REFERENCE

1. "โรงกลั่นน้ำมันฝาง-ทรัพยากรทางภาคเหนือ" วารสารไทยออลย์ 3, 3 (กันยายน 2531): 13-15.
2. ศศิวิมล บุญทรง, การปรับปรุงคุณภาพส่วนกลั่นหนักเพื่อใช้เป็นน้ำมันหล่อลื่นพื้นฐานโดยกระบวนการบำบัดด้วยไฮโดรเจน, วิทยานิพนธ์ปริญญามหาบัณฑิต, สหสาขาวิชาปิโตรเคมีและโพลิเมอร์, บัณฑิตวิทยาลัย, จุฬาลงกรณ์มหาวิทยาลัย., 2536.
3. Kumer, Y., "Deoiling of Slack Wax by Sweating Technique", Indian Journal of Technology, 17 (April 1979): 125-130.
4. Polishuk, A.T., "Decolorizing Petroleum Wax" US. 3200060, (Aug.10, 1965).
5. Stark, F.R., "Wax Refining", US.3249525 (May 3, 1966).
6. Kay, N.L., "Hydrorefining Petroleum Wax Fractions" US 3365385, (Jan 23, 1968).
7. Convery, R.J., "Wax Refining" US 3265609 (Aug. 9, 1966).
8. Hamner,G. P., "Catalyst for The Hydroisomerization and Hydrocracking of Waxes to Produce Liquid Hydrocarbon Fuels and Process for Preparing the Catalyst" US 4923841, (May 8, 1990).
9. Steimetz, I.,"Isomerization of Waxy Lube Streams and Waxes Using Zeolite Catalyst" US 3764516, (Oct. 9,1973).
10. Cody, I.A., "Wax Isomerization Using Small Particle Low Fluoride Content Catalysts" US 423588, (May 8, 1990).
11. Cody, I.A., "Upgrading waxy distillates and raffinating and Hydroisomerization" US 4992159, (Feb. 12, 1991).
12. Cody, I.A., "Method for isomerizing wax to lube base oil" US. 5059299, (Oct. 22, 1991).

13. สุพิน ต่างวิวัฒน์, การทำไขปิโตรเลียมให้บริสุทธิ์ , วิทยานิพนธ์ปริญญามหาบัณฑิต, สหสาขาวิชาปิโตรเคมี และโพลิเมอร์, บัณฑิตวิทยาลัย, จุฬาลงกรณ์มหาวิทยาลัย, 2536.

14. Nebesh, E. ,"Hydrotreating catalyst" US 4900711, (Feb. 13, 1900).

15. Murphy, Jr., "Process for Hydrodesulfurizing and Hydrotreating Lubricating Oils from Sulfur-Containing Stock" US. 3915841, (Oct. 8, 1975).

16. Hobson, G.D., Modern Petroleum Technology, part II, 5th ed., John Wiley & Sons, London, 1984.

17. Grayson, M., Kirk-Othmer Encyclopedia of Chemical Technology, pp. 293-299, 1259-1260. New york: John Wiley&Sons. Inc., 1985.

18. SBP Board of Consultants and Engineers, Industrial Lubricants Greases and Related Products, pp. 333-384. Delhi: Small Business Publications, 1977.

19 .Warth, A.H., The Chemistry and Technology of Waxes, New York: Reiahold Pub.Co., 1947.

20. Asseff, D.A., Lubrication Theory and Practice, Ohio: The Lubrizol Co. Ltd., 1988.

21. ปราโมทย์ ไชยเวช, ปิโตรเลียมเทคโนโลยี, ภาควิชาเคมีเทคนิค, คณะวิทยาศาสตร์, จุฬาลงกรณ์มหาวิทยาลัย, 2533.

22. Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd ed. Vol. 15, Taiwan: Mei Ya Publications, 1985.

23. Mortier, R.M. and Orszulik, S.T., Chemistry and Technology of Lubricants, Blackie and Sons Ltd., 1992.

24. Emmett, P. H., Catalysis, Vol. V, pp. 405-526. The Waverly Press, Inc., USA, 1958.

25. Gates, B. C., Katzer, J. R. and Schuit, G.C.A., Chemistry of Catalytic process, McGraw-Hill, Inc., USA, 1980.

26. Satterfield, C.N., Heterogeneous Catalysis in Practice, pp. 258-269. McGraw-Hill Book Company, 1980.

27 Mata, S., Mirbach, M. S. and Tayim, H. A., Catalysis in Petrochemical Processes, Kluwer Academic Publishers, Netherlands, 1989.

28 Gates, B.C., Catalytic Chemistry, pp. 396-402. John Willey & Sons, Inc., Singapore, 1992.

29. Brandes, K.K., "Impregnated Alumina-Containing Material" US 4831004, (May 16, 1989).

30. Kemball, C., Catalysis, Vol. I, Billing & Sons, Ltd., London, 1977.

31. Cerverny, L., Catalytic Hydrogenation, Vol. 27, Elsevier Science Publishers B.V., Netherlands, 1986.

32. Chang-Yu Yu and Froment, G.F., "Rate-Equations for the Modeling of the Synergy in Multicomponents with Interconversion of Active-Sites", Chemical Engineering Science, lss 12, Vol. 46: 3177-3180, 1991.

33. Friend, C.M., "Catalysis on Surfaces", Scientific American, April, Vol. 268, No. 4, 1993.

34 Poncelet, G., Jacobs, P.A., Grange, P., and Del mon, B., Preparation of Catalysts V, pp. 611-616. Elsevier Science Publishers B.V., Netherlands, 1991.

35 Foreign Trade Statistics of Thailand, Thai Customs Department, Finance Ministry, Bangkok, 1989-1994.

APPENDIX

Table A1 The molecular weight distributions of components in Fang heavy distillate and slack wax

Molecular weight	No. of carbon	Fang heavy distillate		Slack wax	
		t_R(min)	% peak area	t_R(min)	% peak area
212	C_{15}	9.48	0.04		
236	C_{16}	10.95	0.06		
240	C_{17}	12.37	0.10	12.55	0.30
254	C_{18}	13.71	0.18	13.92	0.9
268	C_{19}	14.98	0.41	15.20	0.31
282	C_{20}	16.20	0.70	16.41	0.85
296	C_{21}	17.36	1.24	17.58	1.97
310	C_{22}	18.47	1.87	18.71	3.07
324	C_{23}	19.54	3.35	19.77	5.21
338	C_{24}	20.58	4.20	20.79	6.20
352	C_{25}	21.57	6.51	21.78	8.13
366	C_{26}	22.51	8.05	22.74	9.05
380	C_{27}	23.45	10.40	23.65	10.73
394	C_{28}	24.31	10.25	24.54	9.96
408	C_{29}	25.18	9.97	25.38	10.23
422	C_{30}	25.98	8.69	26.20	7.73
436	C_{31}	26.77	8.03	26.98	5.98
450	C_{32}	27.51	5.00	27.76	1.52
464	C_{33}	28.24	3.73	28.50	2.30
478	C_{34}	28.95	2.08	29.21	1.21
492	C_{35}	29.64	1.33	29.93	0.99
506	C_{36}	30.39	0.56	30.73	0.27
520	C_{37}	31.23	0.29	31.64	0.11
534	C_{38}	32.21	0.14	32.73	0.07
548	C_{39}	33.34	0.12		
562	C_{40}	34.70	0.07		

Table A2 Properties of the desulfurized waxes from reaction using various catalyst types

(the same conditions: reaction temperature 350°C, hydrogen pressure 500 psig, reaction time 4 hrs, catalyst concentration 5 %wt, and agitation speed 500 rpm.)

Properties	Slack wax	Type of catalyst			
		$MoCoNi/Al_2O_3$	$MoNi/Al_2O_3$	NiW/Al_2O_3	Raney nickel
Color	5.5	1	1.5-2.0	0.5-1.0	1.5
Sulfur content, %wt	0.140	0.035	0.066	0.038	0.081
Oil content, %wt	35.10	35.50	35.22	35.09	41.86
Carbon distribution	C_{17}-C_{38}	C_{17}-C_{38}	C_{17}-C_{38}	C_{17}-C_{38}	C_{14}-C_{38}
Characteristic of catalyst					
- before using		Cylinder	Cylinder	Cylinder	Powder
- after using		Cylinder	Cylinder	Powder	Powder

Table A3 The molecular weight distributions of components in the desulfurized waxes from reaction using various catalyst types

Molecular	No. of	% peak area				
weight	Carbon	Slack wax	$MoCoNi/Al_2O_3$	C20-7-06	T-2563	Raney nickel
170	C_{12}					0.03
184	C_{13}					0.05
198	C_{14}					0.75
212	C_{15}					1.02
236	C_{16}					1.36
240	C_{17}	0.30	0.28	0.31	0.30	1.53
254	C_{18}	0.90	0.91	0.93	0.9	1.67
268	C_{19}	0.31	0.30	0.33	0.32	1.87
282	C_{20}	0.85	0.84	0.79	0.85	1.96
296	C_{21}	1.97	1.89	1.99	2.00	2.25
310	C_{22}	3.07	3.11	3.05	3.10	2.70
324	C_{23}	5.21	5.19	5.21	5.20	3.10
338	C_{24}	6.20	6.20	6.20	6.20	3.86
352	C_{25}	8.13	8.20	8.14	8.15	5.12
366	C_{26}	9.09	9.05	9.05	9.05	6.10
380	C_{27}	10.75	10.73	10.80	10.73	6.42
394	C_{28}	10.30	10.22	10.25	10.31	8.17
408	C_{29}	10.23	10.13	10.22	10.23	8.07
422	C_{30}	7.73	7.73	7.73	7.73	7.16
436	C_{31}	5.98	5.99	5.98	5.98	7.22
450	C_{32}	1.52	1.52	1.50	1.45	5.70
464	C_{33}	2.30	2.30	2.30	2.30	4.50
478	C_{34}	1.21	1.25	1.32	1.21	2.28
492	C_{35}	0.99	1.12	0.99	1.05	1.04
506	C_{36}	0.27	0.30	0.25	0.30	0.66
520	C_{37}	0.11	0.11	0.11	0.11	0.16
534	C_{38}	0.07	0.07	0.06	0.07	0.05

Table A4 Properties of the desulfurized waxes produced at various reaction temperatures

(the same conditions: hydrogen pressure 500 psig, reaction time 4 hrs., catalyst concentration 5 %wt, and agitation speed 500 rpm.)

