Properties of Aqueous Solutions

Definitions

A solution is a homogeneous mixture of two or more substances.

The substance present in smaller amount is called the solute.

The substance present in larger amount is called the solvent.

For now we will discuss only aqueous solutions.

Electrolytes vs Nonelectrolytes

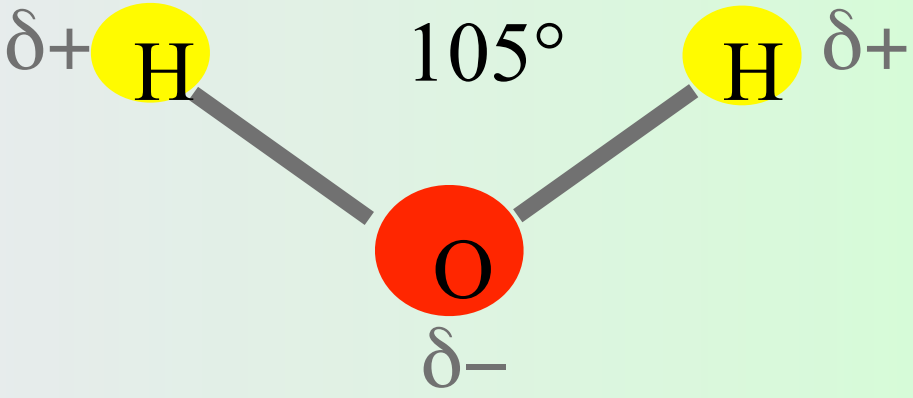
An electrolyte is a substance that, when dissolved in water, gives a solution that can conduct electricity

A nonelectrolyte does not conduct electricity when dissolved in water.

the most import property of water when dealing with aqueous solution is its polarity

Structure of water

O—H bonds are covalent but “polar”

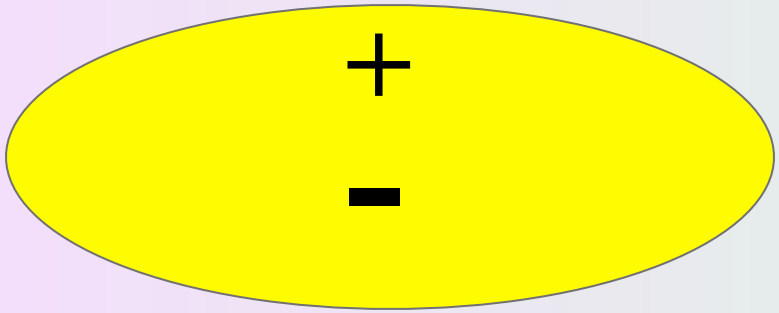


Dipole Moments

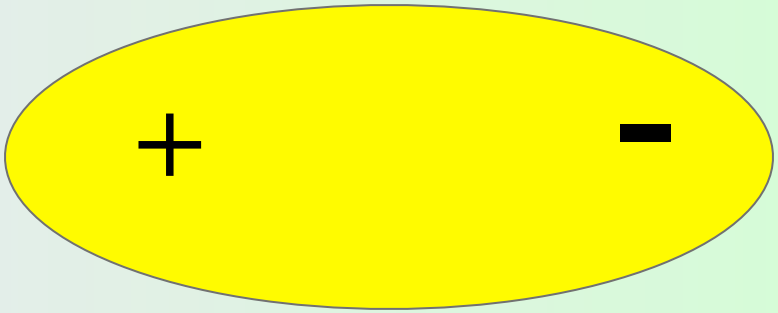
Dipole Moment

a substance possesses a dipole moment if its centers of positive and negative charge do not coincide

