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Study of Electrolytic Conductance Across Peritoneal Membrane as a Function of Concentration and Temperature

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The specific conductance of aqueous solutions of various electrolytes was measured in the two compartments of a special cell developed in the laboratory at several temperatures between 15 to 35°C (±0.1°C) across peritoneum membrane. The values of specific conductance increased with the rise in concentration of electrolyte, which was found due to the progressive accumulation of ionic species within the membrane. The tendency of attaining maximum limiting values of specific conductance at higher concentration seemed to be due to the fact that an electrically neutral pore, which is specific for a particular ion, is unlikely to contain more than one type of ion. The increase in the values of specific conductance with rise in temperature was observed due to the fact that the state of hydration of penetrating ions may be considered to exit in a dynamic condition so that at higher temperature, higher fraction of total number of given species would possess excess energy per mole. The values of specific conductance measured for different electrolytic solution across the membrane attained a particular sequence for anion followed by cation. The sequence of anion were found in a series $SO_4^{-} > Cl^{-} > NO_3^{-} > F^{-} > K^{+}$ and the sequence for the cations found $K^{+} > Na^{+} > Ca^{2+} > Mn^{2+} > Cr^{3+} > Fe^{3+}$. This trend was in good accordance to varying membrane defect and ion solution of different size of these ions.

Key Words: Specific conductance, Peritoneal membrane.

INTRODUCTION

The permeation of ions across the membranes is known[1–4] to depend upon the size of the pores lined by charges, water/fluid soluble carrier molecules as well as on the homogeneous dielectric medium having the rate limiting 'gate mechanism' at their surfaces. The permeation of ions across the membrane, whether natural or artificial, seems to follow similar mechanisms but in biological membranes a large activation energy is required in transferring ions from the polar aqueous environment to the non-polar interior of membrane. To lower the activation energy ion transport is aided by ion channels, carriers and pumps located in biological membranes. In addition, the membrane structure and the boundary conditions at the membrane/electrolyte interface determine the selective nature of ion diffusion/permeation. In order to understand the details of diffusion/permeation, collision-, jump-, and solvent drag mechanisms have been put forward.

In the case of hydrophilic groups in the membrane the permeability has been found[5, 6] to be facilitated through the formation of hydrogen bonds with water. In such cases the hole type and the alignment type diffusion mechanisms have been

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reported[7] for the permeation of ions. These mechanisms find support from the electrical resistance data of several membranes[8]. Attempts have also been made[9–11] to explain the process of permeation of ions in terms of the binding energies of ion-protein and ion-water interactions.

It has also been proposed[12, 13] that a penetrating ion forms an activated complex which is composed of channel sites, a cation and an anion. The anionic channel site attracts and retains a cation as short-lived associated ion-pairs which may either decay by dissociation of anion or of anion-cation pairs. Singh[14] studied the conductance of active side, passive side and across the pericardium using a Sollner type of cell.

Thus, in view of the said investigations, a thorough study of electrical conductance of ions across the biomembranes has yet to be undertaken. This has led/prompted[4] us to study the electrical conductances of ions in both the compartments of the two sides of the pericardial membrane which surrounds the heart and may regulate the flow of ionic/solvated ionic entities as well as those of the solvent molecules through the process of active or passive transport and accumulation of fluid by pericardium. Such an investigation may help in the clinical aspects of heart strokes.

EXPERIMENTAL

The peritoneal membrane of buffalo removed immediately after slaughter of relatively young (aged between 18–24 months) animal from the slaughter house was preserved in ice-cold Ringer's solution of about 7.4 ± 0.2 pH in order to prevent the decay of membrane tissues. The Ringer's solution had the following composition in g/L: NaCl (9.0), KCl (0.42), $CaCl_2$ (0.24), Glucose (1.00) and $NaHCO_3$ (0.15).

