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Comparison of pervaporation of different alcohols from water on CMG-OM-010 and 1060-SULZER membranes

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Abstract

Pervaporation of methanol-water, ethanol-water and iso-propanol-water mixtures through organophillic CMG-OM-010 and 1060-SULZER membranes has been investigated using a laboratory scale (131 cm^2) pervaporation unit. The feed composition was 13–20% of alcohol in water, the recirculation flow rate was kept constant (200 l/h) and the temperature was varied between 40–70°C. The permeate concentration reached 30–60% of alcohol after 5 hours run. The avarage permeate flux (J), selectivity (β), separation factor (α), pervaporation separation index (PSI) and activation energy (E) were calculated.

The permeate fluxes on the two pervaporation membranes were similar in the case of the same alcohol, but different pervaporating different alcohols. The alcohol flux on both membrane increased with an increase in the temperature. CMG-OM-010 membrane exhibited good separation factor of the three alcohols, over the 1060-SULZER membrane. The most important observation was that a good separation of iso-propanol-water is possible with these membranes.

Keywords: Pervaporation of methanol-water; Ethanol-water and iso-propanol-water mixtures; CMG-OM-010; 1060-SULZER membrane

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1. Introduction

Pervaporation has long been studied as a method for separation of organic liquid mixtures which are difficult to separate, such as azeotropic mixtures, or mixtures of components with close boiling points or which are easily decomposed by heat. Today much attention is paid to the pervaporation process, not only as an experimental method, but it is applied in the practice too, because some newly developed membranes have sufficient separtion ability. The separation of alcohol and water mixtures by pervaporation is important for obtaining liquid fuel from biomass sources [1–3]. Many authors have reported pervaporation process principales and experimental results with different membranes [4–7]. In this paper an attempt has been made to report pervaporation results using CMG-OM-010 membrane prepared by the Celfa company and compare results with the data on 1060-SULZER membrane.

2. Materials and methods

The basic target of the experiments is to find commercial industrial membrane, which can separate alcohol from alcohol-water mixture with a great efficiency. The following tasks has been defined at model mixtures: separation of methanol-water, ethanol-water and iso-propanol-water model mixtures on organo-phillic membranes, separation on laboratory size pervaporation equipment; effect of operation parameters and calculation and comparison of pervaporation characteristics. The applied membranes were CMG-OM-010 and 1060-SULZER organophillic membranes with 131 cm^2 surface. The pervaporation equipment was produced by the Hidrofil company (Fig. 1). Alcohol-water mixture was carried by the feed pump (8) towards the membrane (1) from feed tank (6). Retention was circulated back to the feed tank. Permeate passing through membrane was condensed by the condenser (5). Vacuum on the other side

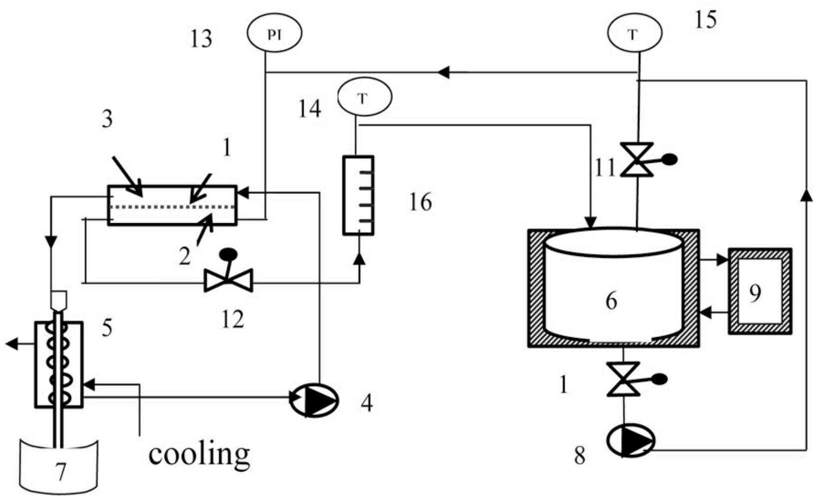

Fig. 1. Pervaporation apparatus: (1) membrane, (2) feed mixture, (3) permeate vapor, (4) vacuum pump, (5) condenser, (6) feed tank, (7) cold trap (permeate collector), (8) feed pump, (9) thermostat, (10) sample collector valve, (11) flow regulator valve, (12) pressure regulator valve (13) pressure meter, (14,15) thermo-meters, (16) flowmeter.