$\mu = e \times d$ **Expressed in debye units**

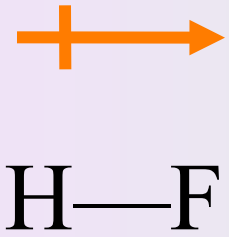


not polar

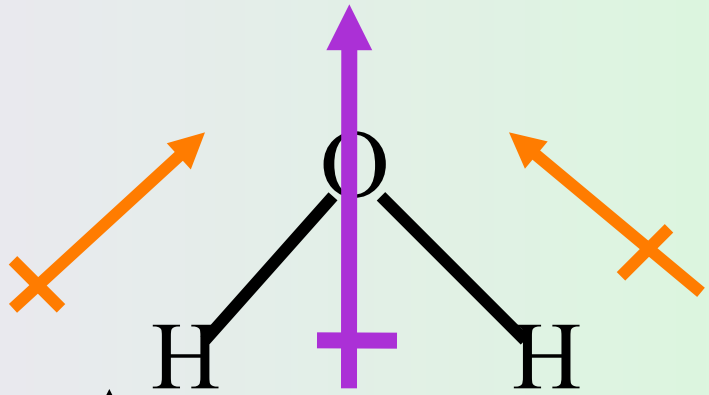


polar

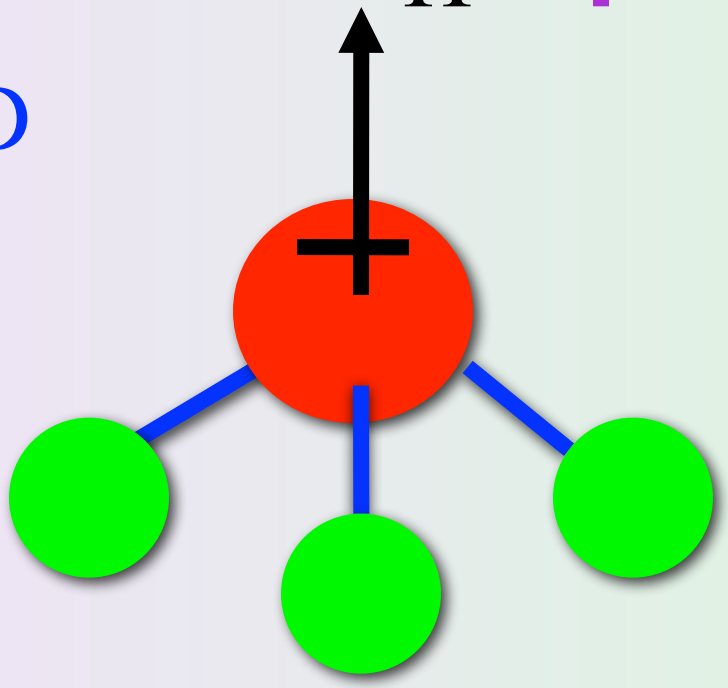
examples



$\mu = 1.7$ D



