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## APPENDIX A

### 1. Determination the Conversion of Graft Copolymerization

The grafted samples are characterized according to the following:

$$\text{Total Conversion (\%)} = \frac{\text{Total weight of polymer formed}}{\text{Weight of monomer charged}} \times 100$$

### 2. Determination the Percentage of Grafted Natural Rubber

The products, therefore, contain three components in quantities a, b, and c respectively.

**a** is the weight of free rubber determined by soxhlet extraction with light petroleum ether for 24 h.

**b** is the weight of graft copolymer determined from the residual weight after extraction of free homopolymers.

**c** is the weight of free PMMA determined by soxhlet extraction with acetone for 24 h.

These quantities combined into a single expression which is the measure of the grafted natural rubber.

$$\% \text{ grafted natural rubber} = \frac{b}{a + b + c} \times 100$$

### 3. Determination the Percentage of Grafting Efficiency

$$\% \text{ grafting efficiency} = \frac{\text{the weight of polymer as grafted copolymer} \times 100}{\text{the total weight of polymer formed}}$$

**Table A-1** Effect of initiator concentration, reaction temperature, monomer concentration, and reaction time on the percentage conversion, percentage grafted natural rubber, percentage grafting efficiency.

Exp.	NRL (g)	DRC (%)	Prod. (g)	Conv. (%)	Samp. (g)	Free NR (g)	Free PMMA (g)	Free NR (%)	Free PMMA (%)	Grafted NR (%)	Total PMMA (g)	Graft PMMA (g)	GE. (%)
50I <sub>0.50</sub>	50.02	60.28	41.72	38.4	2.0535	0.8882	0.3688	43.3	18.0	38.8	11.57	4.08	35.2
	50.02	61.46	42.00	36.5	2.0151	0.8814	0.3024	43.7	15.0	41.3	11.24	4.94	43.9
50I <sub>0.75</sub>	50.04	60.28	42.24	40.0	2.0150	0.6545	0.2677	32.5	13.3	54.2	12.08	6.46	53.5
	50.02	61.46	43.74	42.3	2.0496	0.6516	0.2674	31.8	13.0	55.2	13.00	7.29	56.1
50I <sub>1.00</sub>	50.05	60.28	45.94	52.3	2.0519	0.6369	0.3234	31.0	15.8	53.2	15.77	8.53	54.1
	50.05	61.46	46.88	52.5	2.0358	0.5941	0.3296	29.2	16.2	54.6	16.13	8.54	52.9
50I <sub>1.50</sub>	50.05	60.28	47.09	56.1	2.0231	0.6881	0.3694	34.0	18.3	47.7	16.92	8.32	49.2
	50.04	61.46	48.50	57.7	2.0013	0.6339	0.3974	31.7	19.9	48.5	17.75	8.11	45.7
50I <sub>2.00</sub>	50.02	60.28	50.34	67.0	2.0253	0.6948	0.4296	34.3	21.2	44.5	20.19	9.51	47.1
	50.05	61.46	50.40	63.8	2.0126	0.6968	0.4109	34.6	20.4	45.0	19.64	9.35	47.6
55I <sub>0.50</sub>	50.00	60.28	50.22	66.6	2.0285	0.5696	0.3111	28.1	15.3	56.6	20.08	12.38	61.6
	50.01	61.46	51.70	68.2	2.0530	0.5683	0.3314	27.7	16.1	56.2	20.96	12.62	60.2
55I <sub>0.75</sub>	50.04	60.28	53.66	77.9	2.0241	0.5347	0.3132	26.4	15.5	58.1	23.50	15.19	64.7
	50.01	61.46	53.43	73.8	2.0028	0.5377	0.3094	26.8	15.4	57.7	22.69	14.44	63.6
55I <sub>1.00</sub>	50.04	60.28	55.32	83.4	2.0628	0.5765	0.3894	27.9	18.9	53.2	25.16	14.71	58.5
	50.04	61.46	54.24	76.4	2.0416	0.5786	0.3426	28.3	16.8	54.9	23.49	14.38	61.2
55I <sub>1.50</sub>	50.00	60.28	55.48	84.1	2.0227	0.6454	0.4519	31.9	22.3	45.8	25.34	12.94	51.1
	50.01	61.46	55.37	80.1	2.0185	0.6640	0.4417	32.9	21.9	45.2	24.63	12.52	50.8
55I <sub>2.00</sub>	50.01	60.28	55.50	84.1	2.0080	0.6467	0.4484	32.2	22.3	45.5	25.35	12.96	51.1
	50.05	61.46	55.50	80.4	2.0130	0.6586	0.4457	32.7	22.1	45.1	24.74	12.45	50.3

