REFERENCES

Baker, R.W., Wijmans, J.G., and Kaschemekat, J.H. (1998). The design of membrane vapor-gas separation systems. Journal of Membrane Science, 151, 55-62.

Beuscher, U., and Goodings, C.H. (1999). The influence of the porous support layer of composite membranes on the separation of binary gas mixtures. Journal of Membrane Science, 152, 99-116.

Bickel, S.D., and Koros,W.J. (2000). Olefin/paraffin gas separations with 6FDA-based polyimide membranes. Journal of Membrane Science, 170, 205-214.

Cabasso, I., and Lundy, K.A. (1986). U. S. Patent 4 602 922.

Eldridge, R.B. (1993). Olefin/paraffin sepaeation technology: a review. Industrail Engineering Chemical Research, 32, 2208-2212.

Freeman, B.D. (1999). Basis of permeability/selectivity tradeoff relations in polymeric gas separation membranes. Macromolecules, 32, 375-380.

Grant, M.H. (1991). Membrane technology, Encyclopedia of Chemical Technology, 16, 1212-1270.

Henis, J. S., and Tripodi, M.K (1980). U. S. Patent 4 230 463.

Hayashi, J., Mizuta, H., Yamamoto, M., Kusakabe, K., and Morooka, S. (1996). Separation of ethane/ethylene and propane/propylene systems with a carbonized BPDA-pp'ODA polyimide membranes. Industrial Engineering Chemical Research, 35, 4176-4181.

Ito, A., and Hwang, S.T. (1989). Permeation of propane and propylene through cellulosic polymer membranes. Journal of Membrane Science, 38, 483-490.

Jacobs, M., Gottschlich, D., and Buchner, F. (1999). Monomer recovery in polyolefin plants using membranes-an update. Paper presented at 1999 Petrochemicals World Review, DeWitte Company Incorporated, Houston, Texas, USA.

Kamaruddin, H.D., and Koros, J.W. (1997). Some observations about Fick's first law for membrane separation of multicomponent mixtures. Journal of Membrane Science, 135, 147-159.

Kesting, R.E., and Frotzsche, A.K. (1993). Polymeric Gas Separation Membranes. New York: John wiley.

Koros, W.J., and Mahajan, R. (2000). Pushing the limits on possibilities for large scale gas separation: which strategies? . Journal of Membrane Science, 175, 181-196.

Kulpratipanja, S., and Kulkrani, S.S. (1986). U. S. Patent 4 608 060.

Kulpratipanja, S., and Kulkrani, S.S. (1988). U. S. Patent 4 608 060.

Kulpratipanja, S. and Neuzil, R.W. (1992). U. S. Patent 5 127 925.

Li, J., Wang, S., Nagai, K., Nakagawa, T., and Mau, W.A. (1998). Effect of polyethlene glycol (PEG) on gas permeabilities and selecitivities in its cellulose acetate blend membranes. Journal of Membrane Science, 138, 143-152.

McCabe, W.L., Smith, J.C., and Harriott, P. (1993). Membrane separation process. Unit Operation of Chemical Engineering, 5th ed., Singapore : McGraw-Hill.

Meldon, J., Paboojan, A., and Rajangan, G. (1985). Selective CO_2 permeation in immobilized liquid membranes. Industrial Membrane Process: AIChE symposium series. 82(248).

Okita, K. (1985). U. S. Patent 4 533 369.

Pellegrine, J., and Kang, Y.S. (1995). CO_2/CH_4 transport in polyperfluorosulfonate ionomers: effects of polar solvents on permeation and solubility. Journal of Membrane Science, 99, 163-174.

Petropoulous, J.H. (1990). Some fundamental approaches to membrane gas permeability and permselectivity. Journal of Membrane Science, 53, 229-258.

Pinnau, I., Wijmans, J.G., Blume, I., Kuroda, T., and Peinemann, K.V. (1988). Gas separation through composite membranes. Journal of Membrane Science, 37, 81-88.

Riley, R.L., and Grabowsky, R.L. (1981). U. S. Patent 4 243 701.

Rousseau, R.W. (1987). Handbook of Separation Process Technology. New York : Wiley-Interscience.

Saha, S., and Chakma, A. (1995). Selective CO_2 separation from CO_2/C_2H_6 mixtures by immobilized diethanolamine/PEG membranes. Journal of Membrane Science, 98, 157-171.

Serivalsatit, V. (1999). The mechanism of the mixed matrix membrane separation (Polyethylene glycol/silicone rubber) for polar gases. M.S. Thesis, The Petroleum and Petrochemical College, Chulalongkorn University.

