ELECTROLYTES AND NONELECTROLYTES

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ELECTROLYTES AND NONELECTROLYTES

**Before we can discuss the properties that make a compound an electrolyte, we must first understand something about the properties of electricity.

--Electricity is the flow of electrons in a circuit from a battery or electrical generator along a wire back to the source. The electricity passing through the circuit can do work, such as running a motor or providing heat and light. The flow of electricity stops if the circuit is broken. An electrical circuit can also contain an aqueous solution, as shown in Figure 8-٢.

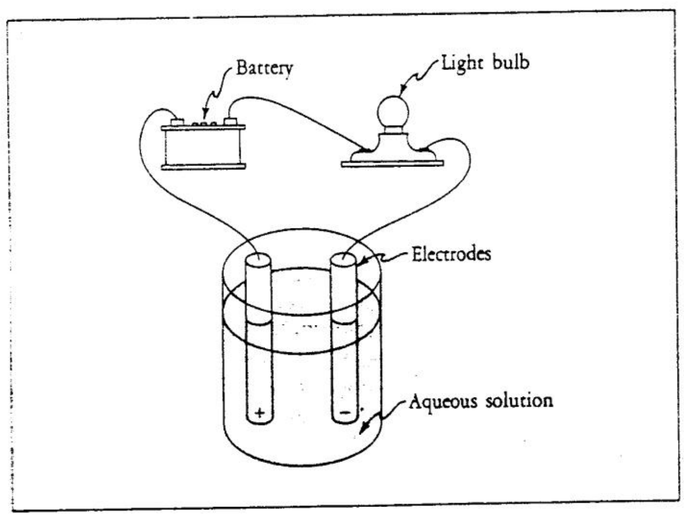


Fig. 8-2. An electrical circuit containing a battery, two electrodes, a light bulb, and an aqueous solution. Wires connect the battery, the electrodes, and the light bulb. The light bulb glows only if the aqueous solution conducts electricity.

--The two electrodes are oppositely charged, just like the two poles of the battery. For electricity to flow through this circuit after all the connections have been made, the solution must be able to conduct electricity. A glowing light bulb indicates that electricity is flowing through the circuit.

** Aqueous solutions either conduct electricity or they do not. One that conducts electricity is called an ***electrolytic solution;*** one that does not is called a ***nonelectrolytic solution***.

--A solute that forms an aqueous electrolytic solution is called an ***electrolyte.***

♦ Example of electrolytes and nonelectrolytes are given in Table 8-4.

♣ In general, the extent to which an electrolyte can break up into ions categorises an electrolyte. This gives a measure of the degree of dissociation (a) of an electrolyte. Based on this degree the electrolytes can be classified as strong or weak electrolyte and non-electrolyte.

1- **Strong Electrolyte**

A strong electrolyte dissociates or ionises completely or almost completely to form free mobile ions in the solution or molten form. The more the availability of free mobile ions in an electrolyte, the greater is its capacity to carry or conduct current i.e. the stronger the electrolyte. The ability to conduct current can be observed by setting up a cell as shown in figure 4.4. The bulb glows brightly.

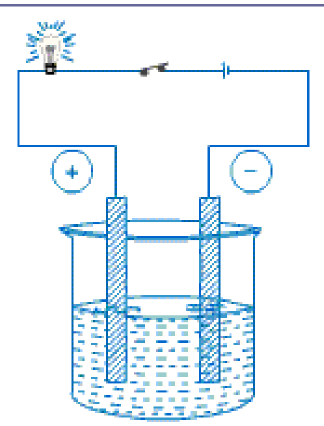


Fig. 4.4. Strong electrolyte

For e.g.,

Sodium chloride even in crystalline form consists of ions. But the ions are not mobile. When melted or dissolved in water, it dissociates completely into free, mobile ions

$$Na^+Cl^-\,(aq) \rightleftharpoons Na^+\,(aq) + Cl^-\,(aq)$$

2-Weak Electrolyte

A weak electrolyte ionises or dissociates only partially to form free mobile ions. Most of the electrolyte remains as un-ionised molecules.

--For example in acetic acid, the number of its dissociated ions (the acetate and hydrogen ions) is less compared to the total amount of acetic acid molecules present. Similarly in ammonium hydroxide the number of its dissociated ions (the ammonium and hydroxyl ions) are less compared to the total amount of the molecules present.

$$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$$

$$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

When the number of mobile ions is less in an electrolyte, the lesser is its capacity to carry or conduct current i.e. the weaker is the electrolyte. This is observed by setting up the cell as shown in figure 4.5. The bulb glows less brightly.