**Table A-1 (Continued)**

Exp.	NRL (g)	DRC (%)	Prod. (g)	Conv. (%)	Samp. (g)	Free NR (g)	Free PMMA (g)	Free NR (%)	Free PMMA (%)	Grafted NR (%)	Total PMMA (g)	Graft PMMA (g)	GE. (%)
60I <sub>0.50</sub>	50.00	60.28	53.01	75.9	2.0464	0.6619	0.4148	32.3	20.3	47.4	22.87	12.13	53.0
	50.03	61.46	51.19	76.4	2.0326	0.7009	0.4323	34.5	21.3	44.2	23.46	11.94	50.9
60I <sub>0.75</sub>	50.01	60.28	54.45	80.6	2.0120	0.5670	0.3867	28.2	19.2	52.6	24.30	13.84	56.9
	50.05	61.46	55.97	52.0	2.0297	0.5580	0.3938	27.5	19.4	53.1	25.21	14.35	56.9
60I <sub>1.00</sub>	50.01	60.28	54.90	82.1	2.0439	0.5960	0.3997	29.2	19.6	51.3	24.75	14.02	56.6
	50.02	61.46	55.45	80.4	2.0825	0.6009	0.4082	28.9	19.6	51.5	24.71	13.84	56.0
60I <sub>1.50</sub>	50.05	60.28	55.51	84.0	2.0053	0.6149	0.4296	30.7	21.4	47.9	25.34	13.45	53.1
	50.03	61.46	56.92	85.1	2.0505	0.6515	0.4581	31.8	22.3	45.9	26.17	13.46	51.4
60I <sub>2.00</sub>	50.03	60.28	55.50	84.0	2.0270	0.6498	0.4576	32.1	22.6	45.4	25.34	12.81	50.6
	50.01	61.46	57.27	86.3	2.0333	0.6251	0.4543	30.7	22.3	46.9	26.53	13.74	51.8
70I <sub>0.50</sub>	50.01	60.28	54.09	79.4	2.0345	0.7387	0.5489	36.3	27.0	36.7	23.94	9.35	39.1
	50.00	61.46	55.65	81.1	2.0068	0.7465	0.4962	37.2	24.7	38.1	24.92	11.16	44.8
70I <sub>0.75</sub>	50.02	60.28	55.54	84.2	2.0186	0.5926	0.4603	29.4	22.8	47.8	25.39	12.72	50.1
	50.05	61.46	57.44	86.7	2.0031	0.5687	0.4643	28.4	23.2	48.4	26.68	13.37	50.1
70I <sub>1.00</sub>	50.04	60.28	55.21	83.0	2.0033	0.7257	0.4830	36.2	24.1	39.7	25.05	11.73	46.9
	50.05	61.46	57.49	86.9	2.0058	0.7114	0.4947	35.5	24.7	39.9	26.73	12.55	47.0
70I <sub>1.50</sub>	50.05	60.28	55.77	84.9	2.0496	0.8298	0.5482	40.5	26.7	32.8	25.60	10.68	41.7
	50.02	61.46	57.53	87.1	2.0703	0.8578	0.6200	41.4	29.5	28.6	26.79	9.56	35.7
70I <sub>2.00</sub>	50.02	60.28	55.88	85.3	2.0584	0.8692	0.5625	42.2	27.3	30.4	25.73	10.46	40.6
	50.02	61.46	57.71	87.7	2.0363	0.8231	0.5747	40.4	28.2	31.4	26.97	10.68	39.6