$\mu = 1.8$ D

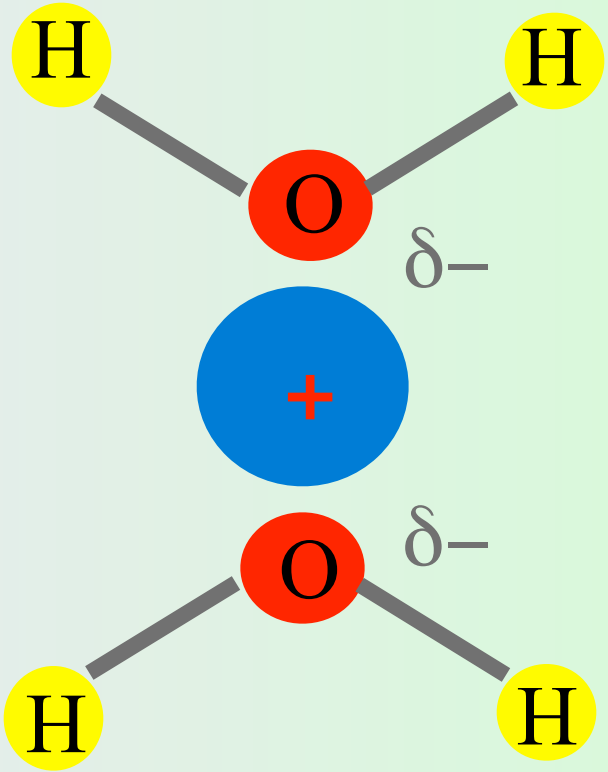


$\mu = 1.5$ D

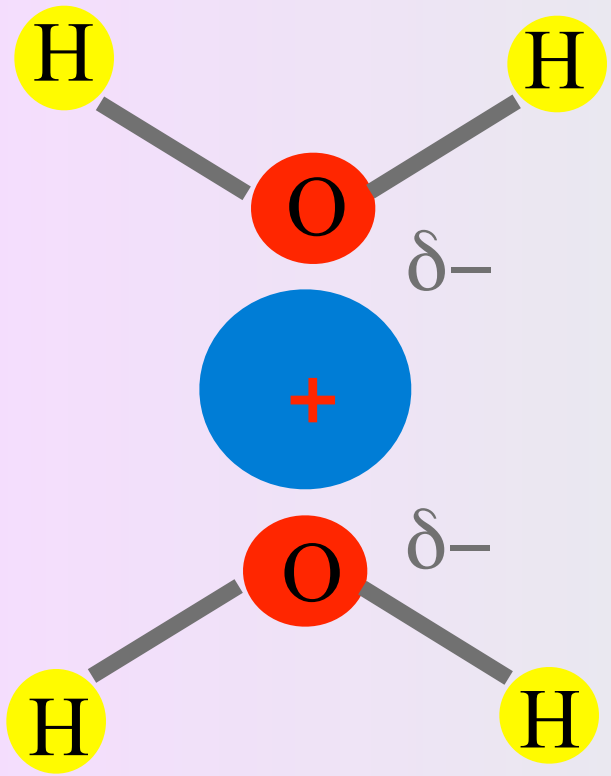
Solvation

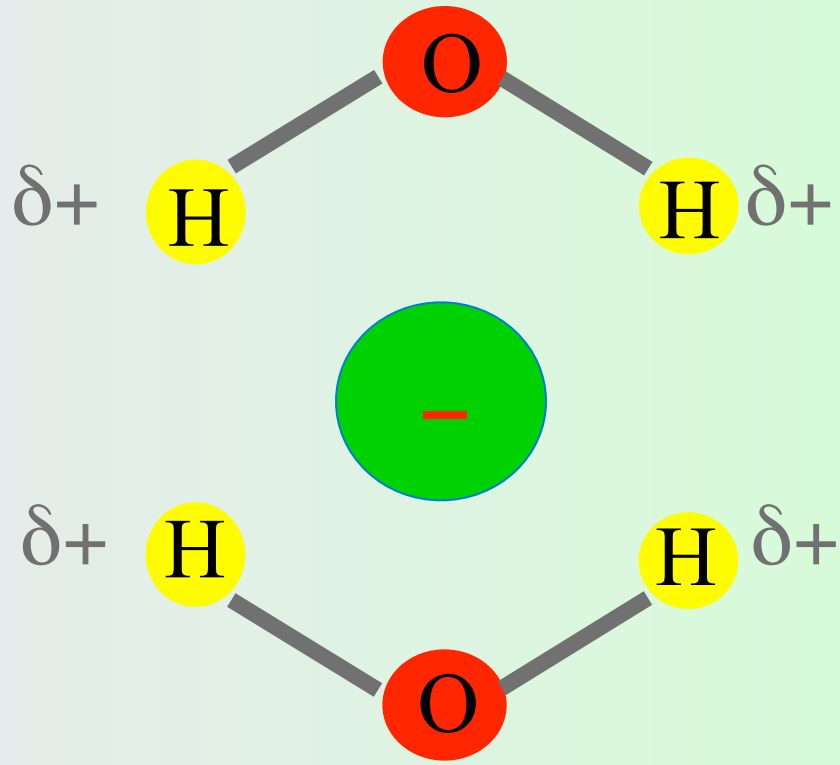
Clustering of molecules of solvent around solute:

hydration is specific term for solvation when water is solvent



Water can solvate both cations and anions

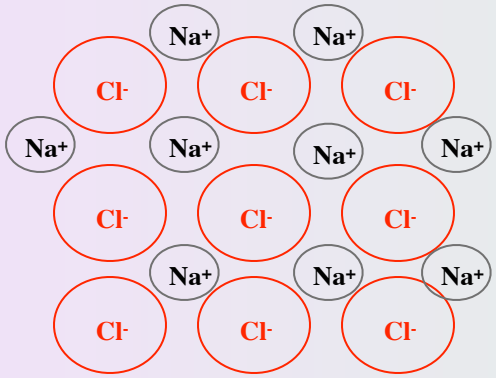


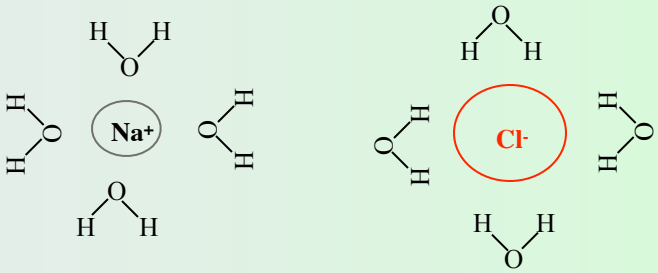


Dissociation

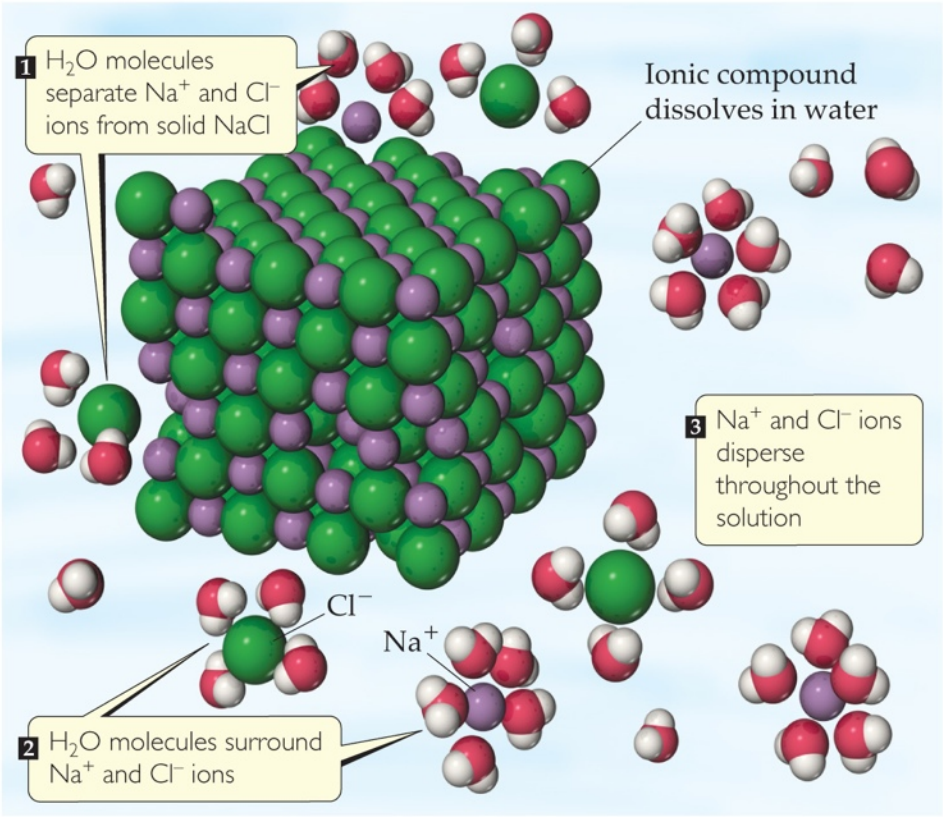
The breaking up of a compound into cations and anions

