Acids, Bases and Salts

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 7.4. An increase or decrease of only 0.2 pH units could mean death

Acids and Bases

• The definition of acid and base has changed over time.

• 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.

Some classifications of acids and bases

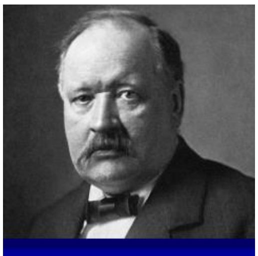
1. Arrhenius acids and bases.

2. Bronsted-Lowry acids and bases.

3. Lewis 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^-.**


Svante Arrhenius (1859–1927)

Namely, if an acid is HA and a base BOH, then

$$HA \longrightarrow H^+ + A^-$$

$$BOH \longrightarrow B^+ + OH^-$$

Acids and bases are electrolytes that form aqueous solutions with unique properties. Svante Arrhenius (1859–1927) 6 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.

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

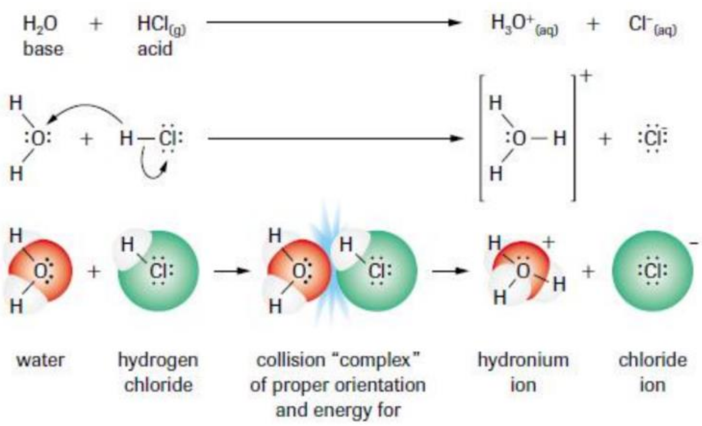
Brønsted-Lowry's acid and base

J. Brønsted (1879–1947) T. Lowry (1874–1936)

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) T. Lowry (1874–1936)

• According to Brønsted and Lowry, when hydrogen chloride reacts with water, a proton is transferred from a hydrogen chloride molecule to a water molecule, forming a hydronium ion and a chloride ion.

• 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.



• 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.

$$\underset{\text{base}}{NH_{3(g)}} + \underset{\text{acid}}{H_2O_{(l)}} \rightleftharpoons NH^{+}_{4(aq)} + OH^{-}_{(aq)}$$

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

• Water can behave as a base:

HA(acid) + H_2O (base) → H_3O(conjugate acid) + A^- (conjugate base)

$$\underset{\text{base}}{HCO^{-}_{3(aq)}} + \underset{\text{acid}}{H_2O_{(l)}} \rightleftharpoons H_2CO_{3(aq)} + OH^{-}_{(aq)}$$

$$\underset{\text{acid}}{HCO^{-}_{3(aq)}} + \underset{\text{base}}{H_2O_{(l)}} \rightleftharpoons CO^{2-}_{3(aq)} + H_3O^{+}_{(aq)}$$

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.

$$\underset{\textbf{acid}}{\mathbf{H{:}A}} + \underset{\textbf{base}}{\mathbf{B{:}}} \rightleftharpoons \underset{\textbf{conj. acid}}{\mathbf{B{:}H^{+}}} + \underset{\textbf{conj. base}}{\mathbf{A^{-}}}$$

• 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.

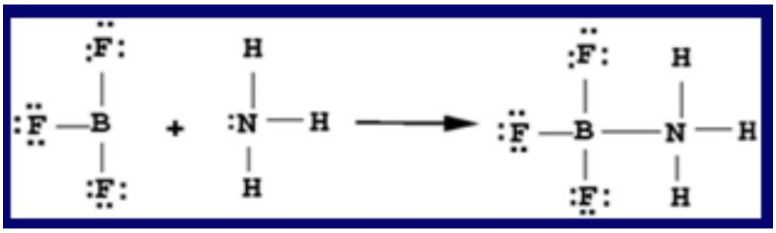
• A strong acid has a very weak attraction for protons.