**Table A-1 (Continued)**

Exp.	NRL (g)	DRC (%)	Prod. (g)	Conv. (%)	Samp. (g)	Free NR (g)	Free PMMA (g)	Free NR (%)	Free PMMA (%)	Grafted NR (%)	Total PMMA (g)	Graft PMMA (g)	GE. (%)
M <sub>40</sub>	50.04	61.20	36.77	50.2	2.0519	1.3436	0.2402	65.5	11.7	22.8	6.15	1.84	30.0
	50.00	61.20	38.16	61.7	2.0339	1.2764	0.2807	62.8	13.8	23.4	7.56	2.29	30.3
M <sub>60</sub>	50.04	61.20	42.30	63.5	2.0034	0.9358	0.3314	46.7	16.5	36.7	11.68	4.68	40.1
	50.00	61.20	42.77	66.3	2.0410	0.9439	0.3182	46.2	15.6	38.2	12.17	5.50	45.2
M <sub>80</sub>	50.02	61.20	48.42	72.7	2.0497	0.6217	0.3888	30.3	19.0	50.7	17.81	8.62	48.8
	50.02	61.20	49.17	75.8	2.0385	0.6603	0.3257	32.4	16.0	51.6	18.56	10.70	57.7
M <sub>100</sub>	50.04	60.28	53.66	77.9	2.0241	0.5347	0.3132	26.4	15.5	58.1	23.50	15.19	64.7
	50.01	61.46	53.43	73.8	2.0028	0.5377	0.3094	26.8	15.4	57.7	22.69	14.44	63.6
M <sub>120</sub>	50.00	61.20	58.71	76.6	2.0362	0.6441	0.4872	31.6	23.9	44.4	28.11	14.06	50.0
	50.05	61.20	58.12	74.8	2.0505	0.6621	0.4868	32.3	23.7	44.0	27.49	13.69	49.8
T <sub>4</sub>	50.03	61.20	51.69	68.8	2.0019	0.8208	0.4821	41.0	24.1	34.9	21.07	8.62	40.9
	50.00	61.20	51.07	66.9	2.0341	0.8633	0.4823	42.4	23.7	33.8	20.47	8.36	40.8
T <sub>6</sub>	50.05	61.20	53.39	74.3	2.0318	0.5986	0.3529	29.5	17.4	53.2	22.76	13.49	59.3
	50.04	61.20	53.48	74.6	2.0287	0.5805	0.3436	28.6	16.9	54.4	22.86	13.8	60.4
T <sub>8</sub>	50.04	60.28	53.66	77.9	2.0241	0.5347	0.3132	26.4	15.5	58.1	23.50	15.19	64.7
	50.01	61.46	53.43	73.8	2.0028	0.5377	0.3094	26.8	15.4	57.7	22.69	14.44	63.6
T <sub>10</sub>	50.00	61.20	53.89	76.1	2.0372	0.6597	0.3697	32.4	18.1	49.5	23.29	13.51	58.0
	50.01	61.20	53.15	73.7	2.0593	0.6220	0.3713	30.2	18.0	51.8	22.54	12.96	57.5

**Table A-2** The average of the percentage conversion, percentage grafted natural rubber, percentage free NR, percentage free PMMA, and percentage grafting efficiency.

Experiment	Avg. Conversion (%)	Avg. Grafted NR (%)	Avg. Free NR (%)	Avg. Free PMMA (%)	Avg. GE. (%)
50I <sub>0.50</sub>	37.5	40.0	43.5	16.5	39.6
50I <sub>0.75</sub>	41.2	54.7	32.1	13.1	54.8
50I <sub>1.00</sub>	52.4	53.9	30.1	16.0	53.5
50I <sub>1.50</sub>	56.9	48.1	32.8	19.1	47.5
50I <sub>2.00</sub>	65.4	44.7	34.5	20.8	47.4
55I <sub>0.50</sub>	67.4	56.4	27.9	15.7	60.9
55I <sub>0.75</sub>	75.9	57.9	26.6	15.4	64.1
55I <sub>1.00</sub>	79.9	54.0	28.1	17.8	59.9
55I <sub>1.50</sub>	82.1	45.5	32.4	22.1	51.0
55I <sub>2.00</sub>	82.3	45.3	32.5	22.2	50.7
60I <sub>0.50</sub>	76.2	45.8	33.4	20.8	52.0
60I <sub>0.75</sub>	81.3	52.9	27.8	19.3	56.9
60I <sub>1.00</sub>	81.3	51.4	29.0	19.6	56.3
60I <sub>1.50</sub>	84.6	46.9	31.2	21.9	52.2
60I <sub>2.00</sub>	85.2	46.1	31.4	22.5	51.2
70I <sub>0.50</sub>	80.3	37.4	36.8	25.9	41.9
70I <sub>0.75</sub>	85.5	48.1	28.9	23.0	50.1
70I <sub>1.00</sub>	85.0	39.8	35.9	24.4	46.9
70I <sub>1.50</sub>	86.0	30.7	41.0	28.3	38.7
70I <sub>2.00</sub>	86.5	30.9	41.3	27.8	40.1

