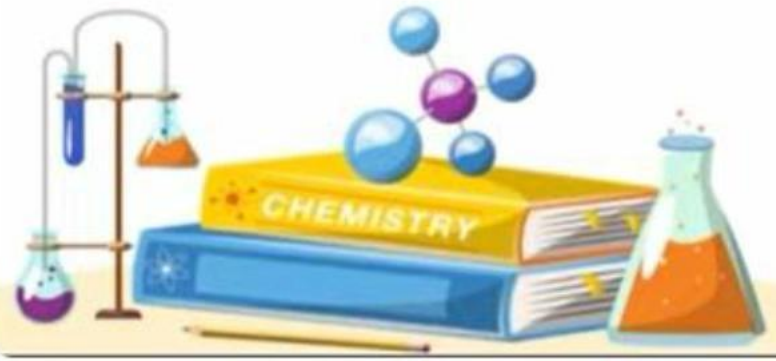
Republic of Iraq Ministry of Higher Education & Scientific Research
University of Al-Maarif
College of Dentistry

Ass.Lec. Qusay Abdulsattar

Medical Chemistry

Acids, Bases and Salts



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Introduction

Acids and bases are substances with specific physical and chemical properties

We can determine if substances are acidic or basic by testing their pH or by indicators.

Introduction

Living organisms are sensitive to the acidity of aqueous solutions in their internal and external environments.

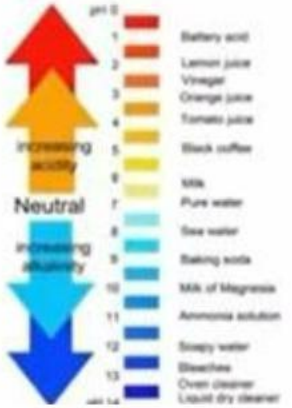
The pH of human blood must be kept at precisely 7.4.

A sustained increase or decrease of only 0.2 pH units

could mean death.

Acids and Bases

The definition of acid and base has changed over course of time. This is not a problem of orthodoxy of one definition but of the convenience of applying the concept of a particular chemical problem. Therefore, ranking the strength of acids and bases depends on the definition of acid and base used.



Acids and Bases

Some classifications of acids and bases

1. Arrhenius acids and bases.
2. Bronsted-Lowry acids and bases.
3. Lewis acids and base.

	Acid	Base
Arrhenius	H^+ in H_2O	OH^- in H_2O
Bronsted-Lowry	H^+ donor	Accepts H^+
Lewis	Accepts e⁻ pair	e⁻ pair donor

Acids and Bases

Arrhenius's acid and base

In 1884, Arrhenius defined that an acid is a substance that gives H+ and a base one that gives OH-. Namely, if an acid is HA and abase BOH, then

$$HA \longrightarrow H^+ + A^-$$
$$BOH \longrightarrow B^+ + OH^-$$

Svante Arrhenius (1859–1927)

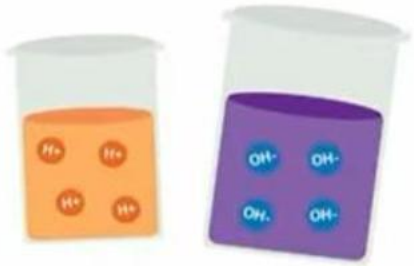
Acids and bases are electrolytes that form aqueous solutions with unique properties.

Acids and Bases

Arrhenius's acid and base

Arrhenius, a Swedish chemist, was the first to characterize acids and bases in terms of their chemical properties.

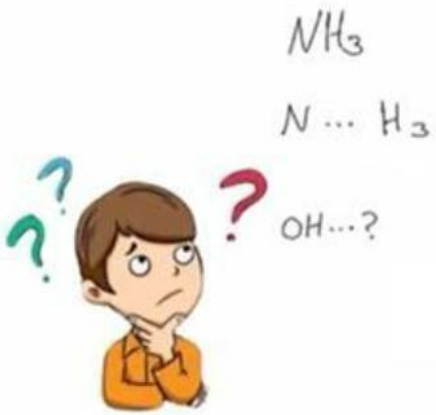
According to Arrhenius, acids are solutes that produce hydrogen ions , H+(aq), in aqueous solutions, while bases produce hydroxide ions, OH-(aq), when dissolved in water.



Acids and Bases

Arrhenius's acid and base

This model fails to satisfactorily account for the basic properties of compounds that do not contain the hydroxide ion, such as ammonia (NH3(aq)).