Properties	Slack wax	Reaction temperature (°C)				
		200	250	300	350	400
Color	5.5	2.5	2.0	1.5	1	0.5-1.0
Sulfur content (%wt)	0.140	0.080	0.060	0.046	0.035	0.030
Oil content (%wt)	35.10	35.79	35.84	36.20	41.60	45.01
Carbon distribution	C_{17}-C_{38}	C_{17}-C_{38}	C_{17}-C_{38}	C_{15}-C_{38}	C_{11}-C_{38}	C_{9}-C_{38}

Table A5 The molecular weight distributions of components in the desulfurized waxes produced at various reaction temperatures

Molecular	No. of	% peak area					
weight	Carbon	Slack wax	200 °C	250 °C	300 °C	350 °C	400 °C
128	C_9						0.12
142	C_{10}						0.90
156	C_{11}					0.06	0.15
170	C_{12}					0.13	0.18
184	C_{13}					0.21	0.20
198	C_{14}					0.25	0.25
212	C_{15}				0.08	0.38	0.39
236	C_{16}				0.18	0.56	0.50
240	C_{17}	0.09	0.10	0.10	0.20	0.50	0.55
254	C_{18}	0.19	0.20	0.20	0.28	0.65	0.68
268	C_{19}	0.31	0.31	0.33	0.60	0.80	0.83
282	C_{20}	0.85	0.80	0.83	0.85	1.0	0.99
296	C_{21}	1.97	1.89	1.99	1.90	1.90	1.89
310	C_{22}	3.12	3.10	3.05	3.07	2.30	2.30
324	C_{23}	5.21	5.25	5.30	5.29	3.54	3.64
338	C_{24}	6.22	6.20	6.21	6.20	4.98	4.98
352	C_{25}	8.13	8.15	8.14	8.11	7.66	7.65
366	C_{26}	9.05	9.04	9.05	9.05	8.90	8.98
380	C_{27}	10.73	10.74	10.80	10.70	10.21	9.12
394	C_{28}	9.86	9.89	9.96	10.06	9.88	9.98
408	C_{29}	10.23	10.23	10.22	10.23	10.25	10.22
422	C_{30}	9.73	9.73	9.73	9.73	10.36	10.50
436	C_{31}	8.98	8.98	7.96	8.98	8.97	9.65
450	C_{32}	5.52	5.45	5.50	5.52	6.99	6.99
464	C_{33}	2.30	2.31	2.36	2.29	2.32	2.30
478	C_{34}	1.24	1.21	1.32	1.26	1.22	1.22
492	C_{35}	0.99	0.99	0.99	0.99	0.90	0.98
506	C_{36}	0.26	0.27	0.25	0.30	0.28	0.28
520	C_{37}	0.11	0.10	0.10	0.10	0.09	0.10
534	C_{38}	0.07	0.06	0.06	0.07	0.03	0.05

Table A6 Properties of the desulfurized waxes produced under various hydrogen pressures

(the same conditions: reaction temperature 400 °C, reaction time 4 hrs., catalyst concentration 5 %wt, and agitation speed 500 rpm.)

Properties	Slack wax	Hydrogen pressure (psig)			
		300	400	500	600
Color	5.5	1.5-2.0	1.0-1.5	1.0	0.5-1.0
Sulfur content (%wt)	0.140	0.040	0.038	0.030	0.027
Oil content (%wt)	35.10	44.32	45.06	45.02	45.20
Carbon distribution	C_{17}-C_{38}	C_9-C_{38}	C_9-C_{38}	C_9-C_{38}	C_9-C_{38}

Table A7 The molecular weight distributions of components in the desulfurized waxes produced under various hydrogen pressures

Molecular weight	No. of Carbon	% peak area				
		Slack wax	300 psig	400 psig	500 psig	600 psig
128	C_9		0.08	0.08	0.09	0.11
142	C_{10}		0.12	0.12	0.11	0.10
156	C_{11}		0.15	0.15	0.15	0.14
170	C_{12}		0.20	0.22	0.18	0.20
184	C_{13}		0.22	0.22	0.20	0.22
198	C_{14}		0.28	0.26	0.25	0.24
212	C_{15}		0.32	0.36	0.39	0.40
236	C_{16}		0.45	0.48	0.50	0.50
240	C_{17}	0.30	0.53	0.54	0.55	0.56
254	C_{18}	0.90	0.60	0.66	0.68	0.68
268	C_{19}	0.31	0.73	0.80	0.83	0.85
282	C_{20}	0.85	0.86	0.96	0.99	1.00
296	C_{21}	1.97	1.97	1.88	1.89	1.90
310	C_{22}	3.07	2.47	2.48	2.30	2.35
324	C_{23}	5.21	4.20	3.60	3.64	3.62
338	C_{24}	6.20	6.22	6.20.	5.98	5.96
352	C_{25}	8.13	8.14	7.98	7.65	7.68
366	C_{26}	9.05	9.00	8.96	8.98	8.98
380	C_{27}	9.73	9.68	9..60	9.12	9.15
394	C_{28}	9.96	9.99	9.89	9.98	9.98
408	C_{29}	10.23	10.22	10.22	10.22	10.20
422	C_{30}	9.73	9.73	9.65	10.10	1.12
436	C_{31}	7.98	7.96	8.98	9.65	9.09
450	C_{32}	5.52	5.50	5.00.	4.99	5.10
464	C_{33}	2.40	2.40	2.30	2.30	2.38
478	C_{34}	1.31	1.34	1.25	1.22	1.34
492	C_{35}	0.99	1.02	0.99	0.98	0.99
506	C_{36}	0.27	0.28	0.28	0.28	0.28
520	C_{37}	0.11	0.16	0.11	0.10	0.11
534	C_{38}	0.07	0.06	0.06	0.05	0.05

Table A8 Properties of the desulfurized waxes after various reaction times (the same conditions: reaction temperature 400 °C, hydrogen pressure 600 psi, catalyst concentration 5 %wt, and agitation speed 500 rpm.)

Properties	Slack wax	Reaction time (hrs.)			
		4	6	8	10
Color	5.5	0.5-1.0	0.5-1.0	0.5	0.5
Sulfur content (%wt)	0.140	0.027	0.020	0.015	0.013
Oil content (%wt)	35.10	45.20	46.98	49.66	51.80
Carbon distribution	C_{17}-C_{38}	C_{10}-C_{38}	C_{17}-C_{38}	C_{17}-C_{38}	C_{17}-C_{38}

Table A9 The molecular weight distributions of components in the desulfurized waxes after various reaction times

Molecular	No. of	% peak area				
weight	Carbon	Slack wax	4 hrs	6 hrs	8 hrs	10 hrs
128	C_9		0.11	0.11	0.11	0.14
142	C_{10}		0.10	0.12	0.13	0.15
156	C_{11}		0.14	0.16	0.15	0.18
170	C_{12}		0.20	0.20	0.21	0.20
184	C_{13}		0.22	0.21	0.26	0.29
198	C_{14}		0.24	0.28	0.32	0.35
212	C_{15}		0.40	0.43	0.50	0.52
236	C_{16}		0.50	0.51	0.53	0.55
240	C_{17}	0.30	0.56	0.59	0.62	0.66
254	C_{18}	0.9	0.68	0.72	0.78	0.81
268	C_{19}	0.31	0.85	0.88	0.89	0.95
282	C_{20}	0.85	1.00	1.05	1.10	1.20
296	C_{21}	1.97	1.90	1.88	1.88	1.89
310	C_{22}	3.07	2.35	2.31	2.35	2.32
324	C_{23}	5.21	3.62	3.62	3.60	3.61
338	C_{24}	6.20	5.96	5.94	5.94	5.91
352	C_{25}	8.13	7.68	7.65	7.64	7.62
366	C_{26}	9.05	8.98	8.98	8.96	8.92
380	C_{27}	10.73	9.15	9.14	9.11	8.95
394	C_{28}	9.96	9.98	9.96	9.89	9.86
408	C_{29}	10.23	10.20	10.20	10.26	10.15
422	C_{30}	7.73	10.12	10.06	10.02	9.92
436	C_{31}	5.98	9.09	9.06	8.98	8.92
450	C_{32}	3.52	5.12	5.10	5.09	5.06
464	C_{33}	2.30	2.38	2.38	2.37	2.35
478	C_{34}	1.21	1.34	1.34	1.32	1.30
492	C_{35}	0.99	0.99	0.99	0.99	0.99
506	C_{36}	0.27	0.28	0.27	0.27	0.26
520	C_{37}	0.11	0.11	0.11	0.11	0.11
534	C_{38}	0.07	0.05	0.05	0.05	0.05

Table A10 Properties of the desulfurized waxes produced using various catalyst concentrations

(the same conditions: reaction temperature 400 °C, hydrogen pressure 600 psig, reaction time 8 hrs, and agitation speed 500 rpm.)