**Table A-2 (Continued)**

Experiment	Avg. Conversion (%)	Avg. Grafted NR (%)	Avg. Free NR (%)	Avg. Free PMMA (%)	Avg. GE. (%)
M <sub>40</sub>	56.0	23.1	64.1	12.8	30.2
M <sub>60</sub>	64.9	37.4	46.5	16.1	42.6
M <sub>80</sub>	74.3	51.2	31.4	17.5	53.0
M <sub>100</sub>	75.9	57.9	26.6	15.4	64.1
M <sub>120</sub>	75.7	44.2	32.0	23.8	49.9
T <sub>4</sub>	67.9	34.4	41.7	23.9	40.9
T <sub>6</sub>	74.5	53.8	29.0	17.2	59.8
T <sub>8</sub>	75.9	57.9	26.6	15.4	64.1
T <sub>10</sub>	74.9	50.6	31.3	18.1	57.8

aI<sub>x</sub> : a = Reaction temperature (°C)

I = Initiator

x = Initiator concentration (phr)

My : M = Monomer

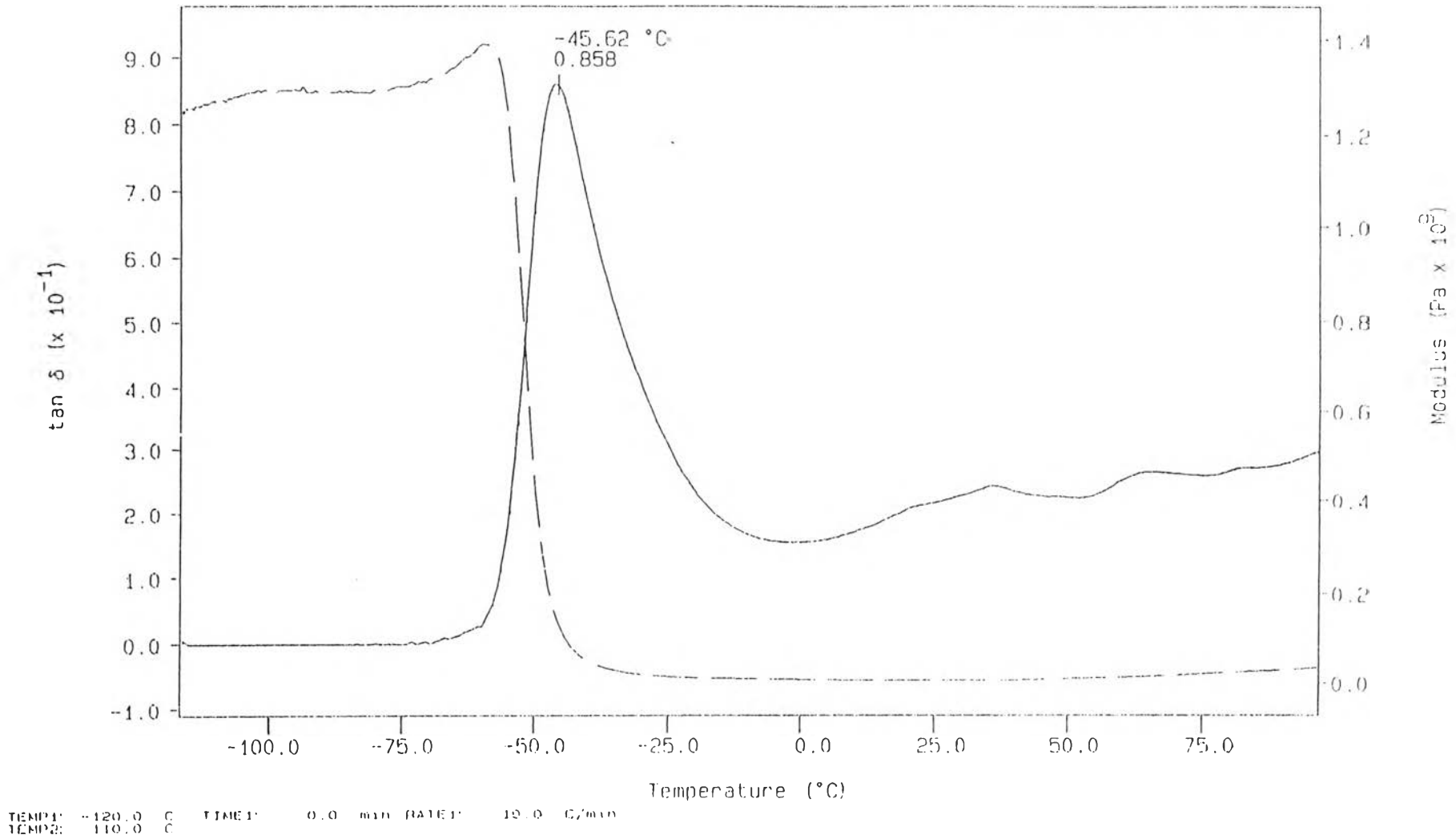
y = Monomer concentration (phr)

