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APPENDICES

APPENDIX A

Gas chromatography analysis

In this work, the concentration of methanol was analyzed by gas chromatography (GC) on a HP 5890 gas chromatography (Hewlett Packard), fitted with DB-Wax column which has a inside diameter of 0.25 mm, length of 40 m, film thickness of 0.25 μm, and equipped with a flame ionization detector (FID).

Methanol Concentration Analysis

Internal standard solutions were prepared by adding 1 g of 10 wt % of isopropanol (internal standard) into 1 g of methanol solutions which concentrations were exactly known. Then, the solutions were analyzed by GC. Table A.1 shows the GC data of the calibration curve. Figure A.1 shows the ratio of peak area between methanol and isopropanol as a function of concentration of methanol.

Table A.1 Gas chromatography data of the calibration curve

MeOH concentration (wt %)	Peak area of MeOH		Peak area of IPA		Ratio		Ratio,avg
	I	II	I	II	I	II	
10.03	3024783	3827984	4376917	4953868	0.6911	0.7727	0.7319
19.82	7820049	8543034	5621280	5573932	1.3912	1.5327	1.4619
30.16	13681664	11746200	6848962	5757862	1.9976	2.0400	2.0188
40.12	15763556	14998163	5602916	4500564	2.8134	3.3325	3.0730
49.85	15343192	17678778	4487346	5209429	3.4192	3.3936	3.4064

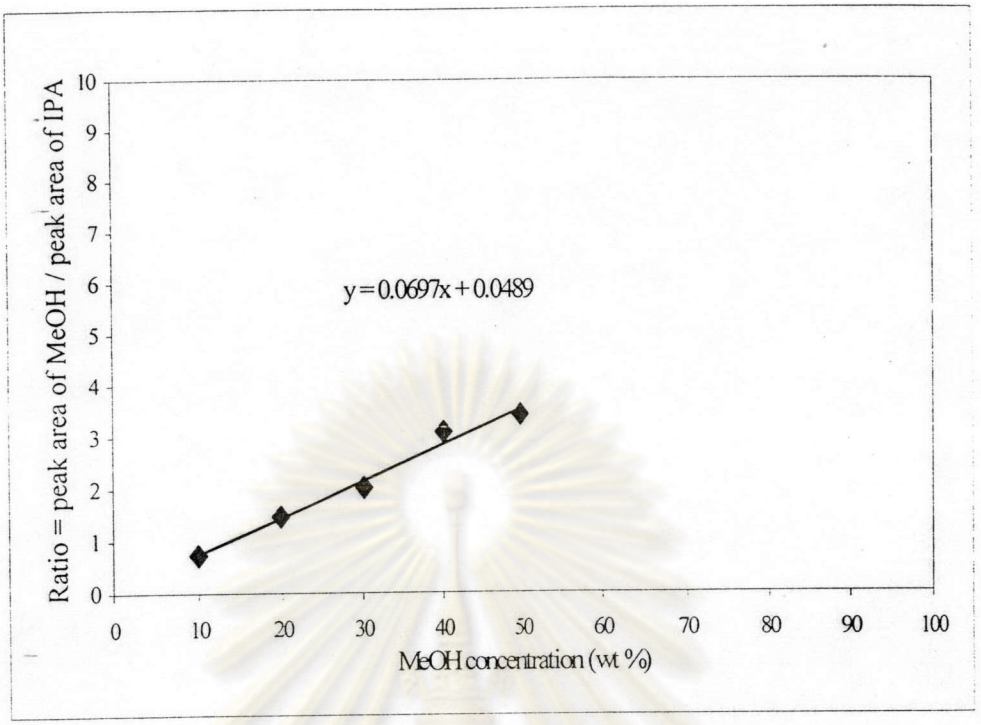

Figure A.1 The calibration curve of internal standard solution.

The feed and the retentate samples from pervaporation experiments were analyzed by GC. Then, the results from GC were used to find the concentration of methanol in feed and in retentate using the equation as shown in Figure A.1.

The following GC conditions were used for analyses.

Injection amount	1 μl
Column initial temperature	30 °C
Column initial time	1 minute
Column parameter rate	20 °C/min
Column final temperature	110 °C
Column final time	1 minute
Injector temperature	220 °C
Detector temperature	220 °C

APPENDIX B

Experimental calculation

This experiment can calculate the values of concentration of methanol in permeate, flux, and selectivity using mass balance from the following equations.