Properties	Slack wax	Catalyst concentration (%wt)				
		5.0	2.0	1.0	0.5	0.2
Color	5.5	0.5	0.5-1.0	1.0-1.5	1.0-1.5	2.0-2.5
Sulfur content (%wt)	0.140	0.015	0.013	0.011	<0.001	<0.001
Oil content (%wt)	35.10	49.66	49.68	49.65	49.66	49.64
Carbon distribution	C_{17}-C_{38}	C_9-C_{38}	C_9-C_{38}	C_9-C_{38}	C_9-C_{38}	C_9-C_{38}

Table A11 The molecular weight distributions of components in the desulfurized waxes produced using various catalyst concentrations

Molecular	No. of	% peak area					
weight	Carbon	Slack wax	5.0 % wt	2.0 % wt	1.0 % wt	0.5 % wt	0.2 % wt
128	C_9		0.11	0.11	0.11	0.11	0.11
142	C_{10}		0.14	0.13	0.14	0.15	0.15
156	C_{11}		0.15	0.15	0.15	0.16	0.15
170	C_{12}		0.19	0.18	0.19	0.20	0.21
184	C_{13}		0.26	0.24	0.26	0.25	0.25
198	C_{14}		0.29	0.28	0.30	0.30	0.29
212	C_{15}		0.40	0.39	0.39	0.40	0.38
236	C_{16}		0.53	0.55	0.54	0.55	0.56
240	C_{17}	0.30	0.60	0.62	0.62	0.61	0.64
254	C_{18}	0.90	0.78	0.79	0.80	0.80	0.79
268	C_{19}	0.31	0.89	0.90	0.91	0.89	0.89
282	C_{20}	0.85	1.11	1.12	1.10	1.11	1.09
296	C_{21}	1.97	1.98	1.98	1.96	2.00	1.99
310	C_{22}	3.07	2.35	2.32	2.36	2.35	2.37
324	C_{23}	5.21	3.61	3.60	3.61	3.59	3.62
338	C_{24}	6.20	5.94	5.97	5.96	5.94	5.96
352	C_{25}	8.13	7.64	7.65	7.62	7.62	7.60
366	C_{26}	9.05	8.96	8.98	8.99	8.99	8.96
380	C_{27}	10.73	9.11	9.18	9.18	9.15	9.16
394	C_{28}	9.96	9.89	9.90	9.89	9.99	9.90
408	C_{29}	10.23	10.22	10.26	10.27	10.26	10.29
422	C_{30}	7.73	10.12	10.02	10.23	10.14	10.00
436	C_{31}	5.98	8.98	9.01	8.98	8.99	9.00
450	C_{32}	1.52	5.09	5.10	5.10	5.12	5.08
464	C_{33}	2.30	2.35	2.39	2.40	2.37	2.37
478	C_{34}	1.21	1.32	1.32	1.30	1.31	1.29
492	C_{35}	0.99	1.00	0.98	0.95	0.99	1.00
506	C_{36}	0.27	0.28	0.28	0.29	0.27	0.27
520	C_{37}	0.11	0.13	0.11	0.11	0.13	0.12
534	C_{38}	0.07	0.04	0.04	0.06	0.06	0.05

Table A12 Results of hydroisomerizatiom of slack wax at various conditions

Various parameter	Constant parameter	Color	Oil content (%wt)
Temperature	***P_H , Time, conc. of catalyst***		
250	600 psig, 4 hrs., 2 %wt	1.0	49.79
300	***600 psig, 4 hrs., 2 %wt***	***0.5-1.0***	***49.98***
350	600 psig, 4 hrs., 2 %wt	0.5-1.0	51.68
400	600 psig, 4 hrs., 2 %wt	0.5	55.30
Hydrogen pressure, psig	***Temp., Time, conc. of catalyst***		
300	300 °C, 4 hrs., 2 %wt	1.0-1.5	47.67
400	300 °C, 4 hrs., 2 %wt	1.0	48.89
500	300 °C, 4 hrs., 2 %wt	1.0	49.65
600	***300 °C, 4 hrs., 2 %wt***	***0.5-1.0***	***49.98***
Conc. of catalyst, %wt	***Temp., P_H , Time***		
2.0	300 °C, 600 psig, 4 hrs.	0.5-1.0	49.98
4.0	300 °C, 600 psig, 4 hrs.	0.5-1.0	50.22
5.0	300 °C, 600 psig, 4 hrs.	0.5-1.0	53.89
6.0	***300 °C, 600 psig, 4 hrs.***	***0.5***	***54.63***
7.0	300 °C, 600 psig, 4 hrs.	0.5	56.10
Reaction time, hours	***Temp.,P_H , conc. of catalyst***		
4	300 °C, 600 psig, 6.0%wt	0.5	54.63
6	300 °C, 600 psig, 6.0%wt	0.5	56.98
8	300 °C, 600 psig, 6.0%wt	0-0.5	61.12
10	300 °C, 600 psig, 6.0%wt	0-0.5	65.20
12	***300 °C, 600 psig, 6.0%wt***	***~0***	***69.13***

Table A13 The molecular weight distributions of components in the isomerized waxes produced at various reaction temperatures

Molecular weight	No. of Carbon	% peak area				
		HDS wax	250 °C	300 °C	350 °C	400 °C
128	C_9	0.11	0.09	0.20	0.12	
142	C_{10}	0.15	0.15	0.50	0.36	0.73
156	C_{11}	0.16	0.26	0.77	0.66	1.00
170	C_{12}	0.20	0.73	0.99	0.78	1.33
184	C_{13}	0.25	1.00	1.09	0.91	1.50
198	C_{14}	0.30	1.33	1.40	1.20	1.84
212	C_{15}	0.40	1.50	1.61	1.41	2.15
236	C_{16}	0.55	1.84	1.92	1.52	2.53
240	C_{17}	0.61	2.15	1.94	1.70	2.62
254	C_{18}	0.80	2.53	2.04	1.88	2.81
268	C_{19}	0.89	2.62	2.39	2.20	3.22
282	C_{20}	1.11	2.81	2.68	2.49	3.34
296	C_{21}	2.00	3.22	3.34	3.13	3.73
310	C_{22}	2.35	3.34	3.91	3.87	4.37
324	C_{23}	3.59	3.73	5.34	5.09	5.34
338	C_{24}	5.94	4.37	5.59	5.79	5.59
352	C_{25}	7.62	5.34	6.92	6.75	6.50
366	C_{26}	8.99	5.59	7.46	7.32	6.84
380	C_{27}	9.15	6.50	8.39	8.30	7.40
394	C_{28}	9.99	6.84	7.72	0.73	6.50
408	C_{29}	10.26	7.40	7.24	7.78	6.14
422	C_{30}	10.14	6.50	5.95	7.35	4.71
436	C_{31}	8.99	6.14	4.86	6.07	3.53
450	C_{32}	5.12	4.71	3.00	4.89	2.20
464	C_{33}	2.37	3.53	1.83	3.05	1.29
478	C_{34}	1.31	2.20	0.92	1.81	0.60
492	C_{35}	0.99	1.29	0.47	0.96	0.43
506	C_{36}	0.27	0.60	0.20	0.58	0.13
520	C_{37}	0.13	0.43	0.11	0.21	0.10
534	C_{38}	0.06	0.13	0.06	0.07	0.04

Table A14 The molecular weight distributions of components in the isomerized waxes produced under various hydrogen pressures

Molecular	No. of	% peak area				
weight	Carbon	HDS wax	300 psig	400 psig	500 psig	600 psig
128	C_9	0.02	0.02	0.02	0.04	0.03
142	C_{10}	0.05	0.05	0.04	0.06	0.04
156	C_{11}	0.16	0.17	0.16	0.15	0.15
170	C_{12}	0.39	0.50	0.49	0.35	0.48
184	C_{13}	0.65	0.70	0.71	0.65	0.68
198	C_{14}	0.80	0.79	0.82	0.82	0.78
212	C_{15}	1.40	1.028	1.08	1.09	1.08
236	C_{16}	1.15	1.24	1.24	1.25	1.22
240	C_{17}	1.21	1.48	1.36	1.51	1.36
254	C_{18}	1.58	1.50	1.53	1.54	1.49
268	C_{19}	1.89	1.78	1.71	1.73	1.73
282	C_{20}	2.11	2.09	2.06	2.04	2.05
296	C_{21}	2.20	2.22	2.25	2.32	2.32
310	C_{22}	2.95	2.90	2.94	2.95	2.95
324	C_{23}	3.59	3.60	3.66	3.63	3.39
338	C_{24}	4.94	4.85	4.99	4.80	4.81
352	C_{25}	6.62	5.89	5.66	5.51	5.49
366	C_{26}	7.99	7.38	6.82	6.61	6.60
380	C_{27}	8.15	8.00	7.47	7.23	7.47
394	C_{28}	8.99	8.45	8.57	8.40	8.56
408	C_{29}	9.26	9021	8.97	8.85	8.66
422	C_{30}	8.14	8.02	7.70	7.42	7.56
436	C_{31}	6.99	6.50	6.47	6.51	6.48
450	C_{32}	5.12	5.24	5.14	5.19	5.20
464	C_{33}	3.37	3.22	3.39	3.51	3.48
478	C_{34}	2.31	2.45	2.06	2.19	2.01
492	C_{35}	0.99	1.08	1.07	1.16	1.09
506	C_{36}	0.67	0.72	0.67	0.73	0.66
520	C_{37}	0.23	0.28	0.25	0.28	0.23
534	C_{38}	0.16	0.14	0.14	0.16	0.10
548	C_{39}	0.09	0.09	0.10	0.10	0.09