Acids and Bases

Brønsted-Lowry's acid and base

In 1923, Johannes Brønsted of Denmark and Thomas Lowry of England recognized that, in most acid–base interactions, a proton (H+ ion) is transferred from one reactant to another.

J. Brønsted (1879–1947)

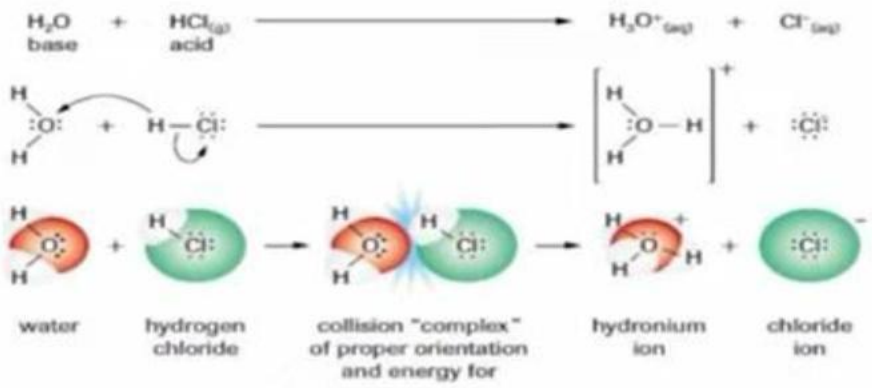
Acids and Bases

Brønsted-Lowry's acid and base

Hydrogen chloride acts as a Brønsted–Lowry acid; water acts as a Brønsted–Lowry base. Notice the single arrow in the equation, indicating that hydrogen chloride is a strong acid, ionizing quantitatively (completely) when it reacts with water.

Acids and Bases

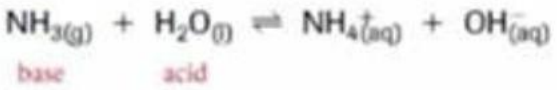
Brønsted-Lowry's acid and base



Acids and Bases

Brønsted-Lowry's acid and base

When ammonia reacts with water, a water molecule acts as a Brønsted–Lowry acid, donating a proton to ammonia, the Brønsted–Lowry base. Notice the double arrow in the equation, indicating that ammonia is a weak base, ionizing incompletely and forming a dynamic equilibrium with the products of the reaction.



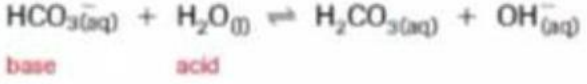
a Brønsted-Lowry acid is a proton donor, and a Brønsted-Lowry base is a proton acceptor.

Brønsted-Lowry's acid and base

Water can behave as base :

$$HA(acid) + H_2O\ (base) \rightarrow H_3O(conjugate\ acid) + A^-\ (conjugate\ base)$$

Water can behave as acid :



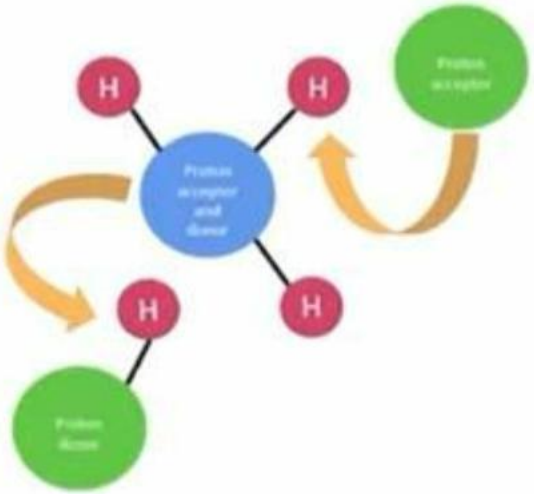
Acids and Bases

Brønsted-Lowry's acid and base

Amphoteric (Amphiprotic) :

in the Brønsted–Lowry model, a substance capable of acting as an acid or a base in different chemical reactions; a substance that may donate or accept a proton.

According to the Brønsted–Lowry concept, acid–base reactions involve the transfer of a proton. These reactions are universally reversible and result in an acid–base equilibrium.



