Describing the Transport of CO_2 through a Cellulose Acetate Membrane with Non-Equilibrium Thermodynamics

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Membranes are nowadays part of a mature technology for purification of natural gas from CO2. Numerous alternatives are available for that purpose. However, due to its features, the membrane technology is particularly interesting when combined with enhance oil/gas recovery, since it allows overcoming the inherent drawback of low selectivity. In such processes, the different composition of the raw gas and operating pressures determine the overall performance and operating cost of the process. Therefore, the development of proper permeation models is an important issue. Engineering models typically account for phenomena such as concentration polarization [1], coupled transport [2], or the composite structure of the membrane using global transport parameters. The limitation is that the parameters will often depend on the operating conditions and the system parameters in non-trivial ways. To gain a proper insight on the permeation of the gas, all the different involved steps should be considered [3]. First, the gas diffuses through the boundary layer at the feed side, and it is absorbed in the surface of the membrane. Then, it diffuses through the active dense layer, to be desorbed at the interface with the porous support layer. Finally, it is transported through the support to the feed side, where it diffuses to the bulk phase. All these steps constitute a relevant resistance towards the permeation of the gas. It should be noticed that due to the large pressure difference between the feed/residue side (typically above 50 bar) and the permeate side in the membrane unit, there will be significant Joule-Thompson effects as gas moves across the membrane [4]. The theory of non-equilibrium thermodynamics combined with a proper description of thermodynamic properties [5-6] enables us to accurately describe the mentioned phenomena, and possibly evaluate the impact on the performance and costs of the membrane unit.

References

[1] X. Feng, Y.M.R. Huang, J. Membrane Sci., 1994, 92, 201-208.
[2] R.Skorpa, M.Volsund, M.Takla, S.K.Schnell, D.Bedeaux, S.Kjelstrup, J. Membrane Sci.,2012, 394-395.
[3] S.Sridhar, B.Smitha, T.M. Aminabhavi, Sep. Purif. Rev., 2007, 36:2, 113-174.
[4] F. Ahmad, L.K. Keong, A.M. Shariff, G. Murshid, Int. J. of Chem. and Environmental Engin., 2012, 3.
[5] H. Li, J.P. Jakobsen, Ø. Wilhelmsen, J. Yan. Appl Energy, 2011, 88, 3567-3569.
[6] H.L. Frisch. Polym. Eng. Sci., 1980, 20(1):2-13.