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Research Paper

Pervaporation Process for Ethanol-Water Mixture

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Abstract-*Binary or ternary mixtures can be separated by partial vaporization through a dense perm selective membrane. Separation technique has been termed pervaporation in order to accentuate the fact that the permeate undergoes a phase change, from liquid to vapor, during the membrane separation process. Pervaporation process, the feed mixture is maintained in direct contact with one side of the membrane, and the permeate is evolve in the vapor state from another side of the membrane at low pressure. The permeate is together, in the liquid state after condensation, on a cooled wall process known as Pervaporation. A batch stirred cell was used to study the PV behavior of water–ethanol mixtures through the membrane. The permeate flux, selectivity, PV separation index (PSI), flux and selectivity were studied as a function of increasing ethanol concentration in the feed. The membrane was originated highly selective to water. Even when the feed was rich in ethanol the permeate contained higher than of water. In Pervaporation experiments, made at different ethanol feed concentration and temperature present in the feed, permeate through the viable Pervaporation membrane.*

Keywords: Pervaporation, water–ethanol mixtures, Flux, PSI (Pervaporation Separation Index), Selectivity, etc.

Introduction

Pervaporation is a very promising membrane technology for the separation of organic/organic mixtures. For the separation of close boiling point mixture and azeotrope PV process is the most important. In the pervaporation process, polymer membranes form a selective barrier between a liquid and a vapor phase .The feed mixture enters the permeator module as a liquid. However, all the components of the mixture PV is a membrane based separation process in which the membrane functions as a selective barrier for the mixture to be separated. Low energy consumption and mild working conditions make the process attractive for separating azeotropic and close-boiling mixtures or dehydrating temperature-sensitive products. Pervaporative dehydration of ethanol has been widely studied using membranes based on poly (vinyl alcohol), polyamides, polysulfonamides, poly (ethyleneimine) polysiloxanes [1-4], etc. Chitosan and its derivatives as well as sodium alginate have also been used for water–ethanol separations [5,6]. The effect of varying ethanol concentrations in the feed, on the permeate composition and flux, selectivity, sorption and PV separation index (PSI) has been studied.

Pervaporation process that no high pressure system is necessary to allowed the liquid through the pervaporation unit. The unit can operate at low temperature, so that responsive element can be handed more safely. Make the process economically attractive, more efficient recovery processes are needed. Several methods (including gas stripping, adsorption, extraction, membrane distillation, perstraction, and pervaporation) [1] have been investigated during last decade in order to improve the recovery of water from ethanol. Among these methods, pervaporation appears to be particularly capable. It is based on the selective permeation of the components through a membrane in preference to water. Pervaporation combined with fermentation so that the products from the fermentation gumbo can be removed continuously as soon as they are formed, thereby enhancing the process productivity.

Only the membrane permeated components suffer liquid–vapor phase change during pervaporation, and from energy consumption point of view pervaporation is more economical than distillation, membrane process that requires an additional separation step for product recovery from the extractants, pervaporation does not involve external mass separating agent. In addition, pervaporation membranes are generally non-porous; in the case of asymmetric composite membranes where a dense skin layer is supported by a micro porous substrate, it is the non-porous skin that is in contact with the feed solution.

Experimental

Materials

De-ionized water and absolute ethanol was used to prepare the binary mixtures the aqueous feed solutions for the pervaporation experiments.

Preparation of membranes for pervaporation

For pervaporation and separation, non porous membranes are requires preferably with anisotropy morphology, an asymmetric structure with a dense top layer and an oper. Porous sub layer, as found in asymmetric and composite membrane. The requirements for the substructure are in fact the same as for gas separation membranes. Polyvinyl alcohol is an example of a hydrophilic membrane material.

The membrane was then allowed to dry at ambient temperature, and was referred to as nascent or untreated membrane. These membranes were rinsed several times with distilled water, until a neutral pH was attained in the drained liquid. The membranes were dried at ambient conditions, prior to use.

