Water Permeation through Elastomer Laminates. IV. NBR/EPDM

TEJRAJ M. AMINABHAVI and LATA S. MANJESHWAR, *Department of Chemistry, Karnatak University, Dharwad-580003, India,* and
PATRICK E. CASSIDY, *Department of Chemistry, Southwest Texas State University, San Marcos, Texas 78666,* and *Texas Research Institute, Inc., 9063 Bee Cave Road, Austin, Texas 78733*

Synopsis

The recent considerable interest in the transport and solubility properties of low-molecular weight penetrants in elastomers arises largely because a number of important practical applications depend wholly or in part on such phenomena. These applications include various protective coatings, packaging materials, selective barriers for the separation of gas and liquid mixtures, biomedical devices, marine applications, etc. The behavior of small molecules in elastomers is strongly dependent on elastomer structure and morphology and any additives to the polymer; therefore, small molecules can be used as very sensitive probes to explore a polymer matrix, especially to gain information about its end applications.

INTRODUCTION

Previous studies[1–5] were undertaken to assess the water resistivity of laminated membranes to determine the usefulness of such elastomers in undersea applications. An attempt is now made to study the permeability properties of nitrile butadiene rubber (NBR), ethylene propylene diene terpolymer (EPDM), and their laminates. The principal purposes of this paper, therefore, are to discover the permeation behavior of EPDM when laminated with NBR and to compare the properties of this laminate with other laminates of EPDM.

EXPERIMENTAL

NBR, EPDM, and their laminates were generously supplied by Mr. A. Kutac, UTEX Industries, Weimer, Texas. The method of sample preparation is the same as reported earlier.[1] The elastomer compositions are given in Table I. The permeation experiments were performed at 23°, 40°, and 60°C by the cup method (ASTM D1653-72) using distilled water and 3.5% sodium chloride solution. Permeation rates were calculated based on an area of 25 cm^2.

RESULTS AND DISCUSSION

A summary of the observed permeation rates and the calculated activation parameters are presented in Table II. The dependence of permeation rates

Journal of Applied Polymer Science, Vol. 32, 3719–3723 (1986)
CCC 0021-8995/86/023719-05$04.00

TABLE I
Elastomer Compositions

	Elastomer	
Compound[a]	NBR	EPDM
Zinc oxide	5	5
Stearic oxide	1	1
Sulfur	2	2
CBTS[b]	1	1
Hycar 1051	100	—
N550 (FEF) carbon black	50	50
Epcar 585	—	100

[a] Parts per hundred parts of elastomer.
[b] N-cyclohexyl-2-benzothiazolesulfonamide.

on temperature is shown in Figures 1 and 2. As found earlier,[1,4,5] lower activation energies (as calculated from the Arrhenius plot) were obtained for salt water than distilled water and salt water exhibited higher permeation rates than distilled water at all temperatures for all samples. The data for arithmetic mean of the permeation rates of single membranes and that calculated from the Rogers et al.[6,7] formula are also included in Figures 1 and 2. For both the permeants, the laminates exhibited intermediate values of permeation rates to their individual membranes and the arithmetic mean of the rate was always higher than that of the calculated rate.[6,7]

When the present results are compared to the data of $\overset{\rightleftarrows}{\text{Neoprene/EPDM}}$[1] and $\overset{\rightleftarrows}{\text{SBR/EPDM}}$[4] laminates, the water permeation rates of NBR/EPDM system were somewhat lower than the previous two systems involving EPDM. This is expected in that for NBR alone, the observed permeation rates for both salt water and distilled water were smaller than SBR and much smaller than Neoprene. Compared to the bilayer composites studied earlier, lower permeation rates were observed for $\overrightarrow{\text{NBR/EPDM}}$-salt water system, but higher values were seen when the direction of the flow was reversed (i.e., $\overrightarrow{\text{EPDM/NBR}}$).

