TRANSPORT STUDIES THROUGH BIOLOGICAL MEMBRANES

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Abstract

Extensive research work has been started to study the complex behaviour of biological membranes by developing various artificial membranes such as parchment or cellophane inorganic precipitate membranes which may mimic some properties of biological membrane in vivo. The mechanism of the bi-ionic potential was considered in detail by Sollner. He found that not only was the relative mobility of the counter-ions important but also the selectivity of the membrane material played a significant role. According to his views, when the membrane is in a bi-ionic cell, one ion is preferred to the same extent as when the membrane is in equilibrium with a mixed solution containing both counter-ions. His equation for the potential (restricted to 1:1 electrolytes).

$$\Delta\phi = \frac{RT}{F} \ln \frac{\overline{D_A}\,\gamma_B}{\overline{D_B}\,\gamma_A} \qquad\qquad (4.1)$$

reflects the two factors relative mobility ($\overline{D_A}/\overline{D_B}$) in, and preferential adsorption (γ_B/γ_A) by the membrane.

Keywords: Biological Membrane, Transportation, Parchament, Cellophane.

Discussion and Results: Electrochemical characterization of membrane is of vital importance from the point of view of determination of their suitability for many applications of practical interest[1]. Therefore the study of membranes is of great interest as they serve as models for biological systems. The use of semipermeable membranes for various separation problems has been of interest, to chemists, biochemists and chemical engineers. For many years and abdunt technical information on the subject has appeared in print. From the point of view of a physical chemist the knowledge of transport process across artificial membranes is applied in right direction can solve many secrets of nature. The biologists have recently employed more quantitative methods or research and accumulated enormous data suitable for theoretical studies.

Membranes may be solid, liquid or gas , and the outer phases are usually liquid or solid. Membranes are usually thin in one dimension relative to the other two dimensions. This property is only functional or operational in order to achieve a measurable chemical change or electrochemical effect and to make chemical measurements on a membrane system in reasonable time, some transport related property must be susceptible to temporal change. Thus, a change in potential, flux, or concentration (among many varying and measurable quantities) requires membrane thickness d such that $d^2/2D$ is comparable with the observation time (D is mean diffusion coefficient). Although irregularly shaped membranes are conceivable, most theories and experiments are restricted to systems with one dimensional, the X direction in parallel-face, planar membranes or along a radius in membranes with spherical shapes.

Membranes are considered to be porous or nonporous depending upon the extent of solvent penetration[28] at the nonporous extreme are membranes at which are nonionic and contain negligible transportable species at equilibrium. Ceramics, quartz, anthracene crystals and teflon films between metal electrodes or electrolyte bathing solutions are solid membrane examples. Organic liquid films such as hydrocarbons and fluorocarbons in contact with aqueous electrolytes are liquid membrane examples. At the other extreme are porous membranes, which can be solvated and will contain components from the outer phase. Among these are nonionic films such as cellophane, inorganic gels, and loosely compressed powder in contact with aqueous solutions. These materials absorb solvent from the surrounding media and may also extract other neutral molecules and ionic salts. Biological membranes such as pig bladders was given by John L. Anderson in his review to trace some of the early history of membrane transport. Moreover H. Arif et al. also took the transport of metal ions across pericardial membrane.

IMPEDANCE: Numerous investigations particularly on living membranes, with alternating currents have shown that they exhibit a composite resistance i.e. an impedance, which is different at different frequencies of the current employed. The leading workers in this field have been Lullies, Gildemeister

and particularly Cole and Collaborators. Plain electrolyte solutions, on the other hand, show a frequency independent resistance. The impedance of the membranes has been resolved into a 'resistance' term (of the ohmictype) and a 'reactance' term, the latter being usually regarded as due to a 'capacity' residing in the membrane structure. Many speculations have been devoted to the significance of these impedance terms. Although it is true that the impedance method have offered excellent service in permeability research as sensitive indicators that something has happened, it is regrettable that no convining or complete view of its theoretical background has as yet been put forward. A common interpretation has been that the resistance term is connected with the ion permeable structures and the capacitance term with the ion impermeable parts (lipoids layers etc.) of the membranes or tissues investigated.

MEMBRANE POTENTIAL:

The earliest efforts toward developing a membrane model was by Michaelis[148] who considered that the charge on the membrane was due to adsorption of one kind of ion. Later Teorell[58] and Meyer and Sievers[59] developed a theory of membranes with charges fixed in the lattice. In the Teorell-Meyer-Sievers (TMS) theory there is an equilibrium process at each solution membrane interface which has formed analogy with the Donnan equilibrium. In addition there is an internal salt diffusion potential which was first represented by the Henderson equation and later by the more-nearly correct Planck expression[149]. Further assumption made are (a) the cation and anion mobilities and fixed charge concentration are constant throughout the membrane phase and are independent of the salt concentration and (b) the transference of water may be neglected. The implications of these assumption have been discussed by Hills, Jacobs and Lakshminarayanaiah.

BI-IONIC POTENTIAL:

A steady electromotive force of a bi-ionic cell containing two electrolytes AY and BY separated by a membrane is called the bi-ionic potential (BIP). This potential is a measure for the selectivity of a membrane for the ions of the same sign and has been the subject of many theoretical and experimental studies.

The fundamental theory of non-equilibrium thermodynamics is[168-170] that the forces and the fluxes are so chosen as to conform to the equation.

$$\phi = T\theta = \Sigma_i \, J_i \, X_i \qquad (1)$$

and the phenomenological coefficient L_{ik} (i, K=1,2…)

$$Ji = \overset{n}{\underset{i}{\Sigma}} \qquad L_{iK}X_k \qquad (2)$$

Satisfy the Onsager reciprocal relations

$$L_{ik} = L_{ki}$$

The theoretical principles of irreversible thermodynamics and other transport equations used in the description of membrane phenomena have been reviewed by Hanley[171]. Similarly, Mikulecky[172] has reviewed the material illustrating the application of various flow equation to transport process in different membrane systems. The application of the onsager reciprocal relation to a simple membrane transport, process has been described by Kedem and Katchalsky· The work described in this thesis is mainly devoted to the study of the following aspects of "Transport Phenomena".

The membrane potential data obtained with silver carbonate, silver tungustate, silver phosphate and strontium phosphate parchment supported membranes, using various 1:1 electrolytes, are plotted as a function of log $[(C_1+C_2)/2]$ with the ratio $\gamma=(C_2/C_1)$ fixed at 10. These values are given in Tables 4.9-4.12 and the plots are shown in Figs. 4.5-4.8.

Equation 4.27 indicates that the intercept of a plot of $1/t^-_{app}$ against $1/C^{II}_N$ at fixed $\gamma=10$, allows the values of V_N to be determined. The values of $1/t^-_{app}$ are calculated from Eq. 4.26 for the four membranes and are given in Tables 4.13-4.16. Plots of $1/t^-_{app}$ against $1/C^{II}_N$ for various 1:1 electrolytes are shown in Figs. 4.9-4.12 for $1/t^-_{app}$ the investigated membranes. For the evaluation of (θ/K_N), the slope of Eq. 4.27 which is given by the following, is first determined.

$$(V_N - 1) \left(\frac{\gamma-1}{\gamma \ln \gamma} \right) \left(\frac{\theta}{K_N} \right)$$

The graphical values of the slope determined from figs. 4.9-4.12 are equated with the above expression and then substituting V_N in it, the values of (θ/K_N) are determined. In this way the values of V_N and (θ/K_N) are obtained

and are given in table (4.17).

By solving various equations Toyoshima et al.[1] gave the equation for BIP in the following form.

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