$$W_F - W_R = W_P \quad \text{(B.1)}$$

$$W_{i,F} = (C_{i,F} \cdot W_F)/100 \quad \text{(B.2)}$$

$$W_{i,R} = (C_{i,R} \cdot W_R)/100 \quad \text{(B.3)}$$

$$W_{i,P} = W_{i,F} - W_{i,R} \quad \text{(B.4)}$$

$$C_{i,P} = 100(W_{i,P}/ W_P) \quad \text{(B.5)}$$

$$W_{j,F} = W_F - W_{i,F} \quad \text{(B.6)}$$

$$W_{j,R} = W_R - W_{i,R} \quad \text{(B.7)}$$

$$W_{j,P} = W_{j,F} - W_{j,R} \quad \text{(B.8)}$$

Where $C_{i,F}$, $C_{i,P}$, and $C_{i,R}$ are the concentrations of component i in feed, in permeate, and in retentate, respectively. W_F, W_P, and W_R are the weights of feed, permeate, and retentate, respectively. $W_{i,F}$, $W_{i,P}$, and $W_{i,R}$ are the weights of component i in feed, in permeate, and in retentate, respectively. $W_{j,F}$, $W_{j,P}$, and $W_{j,R}$ are the weights of component j in feed, in permeate, and in retentate, respectively. In this study, i refer to methanol and j refer to water.

The performance of pervaporation membrane is expressed in the flux, and selectivity.

1. Fluxes (kg m^{-2} h^{-1})

$$J = W_{i,P}/A.t \quad \text{(B.9)}$$

$$J_i = J.y_i \quad \text{(B.10)}$$

$$J_j = J - J_i \quad \text{(B.11)}$$

Where J is the total flux. J_i and J_j are the fluxes of component i and j, respectively. A is the membrane area, t the time, and y_i the weight fraction of component i in permeate.

2. Selectivity

$$\alpha_{ij} = (y_i/y_j)/(x_i/x_j) \quad \text{(B.12)}$$

$$PSI = J.(\alpha_{ij} - 1) \quad \text{(B.13)}$$

Where α_{ij} is the separation factor between component i and j. x_i and x_j are the weight fractions of component i and j in feed, respectively. y_j is the weight fraction of component j in permeate. PSI is the pervaporation separation index.

APPENDIX C

Experimental data

Table C.1 Pervaporation data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration,avg (wt %)	Weight, avg (g)			Weight of MeOH (g)		
	Feed	Retentate	Permeate	Feed	Retentate	Permeate
10.16	200.61	183.67	16.95	18.28	14.29	3.99
20.13	200.42	183.14	17.29	38.14	31.74	6.40
30.23	200.73	181.99	18.74	59.25	51.01	8.24
39.95	200.37	181.07	19.30	77.48	67.99	9.49
49.98	200.79	179.00	21.79	102.04	88.96	13.08
60.04	200.16	177.08	23.09	120.66	104.81	15.85

Table C.1 (Continued) Pervaporation data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration in permeate (wt %)	Fluxes (kg m^{-2} h^{-1})			Selection factor (-)	PSI (kg m^{-2} h^{-1})
	MeOH	Water	Total		
23.53	0.75	2.43	3.18	3.70	8.59
37.04	1.89	3.22	5.11	2.50	7.67
44.83	2.95	3.62	6.57	1.94	6.18
49.76	3.77	3.80	7.57	1.57	4.31
61.56	6.42	4.01	10.43	1.55	5.74
69.74	8.82	3.82	12.64	1.51	6.45

Table C.2 Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	Peak area of MeOH in feed				Peak area of IPA in feed				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in feed (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.16	8023224	8247047	8303988	8233836	11777423	12028607	12151287	12027313	0.6812	0.6856	0.6834	0.6834	0.6846	0.6840	9.10	9.11	9.11
20.13	16225275	16323061	17032088	16636208	12192979	12185319	12047014	11737845	1.3307	1.3396	1.3351	1.4138	1.4173	1.4156	18.45	19.61	19.03
30.23	23976292	24804350	24289406	24723684	11307768	11704801	11608265	11811704	2.1203	2.1192	2.1197	2.0924	2.0932	2.0928	29.71	29.32	29.52
39.95	29507720	31124404	28809716	31583900	10787918	11301288	10583457	11423340	2.7353	2.7541	2.7447	2.7221	2.7649	2.7435	38.68	38.66	38.67
49.98	38386612	38121692	39330096	40994944	10705132	10578124	11022128	11366994	3.5858	3.6038	3.5948	3.5683	3.6065	3.5874	50.87	50.77	50.82
60.04	45951556	44377984	46037336	45163936	10809908	10554082	10757905	10583354	4.2509	4.2048	4.2278	4.2794	4.2675	4.2734	59.96	60.61	60.28

Table C.2 (Continued) Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	Peak area of MeOH in retentate				Peak area of IPA in retentate				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in retentate (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.16	8172586	8012628	8260483	8285928	13728517	13441751	14067580	14156720	0.5953	0.5961	0.5957	0.5872	0.5853	0.5862	7.85	7.71	7.78
20.13	17508976	16895428	15540846	15383678	13993747	13414393	12368361	12209268	1.2512	1.2595	1.2553	1.2565	1.2600	1.2583	17.31	17.35	17.33
30.23	22520076	22387400	24481028	24253794	11341044	11490910	11997438	11907378	1.9857	1.9483	1.9670	2.0405	2.0369	2.0387	27.52	28.55	28.03
39.95	31205298	29279234	31778080	30645430	11620658	11077156	11916966	11486328	2.6853	2.6432	2.6643	2.6666	2.6680	2.6673	37.52	37.57	37.55
49.98	39319680	38052272	39488304	38687116	11300604	10944881	11188253	10845532	3.4794	3.4767	3.4781	3.5294	3.5671	3.5483	49.20	50.21	49.70
60.04	45818668	44230988	46060084	46816960	10944646	10618155	11031563	11227089	4.1864	4.1656	4.1760	4.1753	4.1700	4.1726	59.21	59.16	59.19