Table A15 The molecular weight distributions of components in the isomerized waxes produced at various catalyst concentrations

Molecular	No. of	% peak area					
weight	Carbon	HDS wax	2.0 % wt	4.0 % wt	5.0 % wt	6.0 % wt	7.0 % wt
128	C_9	0.11	0.34	0.41	0.39	0.20	0.50
142	C_{10}	0.15	0.58	0.56	0.61	0.50	0.75
156	C_{11}	0.16	0.7	0.69	0.85	0.77	1.00
170	C_{12}	0.20	0.82	0.82	0.20	0.99	1.02
184	C_{13}	0.25	1.09	1.08	0.90	1.09	1.36
198	C_{14}	0.30	1.25	1.24	1.23	1.40	1.53
212	C_{15}	0.40	1.51	1.36	1.45	1.61	1.97
236	C_{16}	0.55	1.54	1.53	1.61	1.92	1.87
240	C_{17}	0.61	1.73	1.71	1.81	1.94	1.96
254	C_{18}	0.80	2.04	2.06	2.05	2.04	2.39
268	C_{19}	0.89	0.88	2.25	2.31	2.39	2.71
282	C_{20}	1.11	2.95	2.94	2.69	2.68	3.17
296	C_{21}	2.00	3.63	3.66	3.14	3.34	3.98
310	C_{22}	2.35	4.80	4.99	3.87	3.91	5.12
324	C_{23}	3.59	5.51	5.66	5.13	5.34	5.69
338	C_{24}	5.94	6.61	6.82	5.38	5.59	6.53
352	C_{25}	7.62	7.23	7.47	6.81	6.92	6.99
366	C_{26}	8.99	8.40	8.57	6.84	7.46	8.07
380	C_{27}	9.15	7.85	7.97	8.36	8.39	7.16
394	C_{28}	9.99	7.42	7.70	7.21	7.72	7.23
408	C_{29}	10.26	6.51	6.47	7.33	7.24	5.70
422	C_{30}	10.14	5.19	5.14	6.10	5.95	4.48
436	C_{31}	8.99	3.50	3.39	5.09	4.86	2.74
450	C_{32}	5.12	2.19	2.06	3.02	3.00	1.64
464	C_{33}	2.37	1.16	1.07	2.18	1.83	0.86
478	C_{34}	1.31	0.73	0.67	1.09	0.92	0.72
492	C_{35}	0.99	0.28	0.25	0.61	0.47	0.62
506	C_{36}	0.27	0.16	0.14	0.28	0.20	0.16
520	C_{37}	0.13	0.10	0.10	0.17	0.11	0.08
534	C_{38}	0.06	0.08	0.07	0.10	0.06	0.03

Table A16 The molecular weight distributions of components in the isomerized waxes after various reaction times

Molecular	No. of	% peak area					
weight	Carbon	HDS wax	4 hrs.	6 hrs.	8 hrs.	10 hrs.	12 hrs.
128	C_9	0.11	0.12	0.39	0.40	0.50	0.50
142	C_{10}	0.15	0.36	0.61	0.70	0.75	0.78
156	C_{11}	0.16	0.66	0.85	0.88	1.00	1.09
170	C_{12}	0.20	0.78	0.89	1.00	1.02	1.12
184	C_{13}	0.25	0.91	0.90	1.28	1.36	1.39
198	C_{14}	0.30	1.20	1.23	1.39	1.53	1.62
212	C_{15}	0.40	1.41	1.45	1.41	1.97	1.90
236	C_{16}	0.55	1.52	1.61	1.52	1.87	1.98
240	C_{17}	0.61	1.70	1.81	1.70	1.96	2.06
254	C_{18}	0.80	1.88	2.05	1.88	2.39	2.39
268	C_{19}	0.89	2.20	2.31	2.20	2.71	2.71
282	C_{20}	1.11	2.49	2.69	2.49	3.17	3.17
296	C_{21}	2.00	3.13	3.14	3.13	3.98	3.98
310	C_{22}	2.35	3.87	3.87	3.87	5.12	5.12
324	C_{23}	3.59	5.09	5.13	5.09	5.69	5.69
338	C_{24}	5.94	5.79	5.38	5.79	6.53	6.53
352	C_{25}	7.62	6.75	6.81	6.75	6.99	6.99
366	C_{26}	8.99	7.32	6.84	6.89	8.07	8.07
380	C_{27}	9.15	8.30	8.36	8.36	7.16	7.16
394	C_{28}	9.99	0.73	7.21	7.24	7.23	7.23
408	C_{29}	10.26	7.78	7.33	7.36	5.70	5.70
422	C_{30}	10.14	7.35	6.10	6.12	4.48	4.48
436	C_{31}	8.99	6.07	5.09	5.10	2.74	2.74
450	C_{32}	5.12	4.89	3.02	3.21	1.64	1.64
464	C_{33}	2.37	3.05	2.18	2.19	0.86	0.86
478	C_{34}	1.31	1.81	1.09	1.64	0.72	0.72
492	C_{35}	0.99	0.96	0.61	0.86	0.62	0.62
506	C_{36}	0.27	0.58	0.28	0.62	0.16	0.16
520	C_{37}	0.13	0.21	0.17	0.08	0.08	0.08
534	C_{38}	0.06	0.07	0.10	0.03	0.03	0.03

Table A17 The molecular weight distributions of components in the isomerized product

Molecular weight	No. of Carbon	% peak area			
		.HDI wax	Deoiled wax	Lube base	Lube fraction residue
128	C_9	0.50			
142	C_{10}	0.78			
156	C_{11}	1.09			
170	C_{12}	1.12			
184	C_{13}	1.39			
198	C_{14}	1.62			
212	C_{15}	1.90			
236	C_{16}	1.98			
240	C_{17}	2.06			
254	C_{18}	2.39			
268	C_{19}	2.71			
282	C_{20}	3.17			0.98
296	C_{21}	3.98		1.30	1.89
310	C_{22}	5.12		2.26	3.01
324	C_{23}	5.69	0.92	2.63	5.78
338	C_{24}	6.53	2.35	3.30	7.86
352	C_{25}	6.99	4.36	3.84	9.32
366	C_{26}	8.07	6.79	10.59	10.84
380	C_{27}	7.16	7.00		11.00
394	C_{28}	7.23	11.14		7.75
408	C_{29}	5.70	13.66		7.76
422	C_{30}	4.48	11.20		7.65
436	C_{31}	2.74	10.65		7.68
450	C_{32}	1.64	10.24		5.48
464	C_{33}	0.86	8.80		3.10
478	C_{34}	0.72	5.86		1.21
492	C_{35}	0.62	3.10		
506	C_{36}	0.16	2.40		
520	C_{37}	0.08			
534	C_{38}	0.03			
414				4.37	
398				8.65	
412				8.27	
426				2.52	
440					

Table A18 The UV absorption of food and/or pharmaceutical grade wax and wax from hydroisomerization process (HDI)

Wavelength (nm)	Max. Value of UV absorption	
	Food and/or parmaceutical wax	Wax from HDI
280-289	0.15	0.015
290-299	0.12	0.013
300-359	0.08	0.005
360-400	0.02	0.001

Table A19 Statistic of petroleum jelly and paraffin waxes (containing by weight less than 0.75% of oil) import in Thailand [35]

Year	Quantity(ton)		C.I.F. value(million baht)	
	Petroleum jelly	Parffin waxes (containing <0.75% of oil)	Petroleum jelly	Parffin waxes (containing <0.75% of oil)
1989	1367	5712	25.1	84.6
1990	1590	5054	28.4	79.0
1991	1586	4805	29.9	65.8
1992	1282	5656	13.7	82.8
1993	1378	9550	32.2	122.3
1994(Jan.-Jul.)	825	6629	19.9	82.9

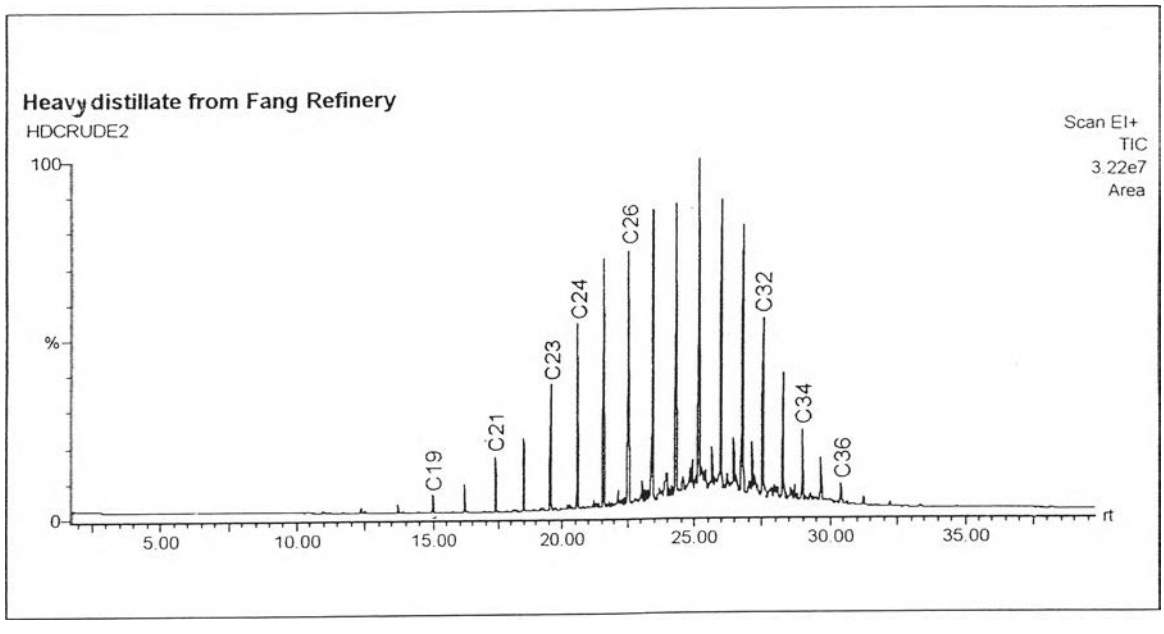


Figure A1 GC/MS Chromatrogram of heavy distillate crude from Fang refinery (DB-1 capillary column 30 m)

