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Research Article

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Determination of electro kinetic parameters involved in the transport of aqueous solution of 1,4-dioxane across anisotropic cellulose acetate membrane

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ABSTRACT

Aqueous solution of 1, 4-dioxane of different concentration was transported across freshly impregnated anisotropic cellulose acetate membrane at 298K, under the influence of pressure difference and electrical potential difference. The transport properties studied were hydrodynamic flow $(J_V)\Delta_{\phi} = o$ *and electro-osmotic flow* $(J_V)\ \Delta P = o$*. The data revealed that both hydrodynamic flow* $(J_V)\Delta_{\phi} = o$ *and electro-osmotic flow* $(J_V)\ \Delta P = o$ *decreases with increase in concentration but increases with increase in potential difference and electrical potential difference across the membrane. The phenomenological coefficients* L_{11} *and* L_{12} *were also studied.*

Keywords: cellulose acetate membrane, hydrodynamic flow, electro-osmotic flow, concentration, henomenological coefficient.

INTRODUCTION

Electro kinetics plays an important role in the transport of electrolyte solution across membranes [1-3]. The main advantages of membrane separation as compared with other unit operations are low energy consumption, no additive requirements, no phase change, easy scale up and integration into other separation or reaction processes [4, 5]. Membrane processes have wide range of industrial application areas such as pharmaceutical, chemical, paper, semiconductor, textile, medical devices, waste water and purifying water [6].However membrane fouling is recognized as the problem in the application of industrial membrane processes. The electro kinetic properties such as zeta potentials of the membrane and the particles have a significant effect on the nature and magnitude of membrane fouling caused by the membrane-particles interfacial interactions. Membrane fouling is influenced by the surface chemistry of the membranes and the colloidal particles as well as by the ionic environment [7-9].

Several researchers have used the membrane zeta potential as a key parameter to study the fouling characteristics of different membranes [10-13]. Data obtained with simple salt solutions such as NaCl and KCl are unable to provide enough information on the extent of ion adsorption that may occur for the wide range of salts encountered in industrial applications of membrane separations [14,15]. The electro kinetic phenomenon can be separately obtained when single membrane is considered and different membrane transport parameters as well as information about the electrical interactions at the membrane / solution interface can be obtained.

However asymmetric or composite membranes are formed by two or more sub layers with different transport properties. In these cases not only direct phenomenon are measured but some other indirect or associated phenomena can also be included in the values determined for the whole membrane. For instance, if one sub layer presents high salt retention the permeate solution has much lower concentration than the feed solution and a diffusion potential in this layer should arise. In general the higher or lower contribution of the indirect effects on the values measured for a composite membrane is related to the different structures and transport properties of the sub layers forming the composite membrane. In order to avoid these effects, streaming potential along with membrane surface is measured [16, 17]. Although this type of measurement does not allow any co-relation between changes in the streaming potential due to adsorption/deposition of particles in the porous wall or on the membrane surface and other characteristics membrane transport parameters such as hydraulic permeability or ion transport number [18,19]. Moreover, according to Lettemann et al. [20] possible difference in the chemistry of inner and outer membrane surfaces can exist and some caution must be taken when comparison between results obtained with both different boundary conditions are made.

EXPERIMENTAL SECTION

(a) Reagents used

1, 4- dioxane of GR grade was refluxed over sodium and was used for the experiment. Doubly distilled water was used. Cellulose acetate obtained from Riedel Germany was used as such. Acetone was purified by refluxing it successively with small portion of $KMnO_4$ and was used for experiment.

(b) Preparation of Membrane

Cellulose acetate was dissolved in acetone and mixed up with water to which potassium bromide had been added. The materials were taken in the proportion 22.2: 66.7:10:1.1 respectively. The cellulose acetate solution was repeatedly impregnated into a thoroughly washed and dried sintered G_2 disc under vacuum at $0\text{-}5^0$ C in one direction only. The disc was then immersed in hot water at $75\text{-}80^0$C. Since the membrane was prepared by impregnating with cellulose acetate, it was expected that the flow and therefore the values of efficiencies of energy conversion would show a significant change on reversal of direction of applied thermodynamic forces due to anisotropic character of the membrane.

(c) Experimental procedure

The experimental cell (Electro-osmotic Cell) was filled with water and left overnight for equilibration of the membrane. The cell was then thoroughly cleaned by forcing conductivity water through respective membrane under pressure. The apparatus was filled by adding the solution under investigation on one side of the membrane and then forcing it to other side under pressure gradient by means of a vacuum pump. This ensured the complete filling of capillaries of the membrane. The whole apparatus was then kept in air thermostat maintained at desired temperature. The temperature was kept constant with the help of a toluene regulator and an electronic relay. For measurement of hydrodynamic permeability desired pressure difference was applied across one side of the cell with the help of the pressure head. The system was kept in the air thermostat for about two hours to allow the experimental solution to attain the temperature of the thermostat. At desired pressure difference, the rate of flow of liquid was measured by noting the time taken by the solution to move a certain distance through horizontal capillary. To record the time of flow a stop watch was used.