Table C.3 Pervaporation data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 20 cmHg

MeOH concentration,avg (wt %)	Weight, avg (g)			Weight of MeOH (g)		
	Feed	Retentate	Permeate	Feed	Retentate	Permeate
10.29	200.26	140.08	60.18	18.48	7.42	11.06
20.16	200.34	138.34	62.00	38.98	16.34	18.64
29.96	200.24	136.56	63.68	52.80	27.95	24.85
40.06	200.43	134.67	65.77	75.38	45.29	30.09
49.94	200.33	133.30	65.54	95.48	60.72	34.76
59.95	200.19	130.35	69.85	109.04	69.43	39.61

Table C.3 (Continued) Pervaporation data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 20 cmHg

MeOH concentration in permeate (wt %)	Fluxes (kg m^{-2} h^{-1})			Selection factor (-)	PSI (kg m^{-2} h^{-1})
	MeOH	Water	Total		
18.38	1.62	7.20	8.82	2.21	10.67
30.07	4.47	10.40	14.87	2.03	15.32
39.02	7.73	12.09	19.82	1.79	15.66
45.76	10.98	13.02	24.00	1.40	9.60
53.04	14.70	13.02	27.72	1.24	6.65
56.71	17.91	13.68	31.59	1.10	3.16

Table C.4 Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 20 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in feed				peak area of IPA in feed				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in feed (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.29	10095296	9071170	11024388	10213300	15412504	12459734	16618010	14126279	0.655	0.728	0.6915	0.6634	0.723	0.6932	9.22	9.24	9.23
20.16	20201980	20964696	21048560	21056733	16091067	16507752	16781121	16394218	1.2555	1.27	1.2627	1.2543	1.2844	1.2693	17.42	17.51	17.46
29.96	29399282	28816038	28446881	29122048	15661993	15182506	15106410	15408491	1.8771	1.898	1.8875	1.8831	1.89	1.8866	26.38	26.37	26.37
40.06	35296736	37827508	35567131	36086577	12878608	15353085	13017763	13152044	2.7407	2.4638	2.6023	2.7322	2.7438	2.7380	36.63	38.58	37.61
49.94	33679872	32431800	33565022	33478653	10018020	9636306	9946960	9904341	3.3619	3.3656	3.3638	3.3744	3.3802	3.3773	47.56	47.75	47.66
59.95	60955056	58792580	59248653	59738464	15656776	15532056	15251404	15639160	3.8932	3.7852	3.8392	3.8848	3.8198	3.8523	54.38	54.57	54.47

Table C.4 (Continued) Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 20 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in retentate				peak area of IPA in retentate				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in retentate (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.29	10275076	10042110	10138765	10278654	25044050	25666324	23748315	23123554	0.4103	0.3913	0.4008	0.4269	0.4445	0.4357	5.05	5.55	5.30
20.16	19302988	21552156	20857423	21973383	24178066	25582950	24448070	22120883	0.7984	0.8424	0.8204	0.8531	0.9933	0.9232	11.07	12.54	11.81
29.96	27857750	27389384	27651001	28295474	19119849	19015260	18529622	18693552	1.4570	1.4404	1.4487	1.4923	1.5136	1.5030	20.08	20.86	20.47
40.06	35605160	38892600	37765333	35541270	14835483	16274416	15736867	14918889	2.4000	2.3898	2.3949	2.3998	2.3823	2.3911	33.66	33.60	33.63
49.94	31144366	32944754	30084216	33764321	9892423	9923664	9956601	9914897	3.1483	3.3198	3.2341	3.0215	3.4054	3.2135	45.70	45.40	45.55
59.95	56448648	57480648	55676823	58650398	14971918	15165853	14716471	15835623	3.7703	3.7901	3.7802	3.7833	3.7037	3.7435	53.53	53.01	53.27

Table C.5 Pervaporation data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 12 cmHg

MeOH concentration,avg (wt %)	Weight, avg (g)			Weight of MeOH (g)		
	Feed	Retentate	Permeate	Feed	Retentate	Permeate
10.28	200.73	59.04	141.69	21.30	5.76	15.54
20.00	200.26	55.81	144.45	35.73	9.09	26.64
29.87	200.60	54.01	146.60	52.42	13.33	39.08
39.76	200.53	49.71	150.82	71.09	15.93	55.16
50.15	200.36	47.48	152.89	93.21	20.64	72.57
59.53	200.42	46.02	154.41	112.07	22.62	89.45