TABLE II
Permation Rates and Activation Parameters

		Permeation rate (mg-cm/cm^2/day)						Activation energy[b] (kcal/mole)	
		Salt water at			Distilled water at				
Elastomer	Thickness (cm)	23°C	40°C	60°C	23°C	40°C	60°C	Salt water	Distilled water
NBR	0.217	0.017	0.047	0.195	0.009	0.052	0.191	11.51 ± 0.9	14.44 ± 0.4
EPDM	0.214	0.006	0.025	0.092	0.003	0.009	0.055	12.81 ± 0.8	13.68 ± 0.7
$\overrightarrow{\text{NBR/EPDM}}$[a]	0.382	0.010	0.032	0.100	0.005	0.023	0.082	10.86 ± 0.9	13.14 ± 0.9
$\overrightarrow{\text{EPDM/NBR}}$[a]	0.382	0.015	0.04	0.116	0.006	0.030	0.128	9.55 ± 0.5	14.44 ± 0.8

[a] Direction of flow of permeant through laminates indicated by arrow.
[b] Standard error at 95% confidence level.

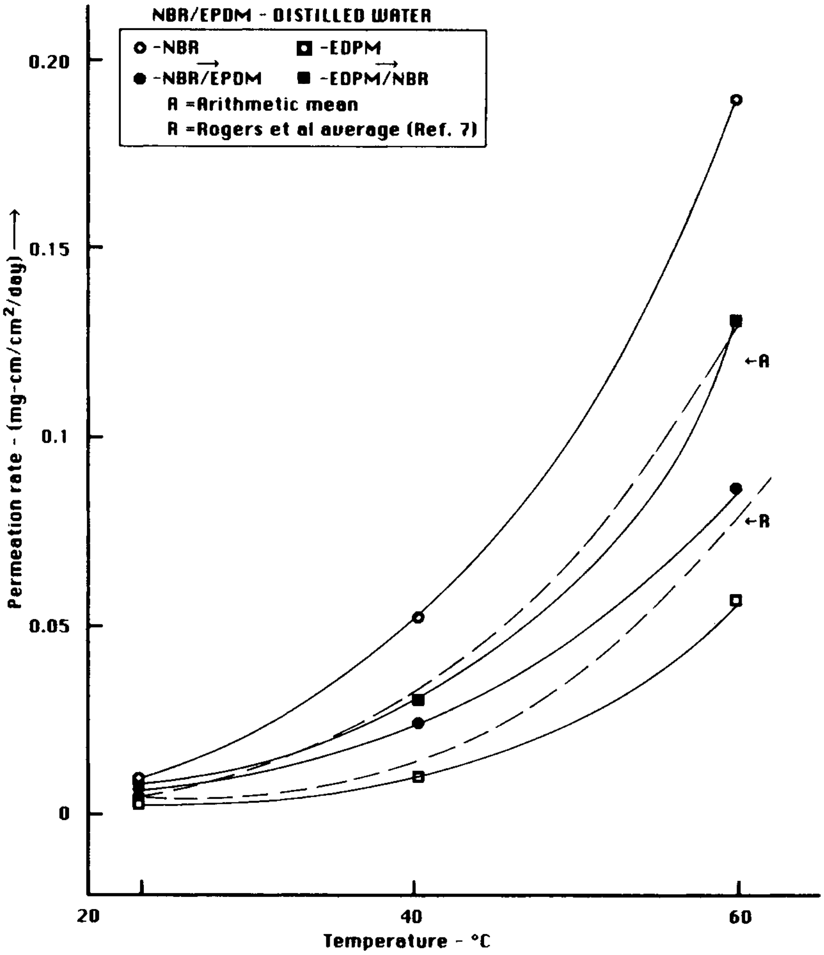

Fig. 1. Temperature dependence of permeation rate of distilled water. Symbols: ○ NBR; □ EPDM; ● $\overrightarrow{\text{NBR/EPDM}}$; ■ $\overrightarrow{\text{EPDM/NBR}}$; R = Rogers et al. average (Ref. 7); A = Arithmetic mean.

It therefore appears, that for distilled water, the $\overset{\rightleftarrows}{\text{NBR/EPDM}}$ system appears to be a better barrier composite than the earlier bilayers. This system also follows the thesis set forth in paper I of this series that permeation rate is less for the laminate when the direction of permeation is through the more permeable layer first. The more permeable material appears to act as an effective rate-limiting device for the less permeable layer. In the reverse direction, the less permeable layer is encountered first by the water and once this barrier is breached there is little effect by the second layer.