For measurement of elctro-osmotic permeability, an electronically regulated variable voltage power supply obtained from, “Oriental Scientific Apparatus Workshop” (OSAW), Ambala (India) was used as a source of e.m.f. Measurements were taken up to a potential difference of 50V. The time taken by the solution at a particular voltage to travel a fixed distance in the capillary was noted. Similar procedure was applied for study in all other cases.

RESULTS AND DISCUSSION

The transport properties of aqueous solution of 1, 4-Dioxane across anisotropic cellulose acetate membrane were studied. The properties investigated were hydrodynamic flow at different pressure gradients and electro-osmotic flow at different applied potential for different concentrations across the membrane. The simultaneous transport of matter and electricity through porous media can be represented by the equations

$$J = L_{11}\Delta P + L_{12}\Delta_{\varphi} \quad (1)$$

$$I = L_{21}\Delta_{\varphi} + L_{22}\Delta P \quad (2)$$

Where ‘ I ‘ and ‘J ‘ denote the electric current and volume flow per unit area of the membrane respectively, while ‘ ΔP’ and ‘ Δ_φ’ are the pressure difference and electric potential difference across the membrane. L_{11}, L_{12}, L_{21} and L_{22} are the phenomenological coefficients related to permeation, electro-osmosis, streaming conductance and electrical conductance respectively.

If the potential difference applied is zero the equation (1) reduces to equation (3) as

$$J_V\ (\Delta_\varphi = 0) = L_{11}\ \Delta p \tag{3}$$

If the potential difference applied across the membrane is zero the equation (1) reduces to equation (4) as

$$J_V\ (\Delta p = o) = L_{12}\ \Delta_\varphi \tag{4}$$

The values of hydrodynamic flow J_V ($\Delta_\varphi = 0$) and phenomenological coefficient L_{11} obtained are given in Tables 1-3 where as the electro-osmotic flow values Jv (Δp = o) and phenomenological coefficient L_{12} are given in Tables 4-6. Figure 1 and 2 depicts the variation of hydrodynamic flow J_V ($\Delta_\varphi = 0$) and phenomenological coefficient L_{11} with pressure; whereas Figure 3 and 4 depicts variation of electro osmotic flow J_V (Δp = o) and phenomenological coefficient L_{12} with variation in potential difference across the membrane.

Table 1: Values of hydrodynamic flow J_V ($\Delta_\varphi = 0$) and phenomenological coefficient L_{11} for 10% aqueous solution of 1, 4- dioxane at 298K

Pressure Difference (ΔP)$_{\Delta_\varphi = 0}$ x1o^{-4} (Nm^{-2})	**Hydrodynamic Flow J_vx1o^{-7} (ms^{-1})**	**Phenomenological Coefficient L_{11}x10^{2} N^{-1}m^{3}s^{-1}K**
3.5	6.24	5.31
4.0	7.89	5.88
4.5	9.61	6.36
5.0	11.26	6.71
5.5	12.84	6.96

Table 2: Values of hydrodynamic flow J_V ($\Delta_\varphi = 0$) and phenomenological coefficient L_{11} for 20% aqueous solution of 1, 4- dioxane at 298K

Pressure Difference (ΔP)$_{\Delta_\varphi = 0}$ x1o^{-4} (Nm^{-2})	**Hydrodynamic Flow J_vx1o^{-7} (ms^{-1})**	**Phenomenological Coefficient L_{11}x10^{2} N^{-1}m^{3}s^{-1}K**
3.5	5.22	4.44
4.0	6.71	4.99
4.5	8.34	5.52
5.0	9.96	5.94
5.5	11.68	6.33

Table 3: Values of hydrodynamic flow J_V ($\Delta_\varphi = 0$) and phenomenological coefficient L_{11} for 30% aqueous solution of 1, 4- dioxane at 298K

Pressure Difference (ΔP)$_{\Delta_\varphi = 0}$x1o^{-4} (Nm^{-2})	**Hydrodynamic Flow J_vx1o^{-7} (ms^{-1})**	**Phenomenological Coefficient L_{11}x10^{2} N^{-1}m^{3}s^{-1}K**
3.5	4.63	3.94
4.0	6.13	4.57
4.5	7.75	5.13
5.0	9.43	5.62
5.5	11.18	6.06

Table 4: Values of electro-osmotic flow Jv (Δp = o) and phenomenological coefficient L_{12} for 10% aqueous solution of 1, 4- dioxane at 298K