$$NaCl_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)}$$





Dissociation



(a) Ionic compounds like sodium chloride, NaCl, form ions when they dissolve

Electrolytes vs Nonelectrolytes

Nonelectrolyte

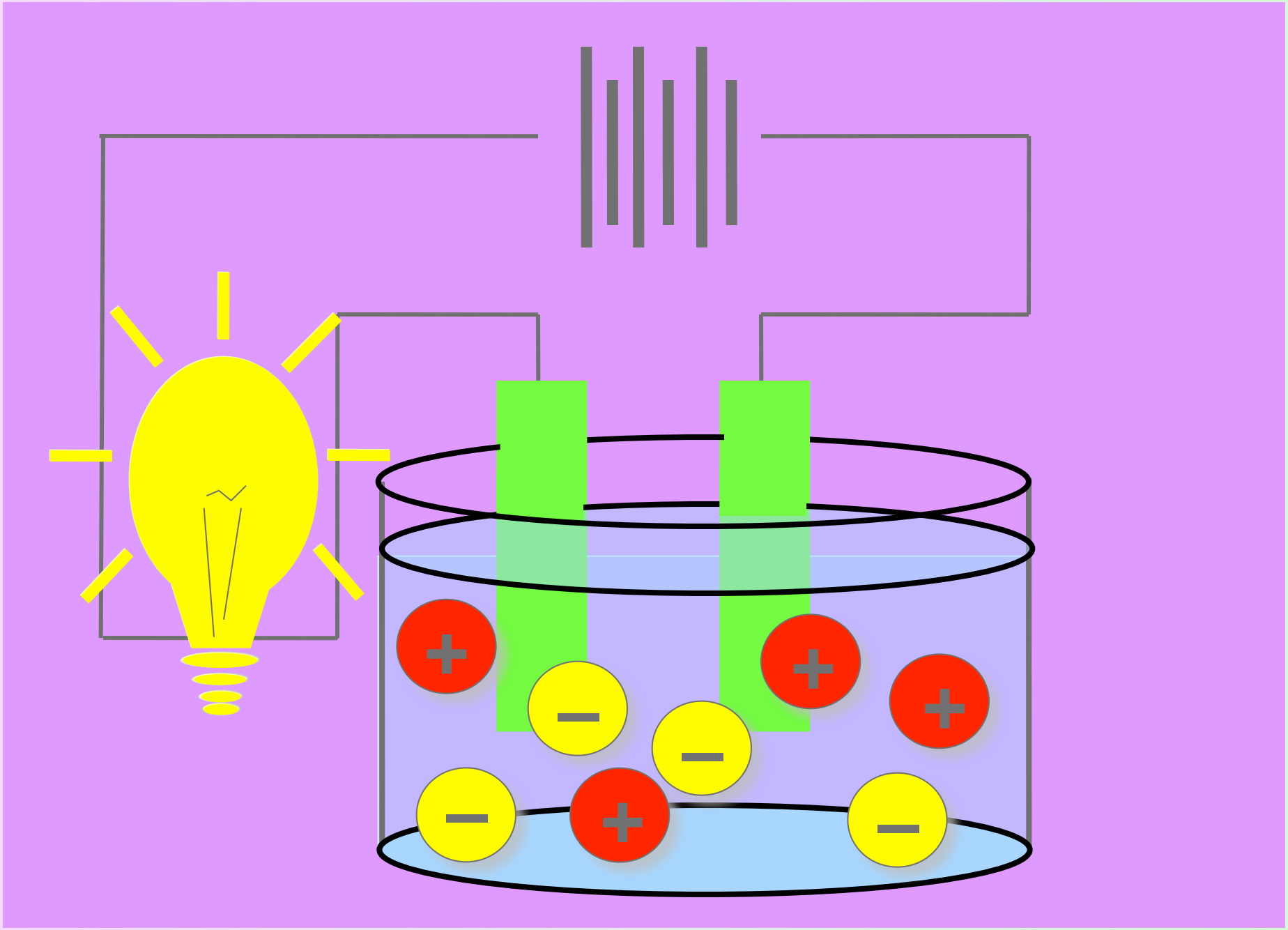
not ionized in water

Weak electrolyte

incompletely ionized in water

Strong electrolyte

completely ionized in water



Electrolytes

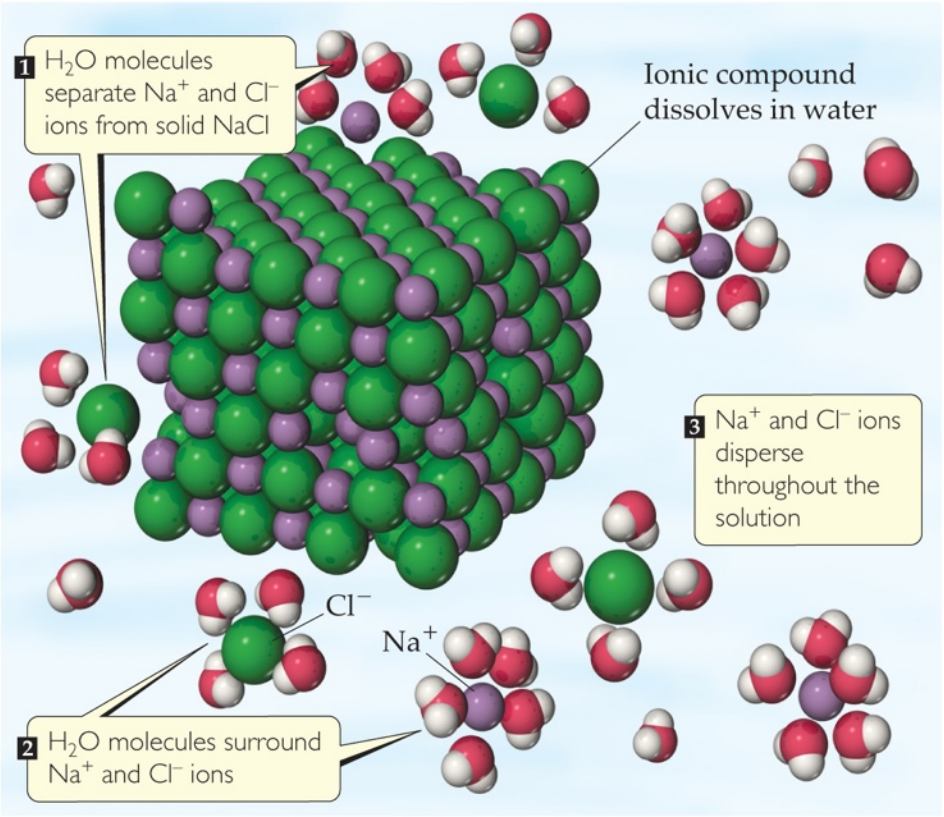
Pure water,
$H_2O(l)$
does not conduct electricity

Sucrose solution,
$C_{12}H_{22}O_{11}(aq)$
Nonelectrolyte
does not conduct electricity

Sodium chloride solution,
$NaCl(aq)$
Electrolyte
conducts electricity

- A **strong electrolyte** dissociates completely when dissolved in water.
- A **weak electrolyte** only dissociates partially when dissolved in water.

