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Experimental investigation and modeling through using the solution-diffusion concept of pervaporation dehydration of ethanol and isopropanol by ceramic membranes HybSi

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ABSTRACT

Results of experimental investigation of pervaporation dehydration of ethanol and isopropanol by HybSi membranes at concentrations of organic component in the feed in the range from ~50 to ~99 wt%, feed temperatures 60, 70 and 80 °C and permeate pressures 5 and 20 mm Hg are presented. The experimental data demonstrate a nonmonotonic dependence of separation factor on water concentration in the feed with maximum value of separation factor reached at water concentration in the feed of several percent for both ethanol dehydration and isopropanol dehydration. Values of both total permeate flux and separation factor for the isopropanol dehydration case are higher than for the ethanol dehydration case. Results of the experimental investigation are compared with similar results of other researchers obtained for pervaporation dehydration of ethanol and isopropanol by membranes coated with a selective layer made of silica-based and zeolite-based materials. Based on the "solution-diffusion" concept, a mathematical model is developed for the pervaporation process, which includes three parameters, two of which are permeability coefficients for pure components and the third parameter defines "active pores fraction". Use of the model can lead to essential reduction of the number of pervaporation experiments needed for designing a pervaporation pilot plant as well as assist in determining optimum operating conditions of the pervaporation process. Results of calculations carried out with use of the proposed model are compared versus results of experimental investigation of pervaporation dehydration of ethanol and isopropanol by HybSi membranes, pervaporation dehydration of glycerin by HybSi membranes (of other researchers) and pervaporation dehydration of ethanol by NaA zeolite-based membranes (of other researchers). Results of calculations agree reasonably well with all considered experimental data. Additionally, the model allows determining the optimum thickness of the selective layer of HybSi membranes.

1. Introduction

Ethanol and isopropanol are important organic solvents, which can be also used in industries for a great variety of other applications. When the two alcohols are used as additives for gasoline (for increasing octane number), antifreezes, deicing liquids, disinfectants, cosmetic products, solutions for offset printing and for some other purposes, absolute ethanol and isopropanol with residual concentration of water in the alcohols not exceeding a few tenths of a percent are required. However, due to formation of an azeotrope with water (for ethanol/water mixture: at concentration of alcohol ~96 wt%, and for isopropanol/water mixture: at concentration of alcohol ~88 wt% at atmospheric pressure), complete removal of water from the alcohols is impossible for conventional distillation; therefore, the distillation column undergoes changes involving either introduction of an azeotropic agent (e.g., benzene, phenol and cyclohexane) to the distillation column or generation of vacuum inside the column. In the former case, it is also required to remove the azeotropic agent from absolute alcohol afterwards to reduce alcohol's toxicity. As a rule, the distillation process is associated with large energy expenses.

As an alternative to conventional distillation processes, pervaporation technologies have been actively used in various industries during the last several decades. In line with data from the open literature [1], energy expenses for carrying pervaporation can be up to 60% lower

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