Table C.5 (Continued) Pervaporation data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 12 cmHg

MeOH concentration in permeate (wt %)	Fluxes (kg m^{-2} h^{-1})			Selection factor (-)	PSI (kg m^{-2} h^{-1})
	MeOH	Water	Total		
10.96	0.26	2.13	2.39	1.04	0.10
18.44	3.92	17.32	21.24	1.04	0.85
26.66	8.31	22.86	31.17	1.03	0.94
36.57	16.09	27.90	43.99	1.05	2.20
47.47	27.47	30.40	57.87	1.04	2.31
57.93	41.32	30.01	71.33	1.09	6.42

Table C.6 Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 12 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in feed				peak area of IPA in feed				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in feed (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.28	3849645	4383676	4746251	5051853	5840488	4636740	5901953	6769973	0.6591	0.9454	0.8023	0.8042	0.7462	0.7752	10.81	10.42	10.61
20.00	11867789	10184205	16312400	16254321	9563704	8070764	12253906	12171874	1.2409	1.2619	1.2514	1.3312	1.3354	1.3333	17.25	18.43	17.84
29.87	17070444	17530700	18253201	18005332	9253296	9472157	9631280	9526631	1.8448	1.8508	1.8478	1.8952	1.8900	1.8926	25.81	26.45	26.13
39.76	22764666	23668786	22876511	22943788	9065807	9363466	9077980	9105400	2.511	2.5278	2.5194	2.5200	2.5198	2.5199	35.44	35.45	35.45
50.15	31039122	31088926	19285120	19735572	9635513	9423966	5930895	5814182	3.2213	3.2989	3.2601	3.2516	3.3944	3.3230	46.07	46.97	46.52
59.53	34357088	33820968	37003342	37172398	8824592	8598950	9347347	9287759	3.8933	3.9332	3.9132	3.9587	4.0023	3.9805	55.44	56.41	55.92

Table C.6 (Continued) Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 17 ml min^{-1}, and P = 12 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in retentate				peak area of IPA in retentate				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in retentate (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.28	5016847	6702225	6854523	6785063	6601983	8805972	9936972	9613294	0.7599	0.7611	0.7605	0.6898	0.7058	0.6978	10.21	9.31	9.76
20.00	10242048	11252208	6747432	6858262	8447278	9456687	5816864	5852457	1.2125	1.1899	1.2012	1.1600	1.1719	1.1659	16.53	16.03	16.28
29.87	16133920	17735646	11390116	12498292	9126336	10112437	6004566	7529996	1.7678	1.7538	1.7608	1.8969	1.6598	1.7784	24.56	24.81	24.69
39.76	20400970	18668860	13665363	13998806	9091160	8235177	5983851	5997863	2.2440	2.2670	2.2555	2.2837	2.3340	2.3088	31.66	32.42	32.04
50.15	27909720	29477010	28109820	28298534	9083717	9646565	9058333	9180682	3.0725	3.0557	3.0641	3.1032	3.0824	3.0928	43.26	43.67	43.47
59.53	31878130	31636938	33246770	33078524	9255876	9131485	9526022	9442104	3.4441	3.4646	3.4543	3.4901	3.5033	3.4967	48.86	49.47	49.16

Table C.7 Pervaporation data of methanol-water mixtures at T = 40 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration,avg (wt %)	Weight, avg (g)			Weight of MeOH (g)		
	Feed	Retentate	Permeate	Feed	Retentate	Permeate
10.06	200.93	181.31	19.62	18.14	14.09	4.06
20.09	200.00	178.99	21.01	37.74	30.66	7.08
30.14	200.20	175.49	24.72	55.68	46.45	9.22
40.10	200.70	174.05	26.65	73.15	62.57	10.58
50.05	200.20	172.68	27.52	93.33	79.95	13.38
59.96	200.56	171.18	29.38	108.44	92.40	16.04

Table C.7 (Continued) Pervaporation data of methanol-water mixtures at T = 40 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration in permeate (wt %)	Fluxes (kg m^{-2} h^{-1})			Selection factor (-)	PSI (kg m^{-2} h^{-1})
	MeOH	Water	Total		
20.67	0.67	2.56	3.23	2.63	5.26
33.69	1.90	3.75	5.65	2.18	6.67
37.32	2.75	4.61	7.36	1.55	4.05
39.72	3.35	5.09	8.44	1.15	1.27
48.63	5.19	5.48	10.67	1.08	0.85
54.59	6.98	5.81	12.79	1.02	0.26