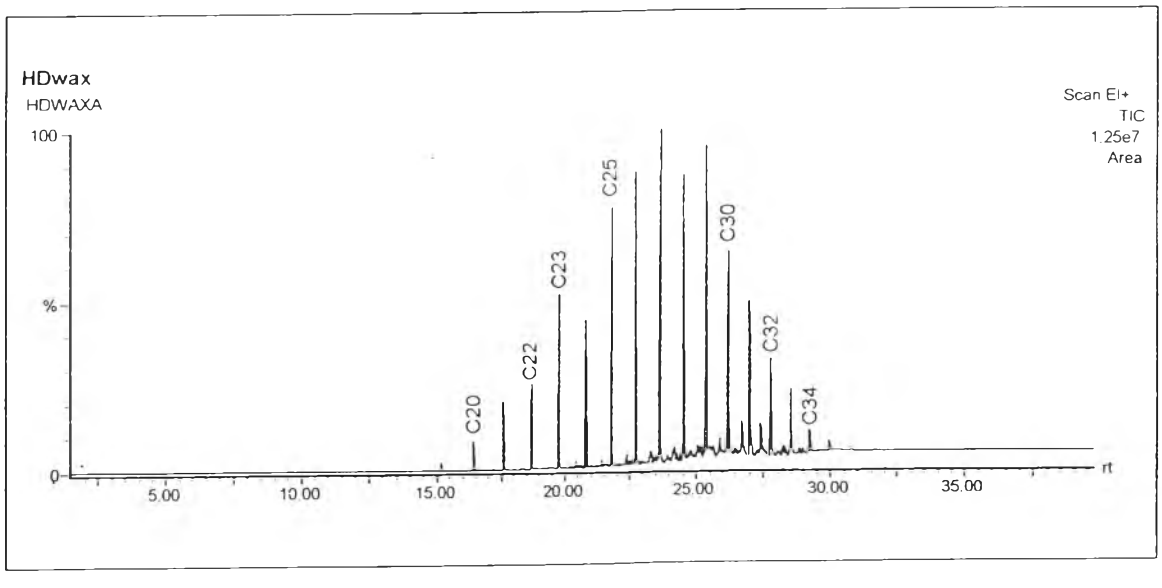


Figure A2 GC/MS Chromatrogram of slack wax from deoiling of heavy distillate crude.

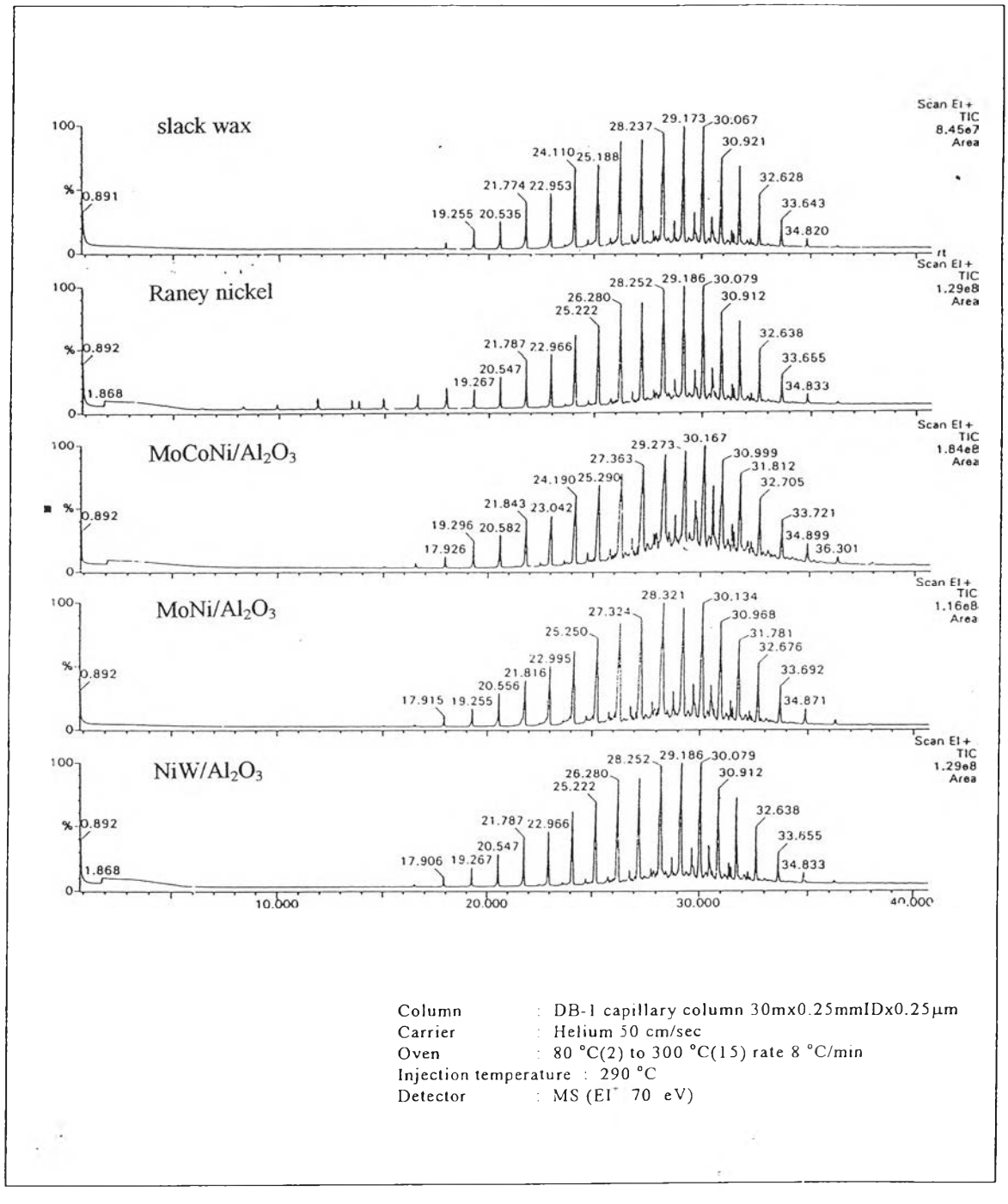
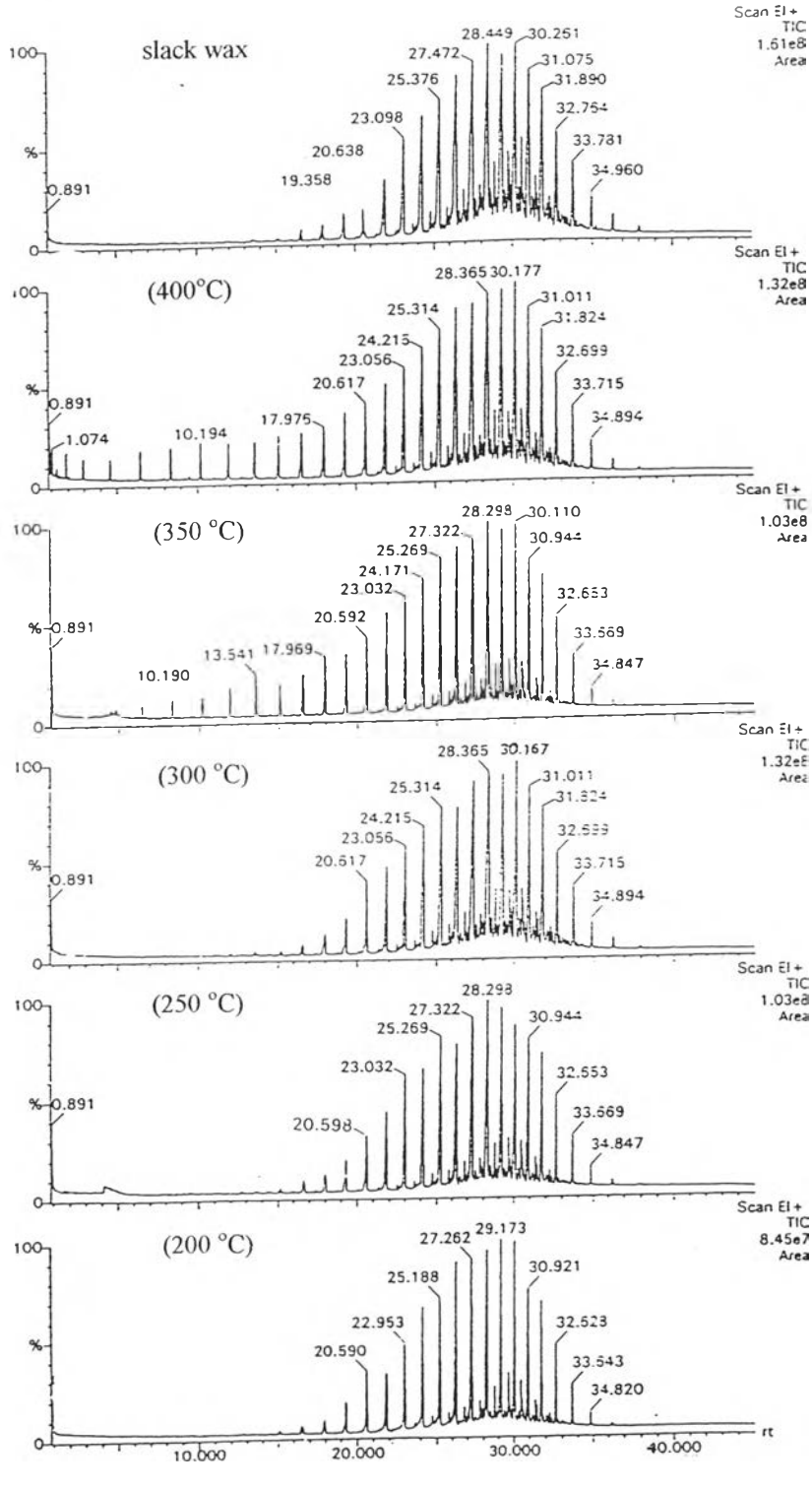


