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Jacobus H. van't Hoff: Osmotic Pressure and Chemical Equilibrium

Jonathan Rosales
Parkland College

JACOBUS H. VAN'T HOFF

Osmotic Pressure and Chemical Equilibrium

Jonathan Rosales
CHE 101-004, Dr. Mullen, Parkland College

Introduction:

Jacobus Henricus van't Hoff is a Dutch physical and organic chemist who won the first nobel prize of Chemistry in 1901. He formulated the osmotic pressure law, and is also considered one of the founders of physical chemistry. His best works were in osmotic pressure, chemical equilibrium, chemical kinetics, and stereochemistry. ("Jacobus H. van 't Hoff - Facts")

(Nobel Prize in Chemistry)

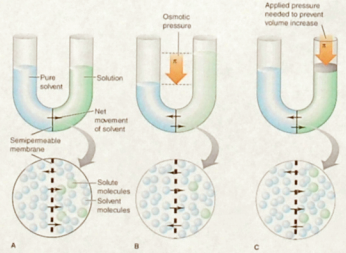
(Jacobus Henricus van't Hoff)

Biography:

Jacobus Henricus van't Hoff was born in Rotterdam, the Netherlands, on August 30, 1852. In 1869, he went to the Polytechnic School at Delft and got his technology diploma in 1871. In 1874, he went to Utrecht in order to obtain his doctor's degree under E. Mulder. In 1878, he married Johanna Francina Mees. They had two daughters and two sons. Van't Hoff wrote most of his professional work in his books — *Bijdrage tot de Kennis van Cyaanazijnzuren en Malonzuur*, *Chimie dans l'Espace*, *Études de Dynamique chimique*, and *L'Équilibre chimique dans les Systèmes gazeux ou dissous à l'État dilué*. He died in Berlin, Germany, on March 1, 1911. ("Jacobus H. van 't Hoff - Biographical")

Chemistry:

Osmosis is a process by which molecules of a solvent tend to pass through a semipermeable membrane from a less concentrated solution into a more concentrated one, equalizing the concentrations on each side of the membrane. The osmotic pressure of a solution is the pressure difference needed to stop the flow of solvent across a semipermeable membrane. ("Osmotic Pressure")



(Osmotic Pressure)

The osmotic pressure of a solution is proportional to the molar concentration of the solute particles in solution. ("Osmotic Pressure")

$$\Pi = iMRT$$

(Osmotic Pressure Formula)

Π is the osmotic pressure
i is the van't Hoff factor
M is the molarity of the solution
R is the ideal gas constant (0.08206 L atm / mol K)
T is the temperature in Kelvin

Contribution:

Jacobus Henricus van't Hoff made major contributions in Chemistry with respect to both the structure of molecules and various sequences of events. He came up with a theory on osmotic pressure that explains how concentrations even out in solutions that are separated by a membrane that allows the solvent to pass through but not the dissolved substance. Through this theory, he formulated the osmotic pressure law. He continued to further relate this discovery with chemical reactions and how temperatures affect them. Van't Hoff was nominated on 11 occasions in 1901 for his work. He had the following named after him: the van't Hoff factor, the van't Hoff equation, and the Le Bel-van't Hoff rule. ("Jacobus H. van 't Hoff - Facts")

In Jacobus Henricus van't Hoff's Nobel Lecture, he states that he first discovered that osmotic pressure was the same as gas pressure. "To some extent this is obvious: just as one imagines the gas pressure *P* to arise as a result of the movement of molecules and of their collisions with the walls (Fig. 1), so can one imagine the osmotic pressure *p* to arise as a result of the collisions of the dissolved molecules with the semi-permeable membrane (Fig. 2) surrounded by the solvent (denoted by shading)." (Van't Hoff)

He then set the pressure from the ideal gas equation to the pressure of osmotic pressure. But he then noticed something was off. "The osmotic pressure was *i times* greater than the theoretical value." The equation then changed into the formula, $\pi = iMRT$. *i* became the van't Hoff factor where non-electrolytes equal 1 and electrolytes equal the number of ions. (Van't Hoff)

Chemical Equilibrium:

Jacobus Henricus van't Hoff continued to relate his osmotic pressure theory to chemical equilibrium. "Introducing the sign for a reversible reaction instead of the sign of equality" creates transformations that take place in either direction with the final state being known as chemical equilibrium. Chemical equilibrium, by definition, is the state in which both reactants and products are present in concentrations which have no further tendency to change with time. Using the basic relationship for osmotic pressure, Van't Hoff created the formula K=-A/2T. This eventually led to the creation of the van't Hoff equation.

$$\frac{d \ln K}{dT} = \frac{\Delta H}{RT^2}$$

(Van't Hoff Equation)

K is the equilibrium constant
T is temperature
H is the enthalpy of the reaction
R is the gas constant

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(Jacobus Henricus van't Hoff)