Table C.8 Gas chromatography data of methanol-water mixtures at T = 40 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in feed				peak area of IPA in feed				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in feed (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.06	8410066	7639476	8527722	8643273	12407546	11251460	12537080	12797265	0.6778	0.6790	0.6784	0.6802	0.6754	0.6778	9.03	9.02	9.03
20.09	15520456	15715821	15438722	15560100	11428610	11515024	11310419	11369356	1.3580	1.3648	1.3614	1.365	1.3686	1.3668	18.83	18.91	18.87
30.14	23265020	22795814	23087650	23295433	11663783	11522103	11641614	11683937	1.9946	1.9784	1.9865	1.9832	1.9938	1.9885	27.80	27.83	27.81
40.10	28451784	28248658	28134502	28377754	11001337	10882013	10931114	10900685	2.5862	2.5959	2.5911	2.5738	2.6033	2.5886	36.47	36.44	36.45
50.05	37905544	39164704	38543274	38765112	11441996	11972918	11665287	11726394	3.3128	3.2711	3.2920	3.3041	3.3058	3.3049	46.53	46.72	46.62
59.96	40307260	39131832	41123998	41255589	10586026	10264020	10782946	10750922	3.8076	3.8125	3.8101	3.8138	3.8374	3.8256	53.96	54.19	54.07

Table C.8 (Continued) Gas chromatography data of methanol-water mixtures at T = 40 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in retentate				peak area of IPA in retentate				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in retentate (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.06	6964931	6962207	5623482	5881820	11667247	11548976	9909366	9907759	0.5970	0.6028	0.5999	0.5675	0.5937	0.5806	7.91	7.63	7.77
20.09	15240640	15132481	15830822	15647658	12225778	12134317	12733930	12676327	1.2466	1.2471	1.2468	1.2432	1.2344	1.2388	17.19	17.07	17.13
30.14	19364024	20182568	20248576	21845533	10562672	11013081	11217800	10381569	1.8333	1.8326	1.8329	1.8050	2.1043	1.9547	25.60	27.34	26.47
40.10	29381444	30199366	30857782	31341198	11436364	11799310	12128201	12306109	2.5691	2.5594	2.5643	2.5443	2.5468	2.5455	36.09	35.82	35.95
50.05	34426644	34350700	35647838	36721895	10581726	10413319	10854014	11237842	3.2534	3.2987	3.2761	3.2843	3.2677	3.2760	46.30	46.30	46.30
59.96	44462956	44899520	46758523	45855531	11780450	11663482	12506961	11813811	3.7743	3.8496	3.8119	3.7386	3.8815	3.8101	53.99	53.96	53.98

Table C.9 Pervaporation data of methanol-water mixtures at T = 50 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration,avg (wt %)	Weight, avg (g)			Weight of MeOH (g)		
	Feed	Retentate	Permeate	Feed	Retentate	Permeate
10.15	200.40	177.91	22.49	18.04	13.95	4.09
20.19	200.23	177.19	23.04	37.78	31.47	6.31
30.05	200.49	175.38	25.12	51.97	44.37	7.60
40.08	200.76	174.13	26.64	71.81	61.88	9.93
50.05	200.16	171.15	29.02	90.07	76.79	13.28
60.00	200.24	168.09	32.15	109.05	91.39	17.66

Table C.9 (Continued) Pervaporation data of methanol-water mixtures at T = 50 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration in permeate (wt %)	Fluxes (kg m^{-2} h^{-1})			Selection factor (-)	PSI (kg m^{-2} h^{-1})
	MeOH	Water	Total		
18.18	0.59	2.67	3.26	2.25	4.08
27.41	1.38	3.66	5.04	1.62	3.12
30.25	1.83	4.23	6.06	1.24	1.45
37.27	2.95	4.97	7.92	1.07	0.55
45.77	4.85	5.74	10.59	1.03	0.32
54.93	7.73	6.35	14.08	1.02	0.28

Table C.10 Gas chromatography data of methanol-water mixtures at T = 50 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in feed				peak area of IPA in feed				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in feed (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.15	8061142	8536165	7892840	7904321	11923108	12657433	11691364	11658290	0.6761	0.6744	0.6752	0.6751	0.6780	0.6766	8.99	9.01	9.00
20.19	15635610	16055879	15738541	15812002	11460730	11767310	11477932	11666791	1.3643	1.3644	1.3644	1.3712	1.3553	1.3633	18.87	18.86	18.87
30.05	20769584	19443336	21307811	21543788	11157896	10511666	11486690	11599520	1.8614	1.8497	1.8556	1.8550	1.8573	1.8562	25.92	25.93	25.92
40.08	25570510	27183074	25830721	24938700	10032502	10736226	10170376	9784487	2.5488	2.5319	2.5403	2.5398	2.5488	2.5443	35.75	35.80	35.77
50.05	37773308	30630500	38836540	37504321	11888124	9587914	12212748	11757209	3.1774	3.1947	3.1860	3.1800	3.1899	3.1850	45.01	44.99	45.00
60.00	41795708	44811376	43277785	43488223	10872235	11640649	11272899	11310331	3.8443	3.8496	3.8469	3.8391	3.8450	3.8420	54.49	54.42	54.46

