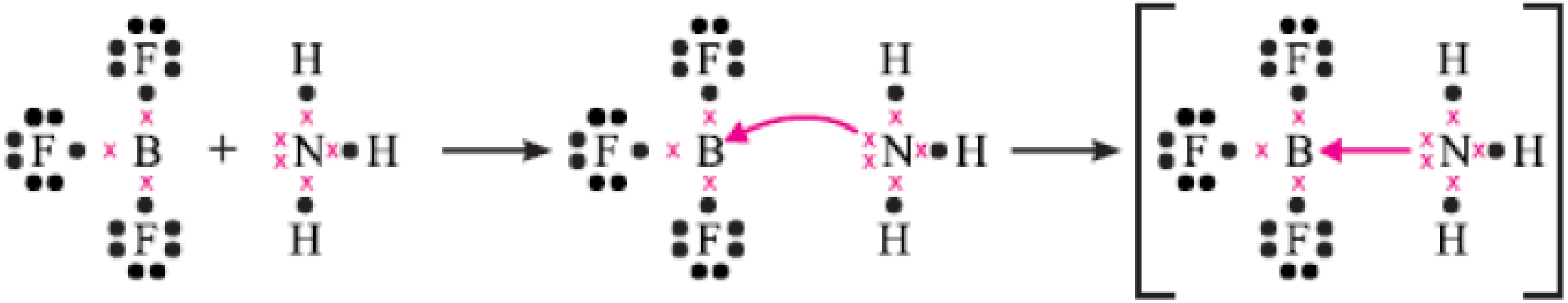
Such a substance that can behave as an acid, as well as, a base is called amphoteric.

It has been observed that there are certain substances which behave as acids.

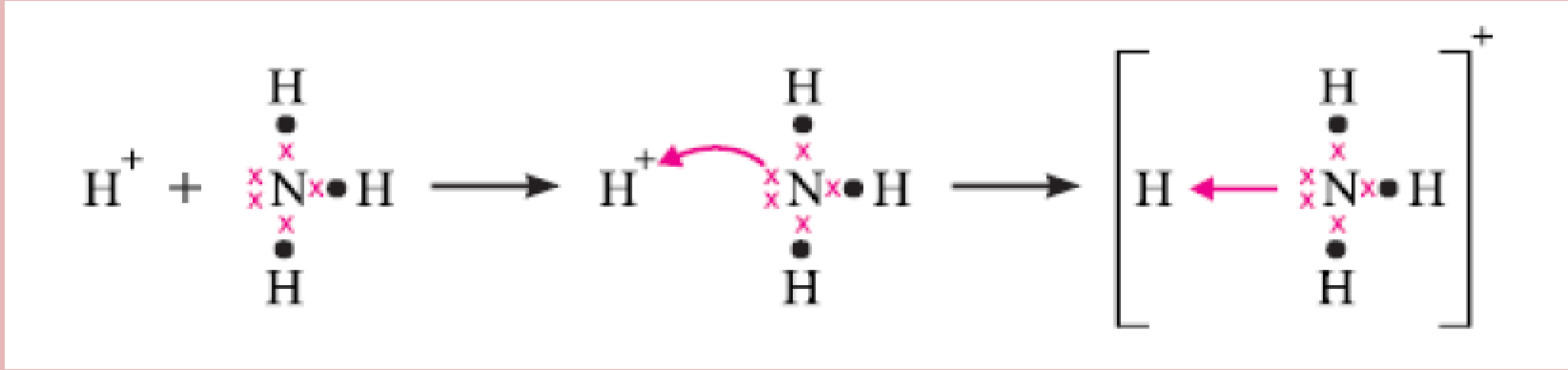
though they do not have the ability to donate a proton, e.g.,SO3 . Similarly, CaO behaves as a base but it cannot accept a proton. These observations prove the limitations of Bronsted-Lowry concept of acids and bases.