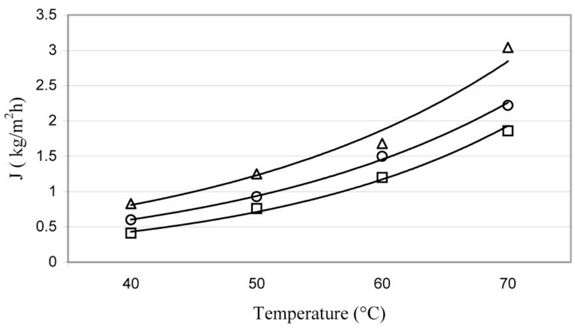

Fig. 2. Permeate flux of methanol-water, ethanol-water and isopropanol-water mixtures versus temperature on CMG-OM-010 membrane (ρisopropanol, □ ethanol and □_ methanol).

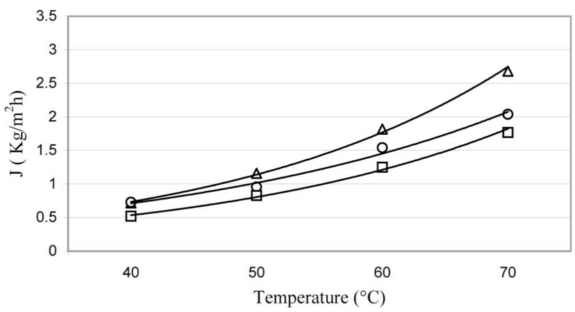

Fig. 3. Permeate flux of methanol-water, ethanol-water and isopropanol-water mixtures versus temperature on 1060-SULZER membrane (ρisopropanol, □ ethanol and □ methanol).

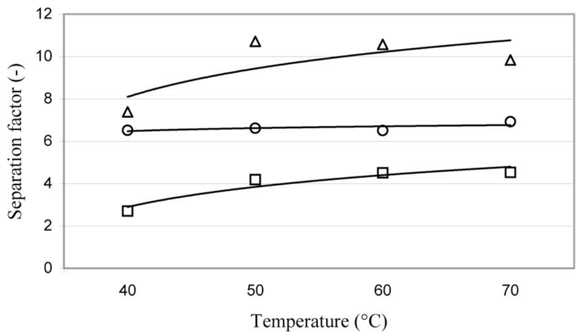

Fig. 4. Separation factor of methanol-water, ethanol-water and isopropanol-water mixtures versus temperature on CMG-OM-010 membrane (ρisopropanol, □ ethanol and _□ methanol).

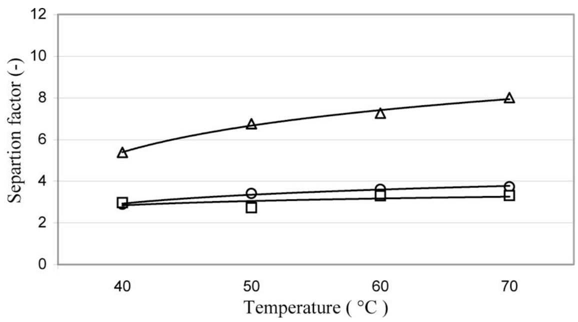

Fig. 5. Separation factor of methanol-water, ethanol-water and isopropanol-water mixtures versus temperature on 1060-SULZER membrane (ρisopropanol, □ ethanol and □ methanol).

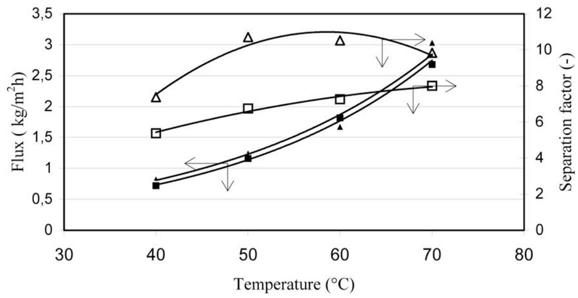

Fig. 6. Comparison of the fluxes and the separation factors of iso-propanol on CMG-OM-010 and 1060-SULZER membranes (ρ separation factor and □ fluxes on CMG-OM-010 membrane, □ separation factor and ■ fluxes on 1060-SULZER membrane).

was assured by vacuum pump (4) condensate was collected on cold trap. Temperature of the mixture was controlled by thermostat (9) and their incoming and outgoing values were read by a cable built-in thermometer. Recirculation flow rate velocity was adjusted by sample collector valve (11). Permeate size pressure was regulated by flow regulated valve (12).

