

Transport Properties of Charged Mosaic Membrane Based on Non-equilibrium Thermodynamics

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Abstract: It is well known as the role of ion exchange membrane with functional group in membrane matrix. Recently, we were reported that the charged mosaic membrane within parallel array of negative and positive charge groups. In this study we are reported the properties for the various transport coefficients of metal and heavy metal ions across charged mosaic membrane based on non-equilibrium thermodynamics is not based on equilibrium state.

Keywords: *ion-exchange membrane, functional group, membrane matrix, negative and positive charge, non-equilibrium thermodynamics*

1. Introduction

A theory for the material transports through ion exchange membrane has been developed on the basis of non-equilibrium thermodynamics by removing the assumption of solvent flow in the previous paper and applied to a detailed study of the ionic transport properties of new charged mosaic membrane (CMM) system. The CMM having two different fixed charges in the polymer membrane with unique selective transport behavior then ion-exchange membrane[1-3].

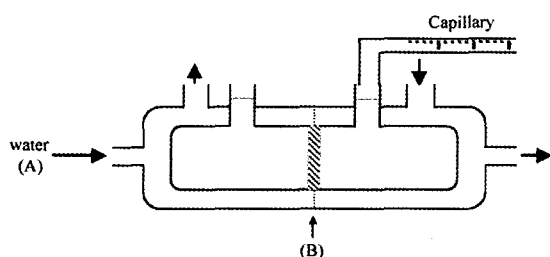
The separation behavior of ion transport across the CMM with a parallel array of positive and negative functional charges were investigated[4]. It was well-known the analysis of the volume flux and solute flux based on non-equilibrium thermodynamics. Particularly, the transport property describing a membrane process must be satisfy the principles of non-equilibrium thermodynamics. It is of interest to determine the phenomenological coefficients by using a variety of membranes and to understand how the coefficients

reflect the membrane characters[5]. Thus a determination of the coefficients in CMM-aqueous solution system has been attempted. In previous studies[1,2], we reported the transport behavior of solvent and solute across the charged mosaic membrane and indicated the unique characteristics in the charged mosaic membrane. This means that one of the membrane parameters, estimated from flux measurements indicates the negative value and the separation between solute and solvent or between electrolyte and non-electrolyte will be realized[5]. The composite charged mosaic membrane was investigated from simultaneous transport such as solute and solvent flux. On the other hand, the reflection coefficient and salt flux coefficient were estimated by taking account of the cross constants of the phenomenological equation. In previous studies[3], we reported transport coefficients of solvent and solute with mono-mono valent electrolyte solution across charged mosaic membrane. In this results, we are reported the transport coefficients of materials across CMM.

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Table 1. The Structure Characteristics of Charged Mosaic Membrane

Membrane thickness	50 μm
Cation exchange group	$-\text{C}_5\text{H}_5^+\text{CH}_3$
Microsphere content (wt%)	23.4~26.1
Anion exchange group	$-\text{C}_6\text{H}_5\text{SO}_3^-$

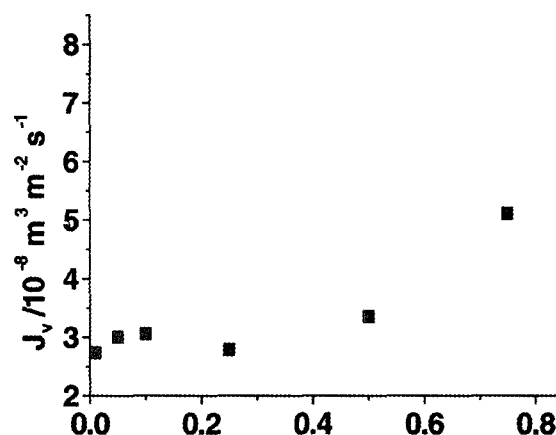
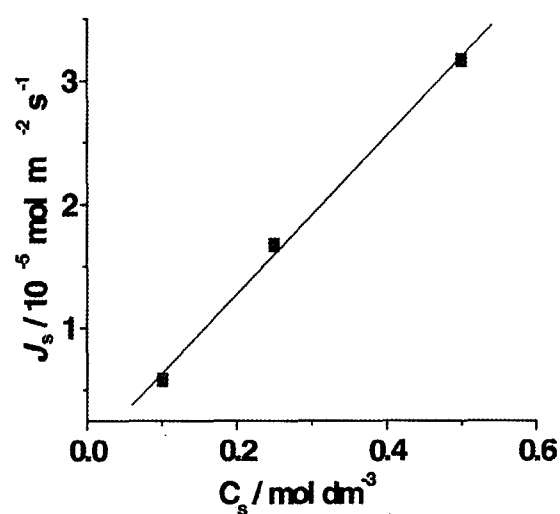
**Fig. 1.** The schematic of membrane experimental apparatus: (A); entrance circulating water for supported constant temperature at 25°C, (B); the supported of charged mosaic membrane (CMM), the glass cell content of left-side and right-side is 25 mL, respectively.

2. Experimental

Our suggests preferential salt transport across the charged mosaic membranes. Transport properties of heavy metal ions; Mg^{2+} , Mn^{2+} and sucrose system across the charged mosaic membrane were estimated. As a result, we were known metal salts transport depended largely on the CMM. The reflection coefficient indicated the negative value that suggested preferential material transport and was independent of charged mosaic membrane thickness.

