396g Pervaporation of Water through Poly(Ethylene Glycol) Hydrogels: the Pumping Mechanism of a Synthetic Leaf

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Inspired by the circulatory system of deciduous trees, the goal of this work is to create a synthetic analogue of natural leaves. In the plant science community, it is believed that nano-capillarity at the air-liquid interface within leaves provides the driving force for the transport of water from reservoirs in the ground to the interface, where it is lost through evaporation. In order to wick water through micron-scale conduits and to great heights, as must be done for mature trees, leaves must generate tens of bars of negative pressure. A synthetic system capable of generating similar pressure gradients would be of great benefit to pressure-intensive microfluidic processes and could serve as a high-performance wick immune to limitations imposed by gravity. Instead of using nano-capillarity to drive fluid motion, our approach is to harness the osmotic gradients induced by exposing poly(ethylene glycol) hydrogel membranes to a controlled atmosphere, a situation encountered in pervaporation processes. I will present experimental and theoretical aspects of our work toward the realization of this goal and toward a fundamental understanding of the thermodynamics, transport and mechanics involved. The synthetic leaf system consists of a PEG membrane, a microfluidic network defined in poly(dimethylsiloxane) used to supply water to the membrane and a water reservoir. To test the ability of the synthetic leaf to pump against hydraulic loads we place a long, narrow microchannel, also defined in PDMS, between the network and the reservoir. We use a Flory-Rehner-based model and experimentally determined thermodynamic properties of water at both surfaces of the membrane to describe the osmotic gradient across pervaporating PEG hydrogels of varying polymer content, cross-link density and mechanical strength. With the osmotic driving force known, we calculate the diffusion coefficient of water through the membranes from gravimetrically measured pervaporation fluxes and various expressions that describe diffusive transport through the membrane. The results are compared to diffusion coefficients measured via a load relaxation technique and those found in the literature. We also investigate the importance of including a mechanical balance between the membrane and the water within in the description of the thermodynamics and transport processes of pervaporation.