Tz : T = Time

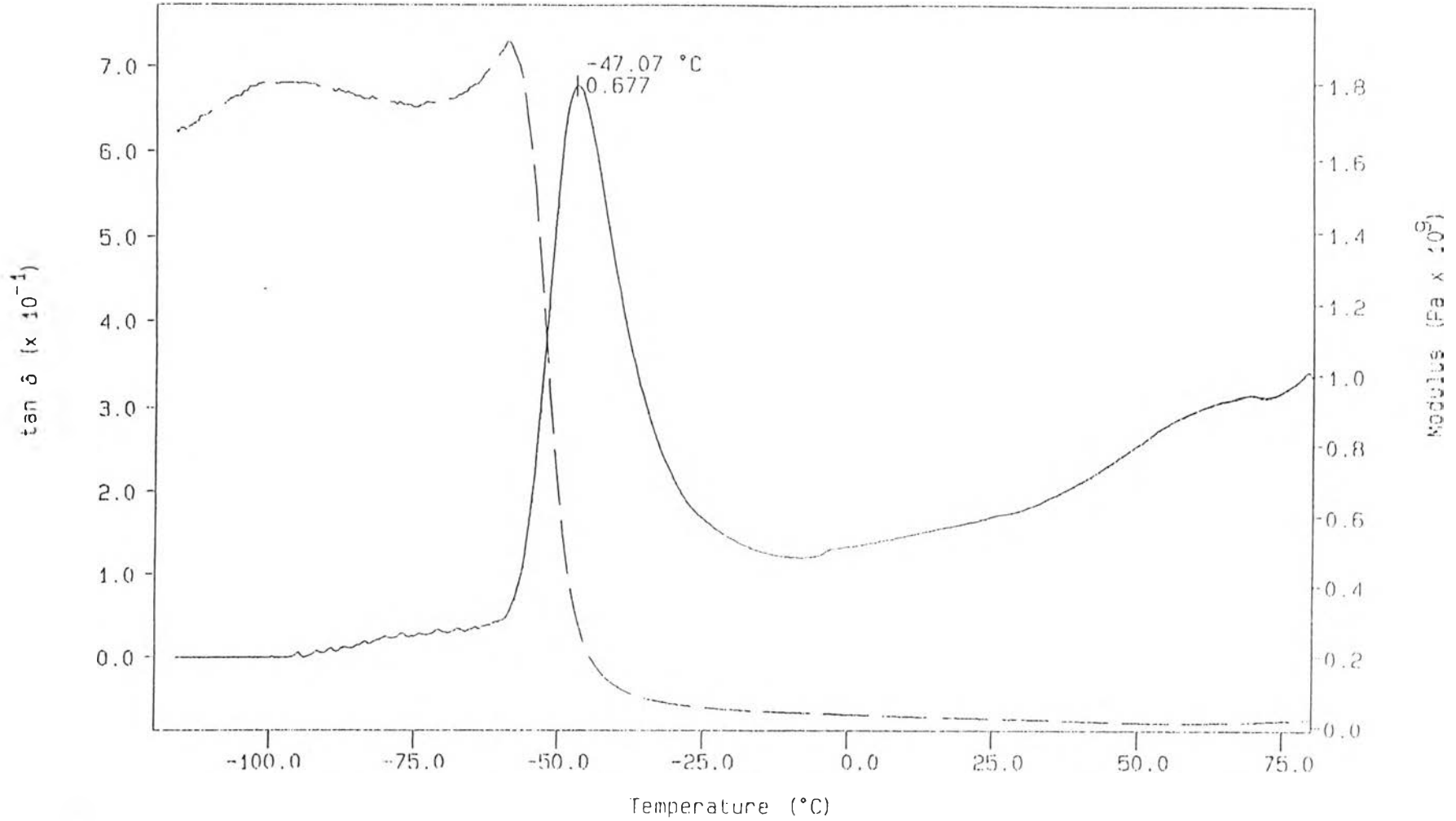
z = Reaction time (hr.)