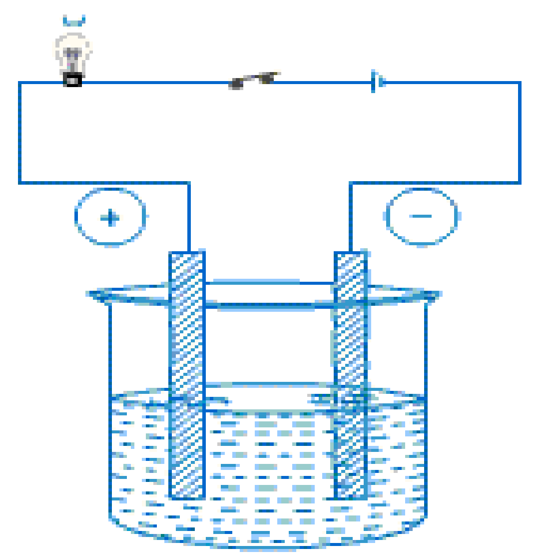


Fig. 4.5. Weak electrolyte

3- Non-electrolyte

A non-electrolyte does not provide ions in a solution and therefore current does not flow through such solution. The bulb in the given set up does not glow (Fig.4.6). Some examples of non-electrolytes are: alcohol, carbon tetrachloride, carbon disulphide.

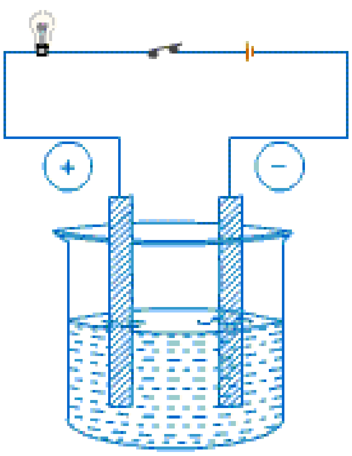


Fig. 4.6. Non-electrolyte does not conduct current in a solution

Examples of Electrolytes

Strong electrolyte	Weak electrolyte	Non-electrolyte
Sea water	Tap water	Chemically pure water
Hydrochloric acid	Carbonic acid	Alcohol
Sulphuric acid	Acetic acid	Kerosene
Aqueous copper sulphate	Ammonium hydroxide	Aqueous sugar solution
Molten lead bromide	Citric acid	Carbon disulphide
Aqueous sodium chloride	Oxalic acid	
Nitric acid		
Aqueous potassium hydroxide		

ARRHEIUS' THEORY OF ELECTROLYTES

In 1887the Swedish scientist Svante Arrhenius proposed that molecules dissolve in water to form particles that mix completely with solvent molecules.

**Electrolytes and nonelectrolytes form different kinds of particles when they dissolve in water.

1- All the electrolytes are compounds that contain ionic bonds. Such compounds are solids at room temperature and contain ions arranged in a crystal lattice. When these compounds are dissolves in water, the ions are released and they distribute themselves uniformly in the water. In addition to salts, many compounds with polar covalent bonds also form ions when dissolved in water.

Swedish scientist Svante Arrhenius

2- When nonelectrolytes dissolve in water, neutral molecules rather than ions are released. Pictorial representations of solutions of electrolytes and nonelectrolytes are shown in Figure 5-3. Water molecules surround ions'. Such close association of water molecules with an ion is called *hydration.* We say that the ion is hydrated.

