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APPENDIX A

DETERMINATION OF MOLECULAR WEIGHT OF PET

Molecular weigth of PET was determined by measured solution viscosity (ASTM D4603) [19]. Solution viscosity was measured in glass capillary viscometer, in this syudy Cannon-Fenske viscometer (FigureA-1) was used. Measurement of solution viscosity was usually made by comparing the flowtime of PET solution and pure solvent in a capillary viscometer at a fixed temperature, the solvent for PET in this study was phenol/1,1,2,2-tetrachloroethane (40/60 % by weigth). The relative viscosity, η_r, was calculated by used equation (A-1) [20].

$$\eta_r = t/t_o \qquad \text{(A-1)}$$

where:

η_r = relative viscosity

t = average flow time of PET solution, (s)

t_o = average flow time of solvent, (s)

The relative viscosity was used to calculated the intrinsic viscosity, η, using Billmeyer relationship in equation (A-2) [19].

$$\eta = 0.25(\eta_r - 1 + 3\ln\eta_r)/C \qquad \text{(A-2)}$$

where:

η = intrinsic viscosity, (dL/g)

C = concentration of PET solution, (g/dL)

Intrinsic viscosity was used to calculated the viscosity-average molecular weigth . The equation of Mark-Houwink equation presents the relation of intrinsic viscosity and viscosity-average molecular weight by equation (A-3).

$$\eta = K\bar{M}_v \qquad \text{(A-3)}$$

K and a were the constants for given polymer type, solvent and temperature. For PET in phenol/1,1,2,2-tetrachloroethane (40/60 % by weight) at 25 °C, $K = 1.4 \times 10^{-3}$ ml/g and a = 0.64 [21].

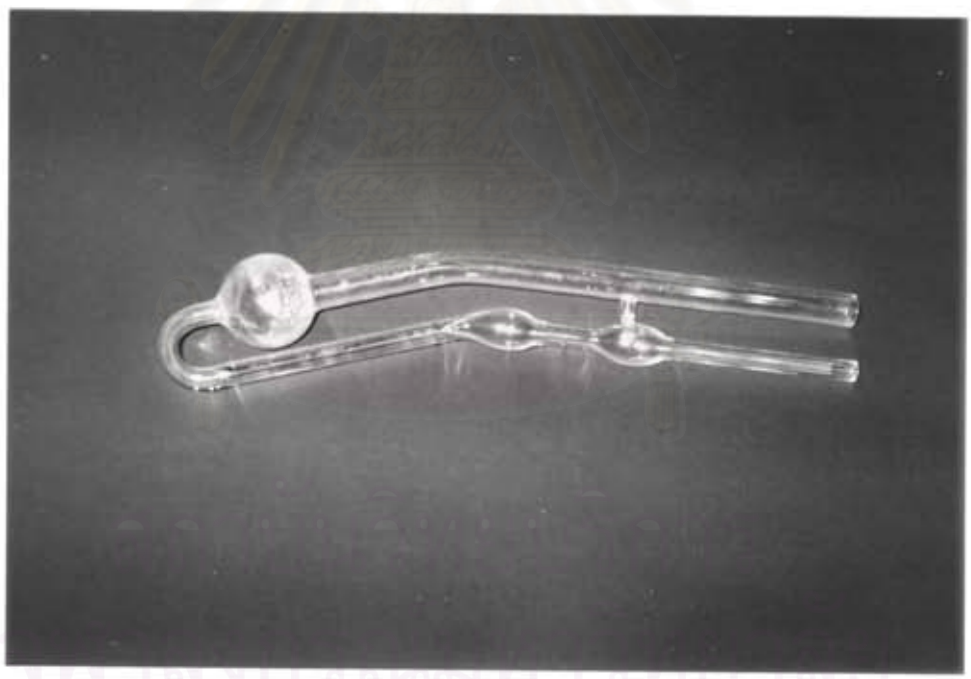

Figure A-1 Cannon-Fenske viscometer used for determined viscosity-average molecular weight

The results of determination of molecular weight of PET by measurement solution viscosity was showed in Table A-1

Table A-1 Results of determined molecular weigth of PET

Variables	Value
t, (s)	129.59
t_o, (s)	168.17
C (g/dL)	0.5034
η_r	1.2977
η	0.5361
M_v	10869

Viscosity-average molecular weight of PET was used in this experiments was 1.09×10^4 g/gmol