Sridhar, S., and Khan, A.A. (1999). Simulation studies for the separation of propylene and propane by ethylcellulose membrane. Journal of Membrane Science, 159, 209-219.

Sukapintha, W. (2000). Mixed matrix membrane for olefin/paraffin separation. M.S. Thesis, The Petroleum and Petrochemical College, Chulalongkorn University.

Wijmans, J.G., and Baker, R.W. (1995). The solution-diffusion model: a review. Journal of Membrane Science, 107, 1-21.

Yamamoto, H., Mi, Y., and Stern, S.A, (1990). Structure/permeability relationships of polyimides membranes. Journal of Polymer Science: Part B: Polymer Physics, 28, 2291-2304.

Yamasaki, A., Tyagi, R.K., Fouda, A.E., Matsuura, T., and Jonasson, K. (1997). Effect of gelation conditions on gas separation performance for asymmtric polysulfone membranes. Journal of Membrane Science, 123, 89-94.

Yang, J.S., and Hsuie, G.H. (1998) Swollen polymeric complex membranes for olefin/paraffin separation. Journal of Membrane Science, 138, 203-211.

APPENDIX

APPENDIX A The experimental fluxes of nitrogen, propylene, and propane of the studied mixed matrix membranes.

Table A1 Silicone Rubber on Polysulfone (SR/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	468.8	1.2798	0.002640	1.2834	1.8665E-06	3.8507E-09	1.8717E-06
	467.1	1.2845			1.8733E-06		
	467.5	1.2834			1.8717E-06		
	466.2	1.2870			1.8770E-06		
	467.9	1.2823			1.8701E-06		
C_3H_6	12.17	49.2745	0.03447	49.2980	7.1862E-05	5.0279E-08	7.1896E-05
	12.16	49.3375			7.1954E-05		
	12.18	49.2520			7.1829E-05		
	12.16	49.3060			7.1908E-05		
	12.16	49.320			7.1927E-05		
C_3H_8	11.40	52.6060	0.04579	52.5435	7.6720E-05	6.6783E-08	7.6629E-05
	11.41	52.5547			7.6646E-05		
	11.43	52.4934			7.6556E-05		
	11.41	52.5598			7.6653E-05		
	11.42	52.5036			7.6571E-05		

[a] Time to reach 10 ml
[b] Flux (ml/min)
[c] Standard deviation of flux
[d] Average flux (ml/min)
[e] Permeability ($cm^3/(cm^2$-sec-cmHg))
[f] Standard deviation of permeability
[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	1.8717E-06
Permeability of C_3H_6	7.1896E-05
Permeability of C_3H_8	7.6629E-05
Selectivity of C_3H_6/C_3H_8	0.9382
Selectivity of C_3H_6/N_2	38.4112
Selectivity of C_3H_8/N_2	40.9400

Table A2 Polyethylene glycol and silicone rubber on polysulfone (SR+PEG/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	426.21	0.035194	0.000119	0.0351	5.1327E-08	1.7360E-10	5.1208E-08
	426.93	0.035135			5.1240E-08		
	429.51	0.034924			5.0932E-08		
	427.53	0.035085			5.1168E-08		
	425.81	0.035227			5.1375E-08		
C_3H_6	98.69	0.151991	0.00049	0.1526	2.2166E-07	7.1402E-10	2.2249E-07
	98.36	0.152501			2.2241E-07		
	97.82	0.153343			2.2363E-07		
	98.41	0.152424			2.2229E-07		
	98.33	0.152548			2.2247E-07		
C_3H_8	187.02	0.080205	0.000553	0.0794	1.1697E-07	8.0620E-10	1.1580E-07
	189.33	0.079227			1.1554E-07		
	188.3	0.07966			1.1618E-07		
	189.43	0.079185			1.1548E-07		
	190.49	0.078744			1.1484E-07		

[a] Time to reach 0.25 ml

[b] Flux (ml/min)

[c] Standard deviation of flux

[d] Average flux (ml/min)

[e] Permeability ($cm^3/(cm^2$-sec-cmHg))

[f] Standard deviation of permeability

[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	5.1208E-08
Permeability of C_3H_6	2.2249E-07
Permeability of C_3H_8	1.1580E-07
Selectivity of C_3H_6/C_3H_8	1.9213
Selectivity of C_3H_6/N_2	4.3449
Selectivity of C_3H_8/N_2	2.2614