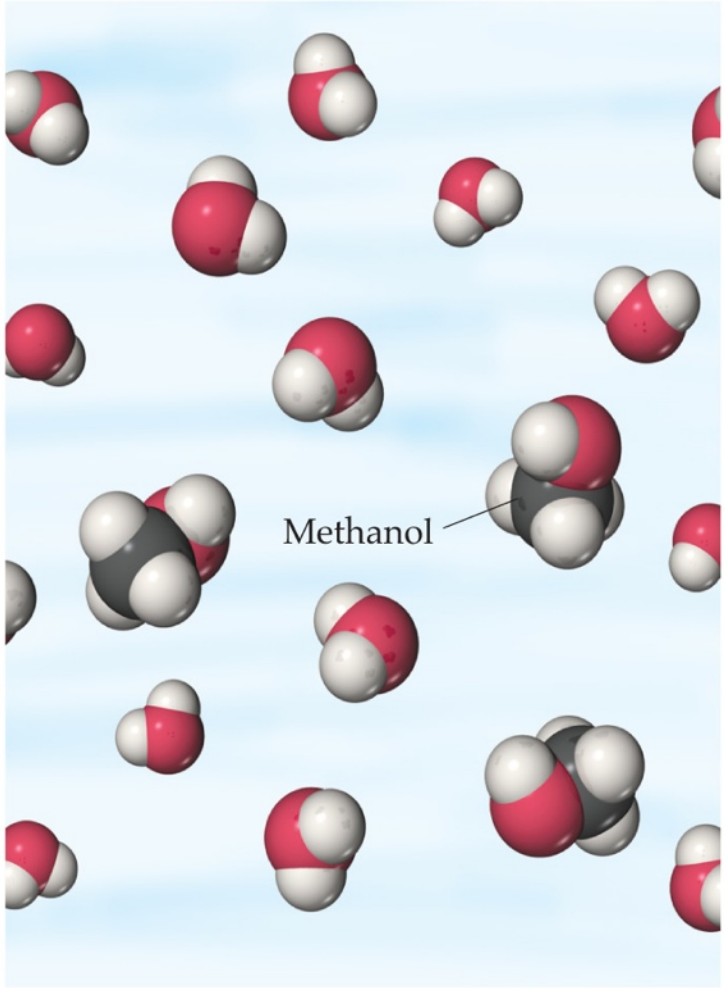
Solutions



(a) Ionic compounds like sodium chloride, NaCl, form ions when they dissolve

- An **electrolyte** is a substances that dissociates into ions when dissolved in water.

Solutions



(b) Molecular substances like methanol, CH_3OH, dissolve without forming ions

- An **electrolyte** is a substance that dissociates into ions when dissolved in water.
- A **nonelectrolyte** may dissolve in water, but it does not dissociate into ions when it does so.

Solubility

The amount of solute that can be dissolved in a given amount of a saturated solution at a fixed temperature is the solubility of the solute in the solvent.

Solubility

Some compounds are very soluble : NaCl, KCl, NH_4Cl

Some are slightly soluble : AgCl

slightly soluble and insoluble can be used interchangeably

Strong electrolytes

Soluble Ionic compounds

Strong acids

Strong bases

Arrhenius definitions of acids and bases

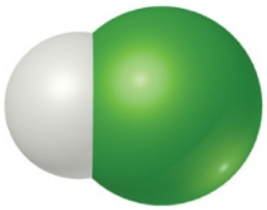
An **acid** dissolves in water to yield protons

$$H-X \longrightarrow H^+ + X^-$$

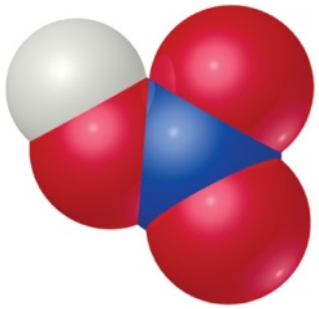
A **base** dissolves in water to yield hydroxide ions

