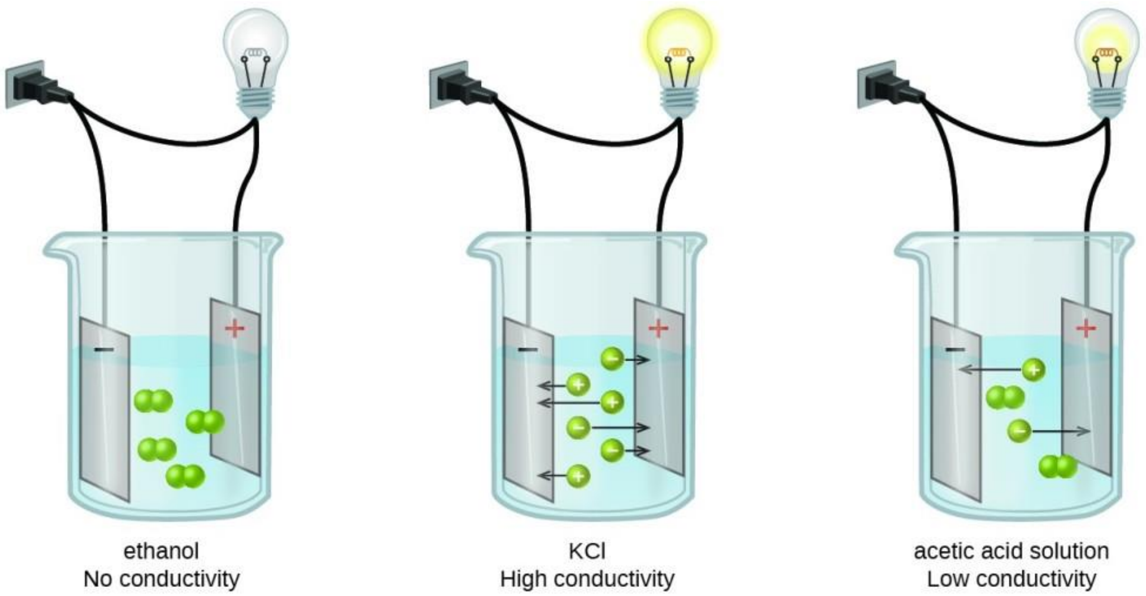
LEC4: Electrolytes

Definition

- ***Conductivity*** is referred to as the ability of electric current to flow through a material.

An **electrolyte** is a compound that dissociates into ions when dissolved in water. Electrolytes conduct electric current in aqueous solutions or in a molten state.

For example, when sulfuric acid dissolves in water, it dissociates into hydrogen ions (H^+) and sulfate anions (SO_4^{2-}).



Types of Electrolytes

There are three types of electrolytes you should remember, and they are based on the degree to which they dissociate in water.

Strong Electrolytes

First up are **strong electrolytes**. In the category of **strong electrolytes**, we have **soluble ionic compounds**, **strong acids,** and **strong bases**.

Strong electrolytes are those that, when dissolved in water, dissociate *completely* into ions.

Compounds containing	**Soluble or Insoluble in H_2O**	**Exceptions**
NO_3^-	soluble	none
CH_3COO^- (acetate)	soluble	none
Cl^-, Br^- and I^-	soluble	Ag^+, Hg_2^{2+} and Pb^{2+}
SO_4^{2-}	soluble	Sr^{2+}, Ba^{2+}, Hg_2^{2+} and Pb^{2+}
S^{2-}	insoluble	NH_4^+, Li^+, Na^+, K^+, Rb^+, Cs^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

CO_3^{2-}	insoluble	NH_4^+, Li^+, Na^+, K^+, Rb^+, and Cs^+
PO_4^{3-}	insoluble	NH_4^+, Li^+, Na^+, K^+, Rb^+, and Cs^+
OH^-	insoluble	NH_4^+, Li^+, Na^+, K^+, Rb^+, Cs^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

Weak Electrolytes

Next, we have **weak electrolytes**, and these are either **weak acids** or **weak bases**.

Weak electrolytes are those that do not completely dissociate in water (H_2O). In other words, they *partially* dissociate in water and can only conduct a weak current in aqueous solutions.

Table 2 shows a list of some common weak acids and weak bases.