APPENDIX B

EXPERIMENTAL DATA OF SYNTHESIS UNSATURATED POLYESTER

Table B-1 Change of acid value with reaction time of unsaturated polyester run UPGLY1,1

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	170	0.55	0.1070	22.20	242.29
60	179	0.48	0.1070	11.90	148.82
90	183	0.61	0.1070	13.50	132.85
120	185	0.52	0.1070	8.20	94.66
150	183	0.60	0.1070	7.60	76.03
180	188	0.51	0.1070	6.00	70.62
210	190	0.63	0.1070	6.70	63.84
240	187	0.49	0.1070	4.90	60.03
270	190	0.45	0.1070	4.30	57.36
300	190	0.50	0.1070	4.40	52.82

Final weight of unsaturated polyester = 170.79 g

weight of styrene = 59.78 g

weight of hydroquinone = 0.342 g

Table B-2 Change of acid value with reaction time of unsaturated polyester run UPGLY2,1

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration(ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	171	0.54	0.1070	22.00	244.55
60	175	0.65	0.1070	17.90	165.30
90	180	0.60	0.1070	11.60	116.05
120	185	0.58	0.1070	10.10	104.53
150	188	0.70	0.1070	9.60	82.32
180	186	0.54	0.1070	7.20	80.04
210	187	0.60	0.1070	7.60	76.03
240	187	0.54	0.1070	6.70	74.48
270	193	0.63	0.1070	7.10	67.65
300	188	1.28	0.1070	13.50	63.31
330	190	0.80	0.1070	7.70	57.78
360	192	0.55	0.1070	4.90	53.48

Final weight of unsaturated polyester = 174.66 g
weight of styrene = 61.13 g
weight of hydroquinone = 0.349 g

Table B-3 Change of acid value with reaction time of unsaturated polyester run UPGLY4,1

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	172	0.54	0.1070	23.60	262.34
60	178	0.63	0.1070	20.10	191.51
90	178	0.78	0.1070	21.30	163.92
120	185	0.74	0.1070	15.10	122.49
150	192	0.74	0.1070	12.90	104.64
180	188	0.69	0.1070	10.80	93.96
210	188	0.79	0.1070	11.50	87.38
240	190	0.61	0.1070	8.00	78.72
270	191	0.66	0.1070	8.10	73.67
300	191	0.72	0.1070	8.00	66.70
330	192	0.81	0.1070	8.10	60.03
360	192	0.75	0.1070	6.50	52.02

Final weight of unsaturated polyester = 180.30 g
weight of styrene = 63.10 g
weight of hydroquinone = 0.360 g

Table B-4 Change of acid value with reaction time of unsaturated polyester run UPGLY6,1

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	170	0.70	0.1048	33.50	281.36
60	175	0.90	0.1048	24.60	160.70
90	175	1.20	0.1048	22.20	108.77
120	181	0.70	0.1048	11.40	95.75
150	181	1.00	0.1048	14.50	85.25
180	184	0.70	0.1048	9.50	79.79
210	185	1.00	0.1048	11.60	68.20
240	185	0.60	0.1048	6.50	63.69
270	185	0.80	0.1048	7.80	57.32
300	186	0.90	0.1048	8.00	52.26

Final weight of unsaturated polyester = 167.58 g

weight of styrene = 58.65 g

weight of hydroquinone = 0.335 g

Table B-5 Change of acid value with reaction time of unsaturated polyester run UPGLY8,1

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titrated (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	168	0.70	0.1023	34.70	284.49
60	176	0.70	0.1023	23.20	190.21
90	179	0.90	0.1023	18.80	119.88
120	179	0.80	0.1023	13.00	93.26
150	182	0.80	0.1023	11.50	82.50
180	182	0.80	0.1023	10.60	76.04
210	182	0.70	0.1023	8.70	71.33
240	182	0.70	0.1023	7.70	63.13
270	182	0.70	0.1023	7.10	58.21
300	183	0.80	0.1023	7.30	52.37

Final weight of unsaturated polyester = 165.68 g

weight of styrene = 57.99 g

weight of hydroquinone = 0.3314 g

Table B-6 Change of acid value with reaction time of unsaturated polyester run UPGLY1,2

