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## Comparative Studies Of Diffusion And Permeability Of Synthetic Membranes For Electrolyte Ions In Solution

E.N.Ejike<sup>2</sup>, I.A.Okoro\*<sup>1</sup>, N.Ocho<sup>2</sup>

<sup>1</sup>Department of Chemistry, Michael Okpara University of Agriculture, Abia State, (NIGERIA)

<sup>2</sup>Department of Chemistry, Federal University of Technology, Owerri, Imo State, (NIGERIA)

E-mail: Okoroia@yahoo.com.

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### ABSTRACT

The diffusion rate and permeability of electrolyte ions through some commercial available synthetic membranes were investigated. The Electrolytes of interest were sodium chloride, calcium chloride, Aluminum chloride, sulphamic acid and butyric acid. The effect of concentration variation was also monitored for each of the electrolytes. The results obtained showed that the rate of diffusion of metal ions derived from these three electrolytes determines for concentration and membranes thickness (break-through time  $t_b$ ). Decrease in metal ion concentrations increase the diffusion rate while increasing membrane thickness causes an increase the rate of electrolyte in diffusion. The trend in the rate of diffusion is thus  $\text{Na}^+ > \text{Ca}^{2+} > \text{Al}^{3+} > \text{NH}_4^+ > \text{H}^+$ . © 2007 Trade Science Inc. - INDIA

### KEYWORDS

Synthetic membrane;  
Electrolyte ions;  
Diffusion;  
Membrane thickness.

### INTRODUCTION

Synthetic membrane processes have emerged into in versatile area of technology and play an increasingly important role in many economic sections: Industry, Agriculture, medicine, biological system, scientific research, environmental pollution management to mention but a few<sup>[1]</sup>. Electro membrane processes both natural (bio membrane) and synthetic membrane that use ion-exchange membrane and an electrical potential difference as the driving force for ionic species have found numerous applications and are strongly gaining wide acceptance as efficient and economic alternatives to conventional methods of separation and purification, lot of which are directly related to environmental pollution control.

There include recovery and reuse of valuable min-

erals, ions, macromolecules posion wastes as well as the removal of harmful chemicals from industrials, biological system, mining effluents, domestic wastes and waste water recovery<sup>[2,3]</sup>. Membranes are generally described as natural (bio membranes) or synthetic membranes that consist of spongy-complex network of materials which are permeable to some ions depending on sizes while been impermeable to large size ions or molecules like protein carbohydrates, enzymes called macromolecules<sup>[4,5]</sup>.

Synthetic membranes have been used by researches to remove hazardous ions such  $\text{Pb}^{2+}$ ,  $\text{As}^{2+}$ ,  $\text{Cd}^{2+}$ , in industrial effluents under concentration gradients in absence of applied electric potential<sup>[1,4,5]</sup>.

In this study we shall use the conductivity values obtained at each concentration level of the electrolytes

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investigated using two different commercial available membranes: nylon and high density polyethylene to evaluate the diffusion rate and permeability of each of these synthetic membrane to electrolyte ions in solutions. In order to determine the diffusion rate, the Fick's law model was adopted and adapted. The rate of diffusion of the electrolyte ions shall be obtained thus:<sup>[6,7]</sup>

$$J = \frac{Ddc}{dx} \quad (1)$$

where J is the diffusion rate (Flux density) of electrolyte ion in horizontal bed area of the membrane ( $\text{mols}^{-1} \text{M}^{-2}$ ),  $dc/dx$  the change in the concentration of the electrolyte ions in mole per unit volume of membrane column at time  $t$  (mole/L) and  $D$  is the electrolyte binary diffusion coefficients ( $\text{M}^2\text{S}^{-1}$ ).