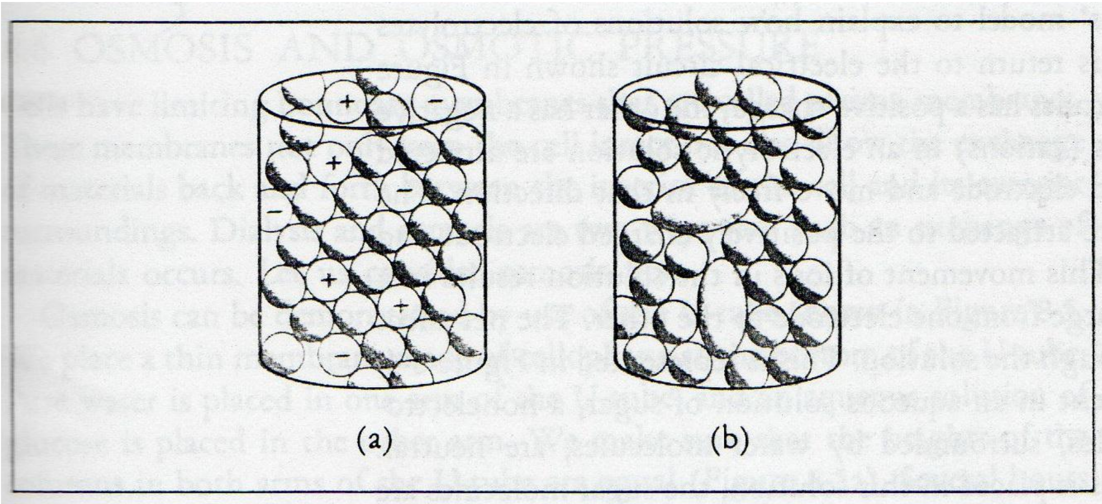


Fig. 8-3. A pictorial representation of (a) an aqueous solution of an electrolyte and (b) an aqueous solution of a nonelectrolyte. The open spheres represent water molecules. The spheres containing a plus or minus sign represent the ions; the spheroids represent neutral molecules.

--According to Arrhenius' model, an aqueous solution of sodium chloride contains an equal number of individual sodium and chloride ions, each surrounded by water molecules.

--Thus, 1 mole of sodium chloride forms ,1 mole of sodium ions and 1 mole of chloride ions when dissolved in water.

***Aqueous solutions of electrolytes are really solutions of hydrated ions.* The total number of ions formed per mole of electrolyte depends on the chemical formula of the electrolyte, as shown in Table 8-5.

--Thus, 1 mole of calcium chloride dissolved in water forms 1 mole of hydrated calcium ions and 2 moles of hydrated chloride ions.

Table 8-5. Number of Ions Formed per Mole of Electrolyte

Chemical Formula	Ions Formed in Aqueous Solution	Number of Ions in 1 Mol of Electrolyte
$NaCl$	Na^{+} Cl^{-}	$2 \times 6.02 \times 10^{23}$
$LiBr$	Li^{+} Br^{-}	$2 \times 6.02 \times 10^{23}$
KNO_3	K^{+} NO_3^{-}	$2 \times 6.02 \times 10^{23}$
$CaCl_2$	Ca^{+2} Cl^{-} Cl^{-}	$3 \times 6.02 \times 10^{23}$
Na_2SO_4	Na^{+} Na^{+} SO_4^{-2}	$3 \times 6.02 \times 10^{23}$
Na_3PO_4	Na^{+} Na^{+} Na^{+} PO_4^{-3}	$4 \times 6.02 \times 10^{23}$

EXERCISE 8-12 Give the correct symbol and the number of moles of each ion formed when one mole of the following electrolytes is dissolved in water:
(a) HCl (b) $NaOH$ (c) $CaCl_2$ (d) Na_2CO_3 (e) Li_3PO_4

--We can use Arrhenius' model to explain how solutions of electrolytes conduct electricity. Let us return to the electrical circuit shown in Figure' 8-2.

**One of the two electrodes has a positive charge; the other has a negative charge. The positive ions (cations) in an electrolytic solution are attracted to the negatively charged electrode and move freely in that direction. The negative ions (anions) are attracted to the positively charged electrode and move in that direction.

**This movement of ions in the solution results in a transport of electrical charge from one electrode to the other. The net effect is a flow of electrons through the solution. This is represented in Figure 8-4.