The feed solutions were methanol-water, ethanol-water and iso-propanol model mixtures containing 13–20% of alcohol. The temperature has been varied during the experiment (40, 50, 60, 70°C) meanwhile the recirculation flow rate velocity has been kept constant (200 L/h). Permeate has been collected every hour during the 5 hours experiment. Alcohol concentration was determined by measuring relative density (GIBERTINI equipment with a standard error of ± 0.05%). 30–60% alcohol content was obtained in the permeate using 13–20% alcohol content in the feed. Permeate flux (J), membrane selectivity (β) separation factor (α), pervaporation separation index (PSI) and activation energy (E_a) were calculated.

3. Results and discussion

Figs. 2 and 3 shows the change in flux of CMG-OM-010 and 1060-SULZER pervaporation membranes versus temperature. Based on experimental results we observed that the flux increases significantly by increasing the temperature. So the higher temperature in the membrane module will favour the transfer of the VOC from liquid into gas phase, because the volatility strongly depends on the temperature, which corresponds to literature results [8–10]. Flux of the 3 measured alcohols was obtained in the following order: iso-propanol-ethanol and methanol, the iso-propanol flux was slightly higher than that of methanol and ethanol fluxes because of difference in molecular size and also the ability to interact with the polymer groups [11].

Separation factor of this 3 alcohols changed in function of temperature, as can be seen in Figs. 4 and 5. Separation index of all 3 alcohols were increased by increasing temperature on CMG-OM-010 and 1060-SULZER membranes. The explanation of this phenomenon is as follows: diffusion and solubility of penetrating components depend on temperature of separation behaviour of membrane changes significantly with temperature.

Table 1
Activation energy of the permeation on 1060-SULZER and CMG-OM-010 membranes (kJ/mol)

Alcohols	1060-SULZER	CMG-OM-010
Methanol	54. 75	52. 62
Ethanol	37. 76	39. 92
Iso-propanol	43. 86	40. 72

Based on experimental data membrane activation energy was calculated. Table 1 shows the activation energy of pervaporation membranes examined for alcohol separation.

The operating temperature influences both the permeability coefficient of a membrane and the driving force of mass transfer in the pervaporation processes.

The data of activation energy obtained in this paper are similar which reported recently to with literature results [12] and it can see that in the CMG-010 membrane the activity energy of the ethanol and iso-propanol were lower than the other membrane. Separation ability of pervaporation membranes are determined by permeate flux and separation factor index. These are usually change in opposite direction.

Pervaporation separation index (PSI) connect these two important membrane characteristic parameter. It follows from the foregoing that a good pervaporation membrane has to possess a high PSI value.

The results of pervaporation separation index of the 3 examined alcohol on CMG-OG-010 and 1060-SULZER membranes are showed on Table 2. Based on the data we can observe that separation factor index of iso-propanol is the highest in the two membranes, but highest in the CMG-010 membrane.

Table 2
Pervaporation separation index on CMG-OM-010 and 1060-SULZER membranes (kg/m^{2}h)

Temperatures (°C)	1060-SULZER			CMG-OM-010		
	Methanol	Ethanol	Iso-propanol	Methanol	Ethanol	Iso-propanol
40	1. 54	2. 11	3. 87	1. 11	3. 91	6. 13
50	2. 27	3. 26	7. 83	3. 18	6. 15	13. 39
60	4. 12	5. 56	13. 21	5. 41	9. 76	17. 76
70	5. 86	7. 61	21. 47	8. 43	15. 36	29. 92

4. Conclusions

It was experimentally demonstrated that alcohol permeate flux of pervaporation membranes increases with an increase in the temperature. Fig. 6 shows the comparison of the fluxes and the separation factors of iso-propanol on CMG-OM-010 and 1060-SULZER membranes. As the graphs show the two membranes' fluxes were almost similar, but the best pervaporation separation factor was reached at 70°C on CMG-OM-010 membrane. CMG-OM-010 membrane exhibited good separation factor of the three alcohols over the 1060-SULZER membrane. The most important observation was that a good separation of iso-propanol-water is possible with these membranes.

Acknowledgements

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