Determination of Concentration of ethanol

For the Pervaporation process different proportions of ethanol and water samples are taken by considering the density (0.789 g/mL and molecular weight 46). We have calculated the concentration of the ethanol such as 5ml, 10ml, 15ml, 20ml, 25 ml with the water 95ml, 90 ml, 85ml, 80ml, 75ml.Also by measuring the weight of solution with the volume of water (50ml) the specific gravity were calculated and from this the density of ethanol obtained for the different collected samples. The standard graph were obtained by considering the initial ethanol water samples

Pervaporation

Pervaporation experiments were carried out in a batch-stirred cell operated under vacuum. The downstream pressure was maintained at 10 mm Hg. The cell had two flanged compartments. The upper one is for feed.

Ethanol- water mixture of 100 ml is introduced in the upper compartment of Pervaporation cell. The PVA (Polyvinyl alcohol) membrane was supported on a porous stainless steel sintered disc and sealed with rubber o-ring. Effective membrane separation area was 19.62 cm^2 the temperature was maintained at 60 ^0C and speed of agitation was maintained at 250 rpm and the experiment was carried out for 1 Hr. The permeate was collected in the condenser cooled by salt and ice mixture.

The flux (J) was determined by measuring the weight of the permeate. The composition of the feed solution and the permeate were determined by Abbe Refractometer. The permeation selectivity was calculated using the following equation:

$$\alpha_p (water/ethanol) = \left[\frac{\left(Y_{water} / Y_{ethanol} \right)}{\left(X_{water} / X_{ethanol} \right)} \right] \quad \text{------ (01)}$$

where X and Y are the weight fractions of species in the feed and permeate, respectively.

The PSI (Pervaporation Separation Index) was calculated by using permeate selectivity and total flux and equation as-

$$PSI = J(\alpha_p - 1) \quad \text{--------------- (02)}$$

Results and Discussion

Present experiment Experiments were conducted with ethanol-water Binary system and effect of variation of ethanol concentration on a flux and selectivity of ethanol was investigated.

Pervaporation properties

The PV process combines the evaporation of volatile components of a mixture with their permeation through a polymeric membrane under reduced pressure conditions. It, therefore, involves a sorption step at the membrane upstream face, followed by a diffusion through the dense film and a desorption into the vacuum. Thus PV performance of a membrane, termed PSI is described in terms of two important parameters namely, flux (J) i.e. the mass crossing the membrane per unit area in a unit time and the selectivity towards the preferentially permeated component.

For the membranes under study, a batch stirred PV cell was used at a temperature of 60 °C. Eqs. (01) and (02) were used to calculate the permeation selectivity and PSI values.

Effect of Selectivity on wt% ethanol and water

Figure 3.1.1 shows Ethanol selectivity for Binary ethanol- water mixture shows effect of wt% of Water in feed the weight % age of ethanol in the feed going to increase from79.18 to 96.02 % water in feed to selectivity of ethanol 2.98 to 3.906, shows as selectivity of ethanol is directly proportional to wt % of water in feed.

Figure 3.1.2 shows Ethanol selectivity for Binary ethanol- water mixture shows effect of wt% of ethanol in feed, the weight % age of ethanol in the feed going to decrease from 3.906 to 2.988 % ethanol in feed to selectivity of ethanol 3.98 to 20.82, shows as selectivity of ethanol is inversely proportional to wt % of ethanol in feed.

Figure 3.3 - shows Permeate Selectivity for Binary ethanol- water mixture shows effect of wt% of water in feed, the weight % age of water in the feed going to increase from 79.18 to 96.02 % ethanol in feed to Permeate selectivity 3.32 to 4.16, shows as wt % of water in feed increases the permeate selectivity

increases means Permeate selectivity is directly proportional to wt % of ethanol in feed.

Effect of Flux on wt % of ethanol and water

Figure 3.3 shows Total flux (J) (gm/m^2.hr) rises in permeate the weight % age of water in the feed going to increase from 79.18 % to 96.02 % with 428.33 to 713.55 (gm/m^2.hr) shows as wt % of water increases in feed the Total flux (J) increases means wt % of water in feed inversely proportional to total flux.