The membrane pieces of adequate/desired size were washed several times with double distilled water to remove any trace of ions of Ringer's solution. It was then placed between the two halves of the cell compartment provided with platinum electrodes shown in Fig. 1. After filling the two halves of the cell compartment with each of the electrolytic solutions of desired concentration the conductances were recorded with the help of an LCR bridge 921 (Elico, Hyderabad). The cell assembly

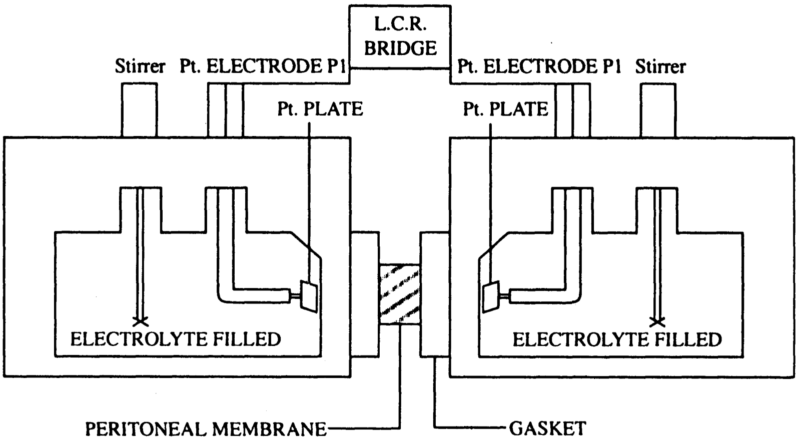

Fig. 1. Schematic diagram of cell assembly used for the measurement of specific conductance (K) of the solution across the peritoneal membrane.

was immersed in a thermostated bath of ±0.1°C. Thermal stability was maintained at 15, 20, 25, 30 and 35°C. All the solutions, equipments and apparatus were maintained at the same temperature during the course of experiment.

RESULTS AND DISCUSSION

The specific conductances of aqueous solutions of electrolytes (*viz.*, NaF, NaCl, $NaNO_3$, Na_2SO_4, KF, KCl, KNO_3, K_2SO_4, $MgCl_2$, $CaCl_2$, $FeCl_3$, $MnCl_2$, $CrCl_3$, $CuCl_2$, $CoCl_2$) have been measured in the two compartments of the cell at several temperatures between 15 and 35°C (±0.1°C). These results are given in Tables 1–4. An examination of these tables shows that the specific conductance increases with an increase in the concentration of electrolyte and attains a maximum limiting value at higher concentrations. This trend has been observed in all the electrolyte solutions under investigation. This may be attributed to a progressive accumulation of ionic species within the membrane. As such the membrane becomes more and more conductive to incoming ions. The tendency to attain a limiting value seems to be due to the fact that an electrically neutral pore which is specific for a particular ion is unlikely to contain more than one type of ion. Consequently, at high electrolyte concentration, the pore saturates and the conductance approaches a limiting value. Also, since the biomembranes possess protein, which acts as a carrier, picks up ion on one side and then returns for more ions. In such a mode, the flow of ions through the membrane reaches a saturation value as the concentration of the electrolyte solution is increased as all the carriers in the membrane get themselves bound to the ions.

In addition, the diffusion of the electrolyte through the membrane depends upon the charge on the membrane and its porosity. The membrane porosity in relation to the size of the hydrated species flowing through the membrane seems to determine the increase of specific conductance with rise in concentration of electrolyte. The diffusion paths in the membrane become more difficult than aqueous solutions due to the non-polar interior of the membrane. The mobility of large hydrated ions gets impeded by the membrane framework due to the interaction with the fixed charge groups on the membrane matrix. Consequently, the conductance of small ion which is much hydrated gets reduced by the membrane pores. When the ions move into the membrane interior, they create a local deformation, while water molecules and polar head groups of peritoneal membrane forming lipids are restricted to the surface of the membrane. Thus, ions enter the non-polar interior of the membrane. As soon as the ions cross the midplane of the membrane, deformation switches sides. The initial defects slowly relax and instead of this a new defect or deformation is formed on the outgoing side of the membrane. During the whole process, ions are solvated by both water and polar lipid had groups. Thus the membrane defect and ion solvation considerably lower the activation energy to ion transport across the membrane. Both membrane defects and ion solvation are regulated by ionic size and concentration as is shown in Tables 1–4. Temperature also affects the membrane effect and ion solvation.

