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Organic Permeation Properties of Hydrophobic Silica Membranes with Different Functional Groups

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Abstract : The separation of organic compounds from aqueous solutions is a key technology for recycling valuable organic compounds and for the treatment of wastewater. The wastewater from chemical plants often contains organic compounds such as ethyl acetate (EA), methylethyl ketone (MEK) and isopropyl alcohol (IPA). In this study, we prepared hydrophobic silica membranes by a sol-gel method. We used phenyltrimethoxysilane (PhTMS), ethyltrimethoxysilan (ETMS), Propyltrimethoxysilane (PrTMS), N-butyltrimethoxysilane (BTMS), N-Hexyltrimethoxysilane (HTMS) as silica sources to introduce each functional groups on the membrane surface. Cetyltrimethyl ammonium bromide (CTAB) was used as a molecular template to create suitable pore that enable the permeation of organic compounds. These membranes with five different functional groups were characterized by SEM, FT-IR, and permporometry. Thicknesses and pore diameters of silica layer for all membrane were about 1.0 μm and about 1 nm, respectively. In other words, functional groups had an insignificant effect on the membrane thicknesses and the formation of the pore by CTAB. We confirmed the effect of functional groups on the flux and separation factor for ethyl acetate (EA), methyl ethyl ketone, acetone and 1-butanol (1-BtOH) /water mixtures. All membranes showed a high flux for ethyl acetate compared with other compounds. In particular, the hydrophobic silica membrane prepared by using BTMS showed 0.75 kg m-2 h-1 of flux for EA. For all membranes, the fluxes of organic compounds showed the large values in the order corresponding to EA > MEK > acetone > 1-BtOH. On the other hand, carbon chain length of functional groups among ETMS, PrTMS, BTMS, PrTMS and HTMS did not have a major effect on the organic flux. Although we confirmed the relationship between organic fluxes and organic molecular diameters or fugacity of organic compounds, these factors had a low correlation with organic fluxes. It is considered that these factors affect the diffusivity. Generally, permeation through membranes is based on the diffusivity and solubility. Therefore, it is deemed that organic fluxes through these hydrophobic membranes are strongly influenced by solubility. We tried to estimate the organic fluxes by Hansen solubility parameter (HSP). HSP, which is based on the cohesion energy per molar volume and is composed of dispersion forces (δd), intermolecular dipole interactions (δp), and hydrogen-bonding interactions (δh), has recently attracted attention as a means for evaluating the resolution and aggregation behavior. Evaluation of solubility for two substances can be represented by using the Ra [(MPa)1/2] value, meaning the distance of HSPs for both of substances. A smaller Ra value means a higher solubility for each substance. On the other hand, it can be estimated that the substances with large Ra value show low solubility. We established the correlation equation, which was based on Ra, of organic flux at low concentrations of organic compounds and at 295-325 K.

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