Figure 3.4 shows Total flux (J) (gm/m^2.hr) rises in permeate the weight % age of Ethanol in the feed going to decrease from 3.98 % to 20.82 % with 713.55 to 428.33 (gm/m^2.hr) shows as wt % of ethanol increases in feed the Total flux (J) decreases means wt % of ethanol in feed inversely proportional to total flux.

PSI (Pervaporation Separation Index) for wt % of ethanol water in feed

Figure shows 3.5 for the water-rich region as the wt% of water increases from 79.18 to 96.02% in feed the Pervaporation separation index (PSI) (gm/m^2.h) is increase from 9.94 $X10^2$ to 2.25 $X10^3$ means wt % of water in feed directly propositional to PSI.

Figure shows 3.6 for the water-rich region as the PSI decreases from 2.25 X 10^3 to 9.94 X 10^2 as wt% of ethanol increases from 3.98 to 20.82 in feed, the Pervaporation separation index (PSI) (gm/m^2.h) is decrease means wt % of ethanol in feed inversely propositional to PSI.

Conclusion

Separation of binary mixture (ethanol-water) by pervaporation the effect of concentration on the flux (J), the selectivity (α_p), the PSI (pervaporation separation index) and separation factor (α) are calculated and studied.

As seen observations for ethanol with the increase in wt% of water and wt% of ethanol in feed the Flux of ethanol get decreased and increased respectively, also with the increase in wt% of water and wt% of ethanol in feed the Selectivity of ethanol increased and decreased respectively. For water with the increase in wt% of water and wt% of ethanol in feed the Flux of water get increased and decreased respectively.

PV analysis for Total flux, with the increasing wt% of water and wt% of ethanol in the feed, total flux (J) get increase and decreased respectively. Comparing Experimental total flux and Experimental flux a straight line obtained shows indicative of a satisfactory agreement.

PV Permeate Selectivity analysis, with the increasing wt% of ethanol and wt% of water in the feed, Permeate Selectivity (α_p) get decreased and increase respectively. The overall contribution of flux and selectivity to PV is defined by the PSI (Pervaporation separation index) increases as wt% of water in feed increase and decreases as wt% of ethanol in feed increases, shows that the membrane may be effective in dehydration of azeotropes of ethanol, also Separation factor (α) in permeate with increase wt% of water and wt% of ethanol in feed get decreased and increased respectively shows reducing water containing in feed the separation factor

PV Experimental analysis shows the effect of concentration on the flux of ethanol. It was observed that, as the ethanol concentration in the feed mixture increases, the selectivity decreases while the flux or permeation rate of ethanol increases.

Summarize the result of PV process for ethanol water separation with the increase in concentration of ethanol in feed, concentration of sorbed ethanol increases and hence the driving force increases which results in increased ethanol flux. It was observed that the increase in concentration of ethanol in the feed, selectivity get decreases. Separation is a function of the rate of permeation of the component of the mixture through membrane.

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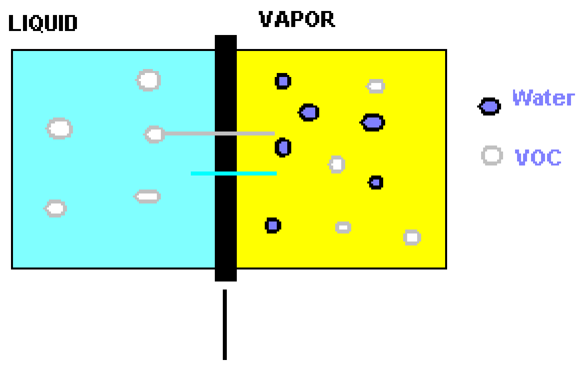

Figure 1: Overview of Pervapoaration process [7]