Table A3 1,2-butanediol and silicone rubber on polysulfone (12BD+SR/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	678.24	0.796178	0.004463	0.8003	1.1611E-06	6.5088E-09	1.1671E-06
	670.32	0.805585			1.1749E-06		
	672.12	0.803428			1.1717E-06		
	678.96	0.795334			1.1599E-06		
	674.28	0.800854			1.1680E-06		
C_3H_6	20.49	26.35432	0.118234	26.3008	3.8435E-05	1.7243E-07	3.8357E-05
	20.43	26.43172			3.8548E-05		
	20.54	26.29017			3.8341E-05		
	20.52	26.31579			3.8379E-05		
	20.68	26.11219			3.8082E-05		
C_3H_8	25.56	21.12676	0.246549	21.2940	3.0811E-05	3.5957E-07	3.1055E-05
	25.62	21.07728			3.0739E-05		
	25.53	21.15159			3.0847E-05		
	25.13	21.48826			3.1338E-05		
	24.97	21.62595			3.1539E-05		

[a] Time to reach 9 ml

[b] Flux (ml/min)

[c] Standard deviation of flux

[d] Average flux (ml/min)

[e] Permeability ($cm^3/(cm^2$-sec-cmHg))

[f] Standard deviation of permeability

[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	1.1671E-06
Permeability of C_3H_6	3.8357E-05
Permeability of C_3H_8	3.1055E-05
Selectivity of C_3H_6/C_3H_8	1.2351
Selectivity of C_3H_6/N_2	32.8647
Selectivity of C_3H_8/N_2	26.6083

Table A4 1,3 - butanediol and silicone rubber on polysulfone (13BD+SR/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	141.74	0.10583	0.000312	0.1055	3.8585E-07	1.1381E-09	3.8466E-07
	142.61	0.10518			3.8349E-07		
	142.64	0.10516			3.8341E-07		
	142.03	0.10561			3.8506E-07		
	141.87	0.10573			3.8549E-07		
C_3H_6	86.66	0.17309	0.000312	0.1727	6.3109E-07	1.1365E-09	6.2984E-07
	86.73	0.17295			6.3058E-07		
	86.96	0.17249			6.2891E-07		
	87.03	0.17235			6.2840E-07		
	86.78	0.17285			6.3021E-07		
C_3H_8	64.63	0.23209	0.000749	0.2321	8.4620E-07	2.7321E-09	8.4618E-07
	64.57	0.23231			8.4699E-07		
	64.79	0.23152			8.4411E-07		
	64.85	0.23130			8.4333E-07		
	64.32	0.23321			8.5028E-07		

[a] Time to reach 0.25 ml

[b] Flux (ml/min)

[c] Standard deviation of flux

[d] Average flux (ml/min)

[e] Permeability ($cm^3/(cm^2$-sec-cmHg))

[f] Standard deviation of permeability

[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	3.8466E-07
Permeability of C_3H_6	6.2984E-07
Permeability of C_3H_8	8.4618E-07
Selectivity of C_3H_6/C_3H_8	0.7443
Selectivity of C_3H_6/N_2	1.6374
Selectivity of C_3H_8/N_2	2.1998

Table A5 1,4 - butanediol and silicone rubber on polysulfone (14BD+SR/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	317.28	0.189107	0.002381	0.1901	6.8948E-07	8.6798E-09	6.9324E-07
	318.88	0.188159			6.8602E-07		
	314.16	0.190985			6.9633E-07		
	309.4	0.193924			7.0704E-07		
	318.28	0.188513			6.8732E-07		
C_3H_6	18.63	3.220612	0.055857	3.2946	1.1742E-05	2.0365E-07	1.2012E-05
	18.27	3.284072			1.1974E-05		
	18.36	3.267974			1.1915E-05		
	17.93	3.346347			1.2201E-05		
	17.89	3.353829			1.2228E-05		
C_3H_8	15.80556	3.796134	0.014578	3.8089	1.3841E-05	5.3153E-08	1.3887E-05
	15.73111	3.814098			1.3906E-05		
	15.69222	3.82355			1.3941E-05		
	15.70778	3.819764			1.3927E-05		
	15.82778	3.790804			1.3821E-05		

[a] Time to reach 1 ml

[b] Flux (ml/min)

[c] Standard deviation of flux

[d] Average flux (ml/min)

[e] Permeability ($cm^3/(cm^2$-sec-cmHg))

[f] Standard deviation of permeability

[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	6.9324E-07
Permeability of C_3H_6	1.2012E-05
Permeability of C_3H_8	1.3887E-05
Selectivity of C_3H_6/C_3H_8	0.8650
Selectivity of C_3H_6/N_2	17.3273
Selectivity of C_3H_8/N_2	20.0322