In conclusion, based on the interpretations advanced earlier[1,4,5] and in accordance with the premises of free volume theories,[8] it can be inferred that the chemical nature of one of the membranes when compounded with another polymer has a profound influence on their transport properties. However, more systematic and extensive measurements are needed for a variety of systems under different conditions. The present knowledge of

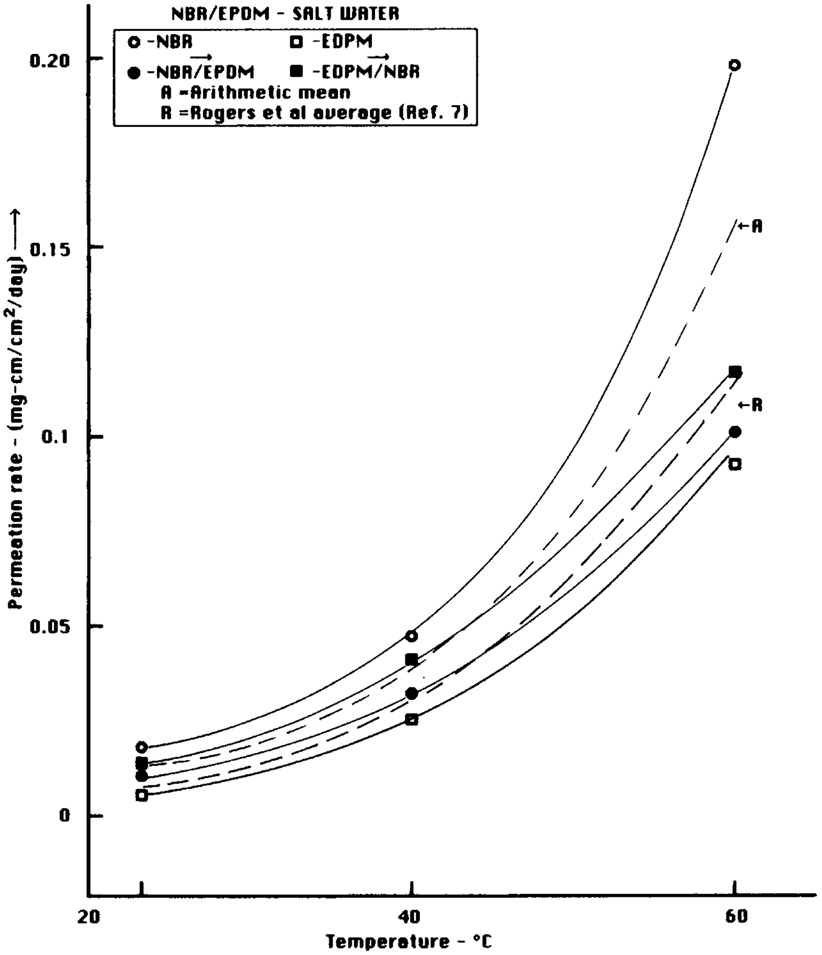

Fig. 2. Temperature dependence of permeation rate of 3.5% salt water. Symbols: ○ NBR; □ EPDM; ● $\overrightarrow{\text{NBR/EPDM}}$; ■ $\overrightarrow{\text{EDPM/NBR}}$; A = Arithmetic mean; R = Rogers et al average (Ref. 7).

these effects is still to a large extent descriptive. One of the greatest needs is for an adequate theoretical scheme which will correlate diverse observed results with a few definitive parameters.

The authors are grteful to the Robert A. Welch Foundation for their support of this study (Grant No. AI-524), and to Mr. A. Kutac of UTEX Industries for supplying the rubber samples.

References

1. P. E. Cassidy, T. M. Aminabhavi, and J. C. Brunson, *Rubber Chem. Technol.*, **56,** 357 (1983).
2. P. E. Cassidy, T. M. Aminabhavi, and C. M. Thompson, *Rubber Chem. Technol., Rub. Rev.*, **56,** 594 (1983).
3. T. M. Aminabhavi, R. W. Thomas, and P. E. Cassidy, *Polym. Eng. Sci.*, **24,** 1417 (1984).

4. P. E. Cassidy and T. M. Aminabhavi, *Rubber Chem. Technol.,* in press.
5. P. E. Cassidy and T. M. Aminabhavi, *Polymer,* in press.
6. C. E. Rogers, V. Stannet, and M. Szwarc, *J. Phys. Chem. Wash.,* **63,** 1406 (1959).
7. E. C. Rogers, V. Stannet, and M. Szwarc, *Ind. Eng. Chem.,* **49,** 1933 (1957).
8. J. S. Vrentas and J. L. Duda, *AIChE,* **25,** 1 (1979).

Received July 31, 1985
Accepted August 20, 1985