Osmosis Reverse Osmosis and Osmotic Pressure what they are

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What is osmosis? It is the phenomenon of water flow through a semi-permeable membrane that blocks the transport of salts or other solutes through it. Osmosis is a fundamental effect in all biological systems. It is applied to water purification and desalination, waste material treatment, and many other chemical and biochemical laboratory and industrial processes.

When two water (or other solvent) volumes are separated by a semi-permeable membrane, water will flow from the volume of low solute concentration, to the volume of high solute concentration. The flow may be stopped, or even reversed by applying external pressure on the volume of higher concentration. In such a case the phenomenon is called reverse osmosis.

If there are solute molecules only in one volume of the system, then the pressure on it, that stops the flow, is called the osmotic pressure.

The thermal movement of a solute molecule within a solvent is over damped by the solvent molecules that surround it. The solute movement is wholly determined by fluctuations of thermal collisions with nearby solvent molecules that vibrate it. However, the average thermal velocity of the solute molecule is the same had it been free in a gas phase, without nearby solvent molecules [1 - 3].

Whenever a solute movement is blocked by the membrane it will transfer momentum to it and, therefore, generate pressure on it. Since the velocity is the same as that of a free molecule, the pressure will be the same as the pressure of an ideal gas of the same molecular concentration. Hence, the osmotic pressure π, is given by van't Hoff formula [4], which is identical to the pressure formula of an ideal gas:

$$\pi = cRT$$

where c is the molar solute concentration, R is the gas constant, and T is the absolute temperature. The osmotic pressure does not depend on the solute type, or its molecular size, but only on its molar concentration, as the formula states.

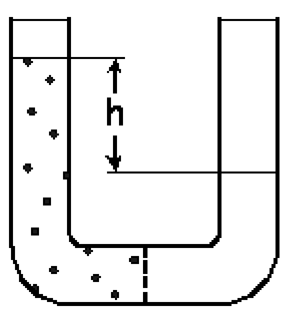

Figure-1 shows connected vessels separated by a semi-permeable membrane. If there is only water in the device, the level will be the same at both arms. When solute molecules are added to one arm, water will start to flow into it, so that its level will go up at this arm, and down at the other arm. The system will stabilize when the osmotic pressure is balanced by the hydrostatic pressure generated by the difference h in the water levels.

$$cRT = \rho h$$

where ρ is the water specific gravity.

The conservation laws of energy and momentum require that whenever particles collide with a moving wall, they will change direction and increase or decrease their speed. Thus, they transfer both momentum and energy to the wall. Therefore, the process of elastic collisions with a moving wall is the mechanism by which the microscopic kinetic energy of the particles is transformed into macroscopic mechanical work [1].

The conservation law of momentum requires that solute molecules, that generate osmotic pressure on the semi-permeable membrane, must generate, via the volume of the solution, the same osmotic pressure on all the solution boundaries, including its free surface. In this respect the osmotic pressure acts according to Pascal law.

When water flows through the membrane the pressure on the moving free surface of the solution is pushing it upward, and thus it is responsible to water pumping from the water arm to the solution arm. This discussion of the flow mechanism usually does not appear in textbooks that deal with osmosis. The effect of the osmotic pressure on the free surface of the solution was first suggested by Hulett in 1902 [5], but received little attention. It seems to have only few proponents since then [6 - 15].

Osmosis is a reversible thermodynamic process. That is, the direction of water flow through the membrane can be reversed at any moment by proper control of the external pressure on the solution. Contrary to that, mixing a teaspoon full of sugar in a cup of tea is an irreversible thermodynamic process of sugar diffusion within water. There is no way to reverse the process at any given moment and un-mix the sugar back to the spoon.

Reversibility is a fundamental idea of thermodynamics. Osmosis is a reversible process, while sugar diffusion in water is not. Diffusion is an irreversible process.

See:
Why the osmotic pressure of a solution is equal to a gas pressure of the same particle concentration?
What do the greatest people of science think on osmosis?
"More on Osmosis" http://urila.tripod.com/osmosis.htm

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Links:

1. Thermodynamics Research Laboratory, http://www.uic.edu/~mansoori/Thermodynamics.Educational.Sites_html
2. Thermodynamik - Warmelehre, http://www.schulphysik.de/thermodyn.html
3. The Blind Men and the Elephant
4. My Spin on Lunacy, http://www.optics.arizona.edu/Palmer/moon/lunacy.htm
5. The first man I saw
6. The First-Class Passenger