• A strong base has a very strong attraction for protons.

• The stronger an acid, the weaker its conjugate base, and conversely, the weaker an acid, the stronger its conjugate base.

Lewis acids and bases

- A Lewis acid is defined to be any species that accepts a lone pair of electrons.
- A Lewis base is defined to be any species that donated a lone pair of electrons.



Properties of acids

1. pH values lower than the neutral value of 7.

2. Sharp sour Taste.

3. React with certain metals to liberate hydrogen gas.

4. Soluble in water release H+ ions in solution.

5. Are often corrosive.

6. Strong acids can damage the skin and be dangerous.

7. Are neutralized bases.

8. They react with carbonates and bicarbonates to give off carbon dioxide gas.

9. React with active metals to release hydrogen gas

• The strength of an acid depends on the concentration of H+ ions formed in the 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. H_2SO_4. An example of a triprotic acid is phosphoric acid, H3PO4.

• Strong acids ionize completely when in solution, e.g. sulfuric 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

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

Dissociation depends on:

• Temperature. (Temp.)

• Concentration. (conc.)

• Nature of solution. (solut.)

Acid	Formula	Strength	Occurrence
Nitric acid	HNO_3	Very strong	Found in the lab
Sulphuric acid	H_2SO_4	Strong	Found in the lab
Hydrochloric acid	HCl	Strong	Produced by the stomach
Ethanoic acid	CH_3COOH	Weak	Found in vinegar
Citric acid	$C_6H_8O_7$	Weak	Found in the juice of citrus fruits (e.g. lemons and oranges)
Tartaric acid	$C_3H_6O_6$	Weak	Found in grape juice
Carbonic acid	H_2CO_3	Weak	Found in lemonade

Some common reactions to all acids

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

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

• Dilute acids react with metal carbonates and to form a salt, carbon dioxide and water.

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

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

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

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

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

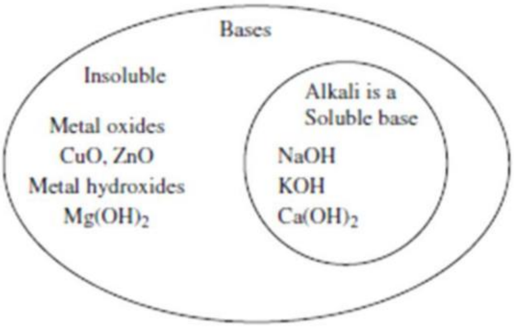
$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Bases and Alkali

• A base is a substance that reacts with an acid to produce 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 the solution. The more an alkali ionizes the stronger it is. Bases and Alkalis



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’ an H+ ion to form a water molecule.

6. Bitter taste.

7. Soapy feeling when in a solution.

8. Restore the blue colour to the litmus that was turned red by an acid.

Bases Containing Nitrogen

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

• Bases referred to in medicine and biology usually contain nitrogen atoms that can 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 ($SO4^{2-}$). **Salts are formed (as well as water) when acids and bases react**.

Salts can be prepared by:

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

$$Zn_{(s)} + S_{(s)} \longrightarrow ZnS_{(s)}$$

$$2Fe_{(s)} + 3\,Cl_{2\,(g)} \longrightarrow 2\,FeCl_{3(s)}$$

2. **The action of an acid on**

(i) a metal,
(ii) an insoluble metal oxide, hydroxide, or carbonate, and
(iii) an alkali or soluble carbonate.

(i) $Mg(s) + H_2SO_4(aq) \text{ --> } MgSO_4(aq) + H_2(g)$

(ii) $CuO(s) + H_2SO_4(aq) \text{ --> } CuSO_4(aq) + H_2O(g)$

$Mg(OH)_2(s) + H_2SO_4(aq) \text{ --> } MgSO_4(aq) + 2\,H_2O(l)$

$PbCO_3(s) + 2\,HNO_3(aq) \text{ --> } Pb(NO_3)_2(aq) + CO_2(g)$

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

$Na_2CO_{3(aq)} + H_2SO_{4(aq)} \quad Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$ 3.

3. Precipitation

$PbNO_3(aq) + H_2SO_4(aq) \text{ --> } PbSO_4(s) + HNO_3(aq)$