Table C.10 (Continued) Gas chromatography data of methanol-water mixtures at T = 50 °C, F = 17 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	peak area of MeOH in retentate				peak area of IPA in retentate				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in retentate (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.15	7366845	6776454	7432000	7398663	12394390	11464940	12339366	12457759	0.5944	0.5911	0.5927	0.6023	0.5939	0.5981	7.80	7.88	7.84
20.19	14447845	13980174	10876410	11954833	11118100	11056226	8416320	9267312	1.2995	1.2645	1.2820	1.2923	1.2900	1.2912	17.69	17.82	17.76
30.05	21535058	21211576	22073899	21938922	11867614	11708141	12217800	12081569	1.8146	1.8117	1.8132	1.8067	1.8159	1.8113	25.31	25.29	25.30
40.08	30856668	31291830	30950223	31021177	12243918	12352235	12003932	12549195	2.5202	2.5333	2.5267	2.5783	2.4720	2.5252	35.55	35.53	35.54
50.05	31392272	39238112	32488910	35085498	9840560	12424562	10034255	11249679	3.1901	3.1581	3.1741	3.2378	3.1188	3.1783	44.84	44.90	44.87
60.00	39616012	39223724	39873122	39558420	10262740	10279224	10331430	10358418	3.8602	3.8158	3.8380	3.8594	3.8190	3.8392	54.36	54.38	54.37

Table C.11 Pervaporation data of methanol-water mixtures at T = 30 °C, F = 10 ml min^{-1}, and P = 34 cmHg

MeOH concentration,avg (wt %)	Weight, avg (g)			Weight of MeOH (g)		
	Feed	Retentate	Permeate	Feed	Retentate	Permeate
10.17	200.53	187.09	13.45	19.09	15.43	3.66
20.04	200.50	186.28	14.23	37.87	32.11	5.76
29.92	200.17	184.85	15.32	55.89	48.41	7.47
40.07	200.22	182.55	17.68	76.46	66.39	10.07
50.06	200.50	179.46	21.05	94.48	80.70	13.77
60.05	200.21	176.82	23.39	113.30	96.15	17.14

Table C.11 (Continued) Pervaporation data of methanol-water mixtures at T = 30 °C, F = 10 ml min^{-1}, and P = 34 cmHg

MeOH concentration in permeate (wt %)	Fluxes (kg m^{-2} h^{-1})			Selection factor (-)	PSI (kg m^{-2} h^{-1})
	MeOH	Water	Total		
27.19	0.79	2.13	2.92	3.55	7.45
40.50	1.86	2.73	4.59	2.92	8.81
48.80	2.91	3.05	5.96	2.46	8.70
56.99	4.58	3.45	8.03	2.14	9.15
65.45	7.19	3.79	10.98	2.13	12.41
73.30	10.02	3.65	13.67	2.11	15.17

Table C.12 Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 10 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	Peak area of MeOH in feed				Peak area of IPA in feed				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in feed (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.17	7977850	8164723	8346298	8793811	11253366	11643351	11634430	12190256	0.7089	0.7012	0.7051	0.7174	0.7214	0.7194	9.41	9.62	9.52
20.04	16757613	16363277	16560698	15779331	12559244	12364649	11859480	11210269	1.3343	1.3234	1.3288	1.3964	1.4076	1.4020	18.36	19.41	18.89
29.92	23624720	24176672	23417354	24483840	11781105	12140410	11795967	12263995	2.0053	1.9914	1.9984	1.9852	1.9964	1.9908	27.97	27.86	27.92
40.07	29189026	29274240	28917354	29056340	11020865	10804055	10571913	10567479	2.6485	2.7096	2.6790	2.7353	2.7496	2.7425	37.74	38.64	38.19
50.06	36643852	38014884	34022431	35100356	11141942	11476910	10109476	10427603	3.2888	3.3123	3.3006	3.3654	3.3661	3.3658	46.65	47.59	47.12
60.05	38777804	37215980	42415316	43115980	9778611	9192048	10695352	10800077	3.9656	4.0487	4.0071	3.9658	3.9922	3.9790	56.79	56.39	56.59

Table C.12 (Continued) Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 10 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	Peak area of MeOH in retentate				Peak area of IPA in retentate				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in retentate (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.17	6917573	7104243	7607023	7161777	11598659	11209824	12069259	11291393	0.5964	0.6338	0.6151	0.6303	0.6343	0.6323	8.12	8.37	8.25
20.04	15537782	15306504	14555723	14359728	12007598	12215332	11915932	11634251	1.2940	1.2531	1.2735	1.2215	1.2343	1.2279	17.57	16.92	17.24
29.92	22090176	20794726	20061788	18226048	11804722	11090520	10748922	9674637	1.8713	1.8750	1.8732	1.8664	1.8839	1.8751	26.17	26.20	26.19
40.07	30330592	29973502	22843102	23143288	11766989	11558500	8835081	8970267	2.5776	2.5932	2.5854	2.5855	2.5800	2.5827	36.39	36.35	36.37
50.06	34618632	36435880	33709796	32698370	10666196	11204026	10752867	10546578	3.2456	3.2520	3.2488	3.1350	3.1004	3.1177	45.91	44.03	44.97
60.05	43979016	42080144	40197184	40745932	11443087	10998709	10547009	10512826	3.8433	3.8259	3.8346	3.8112	3.8758	3.8435	54.31	54.44	54.38