The increase in specific conductance with rise in temperature may be due to the fact that the state of hydration of penetrating electrolyte may also be considered to exist in a dynamic condition so that at a higher temperature, considerably higher fraction of total number of given species would possess excess energy per mole in accordance with the Boltzman distribution, $f \propto e^{-Ea/RT}$. Under these conditions those ionic species which have lost sufficient water of hydration to be smaller than size of the membrane pores would enter through the pores.

The values of specific conductance (Tables 1–4) measured for different electrolyte solutions across the peritoneal membrane at any given temperature follow the sequence for anion: $SO_4^{2-} > Cl^- > NO^{3-} > F^-$ whereas for the cations the sequence is: $K^+ > Na^+ > Ca^{2+} > Mn^{2+} > Co^{2+} > Cu^{2+} > Mg^{2+} > Cr^{3+} > Fe^{3+}$.

TABLE-1

VALUES OF SPECIFIC CONDUCTANCE, K ($m\Omega^{-1}$ cm^{-1}) OF AQUEOUS SOLUTIONS OF VARIOUS ELECTROLYTES ACROSS PERITONEAL MEMBRANE AS FUNCTIONS OF CONCENTRATION AND TEMPERATURE

Electrolyte concentration (mol L^{-1})		Temperature (± 0.1°C)				
		15	20	25	30	35
NaF	0.001	00.085	00.086	00.088	00.089	00.090
	0.002	00.005	00.010	00.011	00.012	00.013
	0.005	00.195	00.225	00.249	00.285	00.345
	0.010	00.495	00.574	00.622	00.772	00.921
	0.020	00.732	00.772	00.933	01.240	02.340
	0.050	00.870	02.990	03.730	04.480	04.980
	0.100	03.600	04.500	05.400	06.400	07.230
	0.200	05.100	06.820	07.160	08.040	08.830
$NaNO_3$	0.001	00.088	00.090	00.091	00.094	00.095
	0.002	00.109	00.115	00.136	00.184	00.226
	0.005	00.299	00.325	00.373	00.448	00.498
	0.010	00.640	00.723	00.862	00.996	01.720
	0.020	00.986	01.040	01.320	02.600	03.490
	0.050	02.490	03.730	04.480	04.860	05.980
	0.100	04.400	05.490	06.560	07.520	08.520
	0.200	06.030	06.930	08.240	08.430	10.020
NaCl	0.001	00.128	00.132	00.155	00.160	00.172
	0.002	00.179	00.197	00.246	00.279	00.295
	0.005	00.373	00.407	00.467	00.528	00.621
	0.010	00.747	00.815	00.996	01.420	02.280
	0.020	01.490	01.720	02.950	03.490	04.730
	0.050	04.480	04.870	06.300	07.290	08.320
	0.100	06.890	07.720	09.530	10.200	10.700
	0.200	09.210	09.840	10.800	11.200	12.200
Na_2SO_4	0.001	00.179	00.204	00.224	00.249	00.269
	0.002	00.249	00.299	00.345	00.408	00.498
	0.005	00.597	00.659	00.723	00.786	00.896
	0.010	01.040	01.510	02.540	03.790	04.940
	0.020	02.790	03.540	04.490	05.390	06.480
	0.050	04.980	06.270	06.960	07.750	08.800
	0.100	08.440	09.690	10.300	10.000	11.800
	0.200	10.400	10.700	11.300	12.100	13.000

TABLE-2

VALUES OF SPECIFIC CONDUCTANCE, K (mΩ^{-1}cm^{-1}) OF AQUEOUS SOLUTIONS OF VARIOUS ELECTROLYTES ACROSS PERITONEAL MEMBRANE AS FUNCTIONS OF CONCENTRATION AND TEMPERATURE.