The permeability of the electrolyte ions shall be determined using the expression<sup>[8]</sup>

$$P_t = \frac{2.303}{2A} e V \log \frac{C_0}{C_0 - 2C_t} \quad (2)$$

Where  $P_t$  is the permeability of electrolyte ion at time  $t$  for each of the synthetic membrane system investigated,  $e$  is the membrane thickness  $e=0.06$  cm for Nylon and  $e=0.01$  cm for High density polyethylene.  $V$  = the volume of permeability bicell apparatus used, that is the volume of the solution used in the bicell compartment  $A$  is the area of the membrane exposed to electrolyte ion called permeant,  $t$  = the contact time interval for diffusion and permeation to take place,  $C_0$  is the initial electrolyte ion concentration and  $C_t$  is the electrolyte ion permeant at time  $t$  (the unit of permeability in  $\text{cm}^2 \text{Min}^{-1}$ ).

The breakthrough time  $t_b$  for each synthetic membrane (Nylon and High density polyethylene) thickness shall be calculated using the expression<sup>[6,7]</sup>

$$t_b = \frac{0.756 I^2}{\eta^2 D} \quad (3)$$

where  $I$  = membrane thickness  $\eta$  = a constant (22/7) and  $D$  is the diffusion coefficient.

The area of membrane exposed is exposed thus

$$A = \frac{\eta D^2}{4} \quad (4)$$

where  $D$  is the diameter of each membrane which is taken as 1.8 cm

$$\text{Therefore } A = \frac{22/7 \times (1.8 \text{ cm})^2}{2.55 \text{ cm}^2}$$

In this work, we report the diffusion rate, and permeability of two synthetic membranes: nylon and high density polyethylene to electrolyte ions in solution.

## MATERIALS AND METHODS

### Sample collection

Two commercially available synthetic membranes more procured at Ihieagwa market Owerri North L.G.A., Imo state Nigeria and were identified and authenticated by a polymer chemist as nylon and high density polyethylene membrane materials.

All chemicals used are analytical grade reagents from May and Baker Chemicals, London. Preparation of synthetic membrane for studies.

### Each of the synthetic membranes

Nylon and HDPE was cut out with respect to the area of the outer radius of the bicell apparatus. Each of the pieces specifically cut was activated by soaking them in ethanol solvent for twenty minutes intervals, then each was washed copiously with double distilled deionised water. Then each of the cuts soaked in double distilled deionised water for 48 hr for membrane swelling. The swelling is to allow the resident of water molecules in the membrane pores and enhanced the easy passage (diffusion) of electrolyte ions. Electrolyte solution preparation: 0.1 M and 0.01 M solutions of each of NaCl,  $\text{CaCl}_2 \cdot \text{AlCl}_3$ ,  $\text{NH}_3 \text{SO}_2\text{OH}$  (Sulphamic acid) and  $\text{CH}_3(\text{CH}_2)_2 \text{COOH}$

Solutions were prepared. The initial conductivity of each of these electrolyte solutions and that of the double distilled deionised water were measured using conductivity meter (Beckman model).

### Diffusion and permeation studies

Thirty milliliters of each of the five electrolyte solutions prepared (0.1 M and 0.01 M) respectively was measured out into the salt arm of the bicell apparatus. The two solutions were separated by the already swelled cut of each of the synthetic membranes sequentially. This experimental set up was monitored at ambient temperature of 25°C at 30 minutes time intervals, for a total of 180 minutes experimental duration time, with continuous stirring of the two solutions using battery powered magnetic stirrer.

At the end of each thirty minutes interval, 10 milliliters of the double distilled deionised water in the bicell apparatus arm was drawn out and the conductivity measured using the conductivity meter (Beckman model). The whole procedure described above was exactly repeated using each electrolyte solution of 0.1 M and 0.01 M concentrations respectively.