The charged mosaic membrane were made two different ion exchange groups and the ion groups, cation and anion exchange groups were arranged parallel with each other inside membrane and the array of charge groups links continuously from one membrane to the other membrane[9]. The membrane characteristics are given the Table 1 and Figure 1 is the experiments apparatus.

The flux measurements were carried out by a set of two glass cells. The membranes were tightly inserted between two cells by using silicon rubbers in order to avoid leak of water from the contact surfaces. The experiment temperature was kept at 25°C by the

**Fig. 2.** The relation of volume fluxes vs. various concentration (mol/L) for only magnesium sulfate solution.**Fig. 3.** The relation of solute fluxes vs. various concentrations (mol/L) for only magnesium sulfate solution.

circulating constant water surround the cells during all experiment.

3. Results and Discussion

The volume change versus time in system was used sucrose as impermeable solute indicated linear relation (Figure 2). All the other relations with various added MgSO_4 concentration in system also indicated linearity. This means the systems are in steady state within examined time. Taking account of membrane area for the slopes of straight lines, one can obtain volume flux and solute flux. L_p is filtration coefficient that means

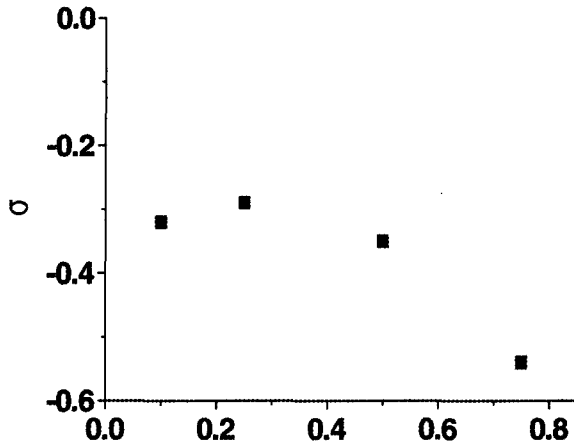


Fig. 4. The reflection coefficients vs. various concentration (mol/L) for only magnesium sulfate solution.

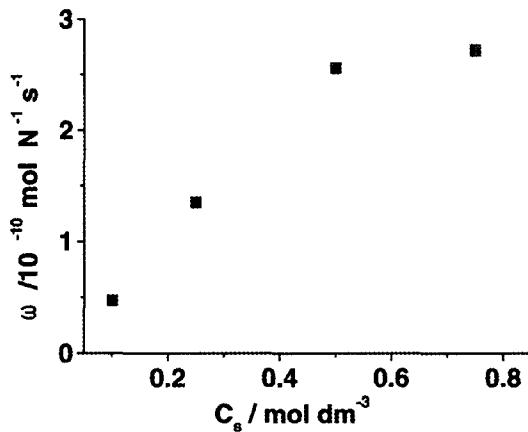


Fig. 5. The permeation coefficients vs. various concentration (mol/L) for only magnesium sulfate solution.

water permeability of water affinity with membrane[7]. Lp 's value were given against added $MgSO_4$ concentration and the result indicated the water affinity in membrane was not affected by existence of electrolytes in outer solutions.

By the *Non-equilibrium thermodynamics equations*[8], in case of two flows of solute and solvent based on non-equilibrium thermodynamics, the practical phenomenological equations can be given as follows:

$$J_v = Lp(\Delta p - \sigma_s \Delta \Pi_s) \quad (1)$$

$$J_s = C_s(1 - \sigma_s) J_v + \omega_s \Delta \Pi_s \quad (2)$$

where J_v and J_s are volume flux and solute flux which can be obtained from volume changes with time and concentration changes with time (Figures 2 and 3), respectively. Lp is defined as the filtration coefficient same as water permeability. The σ is defined as reflection coefficient as shown Figure 4. The ω is defined as permeability coefficient as shown Figure 5. According to Kedem and Katchalsky equations[9], membrane parameters across charged mosaic membrane, Lp , σ and ω in appropriate experimental conditions were given as follow equations,

$$Lp = - \left(\frac{J_v}{\Delta \Pi} \right)_{\Delta P=0} \quad (3)$$

$$\sigma = - \frac{1}{Lp} \left(\frac{J_s}{\Delta \Pi} \right)_{\Delta P=0} \quad (4)$$

$$\omega = \left(\frac{J_s}{\Delta \Pi} \right)_{J_v=0, \Delta P=0} \quad (5)$$

The membrane parameters were estimated using Eqs. (3)~(5)[10]. As described above, the improved equation containing information about active layer thickness would be convenient to explain the discrepancy between present and previous results[11].

4. Conclusions

In this work, $MgSO_4$ and water transports under the mixed $MgSO_4$ and sucrose solution system were investigated. Two kinds of measurements, volume flux and solute flux, were performed. Volume fluxes across charged mosaic membrane could be classified into osmotic flow of water due to $MgSO_4$ concentration difference, water flow dragged by $MgSO_4$ diffusion, and osmotic flow of water due to sucrose and they were found to be additive. In addition, it was elucidated that the presence of non-electrolyte solution can easily change the direction and the magnitude of volume fluxes. From the results, it was suggested that efficient salt enrichment can be performed by controlling the direction of the solvent osmosis and one

can expect negative salt rejection.

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