Weak Acids	**Weak Bases**
Hydrogen fluoride (HF)	Ammonia (NH_3)
Hydrogen cyanide (HCN)	Methylamine (CH_3NH_2)

Hydrogen peroxide (H_2O2)	Diazane (NH_2NH_2)
Hydrogen sulfide (H_2S)	Hydroxylamine (NH_2OH)
Fulminic acid (CHNO)	Ammonium hydroxide (NH_4OH)
Formic acid (HCOOH)	Aluminum hydroxide ($Al(OH_3)$)
Hypochlorous acid (HOCl)	Iron (II) hydroxide ($Fe(OH)_2$)
Acetic acid (CH_3CO_2H)	Aniline ($C_6H_5NH_2$).
Boric acid ($B(OH)_3$)	Pyridine (C_5H5N)

Non-electrolytes

Non-electrolytes are actually **molecular compounds. Molecular compounds** are compounds made of non-metals that are not considered acids or bases.

Non-electrolytes are those that do not dissociate into ions but are still able to dissolve in water. Therefore, they do not make the aqueous solution electrically conductive.
Common examples of non-electrolytes include alcohol methanol (CH_3OH) and glucose sugar ($C_6H_{12}O_6$). Glucose is highly soluble in water, but even though it dissolves into water, it does not dissociate into ions. In other words, a non-electrolyte solution does not conduct electricity.

Ionic compounds

are usually composed of a metal and a non-metal or a metal and a polyatomic ion. A common example of a soluble ionic compound is sodium chloride (NaCl). However, not all ionic compounds are soluble in water (H_2O). Table 1 shows the Solubility rules for ionic compounds in water.

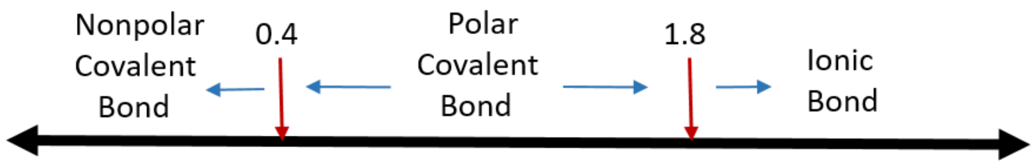
Is the ionic compound potassium nitrate (KNO_3) soluble or insoluble in water?

When KNO_3 is allowed to dissociate in water, it forms K^+ and NO_3^- ions.
The Solubility rules states that all ionic compounds containing NO_3^- are soluble in water. Therefore, KNO_3 is *soluble* in water.

Is the ionic compound barium sulfate ($BaSO_4$) soluble or insoluble in water?

According to the solubility rules for ionic compounds in water, compounds containing SO_4^{2-} tend to be soluble in water unless it has one of the metals in the "exceptions" column.
Strong acids are acids that 100% dissociate in water to produce positive hydrogen ions (H^+) and negative chlorine ions (Cl^-). The seven strong acids are HCl, HBr, HI, $HClO_4$, $HClO_3$, H_2SO_4, and HNO_3.

