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Experimental study of vapor permeation of C_5—C_7 alkane through PDMS membrane

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A B S T R A C T

Vapor permeation through dense membrane is regarded as an effectively way to separate volatile organic compounds (VOC) from industrial gas stream. This study proposes a new method to get the solubility and diffusivity of pure VOC vapor in dense membrane. C_5H_{12}, C_6H_{14} and C_7H_{16} were selected as sample VOC components to conduct newly developed sorption experiment with polydimethylsiloxane (PDMS) membrane. For each considered VOC component, its solubility was obtained from measured sorption equilibrium concentration in PDMS membrane, and its diffusivity was determined by fitting diffusion equation to the measured transient concentration of VOC component. The permeation behavior of VOCs in PDMS membrane was analyzed in terms of their solubility, diffusivity and permeability. Furthermore, the obtained solubility of these VOC components was utilized to get the vapor–membrane interaction parameters in UNIQUAC model. This opens an effective way to obtain the activity coefficient of VOC components for predicting their permeation performance in PDMS membrane.

Keywords: VOC; Vapor permeation; PDMS membrane; Solubility; Diffusivity

1. Introduction

As well known, a great deal of violate organic compound (VOC) exists in the gaseous streams of many chemical and petrochemical industries. Exhausting these VOCs into environment not only causes air pollution, but also wastes a lot of energy and resource (Baker et al., 1998; Ohlrogge et al., 1990; Matsumoto et al., 1991). Traditionally, recovering VOCs from gaseous stream were completed by means of condensation, chemical absorption and combustion (Baker et al., 1989; Cha et al., 1997). Besides these ways, vapor permeation (VP), a membrane-based technology with the virtue of lower energy consumption, simple equipment and free of secondary pollution, is considered an effective way to separate VOC components from gaseous stream. This technology makes use of the high affinity of VOC components to membrane material (such as polydimethylsiloxane, PDMS) to enrich VOCs at the permeate side of the membrane, so the retentate becomes a VOC-lean stream.

The permeation of VOC or gas component through dense membrane is recognized as an equilibrium sorption between VOC/gas and membrane material, followed by the diffusion of sorbed molecules. Although the permeation process can be simply evaluated in terms of VOC/gas permeability, analyzing their diffusivity and solubility could help to understand their permeation behavior. Therefore, more and more attentions have been paid to measuring the solubility and diffusivity of various kinds of VOC/gas in dense membrane. Yeom et al. (1999) measured the permeability, solubility and diffusivity of CO_2, O_2 and N_2 in PDMS membrane by Time-Lag ways, and found that the permeability of these gases ranks the same as their order of solubility, which is just as the inverse order of their diffusivity. Liu et al. (2006) and Choi et al. (2007) obtained the solubility of several light olefins (C_2H_4, C_3H_6 and C_4H_8) in poly ether block amide (PEBA) and PDMS membrane through sorption isotherms. Also by this technique, Ghadimi et al. (2009) measured the solubility and permeability of CH_4, H_2 and C_3H_8 in PDMS membrane and investigated the influence of operation conditions on the permeation properties of these gases. With the same way, Raharjo et al. (2007a,b) obtained the permeability and solubility of CH_4 and C_4H_{10} in PDMS membrane and also studied the influence of

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