## **APPENDIX B**

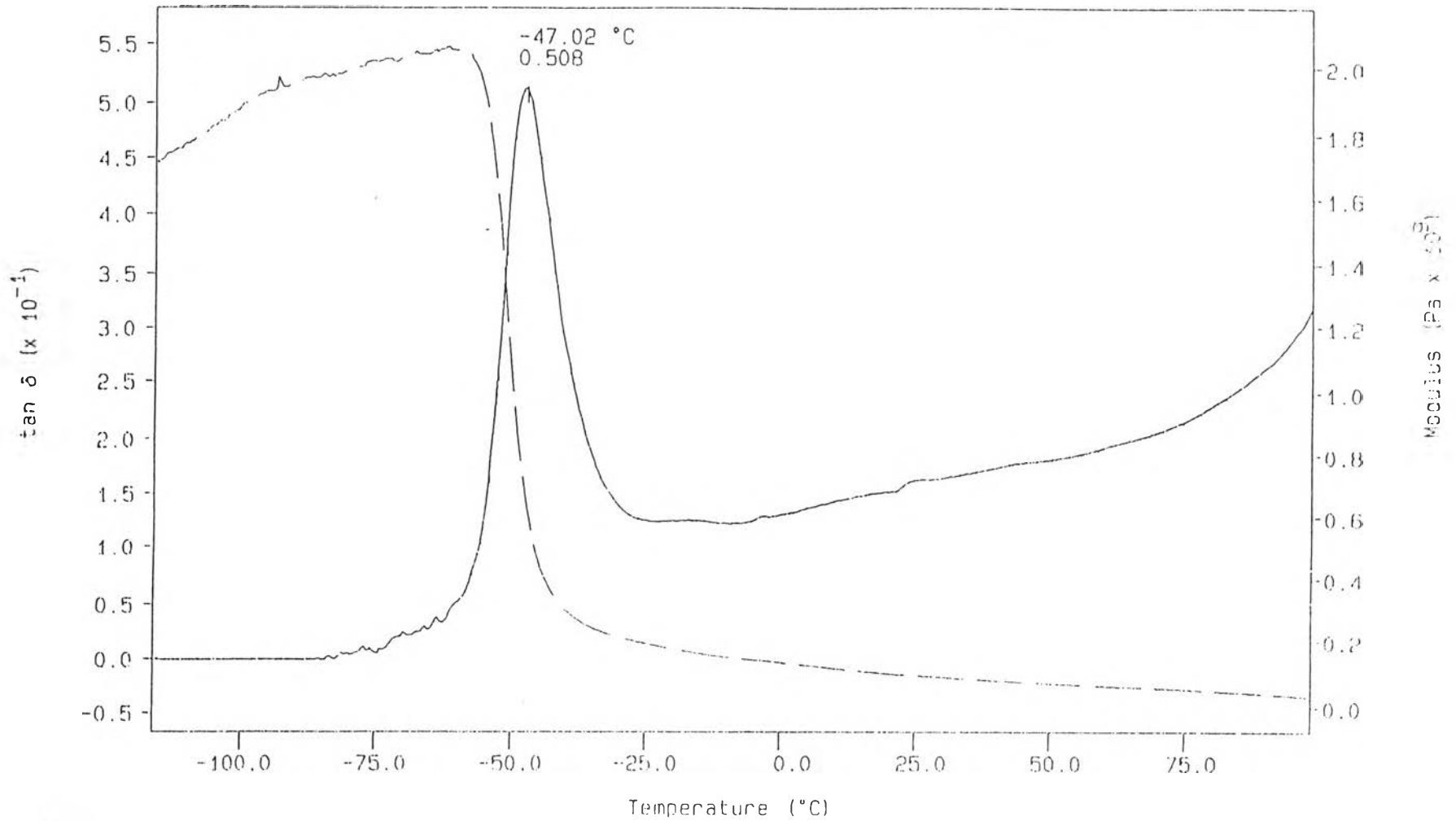
### **Dynamic Mechanical Properties of Grafted Natural Rubber**