A schematic diagram of the bicell is shown below:



## RESULTS AND DISCUSSION

The results from the diffusion and permeability of synthetic membranes: Nylon and high density poly ethylene materials using equations 1,2,3 and 4 respectively are presented in TABLES(1 and 2). From TABLE 1, it was observed that the diffusion rate of  $\text{Ca}^{2+}$  ion permeate is greater than the other electrolyte ions:  $\text{Na}^+$   $\text{Al}^{3+}$   $\text{NH}_4^+$  and  $\text{H}^+$  in the nylon synthetic membrane. This trend is reverse in the high density polyethylene membrane in which  $\text{Na}^+$  ion has the greatest diffusion rate of  $4.00 \times 10^{-3}$  unite per second(TABLE 2). The permeability of the two synthetic membranes: nylon and high density polyethylene is influenced by the concentrations of electrolyte solutions. The decrease in the concentration of the electrolyte solution yielded higher values for permeability and diffusion rate. This may be explained in terms of hydration factor. In the less concentrated electrolyte solution, and so the ions are more free to move and cross the membranes freely<sup>[9,10,11,12]</sup>. The time required for any of the five electrolyte ions;  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Al}^{3+}$   $\text{NH}_4^+$  and  $\text{H}^+$  to permeate the membrane thickness measured by the factor; the breakthrough time  $t_b$  is observed to be greater in the nylon membrane than in the high density polyethylene membrane(TABLE I and 2). This may be explained in terms of swelling effects

**TABLE 1: Determined mean diffusion rate(Dr) mean permeability (P) and break through time( $t_b$ ) of electrolyte ions through nylon membrane at 25°C**

Electrolyte Solution	O. /M Concentration			O.01/M Concentration		
	Dr. $\times 10^{-3}$ umol/sec	P $\times 10^{-7}$ cm <sup>2</sup> min <sup>-1</sup>	$t_b$ sec	Dr. $\times 10^{-3}$ umol/sec	P $\times 10^{-7}$ cm <sup>2</sup> min <sup>-1</sup>	Tb sec
NaCl	3.57	8.22	7.75	3.84	1.79	7.20
CaCl <sub>2</sub>	3.85	5.25	7.18	3.84	7.49	7.20
AlCl <sub>3</sub>	3.57	5.44	7.75	3.33	7.28	8.29
NH <sub>3</sub> SO <sub>2</sub> OH (Sulphamic acid)	1.43	3.56	1.94	1.37	4.17	2.05
CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> COOH (Butyric <sup>2</sup> acid)	0.82	4.52	2.24	1.56	4.63	1.77

Data are means of four determinations

**TABLE 2 : Determined mean diffusion rate(Dr) mean permeability (P) and break through time( $t_b$ ) of electrolyte ions through high density polyethylene membrane**

Electrolyte solution	O.1M concentration			O. 01M concentration		
	Dr. $\times 10^{-3}$ umol/Sec	P $\times 10^{-7}$ cm <sup>2</sup> min <sup>-1</sup>	$t_b$ Sec	Dr. $\times 10^{-3}$ umol /sec	P $\times 10^{-7}$ cm <sup>2</sup> min <sup>-1</sup>	$t_b$ Sec
NaCl	4.00	1.68	1.92	3.57	1.87	2.15
CaCl <sub>2</sub>	2.50	6.79	3.07	3.45	8.34	2.22
AlCl <sub>3</sub>	2.50	6.49	3.07	2.56	8.27	2.99
NH <sub>3</sub> SO <sub>2</sub> OH (Sulphamic-acid)	1.20	0.68	6.39	1.57	0.79	5.67
CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> COOH (Butyric acid)	1.24	0.82	6.89	1.49	0.45	4.48

Data are means of four determinations

and more water molecules residency in the high density polyethylene membrane when compared to the Nylon membrane. This may be the reason for the ease with which the electrolyte ions cross the high density polyethylene membrane to the other section of the experimental set up in ceasing the conductivity of the double distilled deionised water with time. This observation, implies that the high density polyethylene membrane is more susceptible to ion permeability and ion diffusion than the nylon membrane(TABLE 1 and 2).

From this study the preferential use of high density polyethylene membrane is recommended in place of bio membranes for separation processes; water dialysis, electro dialysis, and other filtration uses involving certain ions especially toxic metal ions arising from waste waters and industrial effluents.

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