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	170	0.57	0.1077	21.40	226.84
60	180	0.57	0.1077	15.50	164.30
90	180	0.65	0.1077	13.30	123.63
120	182	0.52	0.1077	8.60	99.92
150	183	0.54	0.1077	7.70	86.15
180	184	0.54	0.1077	7.00	70.49
210	185	0.87	0.1077	9.20	63.89
240	185	0.87	0.1077	8.70	60.42
270	187	0.66	0.1077	6.20	56.76
300	190	0.65	0.1077	5.60	52.05

Final weight of unsaturated polyester = 166.46 g

weight of styrene = 58.26 g

weight of hydroquinone = 0.333 g

Table B-7 Change of acid value with reaction time of unsaturated polyester run UPGLY2,2

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration(ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	170	0.54	0.1084	19.60	220.73
60	175	0.49	0.1084	13.40	166.30
90	180	0.59	0.1084	11.40	117.50
120	175	0.66	0.1084	11.20	103.20
150	186	0.52	0.1084	8.20	95.90
180	190	0.73	0.1084	10.30	85.80
210	185	0.34	0.1084	4.60	82.28
240	190	0.51	0.1084	6.10	72.73
270	200	0.67	0.1084	7.30	66.26
300	200	0.55	0.1084	5.60	61.92
330	200	0.62	0.1084	6.00	58.85
360	200	0.22	0.1084	1.90	52.52

Final weight of unsaturated polyester = 218.07 g

weight of styrene = 76.32 g

weight of hydroquinone = 0.436 g

Table B-8 Change of acid value with reaction time of unsaturated polyester run UPGLY4,2

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	170	0.68	0.1012	23.00	192.03
60	173	0.62	0.1012	17.20	157.59
90	180	0.49	0.1012	11.20	129.77
120	184	0.57	0.1012	10.60	105.58
150	190	0.48	0.1012	8.40	99.35
180	187	0.76	0.1012	12.40	92.63
210	190	0.83	0.1012	13.20	90.29
240	195	0.37	0.1012	5.40	82.86
270	200	0.40	0.1012	5.50	78.06
300	200	0.50	0.1012	6.00	68.13
330	200	0.57	0.1012	6.20	61.75
360	200	0.52	0.1012	5.00	54.58

Final weight of unsaturated polyester = 184.92 g

weight of styrene = 62.27 g

weight of hydroquinone = 0.360 g

Table B-9 Change of acid value with reaction time of unsaturated polyester run UPGLY6,2

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration(ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	155	0.90	0.1055	24.60	161.77
60	169	0.60	0.1055	13.40	132.18
90	174	0.50	0.1055	9.00	106.53
120	174	0.60	0.1055	8.90	87.79
150	180	0.61	0.1055	8.70	84.41
180	185	0.65	0.1055	8.90	81.04
210	185	0.63	0.1055	8.00	75.15
240	186	0.67	0.1055	8.00	70.67
270	188	0.66	0.1055	7.30	65.46
300	190	0.55	0.1055	5.70	61.34
330	191	0.57	0.1055	5.50	57.11
360	192	0.58	0.1055	5.10	52.04

Final weight of unsaturated polyester = 177.62 g

weight of styrene = 62.17 g

weight of hydroquinone = 0.355 g

Table B-10 Change of acid value with reaction time of unsaturated polyester run UPGLY8,2

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	157	0.70	0.1070	39.10	335.29
60	175	0.80	0.1070	28.30	212.34
90	181	1.10	0.1070	24.50	133.70
120	182	1.10	0.1070	19.70	107.50
150	180	0.80	0.1070	12.50	93.79
180	186	0.70	0.1070	10.70	91.76
210	186	0.70	0.1070	9.70	83.18
240	187	0.80	0.1070	10.00	75.03
270	187	0.90	0.1070	9.70	64.70
300	186	1.10	0.1070	10.80	58.94
330	186	0.90	0.1070	7.80	52.02

Final weight of unsaturated polyester = 197.46 g

weight of styrene = 69.11 g

weight of hydroquinone = 0.390 g

Table B-11 Change of acid value with reaction time of unsaturated polyester run UPGLY1,3

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	155	0.60	0.1062	28.70	275.32
60	175	0.90	0.1062	23.30	154.24
90	180	1.00	0.1062	17.80	106.05
120	181	0.80	0.1062	12.80	95.32
150	183	1.10	0.1062	13.40	72.58
180	181	1.00	0.1062	10.20	60.77
210	185	1.00	0.1062	8.90	53.02
240	190	1.20	0.1062	9.30	46.17