Electronegativity Difference

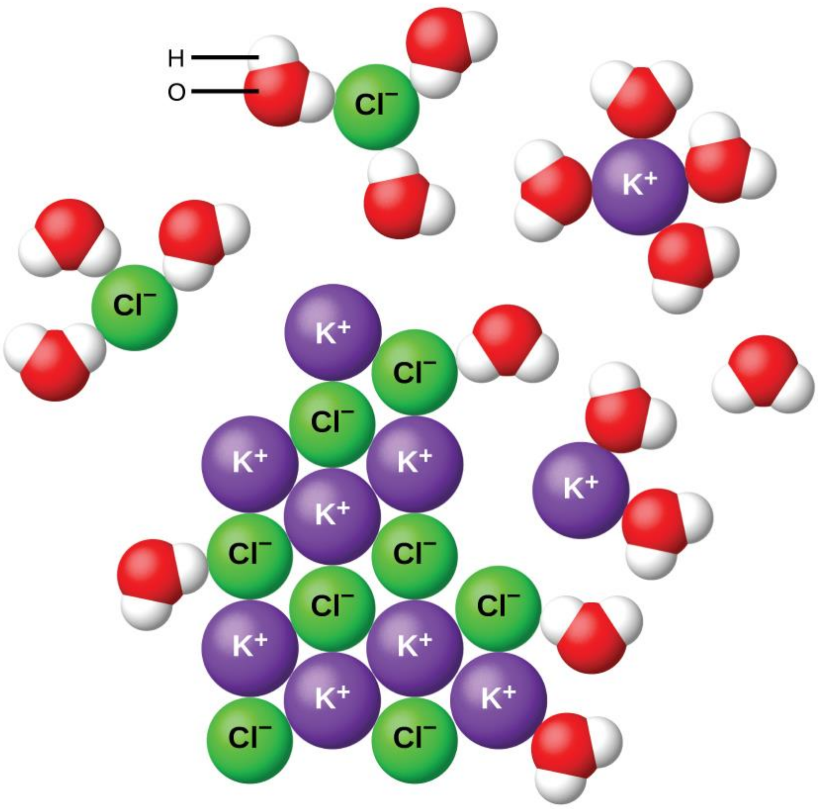


Examples:	C-H	C-O	NaCl
	2.5-2.1 = 0.4	3.5 – 2.5 = 1.0	3.0 – 0.9 = 2.1

Ionic Electrolytes

Water and other polar molecules are attracted to ions, The electrostatic attraction between an ion and a molecule with a dipole is called an **ion-dipole attraction**. These attractions play an important role in the dissolution of ionic compounds in water.

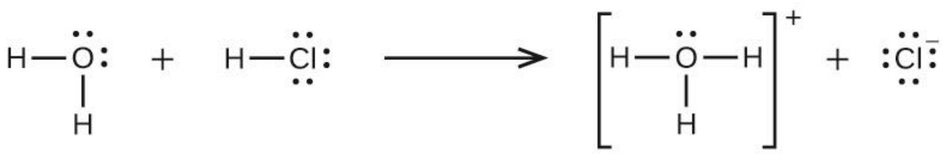
As potassium chloride (KCl) dissolves in water, the ions are hydrated. The polar water molecules are attracted by the charges on the K^+ and Cl^- ions. Water molecules in front of and behind the ions are not shown.



Covalent Electrolytes

Pure water is an extremely poor conductor of electricity because it is only very slightly ionized—only about two out of every 1 billion molecules ionize at 25 °C. Water ionizes when one molecule of water gives up a proton to another molecule of water, yielding hydronium and hydroxide ions.

Hydrogen chloride is an *acid*, and so its molecules react with water, transferring H^+ ions to form hydronium ions (H_3O^+) and chloride ions (Cl^-):



Solubility Rules
1. All common salts of the Group 1A elements (such as Na^+, K^+, and Li^+) and ammonium, NH_4^+, are soluble
2. All common salts containing acetate (CH_3COO^-), or nitrate (NO_3^-) are soluble
F) are soluble, except those of silver (Ag), mercury (Hg), and lead (Pb)
4. All compounds containing sulfate (SO_4^{2-}) are soluble, except those of barium (Ba), strontium (Sr), lead (Pb), calcium (Ca), silver (Ag), and mercury (Hg)
5. Except for those compounds following rule 1, compounds containing carbonate (CO_3^{2-}), hydroxide (OH^-), oxides (O^{2-}) and phosphates (PO_4^{3-}) are insoluble.

Properties of Electrolytes:

The properties of electrolytes depend on the type of electrolyte. **Strong electrolytes** *completely* dissociate in water, forming an aqueous solution with a high conductivity.

Weak electrolytes *partially* dissociate into its ions in water, so its aqueous solution has a low conductivity.

Non-electrolytes, on the other hand, are soluble in water, but they do not dissociate into ions. Therefore, an aqueous solution with a non-electrolyte does not conduct electric current.

Factors that affect the conductivity of electrolytes

The conductivity of an electrolyte is therefore affected by the following factors:

- The **concentration of ions** in solution. The higher the concentration of ions in solution, the higher its conductivity will be.

- The **type of substance** that dissolves in water. Whether a material is a strong electrolyte (e.g. potassium nitrate, KNO_3KNO3), a weak electrolyte (e.g. acetic acid, CH_3COOHCH3COOH) or a non-electrolyte (e.g. sugar, alcohol, oil) will affect the conductivity of water because the concentration of ions in solution will be different in each case. Strong electrolytes form ions easily, weak electrolytes do not form ions easily and non-electrolytes do not form ions in solution.
- **Temperature.** The warmer the solution, the higher the solubility of the material being dissolved and therefore the higher the conductivity as well.