Lewis Concept of Acids and Bases

- The Arrhenius and Bronsted-Lowry concepts of acids and bases are limited to substances which contain protons. G.N. Lewis (1923) proposed a more general and broader concept of acids and bases. According to this concept:
- **An acid** *is a substance (molecule or ion) which can accept a pair of electrons, while a base is a substance (molecule or ion) which can donate a pair of electrons.*
- For example, a reaction between ammonia and boron trifluoride takes place by forming a coordinate covalent bond between ammonia and boron trifluoride by donating an electron pair of ammonia and accepting that electron pair by boron trifluoride.



The cations (proton itself or metal ions) act as Lewis acids. For example, a reaction between H+ and NH3 , where H+ acts as an acid and ammonia as a base.



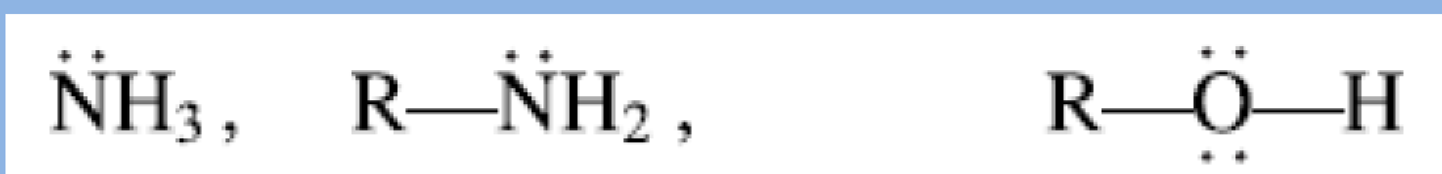
- *The product of any Lewis acid-base reaction is a single specie, called an* **adduct.** So, a neutralization reaction according to Lewis concept is donation and acceptance of an electron pair to form a coordinate covalent bond in an adduct.
- Acids are electron pair *acceptors* while bases are electron pair donors. Thus, it is evident that any substance which has an unshared pair of electrons can act as a **Lewis base** while a substance which has an empty orbital that can accommodate a pair of electrons acts as **Lewis acid**.
- **Lewis acids**. According to Lewis concept, the following species can act as Lewis acids:

(i) *Molecules in which the central atom has incomplete octet*. For example, in BF3 , AlCl3 , FeCl3 , the central atoms have only six electrons around them, therefore, these can accept an electron pair.

(ii) *Simple cations can act as Lewis acids*. All cations act as Lewis acids since they are deficient in electrons. However, cations such as Na+, K+, Ca2+ ions, etc., have a very little tendency to accept electrons. While the cations like H+, Ag+ ions, etc., have a greater electron accepting tendency therefore, act as Lewis acids.

Lewis bases. According to Lewis concept, the following species can act as Lewis bases:

(i)Neutral species having at least one lone pair of electrons. For example, ammonia, amines, alcohols etc. act as Lewis bases because they contain a lone pair of electrons:



(ii) Negatively charged species or anions. For example, chloride, cyanide, hydroxide ions, etc., act as Lewis bases:

$$CN^-,\ Cl^-,\ OH^-,\ \text{etc.}$$

Summery of the concept:

concept	Acid	Base	Product
Arrhenius	give H+	gives OH	salt + H2O
Bronsted-Lowry	donate H+	accepts H+	conjugate acid base
Lewis	electron pair acceptor	electron pair donor	pair adduct

- It may be noted that all **Bronsted bases are also Lewis bases but all Bronsted acids are not Lewis acids.** According to Bronsted concept, a base is a substance which can accept a proton, while according to lewis concept, a base is a substance which can donate a pair of electrons. Lewis bases generally contain one or more ion pair of electrons and therefore, they can also accept a proton (Bronsted base). Thus all Lewis bases are also Bronsted bases. On the other hand, Bronsted acids are those which can give a proton. For example, HCl, H2SO4 are not capable of accepting a pair of electrons. Hence, all Bronsted acids are not Lewis acids.