$$YOH \longrightarrow Y^+ + HO^-$$

Acids

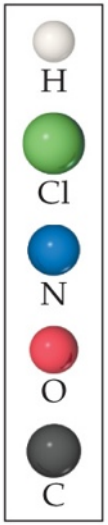


Hydrochloric acid, HCl



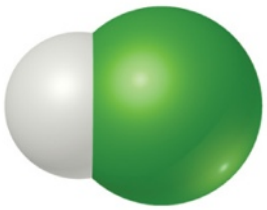
Nitric acid, HNO_3

Acetic acid, CH_3COOH

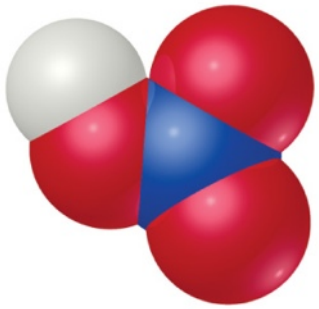


- The Swedish physicist and chemist S. A. Arrhenius defined acids as substances that increase the concentration of H^+ when dissolved in water.
- Both the Danish chemist J. N. Brønsted and the British chemist T. M. Lowry defined them as proton donors.

Acids

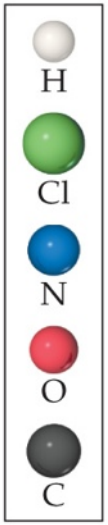


Hydrochloric acid, HCl



Nitric acid, HNO_3

Acetic acid, CH_3COOH



There are only seven strong acids:

- Hydrochloric (HCl)
- Hydrobromic (HBr)
- Hydroiodic (HI)
- Nitric (HNO_3)
- Sulfuric (H_2SO_4)
- Chloric ($HClO_3$)
- Perchloric ($HClO_4$)

Strong Electrolytes Are…

- Strong acids
- Strong bases

TABLE 4.2 • Common Strong Acids and Bases

Strong Acids	Strong Bases
Hydrochloric, HCl	Group 1A metal hydroxides [LiOH, NaOH, KOH, RbOH, CsOH]
Hydrobromic, HBr	Heavy group 2A metal hydroxides [$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$]
Hydroiodic, HI	
Chloric, $HClO_3$	
Perchloric, $HClO_4$	
Nitric, HNO_3	
Sulfuric, H_2SO_4	

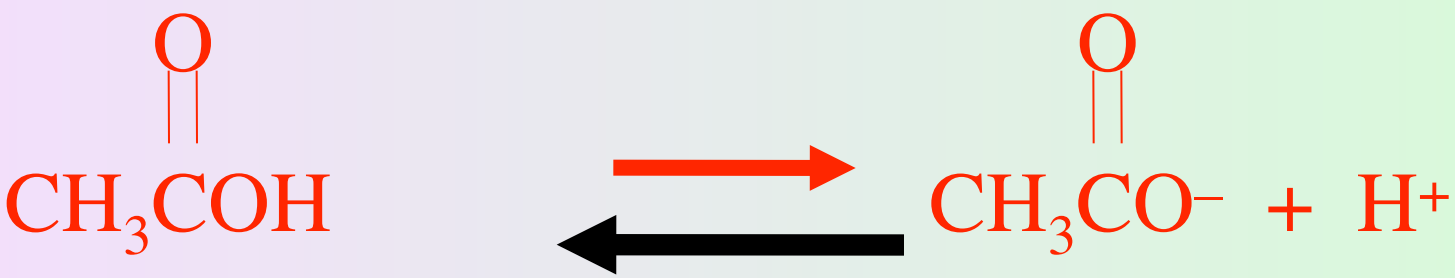
Weak electrolytes

Weak acids

Weak bases

A Weak Acid

Acetic acid:



>99% **<1%**

Reversible reaction

the reaction can occur in both directions

A Weak Base

Ammonia:

$$H_3N: + H_2O \rightleftharpoons HO^- + NH_4^+$$

>99% **<1%**

Nonelectrolytes

produce no ions when dissolved in water

ethanol

ethylene glycol

sucrose

Concentration

Molarity (M)

moles of solute /1L of solution

What is the molarity of a solution made up by dissolving 9.52g of NaCl in enough H_2O to form 575 mL of solution?

$$\boxed{M = n/L}$$

$$9.52\text{g NaCl} \times \frac{1 \text{ mol}}{58.4\text{g NaCl}} \times \frac{1}{575 \text{ mL}} \times \frac{10^3 \text{ mL}}{1 \text{ L}}$$

$$= 0.284 \text{ mol/L}$$

Important point about concentration

Given: Na_2SO_4 concentration = 0.683 M

What is the concentration of Na^+

What is the concentration of SO_4^{2-} ?