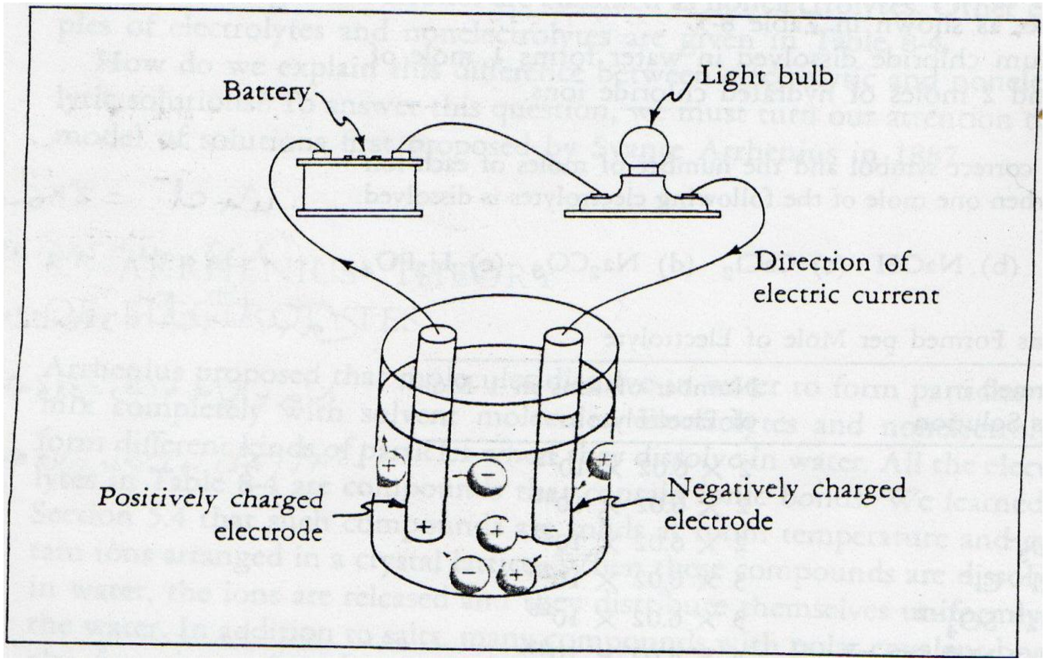


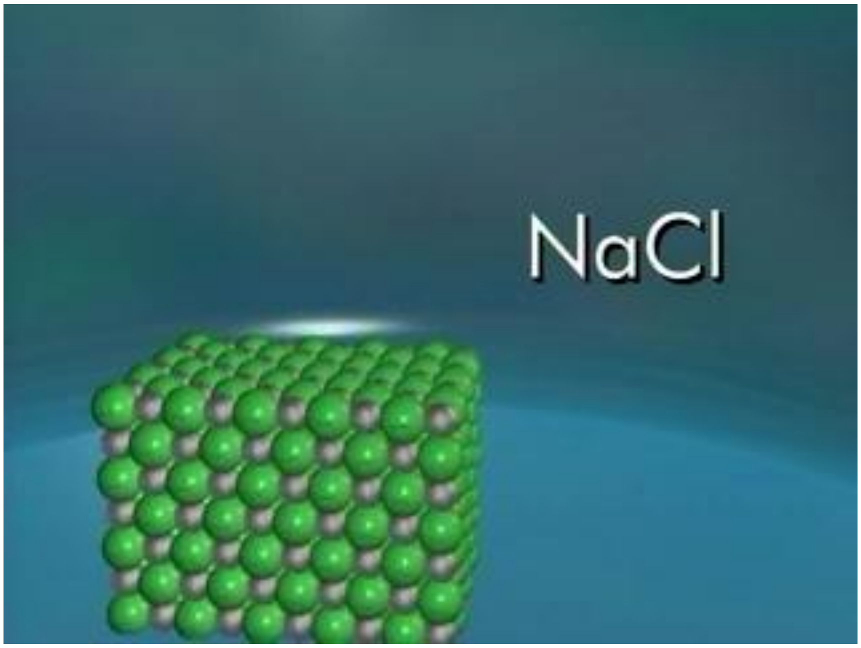
Fig. 8-4. The passage of an electric current through an electrolytic solution by the movement of ions. The spheres containing a plus or minus sign represent ions.

♠The situation is different in an aqueous solution of sugar, a nonelectrolyte. The sugar molecules, surrounded by water molecules, are neutral. When a pair of electrodes is placed in this solution, the sugar molecules are not attracted by either electrode. Consequently no electric current flows through the solution.

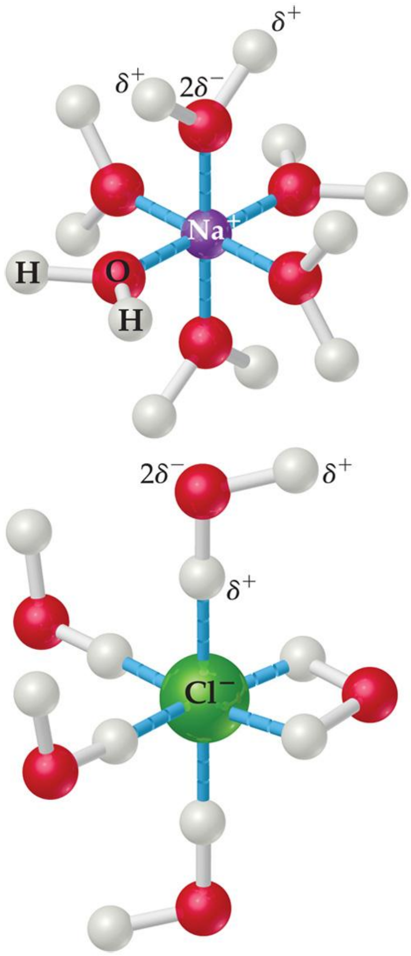
☼ Acids are substances that dissociate in water to yield electrically charged atoms or molecules, called ions, one of which is a hydrogen ion (H^+).

☼Bases ionize in water to yield hydroxide ions (OH^-). It is now known that the hydrogen ion cannot exist alone in water solution; rather, it exists in a combined state with a water molecule, as the hydronium ion (H_3O^+). In practice the hydronium ion is still customarily referred to as the hydrogen ion.