Table C.13 Pervaporation data of methanol-water mixtures at T = 30 °C, F = 3.5 ml min^{-1} , and P = 34 cmHg

MeOH concentration,avg (wt %)	Weight, avg (g)			Weight of MeOH (g)		
	Feed	Retentate	Permeate	Feed	Retentate	Permeate
10.10	200.21	191.50	8.72	17.74	15.26	2.48
20.10	200.88	189.71	11.17	37.30	32.23	5.07
29.96	200.28	187.44	12.84	56.72	49.56	7.16
40.09	200.65	184.92	15.73	74.78	64.63	10.15
49.92	200.40	182.49	17.91	97.23	84.27	12.96
60.09	200.52	180.05	20.47	116.78	100.92	15.86

Table C.13 (Continued) Pervaporation data of methanol-water mixtures at T = 30 °C, F = 3.5 ml min^{-1}, and P = 34 cmHg

MeOH concentration in permeate (wt %)	Fluxes (kg m^{-2} h^{-1})			Selection factor (-)	PSI (kg m^{-2} h^{-1})
	MeOH	Water	Total		
28.42	0.56	1.41	1.97	4.08	6.07
45.40	1.83	2.21	4.04	3.65	10.71
55.76	3.18	2.53	5.71	3.19	12.50
64.54	5.23	2.87	8.10	3.06	16.69
72.36	7.47	2.86	10.33	2.78	18.39
77.50	9.80	2.85	12.65	2.47	18.60

Table C.14 Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 3.5 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	Peak area of MeOH in feed				Peak area of IPA in feed				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in feed (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.10	6537441	7424922	6483728	7127835	9860718	10884845	9872298	10723947	0.6630	0.6821	0.6726	0.6568	0.6647	0.6607	8.95	8.78	8.86
20.10	13624244	15918526	13503662	14234046	10081358	11616366	10179694	10738356	1.3514	1.3704	1.3609	1.3265	1.3255	1.3260	18.82	18.32	18.57
29.96	20264332	21583892	20975084	21352640	9842482	10426267	10569272	10797140	2.0589	2.0701	2.0645	1.9845	1.9776	1.9811	28.92	27.72	28.32
40.09	29693896	31024302	26690574	25763092	10820632	11255681	10486622	10137456	2.7442	2.7563	2.7503	2.5452	2.5414	2.5433	38.76	35.79	37.27
49.92	39533700	38114692	31112064	33230160	10968283	10562530	9590998	10176364	3.6044	3.6085	3.6064	3.2439	3.2654	3.2547	51.04	45.99	48.52
60.09	46238876	40388596	36753816	41465008	10901728	9541402	9283339	10365251	4.2414	4.2330	4.2372	3.9591	4.0004	3.9798	60.09	56.40	58.24

Table C.14 (Continued) Gas chromatography data of methanol-water mixtures at T = 30 °C, F = 3.5 ml min^{-1}, and P = 34 cmHg

MeOH concentration avg (wt%)	Peak area of MeOH in retentate				Peak area of IPA in retentate				Ratio = peak area of MeOH/peak area of IPA						MeOH concentration in retentate (wt%)		
	No. 1		No. 2		No. 1		No. 2		No. 1			No.2					
	I	II	I	II	I	II	I	II	I	II	avg	I	II	avg	No. 1	No. 2	avg
10.10	7186406	7163389	6803959	6537843	11740575	12061608	11119397	10876465	0.6121	0.5939	0.6030	0.6119	0.6011	0.6065	7.95	8.00	7.97
20.10	14297696	13848871	14234502	13962498	11592100	11220929	11621899	11260079	1.2334	1.2342	1.2338	1.2248	1.2400	1.2324	17.00	16.98	16.99
29.96	21241884	19765864	20846052	20220298	11155866	10563767	10954886	10712173	1.9041	1.8711	1.8876	1.9029	1.8876	1.8952	26.38	26.49	26.44
40.09	30227352	27294840	27536862	26311260	12042290	11065326	11118817	10576966	2.5101	2.4667	2.4884	2.4766	2.4876	2.4821	35.00	34.91	34.95
49.92	33259710	34087560	33604480	32757524	10128730	10474299	10238089	10078618	3.2837	3.2544	3.2691	3.2823	3.2502	3.2663	46.20	46.16	46.18
60.09	41052008	42177196	38204492	39904036	10290013	10777910	9647843	10074233	3.9895	3.9133	3.9514	3.9599	3.9610	3.9604	55.99	56.12	56.05

Table C.15 Compare the pervaporation performance at T = 30 °C, F = 17 ml min^{-1}, and various the values of downstream pressure for six different feed concentrations

