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Research Article

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Study of transport properties of aqueous solution of acetonitrile across Nylon ^{TM} bio-bond membrane at 303.15K

Roshan Lal, Mukesh Kumar, Amit Kumar Sharma, Neha Sawhney and Meena Sharma*

Department of Chemistry, University of Jammu, India

ABSTRACT

Transport properties such as hydrodynamic flow $(J_V)\Delta_{\phi=0}$, *electro-osmotic flow* $(J_V)\,\Delta_{P=0}$, *permeability coefficient* (L_P) *and frictional coefficient* (F_{wm}) *were studied for aqueous solution of acetonitrile across Nylon* ^{TM} *Bio-bond membrane. The data revealed that hydrodynamic flow* $(J_V)\Delta_\phi=0$, *electro-osmotic flow* $(J_V)\,\Delta P=0$ *and permeability coefficient* (L_P) *decreases with increase in concentration but increases with increase in pressure difference and electrical potential difference across the membrane, whereas the values of frictional coefficient* (F_{wm}) *shows opposite trend.*

Keywords: hydrodynamic flow, electro-osmotic flow, permeability coefficient, frictional coefficient and Nylon ^{TM} Bio-bond membrane.

INTRODUCTION

Membrane technology have found wider acceptance in recent years. However membrane treatment is still more expensive than conventional water treatment technologies (e.g. coagulation, flocculation, sedimentation, multi media filtration). In an effort to reduce the cost of reverse osmosis and nanofiltration treatment, the metropolitan water district of southern California (MWDSC) initiated desalination research and innovation partnership to evaluate the cost-effective methods to desalinate river water as well as municipal wastewater and brackish groundwater. Reverse osmosis is being widely practiced for water purification processes. Hollow fibre reverse osmosis modules are most extensively used for both domestic and industrial water purification as they provide high specific surface area and recovery factor. Various membrane transport modules are available for mathematically describing transport phenomena through the membrane [1,2] Kimura and Sourirajan [3] introduced the concept of solution-diffusion in which the membrane is assumed to be impermeable to solute. The solute accumulates on the surface of membrane resulting in concentration polarization. This model accounts for polarization was widely adopted many researchers [4-13].

Membranes with high conductivity and selectivity are used as separating films in various electro membrane devices such as electro dialyzers, fuel cells and electrolyzers. Two characteristics of electro membrane processes are: (1) they are ecologically safe and (2) the electrical energy required for these processes is comparatively low. The efficiency of electro membrane processes depends on the physico-chemical characteristics and electro transport properties of the membrane [14]. Recently substantial advances have been made for synthesis and modification of ion-exchange polymeric membrane. Nevertheless the extensive studies are continued to develop novel material and method for membrane modification and to produce more complex membrane structures with wide range of

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functionalities and desired operating behaviours [15,16] Physicochemical properties of ion-exchange membranes were extensively investigated by O.Kedem et al [17] The membrane characterization continues to attract attention in current research due to recent significant expansion of the type of polymeric matrices and development of composite membrane materials. [18-20]

EXPERIMENTAL SECTION

Nylon ^{TM} Bio-bond membrane was used. The reagent used for the experimental study was acetonitrile. 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 different concentrations of Acetonitrile across Nylon ^{TM} Bio-bond membrane were studied. The properties investigated were hydrodynamic flow (J_V), electro-osmotic flow (J_V), permeability coefficient (L_P) and frictional coefficient (F_{wm}). 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

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

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

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

Kedem and Katchalsky [21] have given the frictional coefficient of the phenomenological coefficient in the transport processes through membranes. The explicit treatment of frictional forces may be approached by considering the simple case of water filtration through the membrane. If pure water is placed on both sides of the membrane the driving force is provided by a difference in pressure. Then the driving force is balanced by the mechanical filtration force between the water and the membrane matrix under the condition of steady flow.

Under the simple use of translation of thermodynamic coefficient into frictional coefficient, the permeability coefficient L_P is related to coefficient of friction F_{wm} by the relation as

$L_P = \phi_w V_w / F_{wm\,\delta}$ (5)

Where V_w is the water content of the membrane and is expressed as the volume fraction of the total membrane volume, delta is the thickness of the membrane and ϕ_w is the fraction of the membrane surface available for permeation of the solution.

The values of hydrodynamic flow J_V ($\Delta_\varphi = 0$), permeability coefficient (L_P) and frictional coefficient (Fwm) obtained are given in Tables 1-3 where as the electro-osmotic flow values (Jv) at $\Delta p = 0$, permeability coefficient (L_P) and frictional coefficient (Fwm) obtained are given in Tables 4-6..