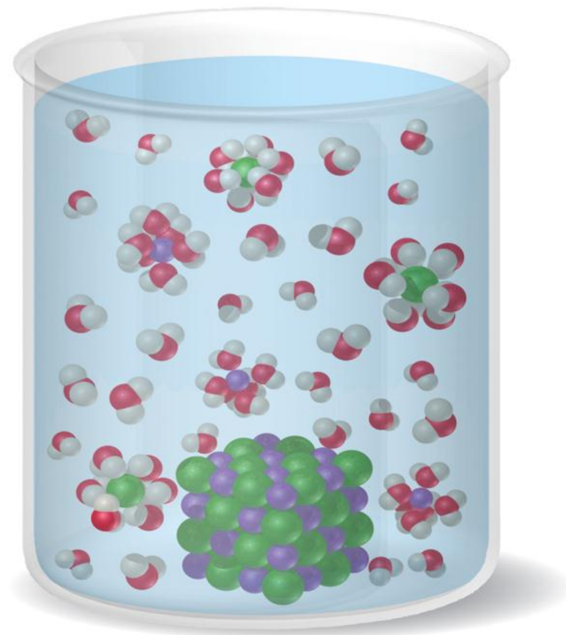
****We now have a model of electrolytic and nonelectrolytie solutions that we have used to explain the difference in electrical conductivity between the two types of solution. This model of solutions has been used successfully to explain all the physical properties of solutions. Osmosis is one physical property of solutions that is vital to the life of any cell. For this reason, we will examine this physical property next.**

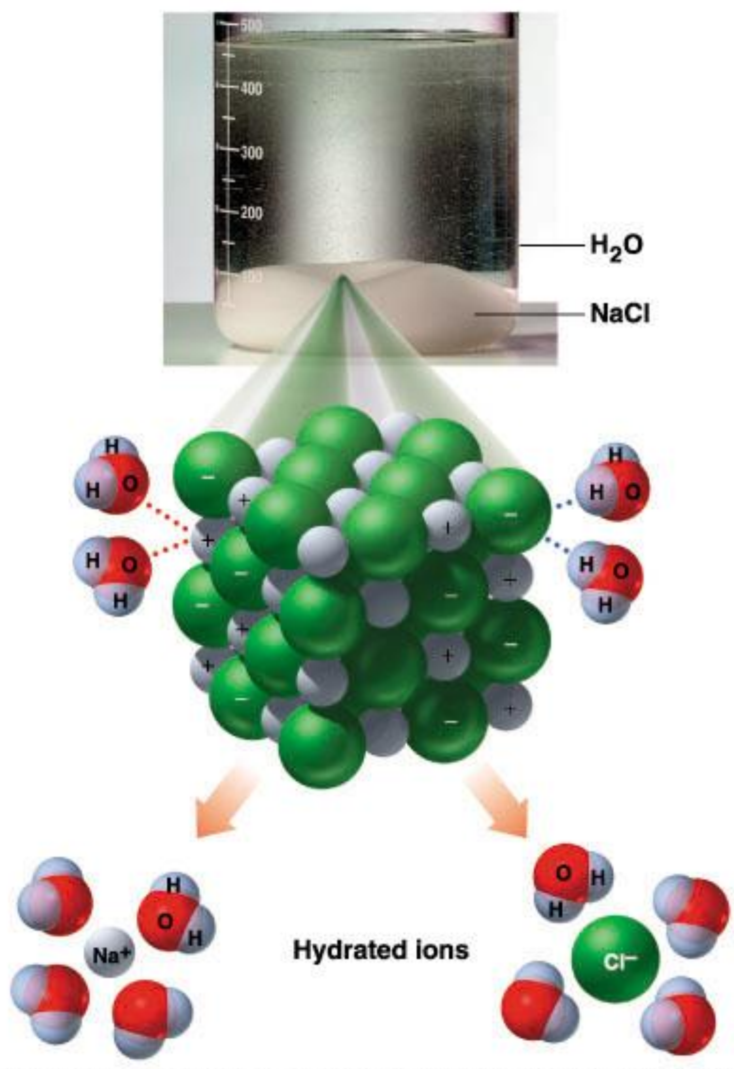


How Does a Solution Form?



