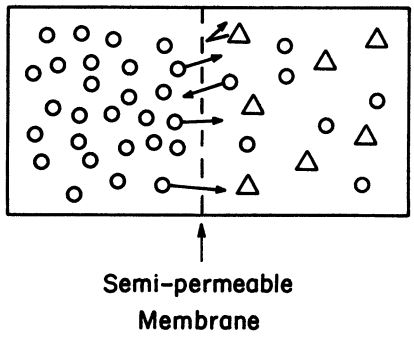

Figure 11.18. A typical dialysis membrane separation. Low-MW component 1 (○) diffuses through membrane from high to low concentration region. High-MW component (Δ) cannot pass.

where C_1 is the concentration and γ_1 is the activity coefficient of diffusing component 1. For ideal (very dilute) solutions, $\gamma_1 \approx 1$ and

$$C_1^{\alpha} = C_1^{\beta} \tag{11.54}$$

The concentrations represented in eqs. 11.51 through 11.54 are concentrations of dissolved (unbound) component 1.

This dialysis equilibrium is based on the assumption of uncharged solute molecules. If macromolecules are polyelectrolytes, such as proteins and nucleic acids, then the charge equilibrium of the macromolecules needs to be considered. This equilibrium is known as the Donnan equilibrium.

11.4.6. Reverse Osmosis

For fermentation broths, osmosis is the transport of water molecules from a high- to a low-concentration region (i.e., from a pure water phase to a salt-containing aqueous phase) when these two phases are separated by a selective membrane. The water passes the membrane easily, while the salt does not. At equilibrium, the chemical potential of water must be the same on both sides of the membrane. As the water passes into the salt solution, its pressure increases. This *osmotic pressure* can be expressed by

$$\pi = CRT(1 + B_2C + B_3C^2 + \cdots) \tag{11.55}$$

where C is the concentration of the solute, T is temperature, R is the gas constant, and B_2, B_3 are the virial coefficients for the solute. For very dilute, ideal solutions, $B_2 = B_3 = 0$, and

$$\pi = CRT \tag{11.56}$$

In reverse osmosis (RO), a pressure is applied onto a salt-containing phase, which drives water (solvent) molecules from a low- to a high-concentration region and results in the concentration of solute (salt) molecules on one side of the membrane. The pressure required to move solvent from a low- to high-concentration phase is equal to or slightly larger than the osmotic pressure. When $\Delta p > \pi$, a solvent flux takes place in the direction against the concentration gradient (see Fig. 11.19).