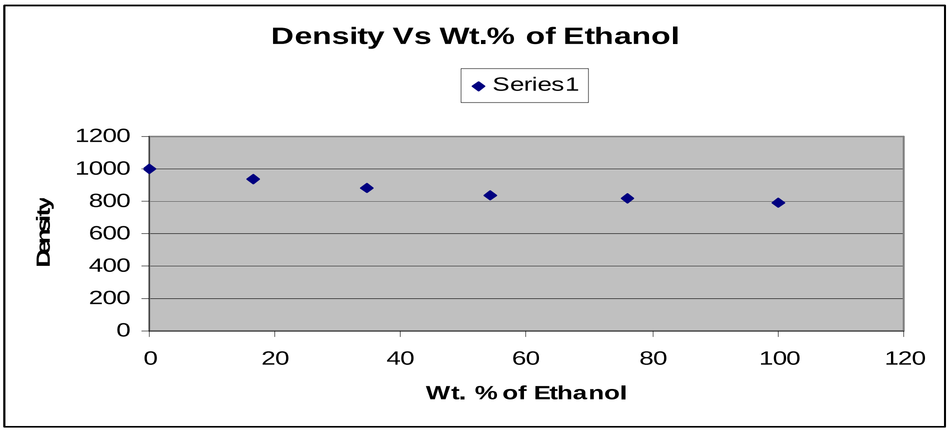

Figure. 2

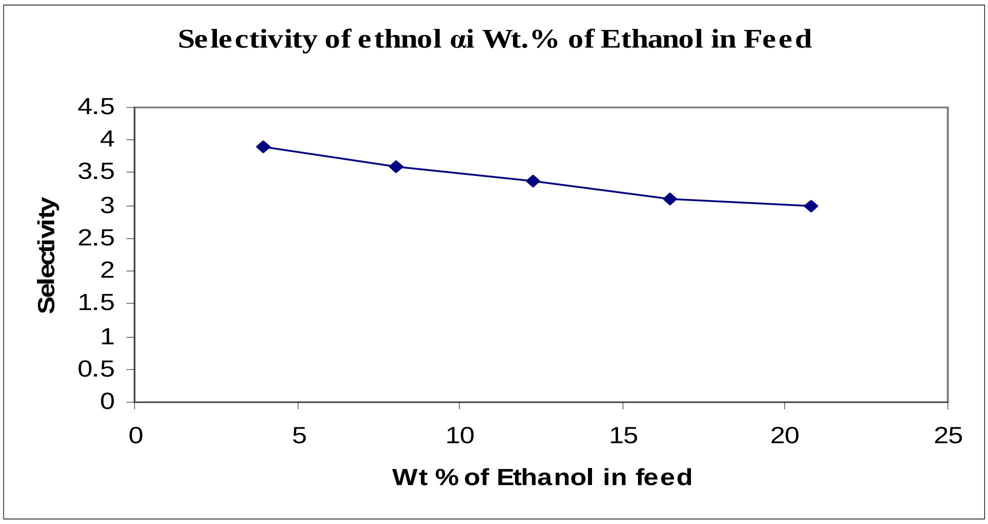

Figure 3.1: Ethanol selectivity for Binary ethanol- water mixture & effect of wt% of Water in feed

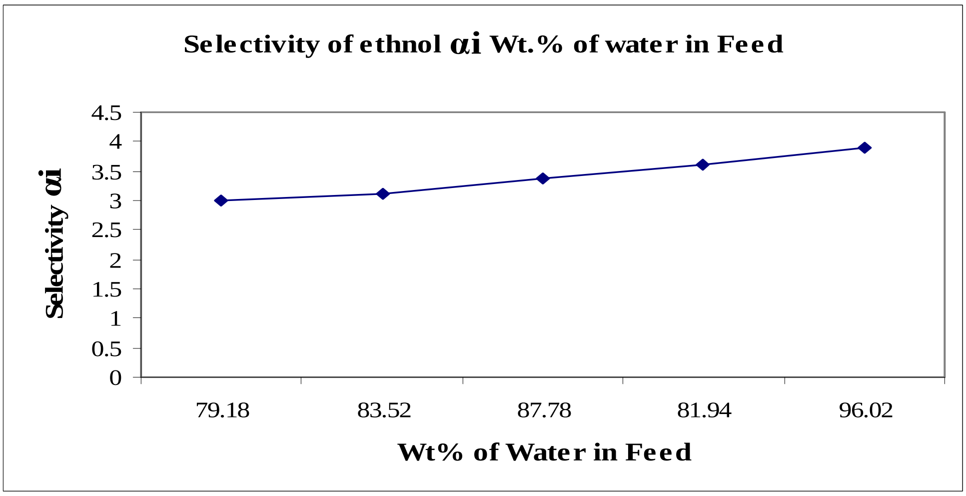

Figure 3.2: Ethanol selectivity for Binary ethanol water mixture & effect of wt% of Ethanol in feed