Acids and Bases

Brønsted-Lowry's acid and base

$$\underset{\text{Acid}^1}{H{:}A} + \underset{\text{base}^2}{B{:}} \longleftrightarrow \underset{\text{conjugate Acid}^2}{B{:}\,H^+} + \underset{\text{conjugate base}^1}{A^-}$$

(conjugate acid-base pairs are HA-A⁻ and B:H⁺-B:)

- A conjugate acid–base pair consists of two substances that differ only by a proton—the acid has one more proton than its conjugate base.
- A strong acid has a very weak attraction for protons.

Acids and Bases

Properties of acids

- pH values lower than the neutral value of 7.
- Sharp sour Taste.
- React with certain metals to liberate hydrogen gas.
- Soluble in water release H+ ions in solution.
- Strong acids can damage the skin and be dangerous.
- Are often corrosive.
- Are neutralized bases,
- They react with carbonates and bicarbonates to give off carbon dioxide gas.

Acids and Bases

Properties of acids →

The strength of an acid depends on the concentration of H+ ions formed in solution. Strong acids produce a high concentration of H+ ions whereas weak acids produce a low H+ concentration in solution.

one H in a molecule that can form hydrogen ions is called a monoprotic acid, e.g. H+ Cl- A diprotic acid will give two H+, e.g. H2SO4. An example of a triprotic acid is phosphoric acid, H3PO4.

Properties of acids

Which one of them is stronger?

*Strong acids ionize completely when in solution, e.g. sulphuric acid.

$H_2SO_4(l) + \text{water} \rightarrow 2\,H^+(aq) + SO_4^{2-}(aq)$

*Weak acids do not ionize completely when in solution, e.g. ethanoic acid

$CH_3COOH(l) + \text{water} \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

Acids and Bases

Dissociation depends on

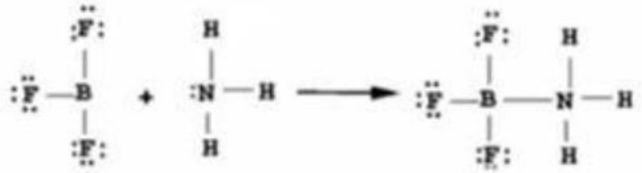
- Temperature. (Temp.)
- Concentration. (conc.)
- Nature of solution. (solut.)

Acids and Bases

Lewis acids and bases

A Lewis acid is defined to be any species that accepts lone pair electrons.

A Lewis base is any species that donates lone pair electrons.



concept	Acid	Base	Product
Arrhenius	+give H	gives OH	O2salt + H
Bronsted-Lowry	+donate H	+accepts H	conjugate acid base
Lewis	electron pair acceptor	electron pair donor	pair adduct

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

Acids and Bases

Some common reactions to all acids

- Dilute acids react with reactive metals to release hydrogen gas and form a salt.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

A Lewis base is any species that donates lone pair electrons.

$$PbCO_3(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$$

Some common reactions to all acids

Dilute acids react with metal oxides to form a salt and water.

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

Dilute acids react with alkalis to form a salt and water. This is called a neutralization reaction.

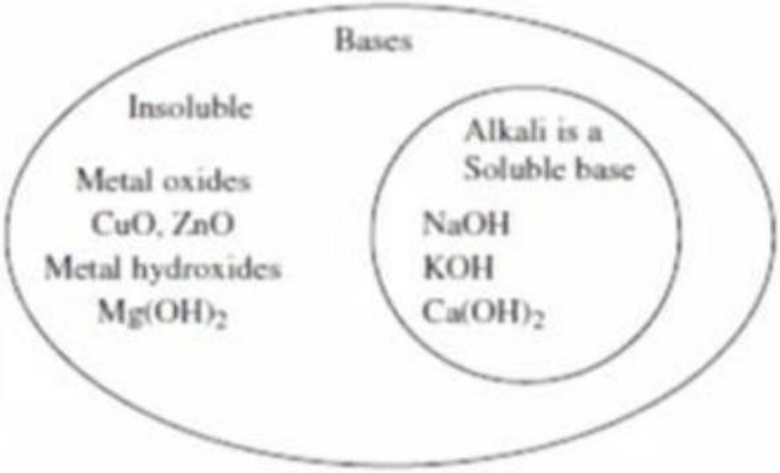
$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Bases & Alkali

A base is a substance that reacts with an acid to produce a salt and water only.

An alkali is a solution of a base in water.

Just as there are weak and strong acids, there are weak and strong alkalis. The strength of an alkali depends on the amount of OH- ions in solution. The more an alkali ionizes the stronger it is.



