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APPENDICES

Appendix A Degree of swelling of membranes

Study of the degree of swelling may gain an insight into the membrane characteristics in liquid mixture. The degree of swelling, D_s , was defined by the following equation.

$$D_s = ((W_t - W_0)/W_0) \times 100\%$$

Where W_t = The weight of the swollen membrane (g)

W_0 = The initial weight of the membrane (g)

Table A1 Degree of swelling of cardanol modified polybenzoxazine membrane with five different cardanol contents in water at 25 °C

Time (h)	Degree of Swelling (D_s)				
	1 wt% cardanol	3 wt% cardanol	5 wt% cardanol	7 wt% cardanol	10 wt% cardanol
1	0.07	0.05	0.09	0.06	0.11
2	0.14	0.10	0.17	0.19	0.17
3	0.28	0.20	0.26	0.25	0.22
4	0.35	0.30	0.26	0.25	0.22
5	0.35	0.30	0.26	0.25	0.22
6	0.35	0.30	0.26	0.25	0.22
7	0.35	0.30	0.26	0.25	0.22
8	0.35	0.30	0.26	0.25	0.22

Table A2 Degree of swelling of cardanol modified polybenzoxazine membrane with five different cardanol contents in ethanol at 25 °C

Time (h)	Degree of Swelling (D_s)				
	1 wt% cardanol	3 wt% cardanol	5 wt% cardanol	7 wt% cardanol	10 wt% cardanol
1	0.43	0.22	0.26	0.09	0.15
2	0.69	0.60	0.77	0.56	0.59
3	1.38	1.36	1.03	0.90	0.73
4	1.90	1.68	1.03	1.00	0.88
5	2.67	1.68	1.03	1.00	0.95
6	2.67	1.68	1.03	1.00	0.95
7	2.67	1.68	1.03	1.00	0.95
8	2.67	1.68	1.03	1.00	0.95

Table A3 Degree of swelling of cardanol modified polybenzoxazine membrane with five different cardanol contents in ethanol:water (10:90) at 25 °C

Time (h)	Degree of Swelling (D_s)				
	1 wt% cardanol	3 wt% cardanol	5 wt% cardanol	7 wt% cardanol	10 wt% cardanol
1	0.25	0.11	0.06	0.06	0.14
2	0.41	0.13	0.11	0.17	0.21
3	0.75	0.40	0.34	0.28	0.35
4	0.75	0.56	0.45	0.45	0.42
5	0.75	0.56	0.45	0.45	0.48
6	0.75	0.56	0.45	0.45	0.48
7	0.75	0.56	0.45	0.45	0.48
8	0.75	0.56	0.45	0.45	0.48

Table A4 Degree of swelling of zeolite-filled cardanol-modified polybenzoxazine membrane with three different zeolite contents in water at 25 °C

Time (h)	Degree of Swelling (D_s)			
	1 wt% cardanol	3 wt% cardanol	5 wt% cardanol	10 wt% cardanol
1	0.31	0.23	0.21	0.43
2	0.31	0.45	0.62	0.85
3	0.31	0.45	0.62	0.85
4	0.31	0.45	0.62	0.85
5	0.31	0.45	0.62	0.85
6	0.31	0.45	0.62	0.85
7	0.31	0.45	0.62	0.85
8	0.31	0.45	0.62	0.85

Table A5 Degree of swelling of zeolite-filled cardanol-modified polybenzoxazine membrane with three different zeolite contents in ethanol at 25 °C

Time (h)	Degree of Swelling (D_s)			
	1 wt% cardanol	3 wt% cardanol	5 wt% cardanol	10 wt% cardanol
1	0.21	0.27	0.21	0.15
2	0.42	0.55	0.41	0.29
3	0.63	0.55	0.41	0.29
4	0.63	0.55	0.41	0.29
5	0.63	0.55	0.41	0.29
6	0.63	0.55	0.41	0.29
7	0.63	0.55	0.41	0.29
8	0.63	0.55	0.41	0.29

Table A6 Degree of swelling of zeolite-filled cardanol-modified polybenzoxazine membrane with three different zeolite contents in ethanol:water (50:50) at 25 °C

Time (h)	Degree of Swelling (D_s)			
	1 wt% cardanol	3 wt% cardanol	5 wt% cardanol	10 wt% cardanol
1	0.31	0.35	0.35	0.85
2	0.46	0.87	0.69	1.28
3	0.77	1.05	1.38	1.71
4	1.00	1.05	1.38	1.71
5	1.00	1.05	1.38	1.71
6	1.00	1.05	1.38	1.71
7	1.00	1.05	1.38	1.71
8	1.00	1.05	1.38	1.71

Appendix B Pervaporation study

Effect of ethanol concentration

Membrane : 5 wt% cardanol-modified PBZ membrane

Feed conditions : Feed temperature = 70°C

Feed rate 900 ml/min

Table B1 Effect of ethanol concentrations on permeation flux and separation factor of 5 wt% cardanol-modified PBZ membrane

Ethanol in Feed (wt%)	Highest permeation flux (kg/m²hr)	Highest separation factor
10	0.06	> 10,000
20	0.07	>10,000
40	0.09	>10,000
50	0.33	>10,000
60	0.34	7,418
80	0.36	1,128
90	0.42	1,045

Effect of zeolite contents incorporate to cardanol modified polybenzoxazine membrane

Feed conditions: Feed temperature = 70°C

Feed rate 900 ml/min

Feed concentration = 50%ethanol

Table B2 Effect of zeolite contents incorporate to cardanol modified PBZ membrane on permeation flux and separation factor of 5 wt% cardanol-modified PBZ membrane

Membrane	Highest permeation flux (kg/m²h)	Highest separation factor
Cardanol-modified polybenzoxazine membrane	0.33	> 10,000
1%NaA incorporate to cardanol-modified polybenzoxazine membrane	0.79	> 10,000
3%NaA incorporate to cardanol-modified polybenzoxazine membrane	0.87	> 10,000
5%NaA incorporate to cardanol-modified polybenzoxazine membrane	0.98	> 10,000
10%NaA incorporate to cardanol-modified polybenzoxazine membrane	1.78	13.08

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2. Homyen, P.; Wongkasemjit, S.; and Chaisuwan, T. (2012, April 24). Polybenzoxazine-based Membrane for Ethanol–Water Separation via Pervaporation. Paper presented at the 3rd Research Symposium on Petroleum, Petrochemical, and Materials Technology and the 18th PPC Symposium on Petroleum, Petrochemical and Polymer, Bangkok, Thailand.

