Pfeffer Cell Apparatus [1]


The Pfeffer Zelle (Pfeffer Cell Apparatus), invented by Wilhelm Pfeffer [6] in 1877, measured the minimum pressure needed to prevent a pure solvent from passing into a solution across a semi-permeable membrane, called osmotic pressure. The apparatus provided Pfeffer with a way to quantitatively measure osmotic pressure. Pfeffer devised the apparatus in the 1870s at the University of Basel [7] in Basel, Switzerland, and he described the Pfeffer Cell Apparatus in his 1877 book Osmotische Untersuchungen: Studien Zur Zellmechanik (Osmotic Investigations: Studies on Cell Mechanics). Pfeffer relied on nineteenth century experiments of Moritz Traube in Germany, who constructed artificial copper ferrocyanide membranes to study osmosis. The apparatus enabled Pfeffer to study osmosis and osmotic pressure as plants grow, and later researchers used it to explain how plants develop.

Pfeffer spent his post-doctoral years in the laboratories of several botanists including Nathanael Pringsheim in Berlin, Germany, who studied reproduction in plants, and Julius von Sachs in Leipzig [8], Germany, who studied plant physiology. Both men encouraged Pfeffer to study plant physiology rather than chemistry. In the late 1860s and early 1870s, at the University of Marburg in Marburg, Germany, Pfeffer studied different stimulants that affect plants including light and temperature. Pringsheim and Sachs introduced him to the research problems in botany that led Pfeffer to study osmotics, which concerns anything relating to osmosis or the passage of water through a membrane, in plant membranes.

In 1872, Pfeffer began to conduct experiments on osmotic pressure. According to Gordon R. Kepner and Eduard J. Stadelmann, the 1985 translators of Pfeffer's Osmotic Investigations into English, Pfeffer experimented on various stimulants and the cause of the pressure exerted by the cell wall on the cell as it forces water to leave the cell, or hydrostatic pressure. In 1873, Pfeffer began his first professorial appointment at the University of Bonn [9] in Bonn, Germany, where he continued researching aspects of osmotic phenomena.

The theory of osmosis describes the spontaneous movement of solvent molecules, such as water, through a semi-permeable membrane from lower to higher concentration of solute to equalize the concentration of solute on both sides of the membrane. By the mid-nineteenth century, the theory of osmosis was over one hundred years old. Tests on how osmosis operates had been repeated numerous times using organic and inorganic materials. Most of those experiments used the osmometer apparatus created by René Henri Dutrochet, who researched osmosis and diffusion in France in the early 1800s.

The osmometer was an inverted funnel with the mouth covered by a diaphragm [10], or membrane, which was filled with a solution and placed in a water bath. Scientists observed that water flowed through the membrane from the lower concentration of solute outside the funnel to the higher concentration of solute inside the funnel. The changing fluid level in the stem of the funnel measured the osmotic pressure of the solution.

By the late 1860s, after several basic experiments on osmosis, Friedrich Wilhelm Ostwald [11], who studied the physical chemistry of chemical equilibrium and reactivity at the University of Leipzig [12] in Leipzig [8], Germany, concluded that osmotic phenomena depended on the nature of the membrane. Ostwald and other physicists and chemists argued that physiologists should study osmotic phenomena but few did until Pfeffer's work.

When Pfeffer began his experiments, he started with a technique published by Traube in 1867. Traube worked out the conditions for forming artificial membranes using, a solution of copper sulfate and crystals or a solution of potassium ferrocyanide. Traube dropped crystals of potassium ferrocyanide into a solution of copper sulfate a film of copper-ferrocyanide formed, or precipitated at the boundary between the crystals and the solution. Traube called those films "cells" because they expanded and budded like the plasma membranes of living cells. Water from the copper sulfate solution could pass through the precipitated film or membrane and dissolve the crystals of potassium ferrocyanide. There is no further passage of the copper sulfate or the potassium ferrocyanide molecules from one side of the membrane to the other and the cell would burst when too much water enter the cell.

Pfeffer could not measure the pressures that developed across a Traube membrane, as the membrane would break with any excess pressure. Pfeffer overcame those difficulties with his apparatus by precipitating the membrane in the walls of a porous porcelain cell, which provided the mechanical support needed to resist pressures reaching several times the atmospheric pressure at sea level, called atmospheres. Pfeffer used porcelain cells that were the unglazed type found in electric batteries. Each cell was approximately forty-six millimeters (1.8 inches) high, sixteen millimeters (0.63 inches) in diameter, and one and a quarter to two millimeters (approximately 0.079 inches) thick.

Pfeffer discusses and illustrates the Pfeffer apparatus, which contains the porcelain cell, in his book Osmotic Investigations. The apparatus consisted of the porcelain cell with a membrane, a connecting piece fused to the porcelain cell, and a narrow closing
Sources

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