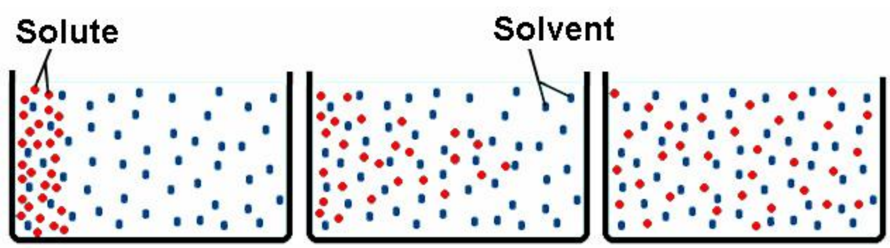
- The ions are **solvated** (surrounded by solvent).
- If the solvent is water, the ions are **hydrated**.
- The intermolecular force here is ion-dipole.




H2O
NaCl
Hydrated ions
Na+
Cl−

Diffusion

- Solute molecules moving from an area of high concentration to an area of low concentration
  - Random motion drives diffusion
  - Movement is based on kinetic energy (speed), charge, and mass of molecules
  - Equilibrium is reached when there is an even distribution of solute molecules



Osmosis

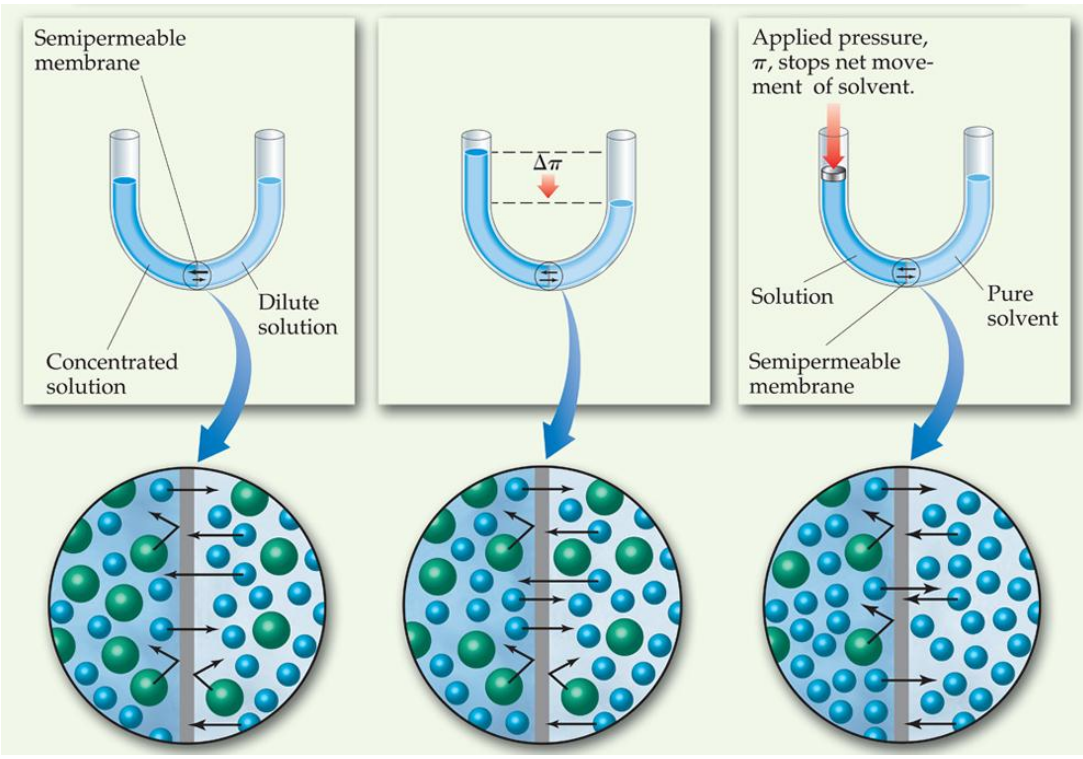
- Semipermeable membranes allow some particles to pass through while blocking others.
- In biological systems, most semipermeable membranes (such as cell walls) allow water to pass through, but block solutes.
- Osmosis can be demonstrated by use of the U-tube shown in Figure 8-5. We place a thin membrane made of cellophane at the bottom of the U-tube. Pure water is placed in one arm of the U-tube, and an aqueous solution of glucose is placed in the other arm. We make sure that the heights of the columns in both arms of the U-tube are equal (Figure 8-5a).
- --Several hours later, we find that the height of the column of glucose solution is greater than the height of the column of pure water (Figure 8-5b). For this change to a occur, water must have passed through the membrane.

Materials that only certain molecules to pass through are called ***semipermeable*** *membranes* or ***osmotic membranes***.

- --In our experiment, cellophane was the *semipermeable* membrane. In cells, the semipermeable membrane is the plasma membrane mentioned earlier.

Osmosis

In osmosis, there is net movement of solvent from the area of **higher solvent concentration** (*lower solute concentration*) to the are of **lower solvent concentration** (*higher solute concentration*).