Na^+ = 2 x 0.683 M = 1.37 M

SO_4^{2-} = 0.683 M

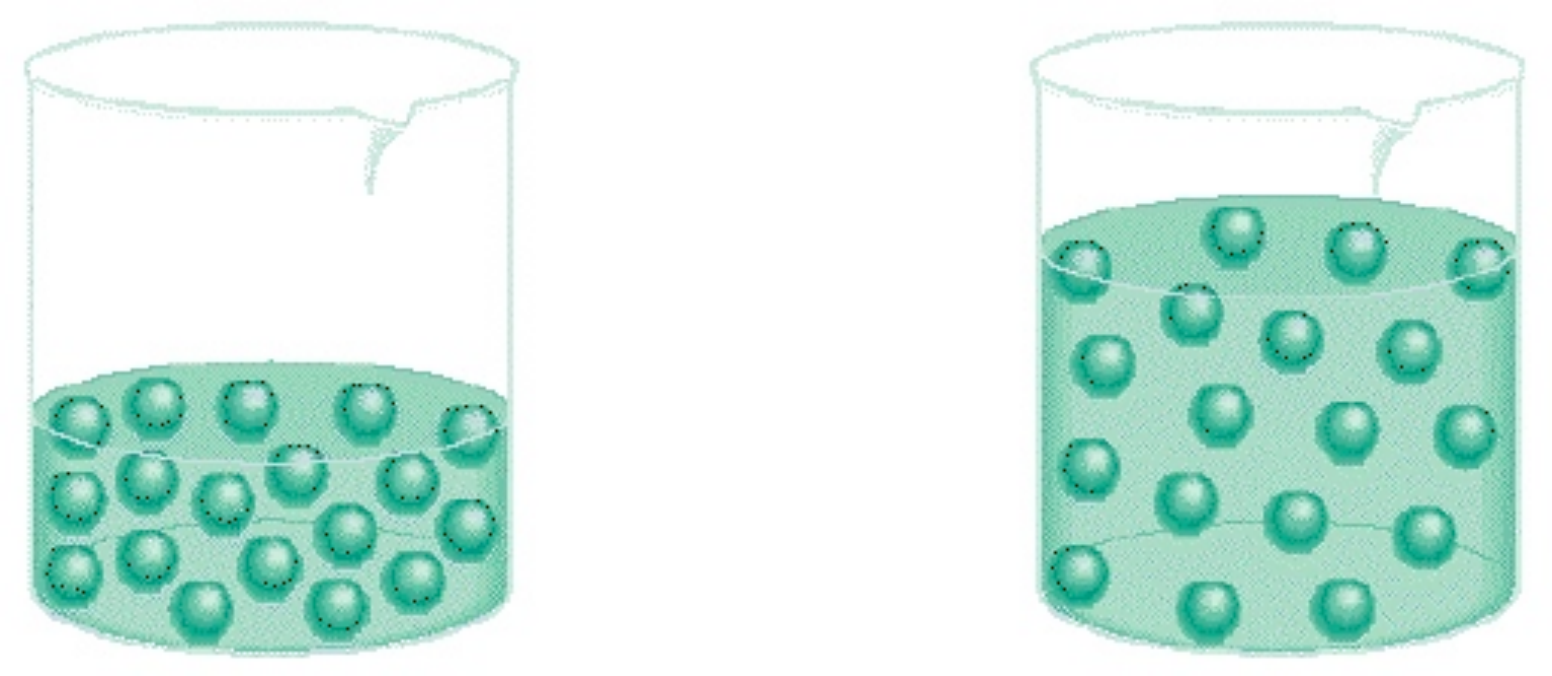
Dilution of solutions

Dilution of solutions

Preparation of a less concentrated solution from a more concentrated one

$$M_{initial} \times V_{initial} = M_{final} \times V_{final}$$

$$\text{Moles of solute}_{initial} = \text{Moles of solute}_{final}$$



The dilution of a more concentrated solution to a less concentrated one does not change the number of moles of solute

Dilution of solutions

How much concentrated HCl (12.5 M HCl) is required in order to prepare 1 L of a 1 M solution?

$$M_{initial} \times V_{initial} = M_{final} \times V_{final}$$

$$(12.5 \text{ mole / L})\, V_{initial} = (1 \text{ mol / L})(1 \text{ L})$$

$$V_{initial} = 0.080 \text{ L} = 80 \text{ ml}$$