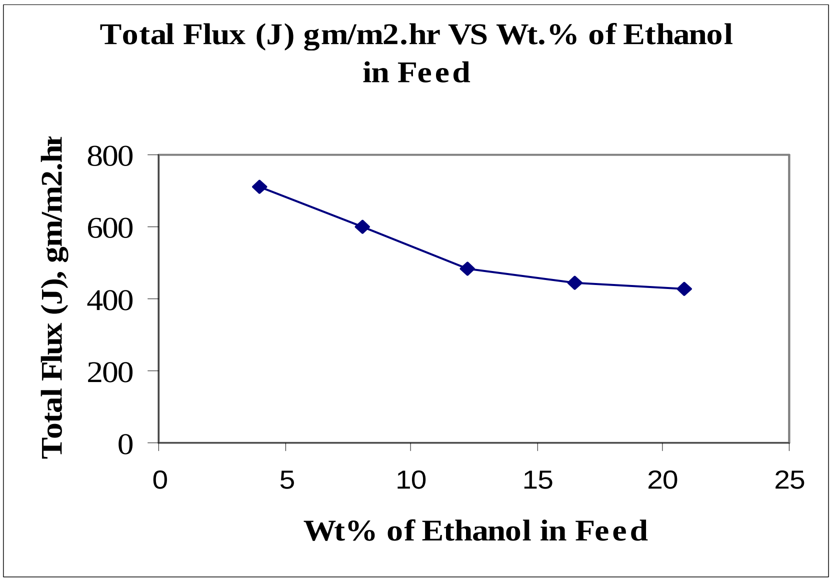

Figure 3.3: Effect of Wt% of Water in feed and Total Flux

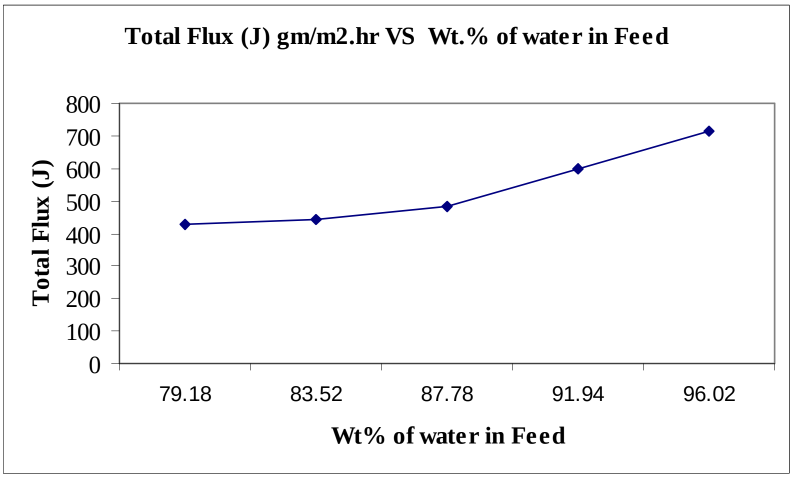

Figure 3.31-Effect of Wt% of Ethanol in feed and Total Flux

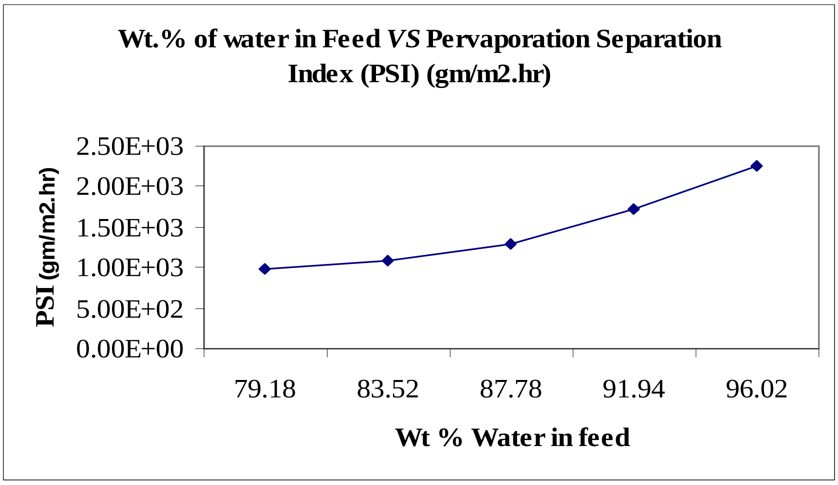

Figure 3.4: Pervaporation Separation Index (PSI) for binary water-alcohol mixtures considering wt% water in feed