MeOH concentration (wt %)	Downstream pressure (cmHg)	MeOH concentration in permeate (wt %)	Flux (kg m^{-2} h^{-1})			Selectivity (-)	PSI (kg m^{-2} h^{-1})
			MeOH	Water	Total		
10.28	12	10.96	0.26	2.13	2.39	1.04	0.10
20.00		18.44	3.92	17.32	21.24	1.04	0.85
29.87		26.66	8.31	22.86	31.17	1.03	0.94
39.76		36.57	16.09	27.90	43.99	1.05	2.20
50.15		47.47	27.47	30.40	57.87	1.04	2.31
59.53		57.93	41.32	30.01	71.33	1.09	6.42
10.29	20	18.38	1.62	7.20	8.82	2.21	10.67
20.16		30.07	4.47	10.40	14.87	2.03	15.32
29.96		39.02	7.73	12.09	19.82	1.79	15.66
40.06		45.76	10.98	13.02	24.00	1.40	9.60
49.94		53.04	14.70	13.02	27.72	1.24	6.65
59.95		56.71	17.91	13.68	31.59	1.10	3.16
10.16	34	23.53	0.75	2.43	3.18	3.70	8.59
20.13		37.04	1.89	3.22	5.11	2.50	7.67
30.23		44.83	2.95	3.62	6.57	1.94	6.18
39.95		49.76	3.77	3.80	7.57	1.57	4.31
49.98		61.56	6.42	4.01	10.43	1.55	5.74
60.04		69.74	8.82	3.82	12.64	1.51	6.45

Table C.16 Compare the pervaporation performance at F = 17 ml min^{-1}, P = 34 cmHg, and various the feed temperatures for six different feed concentrations

MeOH concentration (wt %)	Feed temperature (°C)	MeOH concentration in permeate (wt %)	Flux (kg $m^{-2} h^{-1}$)			Selectivity (-)	PSI (kg $m^{-2} h^{-1}$)
			MeOH	Water	Total		
10.16	30	23.53	0.75	2.43	3.18	3.70	8.59
20.13		37.04	1.89	3.22	5.11	2.50	7.67
30.23		44.83	2.95	3.62	6.57	1.94	6.18
39.95		49.76	3.77	3.80	7.57	1.57	4.31
49.98		61.56	6.42	4.01	10.43	1.55	5.74
60.04		69.74	8.82	3.82	12.64	1.51	6.45
10.06	40	20.67	0.67	2.56	3.23	2.63	5.26
20.09		33.69	1.90	3.75	5.65	2.18	6.67
30.14		37.32	2.75	4.61	7.36	1.55	4.05
40.10		39.72	3.35	5.09	8.44	1.15	1.27
50.05		48.63	5.19	5.48	10.67	1.08	0.85
59.96		54.59	6.98	5.81	12.79	1.02	0.26
10.15	50	18.18	0.59	2.67	3.26	2.25	4.08
20.19		27.41	1.38	3.66	5.04	1.62	3.12
30.05		30.25	1.83	4.23	6.06	1.24	1.45
40.08		37.27	2.95	4.97	7.92	1.07	0.55
50.05		45.77	4.85	5.74	10.59	1.03	0.32
60.00		54.93	7.73	6.35	14.08	1.02	0.28

Table C.17 Compare the pervaporation performance at T = 30 °C, P = 34 cmHg, and various the feed flow rates for six different feed concentrations

MeOH concentration (wt %)	Feed flow rate (ml min^{-1})	MeOH concentration in permeate (wt %)	Flux (kg $m^{-2} h^{-1}$)			Selectivity (-)	PSI (kg $m^{-2}h^{-1}$)
			MeOH	Water	Total		
10.16	17	23.53	0.75	2.43	3.18	3.70	8.59
20.13		37.04	1.89	3.22	5.11	2.50	7.67
30.23		44.83	2.95	3.62	6.57	1.94	6.18
39.95		49.76	3.77	3.80	7.57	1.57	4.31
49.98		61.56	6.42	4.01	10.43	1.55	5.74
60.04		69.74	8.82	3.82	12.64	1.51	6.45
10.17	10	27.19	0.79	2.13	2.92	3.55	7.45
20.04		40.50	1.86	2.73	4.59	2.92	8.81
29.92		48.80	2.91	3.05	5.96	2.46	8.70
40.07		56.99	4.58	3.45	8.03	2.14	9.15
50.06		65.45	7.19	3.79	10.98	2.13	12.41
60.05		73.30	10.02	3.65	13.67	2.11	15.17
10.10	3.5	28.42	0.56	1.41	1.97	4.08	6.07
20.10		45.40	1.83	2.21	4.04	3.65	10.71
29.96		55.76	3.18	2.53	5.71	3.19	12.50
40.09		64.54	5.23	2.87	8.10	3.06	16.69
49.92		72.36	7.47	2.86	10.33	2.78	18.39
60.09		77.50	9.80	2.85	12.65	2.47	18.60

VITA

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