Electrolyte	concentration (mol L^{-1})	Temperature (± 0.1°C) 15	20	25	30	35
KF	0.001	00.095	00.096	00.097	00.098	00.103
	0.002	00.132	00.140	00.149	00.165	00.189
	0.005	00.320	00.345	00.373	00.448	00.472
	0.010	00.597	00.689	00.772	00.869	00.996
	0.020	00.933	01.070	01.320	01.790	02.620
	0.050	01.950	03.200	03.730	04.480	05.380
	0.100	04.980	05.600	06.400	07.470	08.530
	0.200	06.190	06.720	07.500	08.640	09.400
KCl	0.001	00.102	00.104	00.109	00.115	00.121
	0.002	00.140	00.155	00.166	00.179	00.205
	0.005	00.373	00.448	00.482	00.527	00.560
	0.010	00.747	00.845	00.933	01.070	01.280
	0.020	00.932	01.280	01.600	01.950	02.990
	0.050	02.990	04.480	04.770	05.430	05.600
	0.100	07.470	08.280	08.900	09.280	10.000
	0.200	09.120	09.790	10.100	10.500	11.100
KNO_3	0.001	00.128	00.143	00.145	00.154	00.166
	0.002	00.179	00.195	00.213	00.234	00.264
	0.005	00.498	00.527	00.560	00.640	00.700
	0.010	00.896	00.996	01.090	01.320	01.790
	0.020	01.540	01.660	02.450	02.990	03.800
	0.050	04.980	05.330	05.600	06.400	07.430
	0.100	08.300	09.260	09.860	10.500	11.100
	0.200	10.100	11.100	11.400	11.700	12.200
K_2SO_4	0.001	00.140	00.149	00.154	00.179	00.213
	0.002	00.264	00.295	00.362	00.373	00.448
	0.005	00.454	00.600	00.660	00.726	00.814
	0.010	01.120	01.280	01.710	02.460	03.830
	0.020	02.190	02.740	03.500	04.480	05.420
	0.050	05.600	06.140	06.600	07.390	08.460
	0.100	09.960	11.100	11.600	12.400	13.400
	0.200	12.000	12.600	13.100	13.800	14.600

TABLE-3

VALUES OF SPECIFIC CONDUCTANCE, K ($m\Omega^{-1}cm^{-1}$) OF AQUEOUS SOLUTIONS OF VARIOUS ELECTROLYTES ACROSS PERITONEAL MEMBRANE AS FUNCTIONS OF CONCENTRATION AND TEMPERATURE

Electrolyte concentration (mol L^{-1})		Temperature (±0.1°C)				
		15	20	25	30	35
$MgCl_2$	0.001	00.132	00.140	00.149	00.154	00.166
	0.002	00.204	00.224	00.264	00.272	00.302
	0.005	00.448	00.492	00.515	00.546	00.605
	0.010	00.896	00.974	01.090	01.380	01.570
	0.020	01.490	01.680	02.040	02.490	03.200
	0.100	07.320	07.960	08.460	09.200	10.100
	0.200	08.430	09.010	09.430	10.000	11.600
$FeCl_3$	0.001	00.160	00.172	00.179	00.204	00.224
	0.002	00.249	00.279	00.315	00.358	00.401
	0.005	00.521	00.560	00.622	00.669	00.747
	0.010	00.996	01.190	01.610	02.190	03.000
	0.020	01.790	02.230	02.690	03.230	04.670
	0.050	04.980	05.370	05.770	06.400	06.790
	0.100	07.930	08.300	09.000	09.790	10.070
	0.200	09.040	09.420	10.010	10.800	11.100
$CrCl_3$	0.001	00.179	00.187	00.213	00.224	00.242
	0.002	00.299	00.345	00.400	00.438	00.553
	0.005	00.589	00.640	00.679	00.728	00.802
	0.010	01.120	01.380	01.600	02.390	03.200
	0.020	02.240	02.990	03.820	04.880	05.370
	0.050	05.460	05.890	06.690	07.400	08.210
	0.100	08.340	08.900	09.490	10.300	10.900
	0.200	09.700	10.200	10.700	11.600	12.000
$CuCl_2$	0.001	00.187	00.204	00.224	00.230	00.240
	0.002	00.320	00.353	00.372	00.410	00.440
	0.005	00.614	00.700	00.700	00.747	00.800
	0.010	01.210	02.190	02.190	02.840	03.600
	0.020	03.200	04.400	04.400	05.000	06.040
	0.050	06.220	07.890	07.890	08.390	09.470
	0.100	09.000	10.60	10.600	11.500	12.000
	0.200	10.200	11.70	11.700	12.300	13.200