Final weight of unsaturated polyester = 177.55 g

weight of styrene = 62.14 g

weight of hydroquinone = 0.355 g

Table B-12 Change of acid value with reaction time of unsaturated polyester run UPGLY2,3

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	169	0.60	0.1063	26.70	265.37
60	179	1.10	0.1063	27.20	147.46
90	182	0.80	0.1063	14.50	108.09
120	183	0.90	0.1063	14.40	95.41
150	184	0.90	0.1063	12.70	84.15
180	186	0.70	0.1063	8.50	72.41
210	190	0.60	0.1063	6.90	68.58
240	190	0.60	0.1063	5.90	58.64
270	189	0.99	0.1063	8.60	52.48

Final weight of unsaturated polyester = 171.09 g

weight of styrene = 59.88 g

weight of hydroquinone = 0.342 g

Table B-13 Change of acid value with reaction time of unsaturated polyester run UPGLY4,3

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	175	0.68	0.1091	30.30	272.72
60	180	0.63	0.1091	20.70	201.02
90	183	0.54	0.1091	14.20	160.95
120	182	0.74	0.1091	14.70	121.58
150	185	0.64	0.1091	10.60	101.37
180	185	0.52	0.1091	7.20	84.74
210	189	0.87	0.1091	10.20	71.76
240	185	0.58	0.1091	6.00	63.31
270	188	0.58	0.1091	5.20	54.87

Final weight of unsaturated polyester = 204.74 g

weight of styrene = 71.66 g

weight of hydroquinone = 0.409 g

Table B-14 Change of acid value with reaction time of unsaturated polyester run UPGLY 6,3

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	152	0.45	0.1077	23.70	318.21
60	176	0.42	0.1077	14.00	201.40
90	181	0.72	0.1077	16.50	138.46
120	181	0.66	0.1077	11.70	107.11
150	183	0.81	0.1077	12.00	89.51
180	183	0.81	0.1077	10.90	81.30
210	184	0.81	0.1077	9.40	70.12
240	187	0.60	0.1077	6.50	65.45
270	191	0.61	0.1077	5.90	58.44
300	191	0.71	0.1077	6.10	51.91

Final weight of unsaturated polyester = 199.65 g

weight of styrene = 69.88 g

weight of hydroquinone = 0.400 g

Table B-15 Change of acid value with reaction time of unsaturated polyester run UPGLY8,3

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	151	1.00	0.1051	51.50	303.65
60	170	1.00	0.1051	44.30	261.20
90	175	1.00	0.1051	30.80	181.60
120	178	0.80	0.1051	18.30	134.87
150	180	0.80	0.1051	13.70	100.97
180	180	0.70	0.1051	10.30	86.76
210	186	0.80	0.1051	10.30	75.91
240	186	0.80	0.1051	8.90	65.59
270	187	0.80	0.1051	7.50	55.27
300	188	0.90	0.1051	7.90	51.75

Final weight of unsaturated polyester = 177.59 g

weight of styrene = 62.15 g

weight of hydroquinone = 0.355 g

Table B-16 Change of acid value with reaction time of unsaturated polyester run UPGLY1,4

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	145	0.83	0.1048	43.60	308.84
60	170	0.70	0.1048	30.20	253.65
90	173	0.74	0.1048	23.60	182.49
120	181	0.82	0.1048	23.90	166.78
150	190	0.73	0.1048	17.30	135.61
180	189	0.89	0.1048	18.30	117.66
210	193	0.67	0.1048	13.00	111.03
240	200	0.61	0.1048	9.90	92.87
270	200	0.52	0.1048	7.00	79.14
300	198	0.52	0.1048	6.10	68.97
330	198	0.51	0.1048	5.40	62.25
360	198	0.61	0.1048	6.10	58.79
390	197	0.55	0.1048	5.00	53.45

Final weight of unsaturated polyester = 163.22 g

weight of styrene = 57.13 g

weight of hydroquinone = 0.3264 g

Table B-17 Change of acid value with reaction time of unsaturated polyester run UPGLY2,4