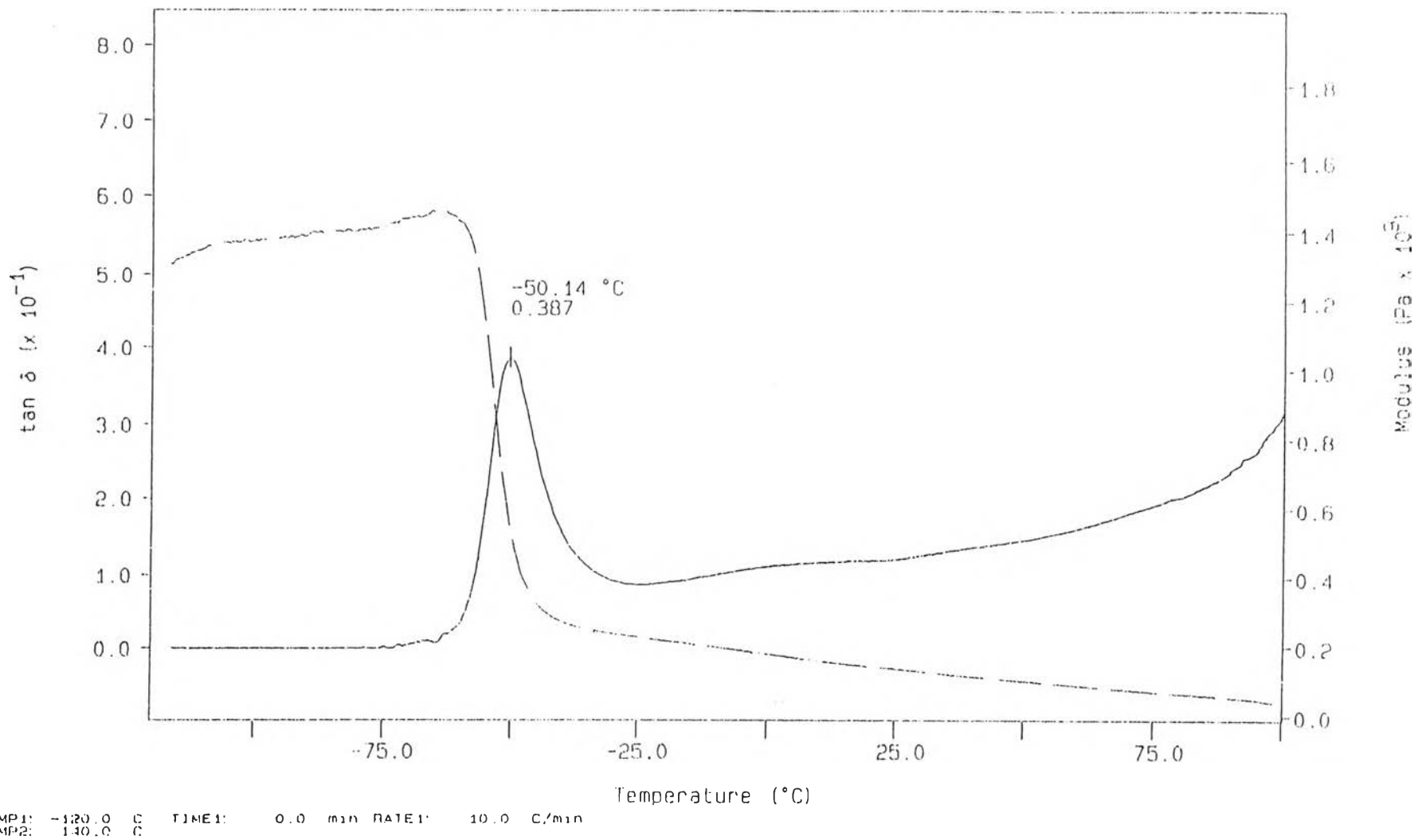
**Figure B-1** Dynamic mechanical properties of grafted natural rubber (MMA 60 phr).