TABLE-4

VALUES OF SPECIFIC CONDUCTANCE, K (mΩ^{-1}cm^{-1}) AQUEOUS SOLUTIONS OF VARIOUS ELECTROLYTES ACROSS PERITONEAL MEMBRANE AS FUNCTIONS OF CONCENTRATION AND TEMPERATURE.

Electrolyte concentration (mol L^{-1})		Temperature (± 0.1°C)				
		15	20	25	30	35
$CoCl_2$	0.001	00.249	00.253	00.262	00.283	00.300
	0.002	00.373	00.412	00.458	00.513	00.549
	0.005	00.727	00.768	00.836	00.912	01.540
	0.010	02.040	02.620	03.600	04.320	05.020
	0.020	04.067	05.290	05.970	06.640	07.190
	0.050	07.230	07.860	08.960	09.530	10.300
	0.100	09.820	10.600	11.200	11.700	12.500
	0.200	10.900	11.700	12.300	12.300	13.400
$MnCl_2$	0.001	00.280	00.300	00.313	00.324	00.342
	0.002	00.418	00.451	00.470	00.522	00.564
	0.005	00.853	00.854	00.904	00.950	01.020
	0.010	03.940	04.490	05.020	05.680	06.490
	0.020	05.420	06.100	06.530	07.220	08.100
	0.050	08.300	08.760	09.600	10.300	11.100
	0.100	10.300	10.800	11.500	12.200	13.000
	0.200	11.200	11.700	12.300	13.000	14.100
$CaCl_2$	0.001	00.373	00.382	00.402	00.402	00.434
	0.002	00.516	00.549	00.602	00.630	00.683
	0.005	00.922	01.040	01.320	01.840	02.210
	0.010	04.960	05.900	06.480	07.020	08.010
	0.020	07.000	07.800	08.210	08.900	09.810
	0.050	09.860	11.600	11.700	11.900	12.800
	0.100	11.800	12.400	12.800	13.500	14.400
	0.200	12.600	13.200	13.500	14.200	15.300

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REFERENCES

1. T. Teorell, Progr. *Biophys. Chem.*, **3,** 35 (1953).
2. J.L. Lovanam, Structure and Function in Biological Membranes, Holden-Day, San Francisco (1964).
3. J.F. Danielli and H. Davson, *J. Cell. Comp. Physiol.*, **5,** 495 (1934).
4. D.E. Goldman, *J. Biophys.*, **4,** 167 (1964).
5. C.E. Ried and E.J. Breton, *J. Appl. Polym. Sci.*, **1,** 133 (1959).
6. A.L. Vincent, M.K. Bassh and R.E. Kesting, *J. Appl. Polym. Sci.*, **9,** 2365 (1965).
7. R.E. Kesting and J. Eberlin, *J. Appl. Polym. Sci.*, **10,** 961 (1966).
8. R.C. Ried, *J. Appl. Polym. Sci.*, **4,** 354 (1960).
9. B. Hille, Ionic Channel of Excitable Membrane, Sinaner Associates Inc., Sunderland (1984).
10. G. Eiesenmand and R. Horn, *J. Membr. Bio.*, **76,** 197 (1983).
11. P. Langer, *Biochem. Biophy. Acta,* **311,** 423 (1973).
12. F. Francioline and A. Petris, *Biochem. Biophy. Acta,* **1031,** 247 (1990).
13. F. Francioline and W. Nonner, *J. Gen. Physiol.*, **90,** 453 (1987).
14. K.P. Singh, Study of conductance with pericardium: effect of binding site asymmetry on conductance of ions, Desalination Elsevier, 163 pp. 223–230 (2004).

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