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	148	0.81	0.1027	45.00	317.90
60	158	0.60	0.1027	26.90	256.54
90	171	0.46	0.1027	16.60	207.91
120	184	0.52	0.1027	15.80	175.06
150	183	0.74	0.1027	17.40	143.39
180	183	0.75	0.1027	16.70	128.29
210	192	0.81	0.1027	16.20	115.23
240	190	0.72	0.1027	11.90	100.79
270	195	0.55	0.1027	7.40	82.05
300	195	0.77	0.1027	9.30	73.65
330	193	0.78	0.1027	9.00	70.36
360	195	1.03	0.1027	10.50	62.16
390	195	0.82	0.1027	8.10	56.91
420	194	0.78	0.1027	6.70	52.38

Final weight of unsaturated polyester = 165.44 g

weight of styrene = 57.90 g

weight of hydroquinone = 0.331 g

Table B-18 Change of acid value with reaction time of unsaturated polyester run UPGLY4,4

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	147	0.74	0.1012	42.90	329.13
60	150	0.45	0.1012	20.90	263.68
90	178	1.04	0.1012	40.20	217.93
120	178	0.57	0.1012	18.00	178.04
150	181	0.38	0.1012	10.50	155.79
180	190	0.49	0.1012	12.00	138.07
210	192	0.47	0.1012	10.80	129.56
240	195	0.51	0.1012	10.00	112.20
270	195	0.84	0.1012	13.80	94.01
300	197	0.47	0.1012	7.00	85.22
330	200	0.51	0.1012	6.90	77.42
360	203	0.69	0.1012	8.50	70.49
390	206	0.39	0.1012	4.60	67.49
420	205	0.85	0.1012	8.50	57.22
450	210	0.75	0.1012	6.90	52.64

Final weight of unsaturated polyester = 172.78 g

weight of styrene = 60.47 g

weight of hydroquinone = 0.345 g

Table B-19 Change of acid value with reaction time of unsaturated polyester run UPGLY6,4

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	162	0.53	0.1020	30.60	330.38
60	164	0.50	0.1020	24.10	275.81
90	165	0.65	0.1020	27.60	242.97
120	170	0.84	0.1020	29.40	200.28
150	179	0.59	0.1020	17.20	167.96
180	182	0.56	0.1020	14.30	147.12
210	186	0.61	0.1020	13.90	131.28
240	192	0.54	0.1020	10.80	115.23
270	202	0.53	0.1020	8.70	94.58
300	201	0.56	0.1020	8.60	88.48
330	209	0.66	0.1020	9.90	86.42
360	210	0.78	0.1020	10.80	79.77
390	211	0.73	0.1020	8.10	63.93
420	212	0.61	0.1020	6.10	57.61
450	214	0.66	0.1020	6.00	52.38

Final weight of unsaturated polyester = 175.72 g

weight of styrene = 61.50 g

weight of hydroquinone = 0.3514 g

Table B-20 Change of acid value with reaction time of unsaturated polyester run UPGLY8,4

reaction time (min)	batch temperature (°C)	sample weight (g)	normality of KOH (N)	volume of KOH required for titration (ml)	Acid Value (mgKOH/g)
0	-	-	-	-	-
30	143	0.32	0.1062	20.40	379.81
60	152	0.30	0.1062	16.00	317.75
90	165	0.32	0.1062	14.30	266.24
120	181	0.66	0.1062	23.20	209.43
150	185	0.60	0.1062	19.60	194.62
180	192	0.44	0.1062	13.00	176.03
210	191	0.49	0.1062	12.40	150.77
240	191	0.57	0.1062	12.90	134.83
270	198	0.45	0.1062	9.10	120.48
300	197	0.52	0.1062	8.80	100.82
330	198	0.61	0.1062	9.00	87.90
360	200	0.55	0.1062	7.50	81.24
390	202	0.63	0.1062	7.80	73.76
420	208	0.49	0.1062	5.50	66.43
450	205	0.39	0.1062	4.10	62.22
480	205	0.41	0.1062	3.90	52.67
510	205	0.70	0.1062	6.20	52.77

Final weight of unsaturated polyester = 177.82 g

weight of styrene = 62.24 g

weight of hydroquinone = 0.3556 g

VITA

Mr. Amnat Permsubscul was born on April 24, 1972, in Ratchaburi, Thailand. He graduated from Chiangmai University , with a Bachelor degree of Science in Industrial Chemistry in 1994. He continues his Master's Study at Chulalongkorn University in 1994. He was granted the degree in October, 1997.