

Diffusion in nanoporous materials as rate-limiting step in gas separation: Membrane permeation and pressure swing adsorption

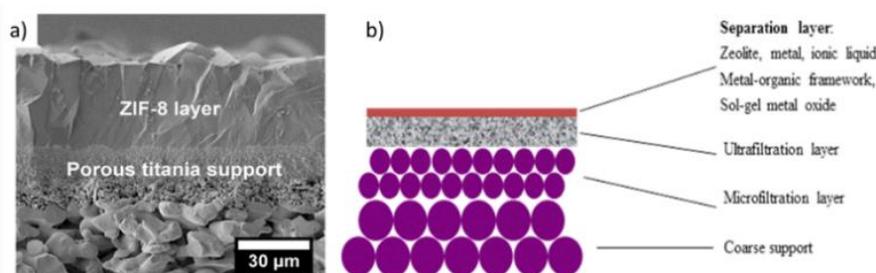
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Nanoporous materials like zeolites are widely used for industrial gas separation through pressure swing adsorption (psa), new disruptive materials like metal-organic frameworks (MOFs) and covalent organic frameworks (COFs) are under evaluation. First LTA zeolite membranes are used in about 500 plants worldwide for the de-watering of solvents, especially bio-ethanol. MOF membranes are tested for their unique ability to separate short chain olefin/paraffin mixtures.

Industrial adsorbents and membranes usually show a hierarchical transport-optimized structure. Such hierarchical structure as shown in the figure allows an effective interplay of nanopore diffusion [1] in the separation layer with fluid flow through the macroporous support [2] to minimize the overall transport resistance [3].

Typical planar ceramic membrane obtained by sequential tape casting with a gas selective layer on top.



a) A metal-organic framework (MOF) type ZIF-8 layer on an asymmetric graded titania support [4], b) Principle of a supported membrane: The μm -thick separation layer is deposited on a

macroporous ceramic or metallic support. To reduce the pressure drop across the support, i.e. to minimize the flow resistance, usually asymmetric (graded) supports with hierarchical cross section are used. As a rough estimate, mass transport through a membrane can be described using 1st Fickian Law. The flux density of component A through the membrane is described by $j_A = -D_{TA} \frac{\partial c}{\partial x}$ with j_A as the flux density in mol of A per time and area. D_{TA} is the transport diffusivity of A, and $\partial c/\partial x$ is the concentration gradient of component A across the membrane. Exact knowledge of the transport diffusivity is thus an important prerequisite for a knowledge-based optimization of separation devices [5]. A discussion of the challenges and traps of such measurement is the focus of the Conference Workshop on “Diffusion in Nanoporous Materials” and part of an IUPAC initiative (<https://iupac.org/project/2015-002-2-100>).

Adsorbents for rapid cycle pressure swing adsorption (psa) processes must allow a quick fluid flow of the feed into the nanopores of a zeolite or coal, where a diffusion-limited adsorption into the micropore system takes place. The shaped zeolite or carbon powders should show transport path like a human lung. For a short cycle time, however, the pressure drop in a packed adsorbent bed becomes a problem. The choice of an appropriate model accounting for intra-particle diffusional limitations is essential to simulate accurately the pressurization and blowdown steps of a psa processes [6].



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