Water tries to equalize the concentration on both sides until pressure is too high.

♦ There are microscopic pores in the membrane.

♦ Molecules below a certain size can diffuse through the pores.

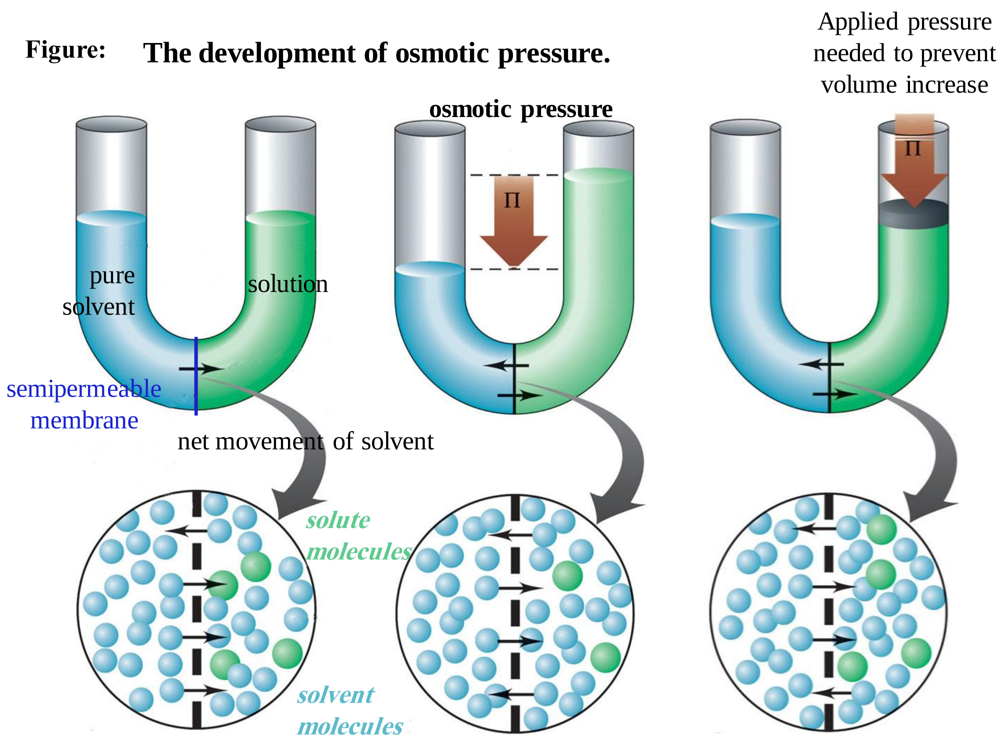
♦ Water molecules can easily diffuse through the pores.

H.W : EXERCISE 8-13 Each of the following pairs of aqueous solutions is separated by an osmotic membrane. In which direction will the water move? (a) water, 1M NaCl (b) 1M glucose, 0.5 M glucose (c) 0.5 M NaBr, 1.0 M NaCl

We can prevent osmosis from occurring by applying pressure to the right arm of the U-tube in Figure 8-5. If we apply just the right amount of pressure, we can keep the heights of the columns in both arms equal and osmosis does not occur. The pressure needed to prevent osmosis is called the ***osmotic pressure*** of a solution.

Notice that a high solute concentration means high osmotic pressure. Water moves from dilute to more concentrated solutions. The purpose of this movement of water is to make the concentrations of the solutions equal.

Figure: The development of osmotic pressure.



We must look at the structure of the osmotic membrane at the molecular level to understand osmosis. An osmotic membrane contains small holes. The size of these holes is an important property, which determines what kinds of molecules will pass through the membrane.

♣Molecules larger than the holes will not pass through. The membrane therefore acts like a molecular sieve. Certain molecules pass through the membrane, and others do not. This selectivity of the membrane is responsible for osmosis, as we will learn from the diagram in Figure 8-6.

