



## Electro-Kinetic Studies on Comparative Properties of a Liquid Membrane and an Animal Membrane

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Two sets of membrane *i.e.*, liquid membrane generated by cholesterol and urinary bladder of goat as animal membrane have been chosen for experimental studies. Maximum conversion efficiency, figure of merit and degree of coupling have been computed for number of permeants. Alternative explanations of micturition phenomena in terms of frictional co-efficient have been given and results have been analyzed in terms of non-equilibrium thermodynamics.

**Key Words:** Conversion efficiency maxima, Degree of coupling, Figure of merit, Micturition phenomena.

### INTRODUCTION

Biological processes are quite complex due to complex surface behaviour and multiplicity of fluxes and forces involved<sup>1,2</sup>. The permeability of membrane depends upon the molecular size of the permeant, the pores of the membrane, the physiological state of membrane, the density and viscosity of the permeant, the association in the liquid state, the solubility of the permeant in the membrane, the number of hydrogen bonds, *etc.* To characterize fully the behaviour of membrane to a particular solute-solvent system, knowledge about reflection co-efficient<sup>3</sup>, permeability co-efficient, degree of coupling<sup>4</sup>, conversion efficiency maxima<sup>5</sup> *etc.* are quite essential. An alternative explanation may also be given in terms of fractional co-efficients<sup>6</sup>.

Attempts have been made to examine the nature of two identical types (membrane elements arranged in series) of the membrane and their behaviour with different permeants. Alternative explanations of the micturition phenomena in terms of frictional co-efficient have been given.

### EXPERIMENTAL

**Choice of membrane:** (i) Liquid membranes generated by cholesterol have been reported earlier<sup>7-9</sup>. (ii) Urinary bladder of goat was isolated and preserved by formalin-alcohol system as described earlier<sup>10,11</sup>.

**Procedure:** The apparatus is filled with liquid whose permeability is to be measured 8-10 h before observations are started. This is done to familiarize the membrane with permeating material. Hydrodynamic permeability is measured by noting the changes in liquid level in a horizontal capillary tube<sup>10,11</sup>.

Electro-osmotic permeability<sup>12,13</sup> was measured by noting the rate of advancement of liquid column in horizontal capillary tube application of electromotive force across the membrane.

**Theoretical:** Fluxes  $J_i$  can be expressed<sup>14</sup> as a function of forces  $X_1$ ,  $X_2$  and the structural factor  $G$ :

$$J_i = f(X_1, X_2 \dots G) \quad (1)$$

If the structural factor does not change and forces are  $\Delta P$  and  $\Delta\psi$  as in the case of electro-osmotic flux, volume flow may be written as:

$$J_v = L_{11}(\Delta P) + L_{12}(\Delta\psi) + 1/2L_{111}(\Delta P)^2 + L_{1112}\Delta P\Delta\psi + 1/2L_{122}(\Delta\psi)^2 + 1/6L_{1111}(\Delta P)^3 + 1/2L_{1112}(\Delta P)^2\Delta\psi + 1/2L_{1122}\Delta P(\Delta\psi)^2 + 1/6L_{1222}(\Delta\psi)^3 \quad (2)$$

where  $L_{ij}$ ,  $L_{ijk}$  and  $L_{ijkl}$  (1, 2) are phenomenological co-efficient.

Srivastava *et al.*<sup>15</sup> have theoretically tested the stability of steady state in non-linear situation. They have found that steady state remains stable within the frame work of local equilibrium concept even in non-linear situations. The efficiency of energy conversion in electro-osmosis and streaming potential may be expressed<sup>4</sup> as:

$$\eta_{eo} = \frac{J\Delta P}{I\Delta\psi} \quad (3)$$

$$\text{and} \quad \eta_{sp} = \frac{I\Delta\psi}{J\Delta P} \quad (4)$$

where  $eo$  and  $sp$  represent phenomena of electro-osmosis and streaming potential. Maximum energy conversion  $\eta_{max}$  and figure of merit  $\beta$  may be given as:

$$\eta_{\max} = \frac{(1 + B_{io})^{1/2} - 1}{(1 + B_{io})^2 + 1} \quad (5)$$

$$\text{where } B_{io} = \frac{(L_{ii}L_{oo} - 1)^{-1}}{L_{io}} \quad (6)$$

Degree of coupling (q) is defined as

$$\eta_{\max} = \frac{q^2}{(1 + \sqrt{1 - q^2})^2}$$

or

$$q = \frac{2\sqrt{\eta_{\max}}}{1 + \eta_{\max}} \quad (7)$$

The degree of coupling q lies between zero and unity, it has a value of zero when there is no coupling between two processes and a value of one when two processes are tightly coupled.

## RESULTS AND DISCUSSION

Urinary process may be defined as a process of development of pressure, sustenance of pressure<sup>16</sup> and finally release of pressure. Development of pressure given rise to streaming potential, which in turn produced streaming current. This current is probably micturition wave responsible for micturition reflux.

Urination is the collective property of the bladder and urine. There are three types of interactions taking place in the system *i.e.*, membrane-membrane interaction, membrane-urine constituents interaction and urine constituents-urine constituents interaction, respectively. Of these bladder membrane and urine constituents interaction is of prime importance. Effective pressure plays a vital role in deciding micturition waves. When pressure build up is not significant there are no sensations as soon as pressure build up becomes significant micturition waves are produced and voiding takes place. The process is regenerative.

Since bladder membrane remains the same and only change is the composition of urine, thus composition of urine plays vital role.