Potential Difference (V)$_{\Delta p = 0}$	**Electro-osmotic Flow J_vx10^{-7} (ms^{-1})**	**Phenomenological Coefficient L_{12} x 10^{1} ms^{-1}V^{-1}K**
10	2.24	6.68
20	4.58	6.82
30	9.27	9.21
40	19.27	14.21
50	40.12	23.91

Table 5: Values of electro-osmotic flow Jv ($\Delta p = o$) and phenomenological coefficient L_{12} for 20% aqueous solution of 1, 4- dioxane at 298K

Potential Difference $(V)_{\Delta p,0}$	Electro-osmotic Flow $J_v x 10^{-7}$ (ms^{-1})	Phenomenological Coefficient L_{12} x 10^1 $ms^{-1}V^{-1}K$
10	2.02	6.02
20	4.52	6.73
30	8.63	8.57
40	18.21	13.57
50	37.93	22.61

Table 6: Values of electro-osmotic flow Jv ($\Delta p = o$) and phenomenological coefficient L_{12} for 30% aqueous solution of 1, 4- dioxane at 298K

Potential Difference $(V)_{\Delta p,0}$	Electro-osmotic Flow $J_v x 10^{-7}$ (ms^{-1})	Phenomenological Coefficient L_{12} x 10^1 $ms^{-1}V^{-1}K$
10	1.78	5.30
20	3.72	5.54
30	7.57	7.52
40	15.29	11.39
50	32.84	19.57

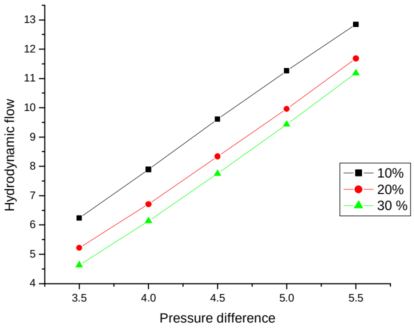

Figure 1 Plot of hydrodynamic flow values versus pressure difference for different concentrations of aqueous solutions of 1,4-dioxaneat 298K.

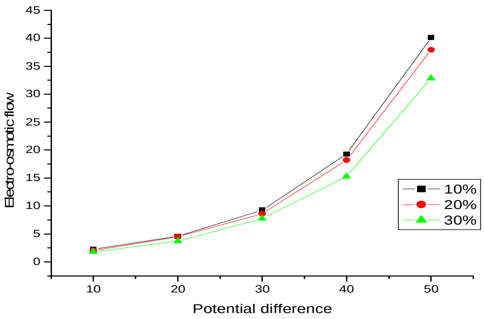

Figure 2 Plot of electro osmotic flow values versus potential difference for different concentrations of aqueous solutions of 1,4-dioxane at 298K

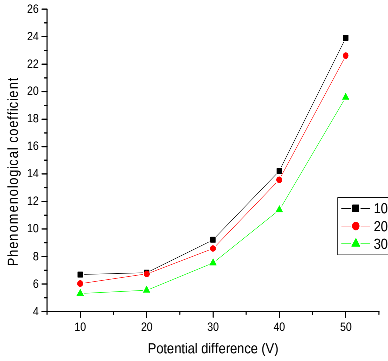

Figure3 Plot of phenomenological coefficients L_{12} versus potential different for different conc. of aqueous solutions of 1, 4-dioxane at 298K.

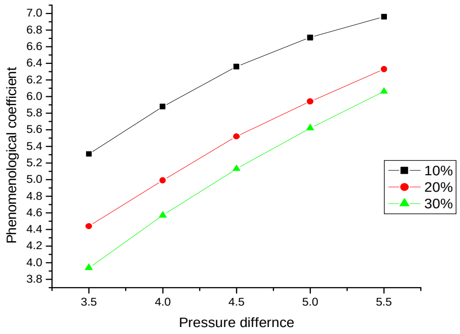

Figure4 Plot of phenomenological coefficient L_{11} versus pressure difference for different conc. of aqueous solutions of 1, 4-dioxane at 298K

CONCLUSION

Transport properties such as hydrodynamic permeability and electro osmotic flow were studied at 298K for aqueous solutions of different concentrations at different values of pressure difference and potential difference respectively across anisotropic cellulose acetate membrane. It has been observed that there occurs an increase in the value of hydro dynamic permeability and electro osmotic flow with increase in pressure difference and potential difference on both sides of the membrane respectively. However there occurs a decrease in the value of these parameters with increase in concentration due to decrease in solvent membrane interactions. Phenomenological coefficients L_{11} and L_{12} were also studied at 298K and their values showed an increase with increase in the values of pressure difference and potential difference respectively.

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