Thermodynamics in Membrane Process Design

R. Lichtenthaler[C, S]
Applied Thermodynamics, Institute of Physical Chemistry, University of Heidelberg, Heidelberg, Germany
R.Lichtenthaler@urz.uni-heidelberg.de

For process as well as membrane-module design reliable equations describing the separation process are necessary in order to calculate membrane selectivity and permeate flux at different operating conditions of a separation unit. The knowledge of thermodynamic and transport properties is of particular importance for modeling the separation of gaseous and liquid mixtures using selective nonporous membranes. Most nonporous membranes used in industrial applications are composite membranes consisting of a thin, nonporous, polymeric top layer (thickness 0.5-5 μm) covering the surface of a porous support (thickness 100-500 μm). The thin top layer is mainly responsible for the separation. The support has usually no or little influence on the separation characteristics of such membranes. Its purpose is to provide mechanical stability in a membrane-separation unit. Therefore the separation mechanism is nearly exclusively due to the differences in solubility and diffusivity of the various permeating components in the dense membrane polymer. Furthermore it is important to know the state of aggregation and the phase behavior of the mixture to be separated.

Equations modeling the separation process should contain a number as small as possible of system-specific material properties and those should be obtainable from simple experiments, such as sorption, permeation-flux and phase-equilibrium measurements. For practical reasons a compromise between an exact physico-chemical model and a simple empirical description has to be found, combining a minimum of experimental effort with a maximum of flexibility and accuracy. The so-called solution-diffusion model has proven to be a valuable tool to describe the material transport in the selective layer and it can be used for prediction and calculation of the separation characteristics if the solubility and diffusivity of the various permeating components are known. However, due to swelling of the membrane polymer coupling effects between the transport rates of different components are occurring and have to be taken into account. The important features of the model are discussed and its applicability and limitations are demonstrated using experimental results of the separation of some liquid mixtures by pervaporation.