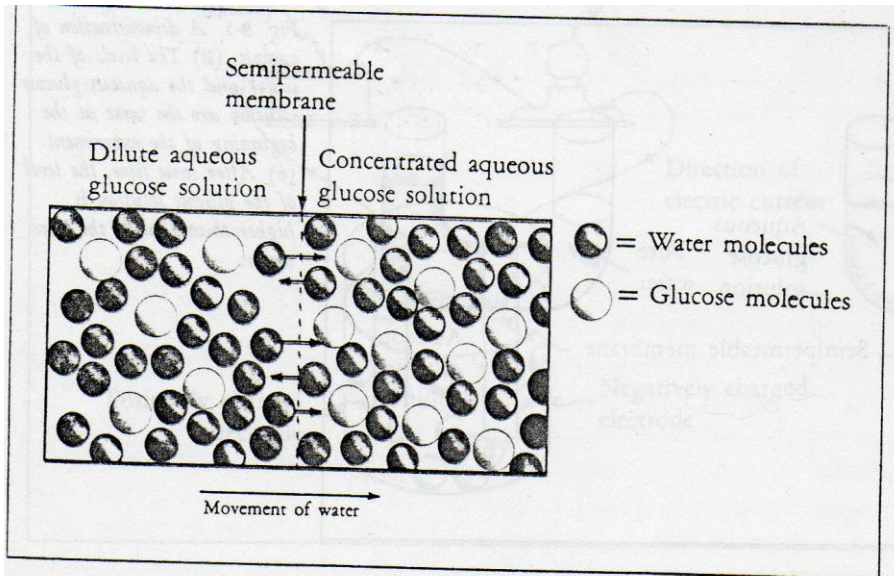


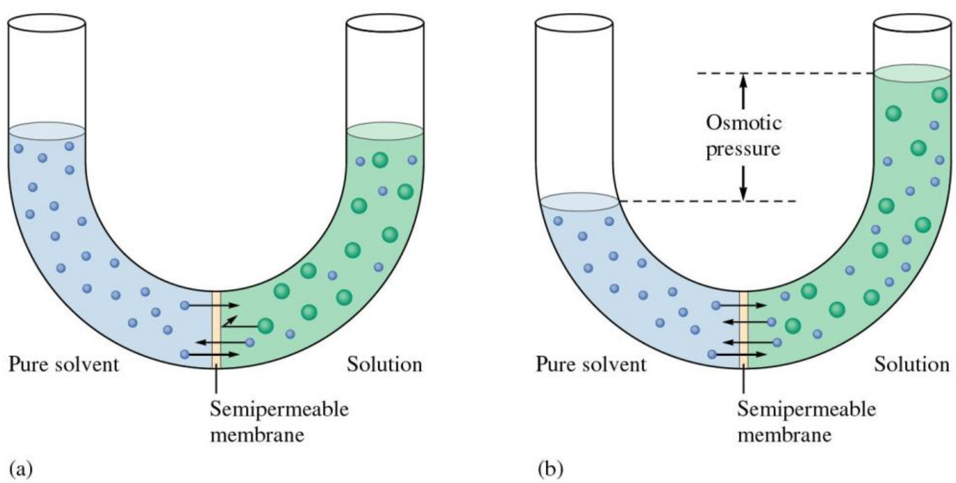
Fig. 8-6. A molecular view of osmosis.

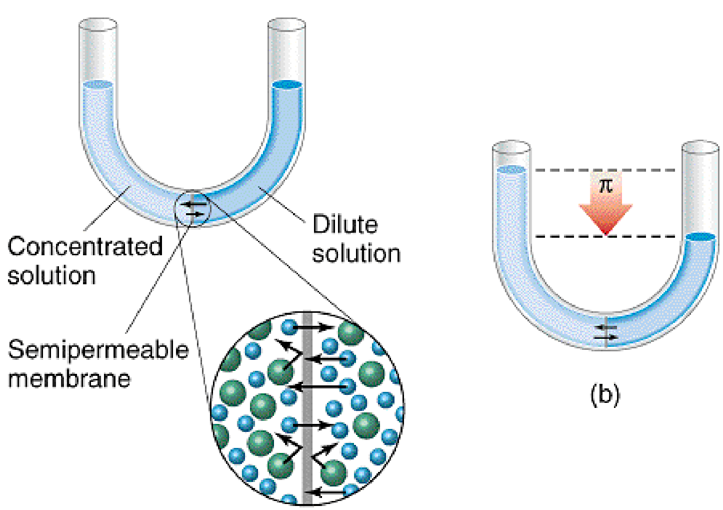
☺Figure 8-6 shows a molecular view of two aqueous glucose solutions of different concentrations separated by an osmotic membrane. The more concentrated solution is in the right compartment. The holes in the osmotic membrane are large enough that water molecules can pass in both directions. But the holes are so small that glucose molecules cannot get through. All the molecules in both solutions are in continual motion.

--As a result of this motion, water molecules reach the membrane and collide with it. A water molecule that happens to find a hole in the membrane passes through it.

☼The amount of water in the concentrated solution is less than that in the dilute solution, so the number of water molecules that collide with the membrane is smaller.

☻As a result, more water molecules pass through the membrane from the dilute glucose solution to the more concentrated glucose solution. The result is a net movement of water into the more concentrated glucose solution. This is visible as an increase in its volume. As *shown in the following figure* .





(a)