Figure A3 GC/MS Chromatrograms of desulfurized wax at various catalyst types



Column : DB-1 capillary column 30mx0.25mmIDx0.25μm
Carrier : Helium 50 cm/sec
Oven : 80 °C(2) to 300 °C(15) rate 8 °C/min
Injection temperature : 290 °C
Detector : MS (EI° 70 eV)

Figure A4 GC/MS Chromatrograms of desulfurized wax at various reaction temperatures

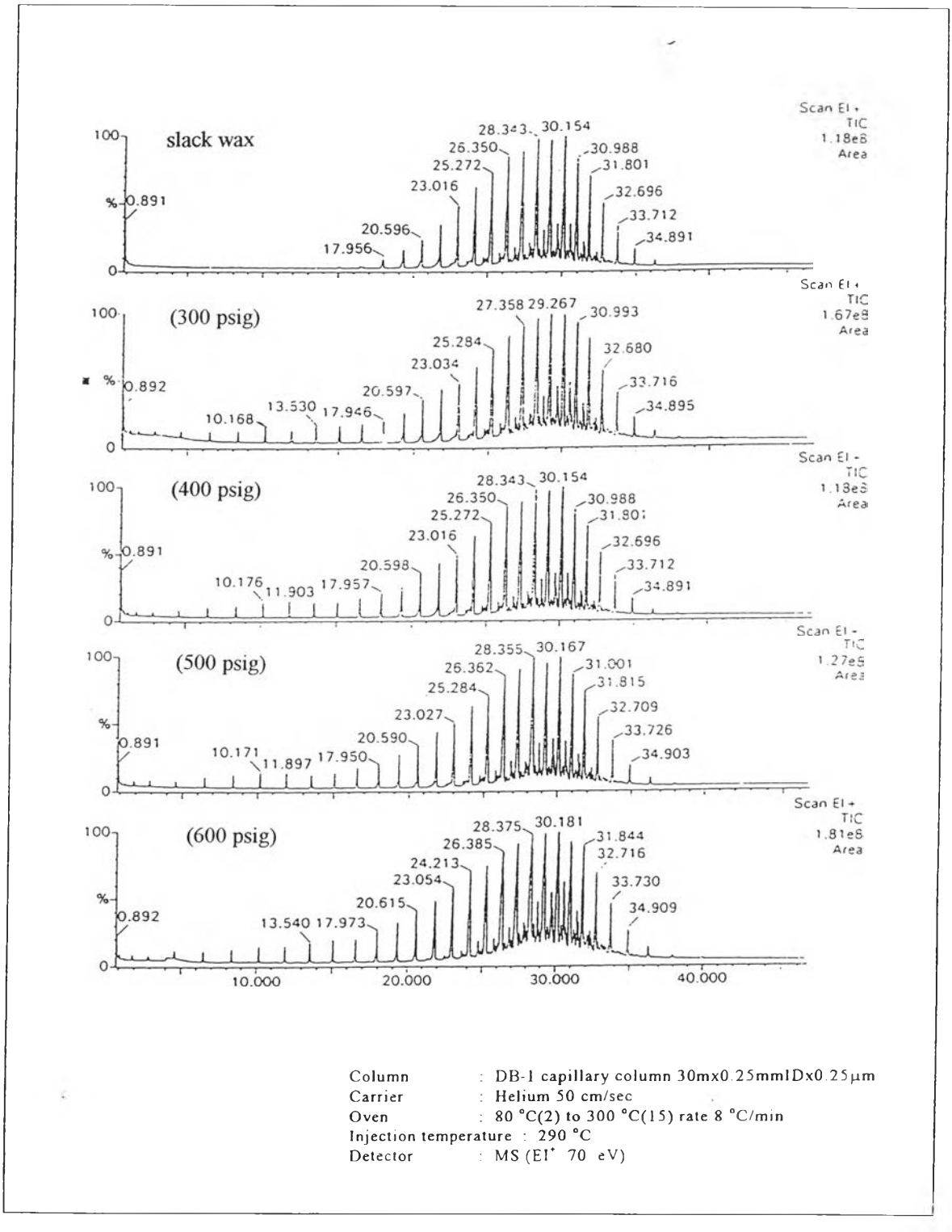


Figure A5 GC/MS Chromatograms of desulfurized wax at various hydrogen pressures

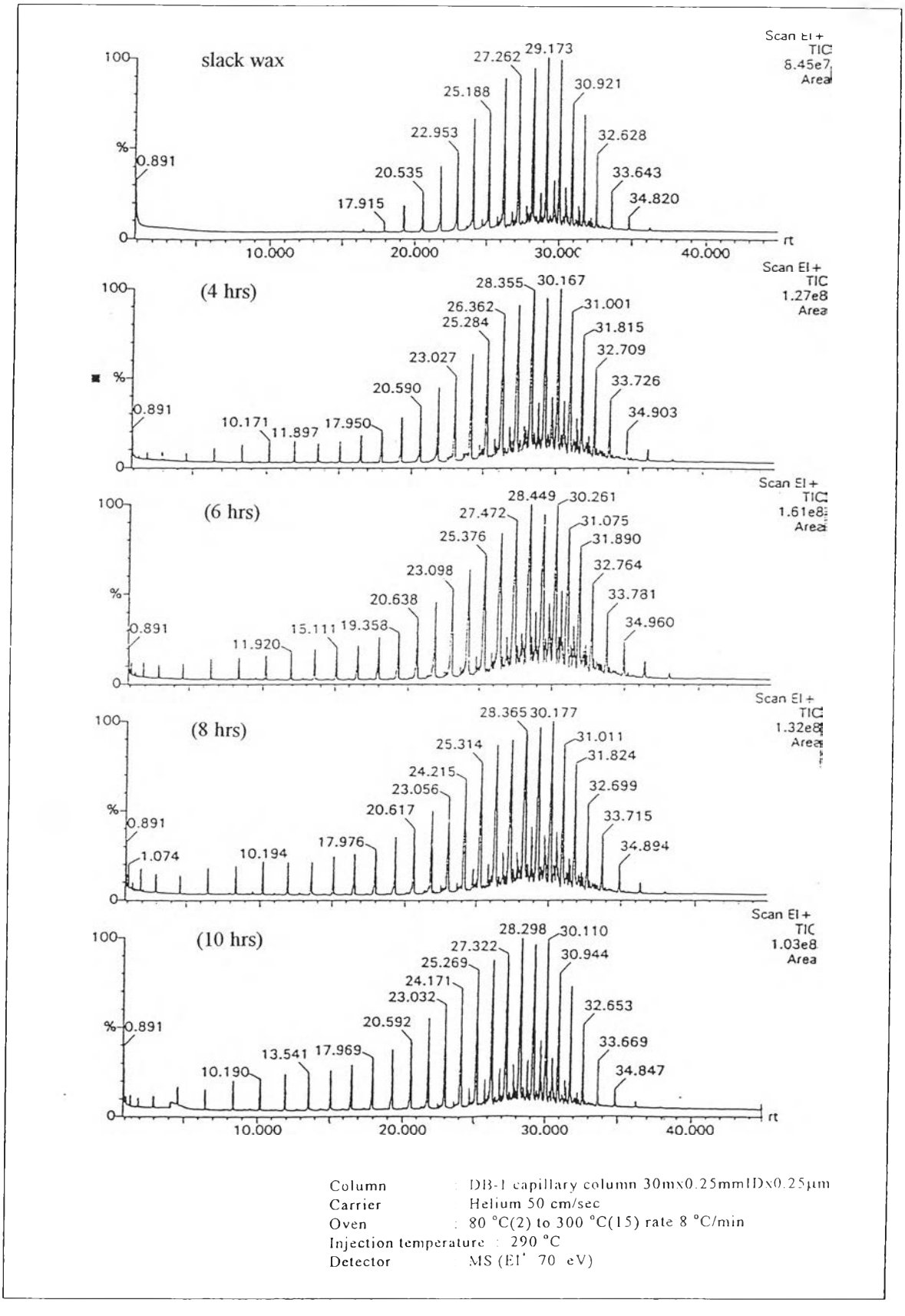


Figure A6 GC/MS Chromatograms of desulfurized wax at various reaction times

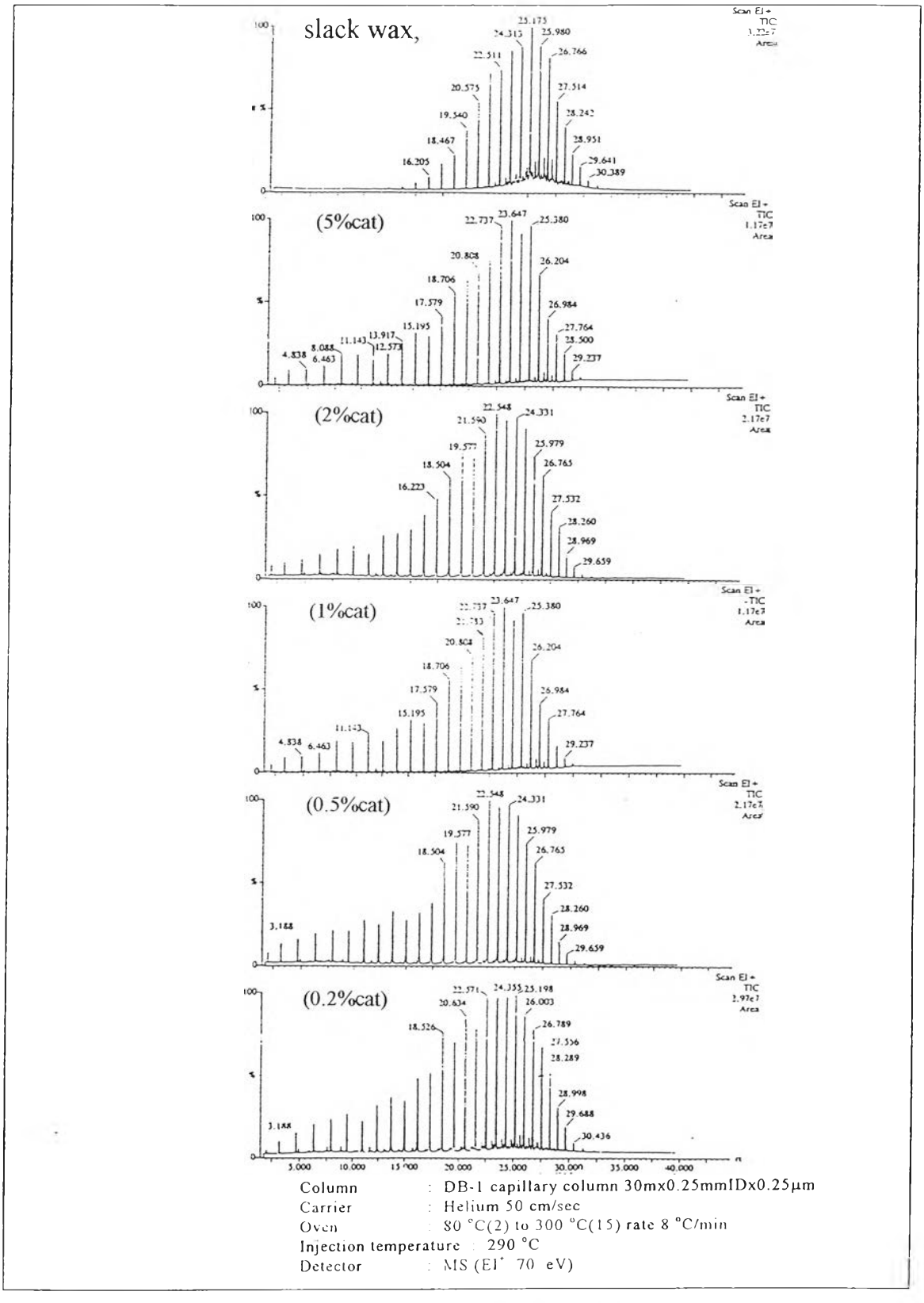


Figure A7 GC/MS Chromatograms of desulfurized wax at various catalyst concentrations