Table A6 2,3- butanediol and silicone rubber on polysulfone (23BD+SR/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	912.87	0.591541	0.006278	0.5892	2.1568E-06	2.2889E-08	2.1481E-06
	903.33	0.597788			2.1795E-06		
	926.28	0.582977			2.1255E-06		
	926.19	0.583034			2.1257E-06		
	914.49	0.590493			2.1529E-06		
C_3H_6	47.89	11.27584	0.094933	11.2798	4.1112E-05	3.4612E-07	4.1126E-05
	48.42	11.15242			4.0662E-05		
	48.07	11.23362			4.0958E-05		
	47.37	11.39962			4.1563E-05		
	47.63	11.33739			4.1336E-05		
C_3H_8	54.49	9.910075	0.029339	9.8989	3.6132E-05	1.0697E-07	3.6091E-05
	54.64	9.88287			3.6033E-05		
	54.39	9.928296			3.6198E-05		
	54.45	9.917355			3.6159E-05		
	54.79	9.855813			3.5934E-05		

[a] Time to reach 1 ml

[b] Flux (ml/min)

[c] Standard deviation of flux

[d] Average flux (ml/min)

[e] Permeability ($cm^3/(cm^2$-sec-cmHg))

[f] Standard deviation of permeability

[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	2.1481E-06
Permeability of C_3H_6	4.1126E-05
Permeability of C_3H_8	3.6091E-05
Selectivity of C_3H_6/C_3H_8	1.1395
Selectivity of C_3H_6/N_2	19.1453
Selectivity of C_3H_8/N_2	16.8015

Table A7 NaX and silicone rubber on polysulfone (NaX+SR/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	389.76	0.153941	0.001731	0.1537	5.6127E-07	6.3126E-09	5.6036E-07
	394.56	0.152068			5.5444E-07		
	395.36	0.15176			5.5332E-07		
	386.8	0.155119			5.6556E-07		
	385.68	0.155569			5.6720E-07		
C_3H_6	30.75	1.95122	0.006163	1.9460	7.1141E-06	2.2471E-08	7.0953E-06
	30.86	1.944264			7.0888E-06		
	30.71	1.953761			7.1234E-06		
	30.93	1.939864			7.0727E-06		
	30.91	1.941119			7.0773E-06		
C_3H_8	30.56	1.963351	0.016387	1.9691	7.1584E-06	5.9747E-08	7.1794E-06
	30.27	1.982161			7.2269E-06		
	30.87	1.943635			7.0865E-06		
	30.25	1.983471			7.2317E-06		
	30.41	1.973035			7.1937E-06		

[a] Time to reach 1 ml

[b] Flux (ml/min)

[c] Standard deviation of flux

[d] Average flux (ml/min)

[e] Permeability ($cm^3/(cm^2$-sec-cmHg))

[f] Standard deviation of permeability

[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	5.6036E-07
Permeability of C_3H_6	7.0953E-06
Permeability of C_3H_8	7.1794E-06
Selectivity of C_3H_6/C_3H_8	0.9883
Selectivity of C_3H_6/N_2	12.6620
Selectivity of C_3H_8/N_2	12.8122

Table A8 PEG adsorbed NaX and silicone rubber on poly sulfone ([PEG-NaX] + SR/PS)

Gas	Time[a]	Flux[b]	Std Dev[c]	Ave flux[d]	Permeability[e]	Std Dev[f]	Average[g]
N_2	108.83	0.13783	0.000493	0.1384	5.0253E-07	1.7980E-09	5.0458E-07
	108.43	0.138338			5.0438E-07		
	108.68	0.1380			5.0322E-07		
	108.08	0.138786			5.0601E-07		
	107.92	0.1390			5.0676E-07		
C_3H_6	15.53	0.965873	0.010315	0.9765	3.5216E-06	3.7609E-08	3.5604E-06
	15.32	0.979112			3.5698E-06		
	15.53	0.965873			3.5216E-06		
	15.26	0.9830			3.5839E-06		
	15.17	0.988794			3.6051E-06		
C_3H_8	23.61	0.635324	0.00258	0.6375	2.3164E-06	9.4079E-09	2.3243E-06
	23.56	0.636672			2.3213E-06		
	23.45	0.639659			2.3322E-06		
	23.41	0.640752			2.3362E-06		
	23.62	0.635055			2.3154E-06		

[a] Time to reach 0.25 ml

[b] Flux (ml/min)

[c] Standard deviation of flux

[d] Average flux (ml/min)

[e] Permeability ($cm^3/(cm^2$-sec-cmHg))

[f] Standard deviation of permeability

[g] Average permeability ($cm^3/(cm^2$-sec-cmHg))

Permeabilty of N_2	5.0458E-07
Permeability of C_3H_6	3.5604E-06
Permeability of C_3H_8	2.3243E-06
Selectivity of C_3H_6/C_3H_8	1.5318
Selectivity of C_3H_6/N_2	7.0562
Selectivity of C_3H_8/N_2	4.6064

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