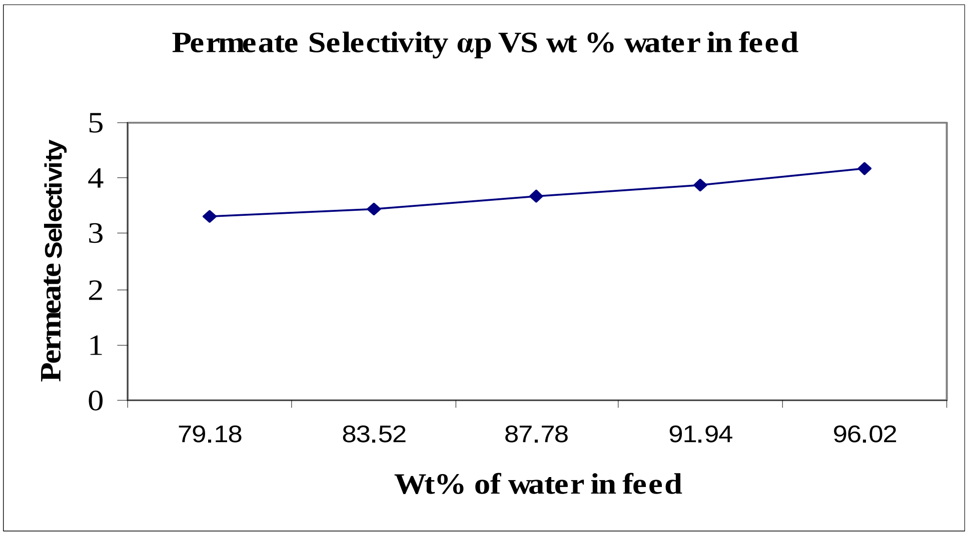

Figure 3.5: Permeate Selectivity for Binary ethanol water mixture & effect of Wt% of water in feed

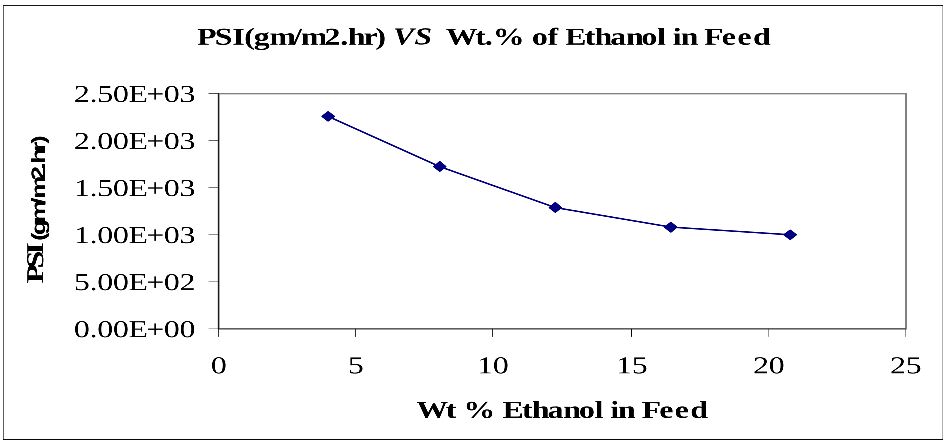

Figure 3.6: Pervaporation Separation Index (PSI) for binary water-alcohol mixtures considering wt% ethanol in feed