Kedem and Katchalky<sup>4</sup> have shown how it is possible to translate the phenomenological co-efficient in to frictional co-efficient having readily interpretable physical meaning. Frictional co-efficient  $f_{wm}$  represents interaction between membrane and solvent w,  $f_{sm}$  describe the interaction between solute and membrane and co-efficient  $f_{sw}$  shows interaction between solute and solvent.

At low concentration<sup>17</sup>.

$$\frac{W}{Lp} = \left[ \frac{f_{wm}}{f_{sw} + f_{sm}} \right] \times \frac{1}{\bar{V}_w} \quad (8)$$

where Lp is permeability co-efficient and w represents solute permeability,  $\bar{V}_w$  is the partial molar volume of the solvent. Putting value of w in terms of water content and thickness of the membrane:

$$W = \frac{\phi w}{\Delta x (f_{sw} + f_{sm})} \quad (9)$$

$$\frac{\phi W}{\Delta x (f_{sw} + f_{sm}) \times Lp} = \frac{f_{wm}}{(f_{sw} + f_{sm})} \times \frac{1}{\bar{V}_w}$$

$$\frac{\phi w}{\Delta x \cdot Lp} = \frac{f_{sm}}{\bar{V}_w} \quad (10)$$

$$\frac{\phi w}{\Delta x} \frac{\Delta P}{Jv} = \frac{f_{wm}}{\bar{V}_w} \quad (11)$$

Keeping  $\Delta x$  and  $dw$  constant, it can be shown that

$$\Delta P \propto f_{wm}$$

Thus solvent membrane interaction is proportional to pressure difference across the membrane. As soon as pressure build up become negligible solvent membrane interaction becomes quite low.

Ginzburg and Katchalsky<sup>18</sup> have calculated frictional co-efficient for cellophane dialysis tubing and wet gel. Recently, frictional co-efficients<sup>19</sup> for cellulose acetate and zeocarbs-225 composite membranes have been evaluated.

Membrane parameters such as energy conversion maxima, figure of merit and degree of coupling for the two sets of membranes are given in Tables 1-4.

TABLE-1  
VALUES OF PHENOMENOLOGICAL CO-EFFICIENTS, FIGURE OF MERIT  $B_e$ ,  $\eta_{\max}$  AND DEGREE OF COUPLING AT DIFFERENT CONCENTRATIONS OF CHOLESTEROL<sup>8</sup>

Conc. of cholesterol (nm)	$B_e \times 10^{-3}$	$\eta_{\max} \times 10^{-5}$	$q \times 10^{-2}$
0.00	2.63	66.00	5.12
9.40	2.76	68.00	5.22
15.04	2.45	62.00	4.94
28.20	2.05	57.00	4.50
30.08 (CMC)	1.96	50.50	4.46
37.60	2.05	52.00	4.54
56.40	2.08	54.50	4.59
	1.65	43.00	4.13

TABLE-2  
VALUES OF FIGURE OF MERIT, CONVERSION EFFICIENCY MAXIMA,  $\eta_{\max}$  AND DEGREE OF COUPLING FOR UREA-GLUCOSE MIXTURE<sup>20</sup> (KEEPING GLUCOSE CONCENTRATION CONSTANT)

Urea-glucose conc.	$B_e \times 10^{-5}$	$\eta_{\max} \times 10^{-5}$	$q \times 10^{-2}$	$L_{112} \times 10^{-14}$ ( $m^5 s^{-1} v^{-1} N^{-1}$ )
0.01 + 0.01	8.40	2.09	0.9143	-1.40
0.02 + 0.01	7.19	1.79	0.8461	-1.01
0.03 + 0.01	8.83	2.20	0.9400	-0.52
0.04 + 0.01	11.50	2.87	1.0730	-0.24
0.05 + 0.01	14.36	3.58	1.1540	-0.13

TABLE-3  
VALUES OF FIGURE OF MERIT, MAXIMUM CONVERSION EFFICIENCY  $\eta_{\max}$  AND DEGREE OF COUPLING FOR UREA SYSTEM<sup>21</sup>

Conc. of urea (nm)	$B_e \times 10^{-5}$	$\eta_{\max} \times 10^{-5}$	$q \times 10^{-2}$	$L_{112} \times 10^{-14}$ ( $m^5 s^{-1} v^{-1} N^{-1}$ )
0.02	7.36	1.59	0.8555	-1.17
0.04	8.29	2.15	0.9077	-0.89
0.06	9.09	2.79	0.9507	-0.74
0.08	11.31	2.70	1.0620	-0.62
0.10	12.54	3.29	1.1170	-0.44

Since the membranes are geometrically of the same type (series array of elements), similar results were expected. A plot of  $\eta_{\max}$  versus  $\Delta P$  given a typically curve for all types of permeants where the value first rises to maxima and then gradually

TABLE-4

FIGURE OF MERIT ( $\beta$ ), MAXIMUM CONVERSION EFFICIENCY  $\eta_{\max}$  AND DEGREE OF COUPLING FOR ACIDS<sup>22</sup>

Permeant (0.001 M)	$Be \times 10^{-5}$	$\eta_{\max} \times 10^{-5}$	$q_e \times 10^{-2}$
L-Tyrosine	1.51	0.37	0.38
Oxalic acid	4.90	1.21	0.69
L-Cystine	5.10	1.26	0.70
Uric acid	7.97	1.98	0.88

decreases to minimum value. Similar observation may also be observed for micturition phenomena in which pressure build up reaches to the highest value and reaches to the lowest value when there is no urine in the bladder. A close relationship exists for degree of coupling and second order phenomenological coefficient ( $L_{112}$ ).

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