**Figure B-2** Dynamic mechanical properties of grafted natural rubber (MMA 80 phr).



**Figure B-3** Dynamic mechanical properties of grafted natural rubber (MMA 100 phr).



**Figure B-4** Dynamic mechanical properties of grafted natural rubber (MMA 120 phr).



## **APPENDIX C**

### **Mechanical Properties of Grafted Natural Rubber/PMMA Blends**

**Table C-1** Hardness of grafted natural rubber and grafted natural rubber/PMMA blends.

	GNR Type					GNR60/PMMA			GNR100/PMMA		
	GNR40	GNR60	GNR80	GNR100	GNR120	70/30	60/40	50/50	70/30	60/40	50/50
Hardness	2.5	14.8	21.2	32.3	38.9	21.2	37.6	47.8	48.3	55.9	60.9
(Shore D)	2.5	15.3	21.9	31.4	38.6	21.3	36.5	47.0	50.8	57.1	60.7
	2.4	15.0	20.9	32.0	38.2	21.6	35.8	49.1	49.8	55.7	61.0
	2.3	15.3	21.8	31.0	37.8	22.5	35.8	49.3	49.8	58.1	62.9
	2.4	14.9	21.2	30.9	38.9	22.4	35.6	46.8	48.9	56.1	60.6
Median	2.4	15.0	21.2	31.4	38.6	21.6	35.8	47.8	48.9	56.1	60.9
S.D.	0.08	0.23	0.43	0.61	0.48	0.61	0.82	1.16	0.96	1.01	0.95

**Table C-2** Stress at maximum load of GNR/PMMA blends.

	GNR60/PMMA				GNR100/PMMA			
	100/00	70/30	60/40	50/50	100/00	70/30	60/40	50/50
Stress at max.load, (MPa)	3.7	4.0	5.3	7.9	5.1	7.2	11.7	22.6
	3.4	4.1	5.3	8.2	5.2	6.9	11.5	17.8
	3.3	4.2	5.4	8.1	5.1	6.7	11.3	23.5
Mean	3.5	4.1	5.3	8.1	5.1	6.9	11.5	21.3
S.D.	0.21	0.10	0.06	0.15	0.06	0.25	0.20	3.06

**Table C-3** Strain at maximum load of GNR/PMMA blends.

	GNR60/PMMA				GNR100/PMMA			
	100/00	70/30	60/40	50/50	100/00	70/30	60/40	50/50
Strain at max.load,	421.2	106.5	25.1	21.3	123.2	78.8	20.0	7.1
(%)	429.2	107.3	21.3	18.7	82.0	82.0	20.0	6.0
	379.8	103.2	18.6	21.3	67.2	82.8	18.4	6.4
Mean	410.1	105.7	21.7	20.4	90.8	81.2	19.5	6.5
S.D.	26.50	2.17	3.27	1.50	29.02	2.11	0.92	0.56

**Table C-4** Stress @ 100% Modulus of GNR/PMMA blends.

	GNR60/PMMA				GNR100/PMMA			
	100/00	70/30	60/40	50/50	100/00	70/30	60/40	50/50
Stress@100%	1.8	4.0	-	-	-	-	-	-
Modulus, (MPa)	1.8	4.0	-	-	-	-	-	-
	1.6	4.2	-	-	-	-	-	-
Mean	1.7	4.1	-	-	-	-	-	-
S.D.	0.12	0.12	-	-	-	-	-	-

**Table C-5** Tear strength of GNR/PMMA blends.

	GNR60/PMMA				GNR100/PMMA			
	100/00	70/30	60/40	50/50	100/00	70/30	60/40	50/50
Tear strength, (N/mm)	14.3	16.0	16.8	25.5	29.7	65.0	46.9	44.2
	14.6	15.8	16.2	25.0	27.7	65.0	47.0	45.6
	14.6	14.8	15.8	24.4	28.7	55.7	44.4	42.8
Mean	13.2	15.5	16.3	25.0	28.7	61.9	46.1	44.2
S.D.	2.48	0.64	0.50	0.55	1.00	5.37	1.47	1.40

## VITA

Miss Linda Thiraphattaraphun was born on May 6, 1975 in Bangkok, Thailand. She received her Bachelor's degree of Science in Industrial Chemistry, from the Faculty of Science, Chiang Mai University in 1997. She has pursued Master Degree in Petrochemistry and Polymer Science, Program of Petrochemistry and Polymer Science, Graduate School, Chulalongkorn University since 1997 and finished her study in 1999.

