Biomimetic Liquid Membrane for CO_2 Removal from Natural Gas

Yingjie Qin[1], Jijun Ge[2], Robert M. Cowan[2], Michael C. Trachtenberg[1,2]
[1]Carbozyme, Inc., Bordentown, NJ, [2]Sapient's Institute, New Brunswick, NJ

Abstract:
A biocatalyst-based facilitated-transport liquid membrane was studied for CO_2 separation from natural gas. The presence of a biocatalyst, carbonic anhydrase (CA – E.C. 4.2.1.1), accelerated the kinetic rates of hydration or dehydration of CO_2 occurring at the gas-liquid interfaces. These are the controlling steps under conditions in which mass transport resistance is minimized by use of thin and efficient liquid membranes. In addition to CA several carriers were added to the liquid membrane to facilitate the transport of the bicarbonate ions generated by the CA.

In this paper, we report the detailed studies on a hollow fiber, enzyme-based, contained liquid membrane (HF-EBCLM) configuration for CO_2 separation from natural gas over a wide range of CO_2 partial pressure. The HF-EBCLM consists of two sets of porous hydrophobic polypropylene hollow fibers separated by a hydrophilic macroporous mesh. The porous hydrophobic polypropylene hollow fibers were surface treated to add an ultrathin hydrophobic coating for bearing a high transmembrane pressure difference and reduce water evaporation. The liquid membrane is contained on the shell side of the hollow fibers and is accessible via a reservoir.

The feed gas passed through the bore of one set of fibers while the permeate was extracted from the bore of another set of fibers. The liquid phase was circulated between the module shell and a reservoir to ensure long-term operational stability. Vacuum or air sweep was used to remove CO_2 from the permeate side. The detailed structural parameters included CA concentration, overall feed pressure, CO_2 partial pressure in the feed and in the permeate, carrier species and their concentration ratio to control pH, and temperature. The results show that this membrane system separated CO_2 from natural gas very efficiently. The CO_2 selectivity and permeance increased 2–10-fold in the presence of CA as compared to its absence. Selectivity values (CO_2/CH_4) ranged from 200 to 1,000 and CO_2 permeance from $2x10^{-9}$ to $2x10^{-8}$ mol/m^{2}s Pa, respectively, for a partial pressure of CO_2 of 1 to 5 atm in the feed.