Table 1: Values of hydrodynamic flow J_V ($\Delta_\varphi = 0$), permeability coefficient L_P and frictional coefficient F_{wm} for 10% aqueous solution of acetonitrile at 303.15 K

Pressure Difference (ΔP) $\Delta_{\varphi = 0}$ x10^{-4} (Nm^{-2})	**Hydrodynamic Flow J_vx10^{-7} (ms^{-1})**	**Permeability Coefficient L_Px10^{2} (N^{-1}m^{3}s^{-1})**	**Frictional coefficient F_{wm} x 10^2(mNmol^{-1}s)**
3.0	8.54	8.62	4.95
3.5	10.52	9.11	4.68
4.0	12.66	9.57	4.45
4.5	14.97	10.09	4.22
5.0	17.29	10.48	4.08

Table 2: Values of hydrodynamic flow J_V ($\Delta_\varphi = 0$), permeability coefficient L_P and frictional coefficient F_{wm} for 20% aqueous solution of acetonitrile at 303.15 K

Pressure Difference (ΔP) $\Delta_{\varphi = 0}$ x10^{-4} (Nm^{-2})	**Hydrodynamic Flow J_vx10^{-7} (ms^{-1})**	**Permeability Coefficient L_Px10^{2} N^{-1}m^{3}s^{-1}K**	**Frictional coefficient F_{wm} x 10^2(mNmol^{-1}s)**
3.0	7.12	7.19	5.93
3.5	9.14	7.91	5.39
4.0	11.22	8.50	5.05
4.5	13.38	9.01	4.73
5.0	15.92	9.65	4.42

Table 3: Values of hydrodynamic flow J_V ($\Delta_\varphi = 0$), permeability coefficient L_P and frictional coefficient F_{wm} for 30% aqueous solution of acetonitrile at 303.15 K

Pressure Difference (ΔP)$\Delta_{\varphi = 0}$ x1o^{-4} (Nm^{-2})	**Hydrodynamic Flow J_vx1o^{-7} (ms^{-1})**	**Permeability Coefficient L_Px10^{2} N^{-1}m^{3}s^{-1}K**	**Frictional coefficient F_{wm} x 10^2(mNmol^{-1}s)**
3.0	6.22	6.30	6.77
3.5	8.33	7.21	5.91
4.0	10.22	7.74	5.51
4.5	12.47	8.40	5.08
5.0	14.89	9.02	4.73

Table 4: Values of electro-osmotic flow Jv ($\Delta p = 0$), Permeability coefficient L_P and Frictional coefficient F_{wm} for 10% aqueous solution of Acetonitrile at 303.15K

Potential Difference (V)$_{\Delta p = 0}$	**Electro-osmotic Flow J_vx10^{-7} (ms^{-1})**	**Permeability Coefficient L_Px10^{2} N^{-1}m^{3}s^{-1}K**	**Frictional coefficient F_{wm} x 10^2(mNmol^{-1}s)**
10	5.23	1.58	26.98
20	13.74	2.08	20.49
30	28.35	2.86	14.90
40	57.07	4.33	9.85
50	116.43	7.05	6.05

Table 5: Values of electro-osmotic flow Jv ($\Delta p = 0$), Permeability coefficient L_P and Frictional coefficient F_{wm} for 20% aqueous solution of Acetonitrile at 303.15K

Potential Difference (V)$_{\Delta p = 0}$	**Electro-osmotic Flow J_vx10^{-7} (ms^{-1})**	**Permeability Coefficient L_Px10^{2} N^{-1}m^{3}s^{-1}K**	**Frictional coefficient F_{wm} x 10^2(mNmol^{-1}s)**
10	4.93	1.49	28.61
20	12.37	1.87	22.78
30	26.74	2.70	15.78
40	53.67	4.07	10.47
50	99.24	6.01	7.09