Bases & Alkali

Properties of bases

1. The pH of the solution lies between 8 and 14.
2. Soluble bases are called alkalis, e.g. sodium hydroxide, NaOH, potassium hydroxide, KOH, and ammonium hydroxide, NH4OH.
3. Bases are oxides or hydroxides of metallic elements.
4. Bases and alkalis will react with acids to neutralize them, forming salts plus water:

$$\text{Acid} + \text{base} \rightarrow \text{salt} + \text{water}$$
$$\text{Acid} + \text{alkali} \rightarrow \text{salt} + \text{water}$$

5. All alkalis contain a hydroxide ion, OH-, that will react with and 'pick up' a H+ ion to form a water molecule.
6. Bitter taste.
7. Soapy feeling when in a solution.
8. Restore blue color to litmus that was turned red by an acid.

Bases & Alkali

Bases Containing Nitrogen

These are best called 'nitrogenous bases', which is a term often used in relation to amines, amino acids and proteins.

Bases referred to in medicine and biology usually contain nitrogen atoms that have the ability to pick up a proton and become a positive ion:

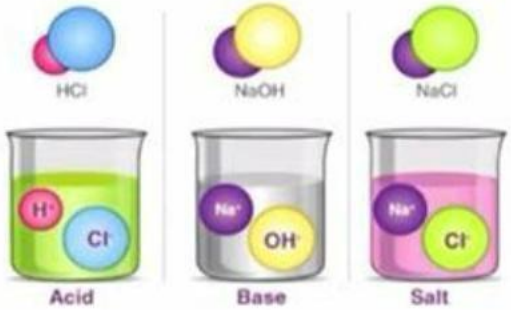
$$NH_3 + H^+ \rightarrow NH_4^+$$

Ammonia

$$HOOCCH_2NH_2 + H^+ \rightarrow HOOCCH_2NH_3^+$$

Salts

A salt is any ionic compound composed of positively charged cations and negatively charged anions, so that the product is neutral and without a net charge. These ions can be inorganic (Cl–) as well as organic (CH3COO–) and monoatomic (F–) as well as polyatomic ions (SO42–). Salts are formed (as well as water) when acids and bases react.



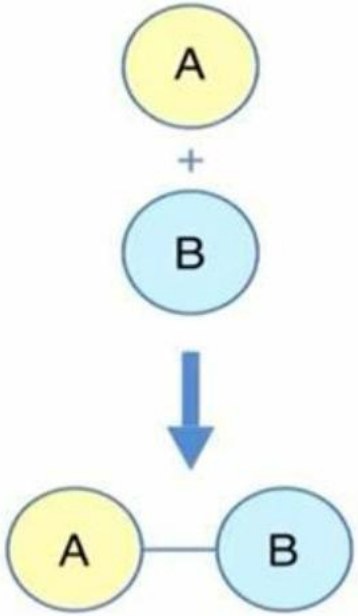
Salts

Salts can be prepared by

1. Synthesis (or direct combination of elements) e.g. :

$$Zn(s) + S(s) \rightarrow ZnS(s)$$

$$2\,Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$$



Salts

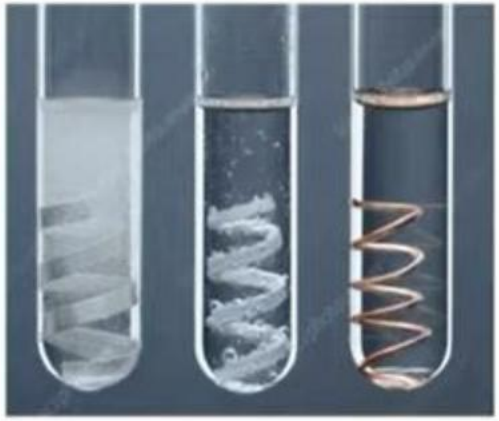
Salts can be prepared by

2. The action of an acid on:

(i) a metal.

(ii) an insoluble metal oxide, hydroxide, or carbonate.

(iii) an alkali or soluble carbonate.



(i) $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

(ii) $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(g)$

$Mg(OH)_2(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + 2\ H_2O(l)$

(iii) $2\ NaOH_{(aq)} + H_2SO_{4(aq)}\ \ Na_2SO_{4(aq)} + 2\ H_2O_{(l)}$

Salts

Salts can be prepared by

3. Precipitation

$$PbNO_3(aq) + H_2SO_4(aq) \rightarrow PbSO_4(s) + HNO_3(aq)$$