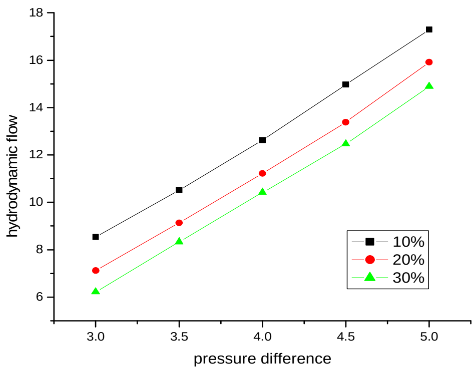

Fig.1

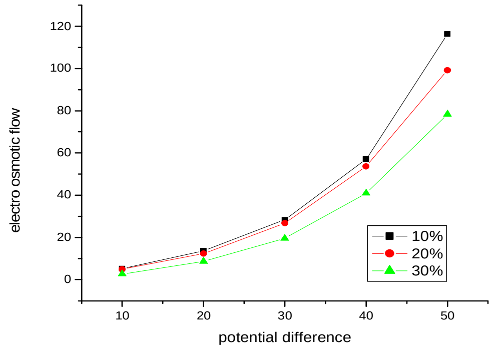

Fig.2

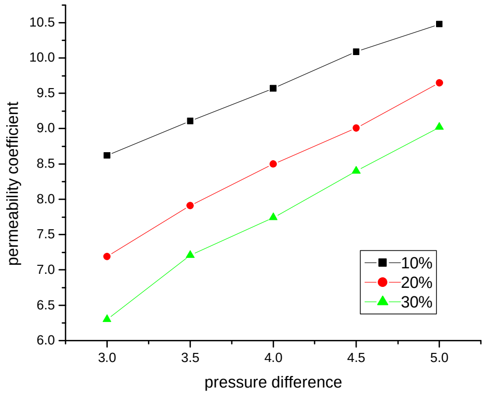

Fig.3

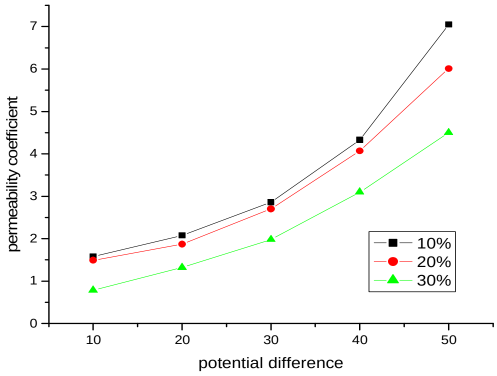

Fig.4

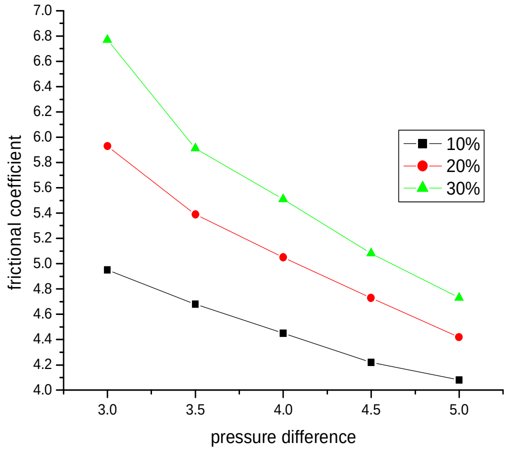

Fig.5

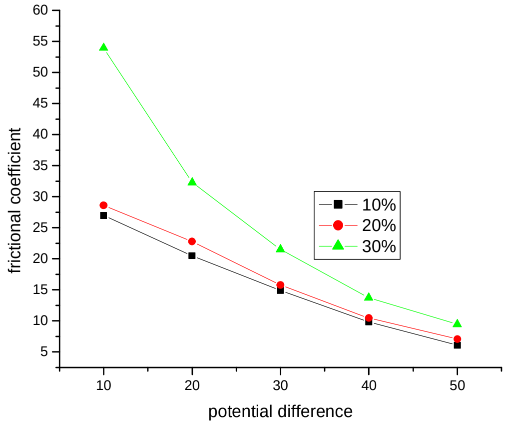

Fig.6

Figure 1 and 2 depicts the variation of hydrodynamic flow J_V ($\Delta_\varphi = 0$) and electro osmotic flow with pressure difference and potential difference respectively, Figure 3 and 4 depicts variation of permeability coefficient with variation in pressure difference and potential difference across the membrane and Figure 5 and 6 depicts variation of frictional coefficient with pressure difference and potential difference across the membrane

Table 6: Values of electro-osmotic flow Jv ($\Delta p = 0$), Permeability coefficient L_P and Frictional coefficient F_{wm} for 30% aqueous solution of Acetonitrile at 303.15K

Potential Difference $(V)_{\Delta p = 0}$	Electro-osmotic Flow $J_v x10^{-7}$ (ms^{-1})	Permeability Coefficient $L_P x10^2$ $N^{-1}m^3s^{-1}K$	Frictional coefficient F_{wm} x $10^2(mNmol^{-1}s)$
10	2.62	0.79	53.96
20	8.73	1.32	32.30
30	19.58	1.98	21.53
40	40.92	3.10	13.75
50	78.37	4.50	9.47

CONCLUSION

The transport properties such as hydrodynamic flow, electro osmotic flow, permeability coefficient and frictional coefficient were studied at 303.15K for various aqueous solutions of acetonitrile at different values of pressure difference and potential difference across the Nylon TM Bio-bond membrane. It has been observed that there occurs an increase in the value of hydrodynamic flow, electro osmotic flow and permeability coefficient with increase in pressure difference and potential difference across the membrane. However there occurs a decrease in the value of these parameters with increase in concentration due to decrease in solvent membrane interactions. Whereas the values of frictional coefficient increases with increase in concentration of the solution and decreases with increase in pressure difference and potential difference across the membrane.

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