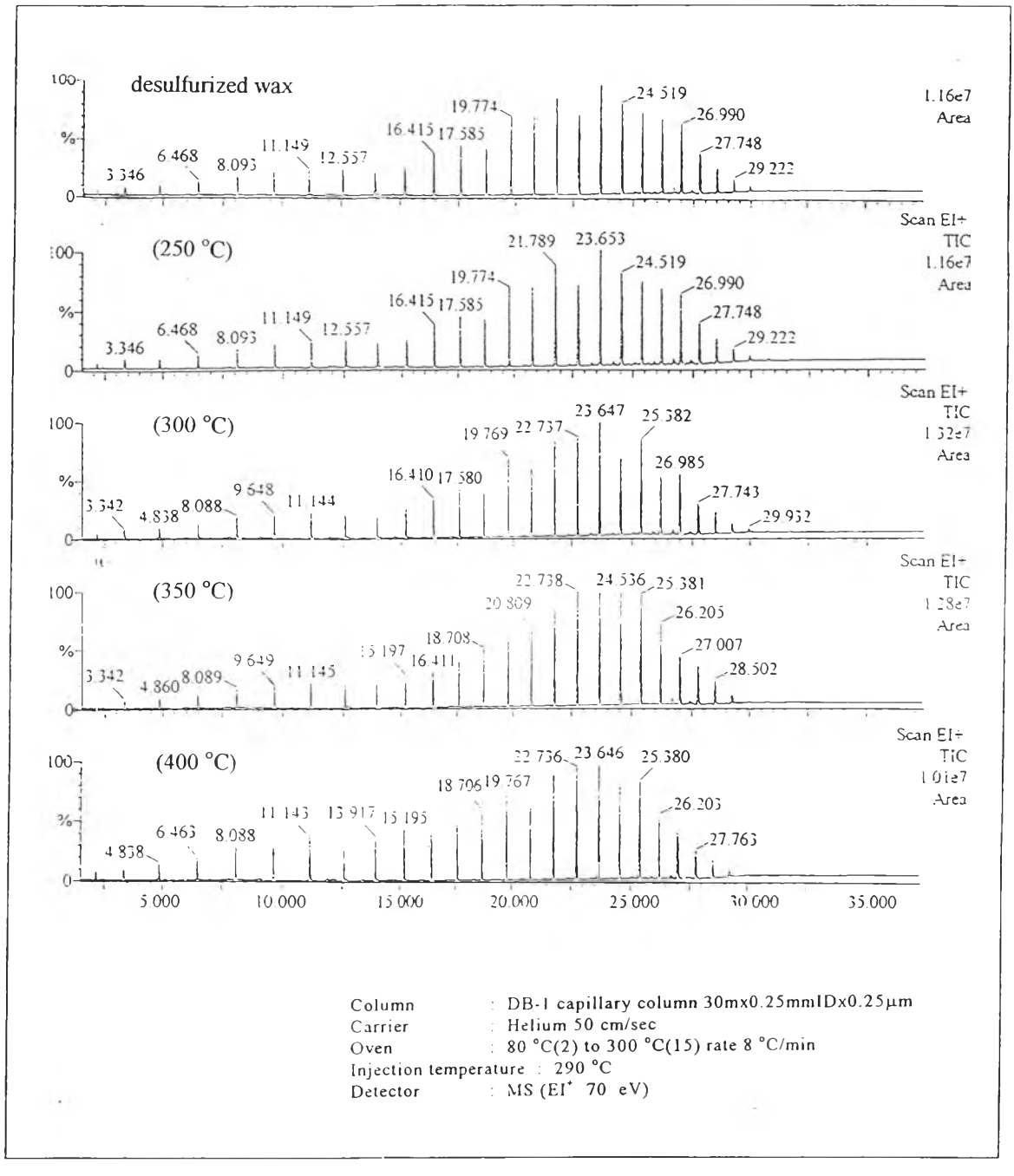


Figure A8 GC/MS Chromatograms of isomerized wax at various reaction temperatures

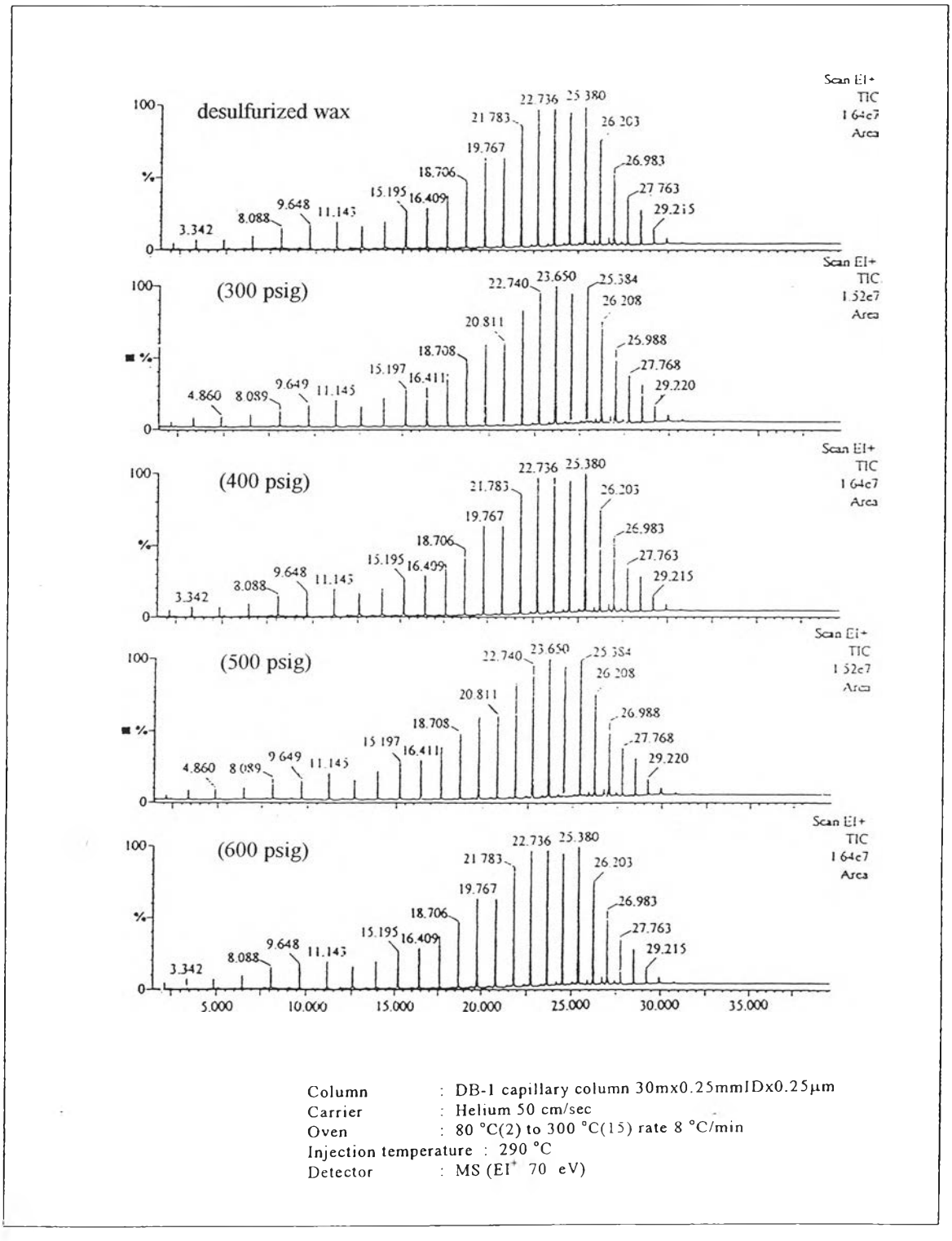


Figure A9 GC/MS Chromatograms of hydroisomerized wax at various hydrogen pressure

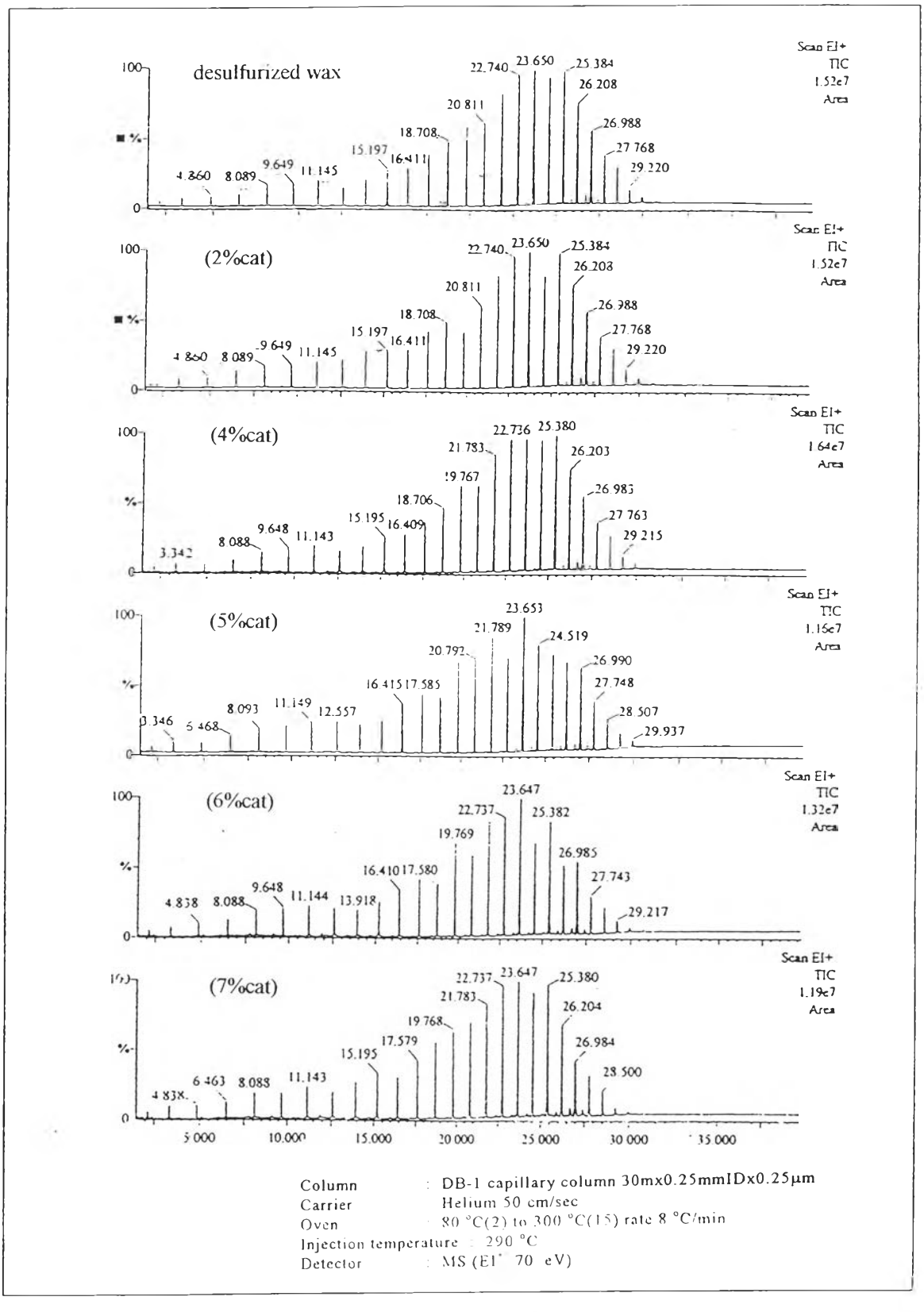
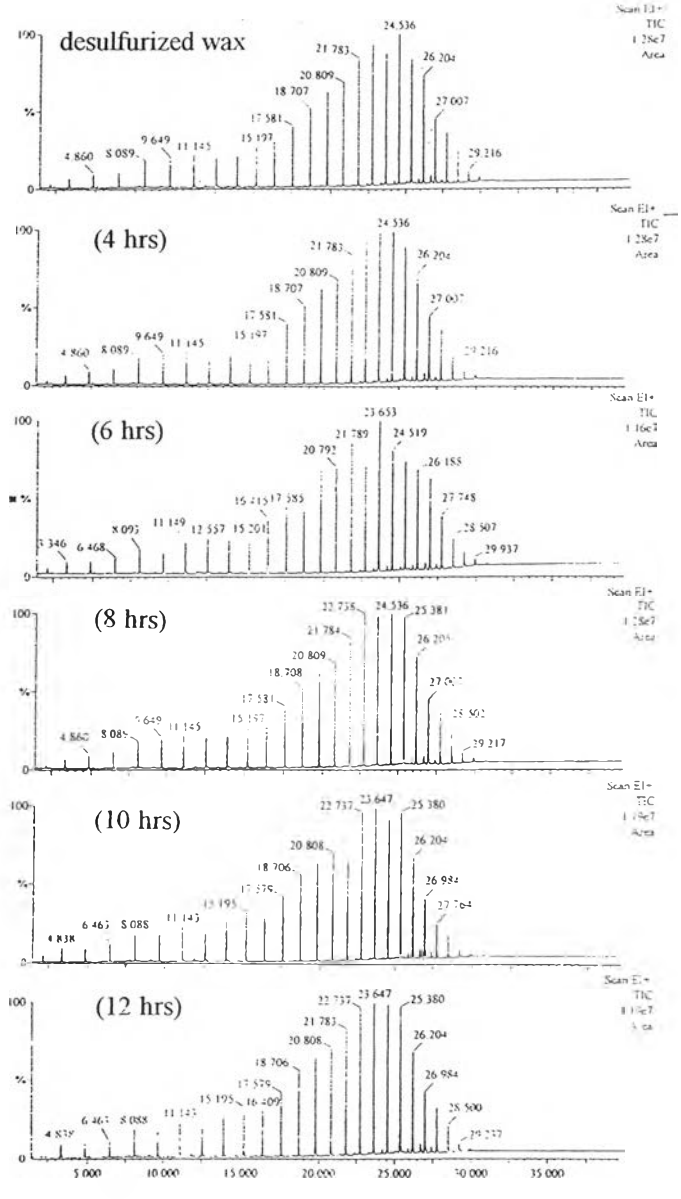


Figure A10 GC/MS Chromatograms of isomerized wax at various concentration of catalysts



Column : DB-1 capillary column 30mx0.25mmIDx0.25μm
Carrier : Helium 50 cm/sec
Oven : 80 °C(2) to 300 °C(15) rate 8 °C/min
Injection temperature : 290 °C
Detector : MS (EI⁻ 70 eV)

Figure A11 GC/MS Chromatograms of hydroisomerized wax at various reaction times

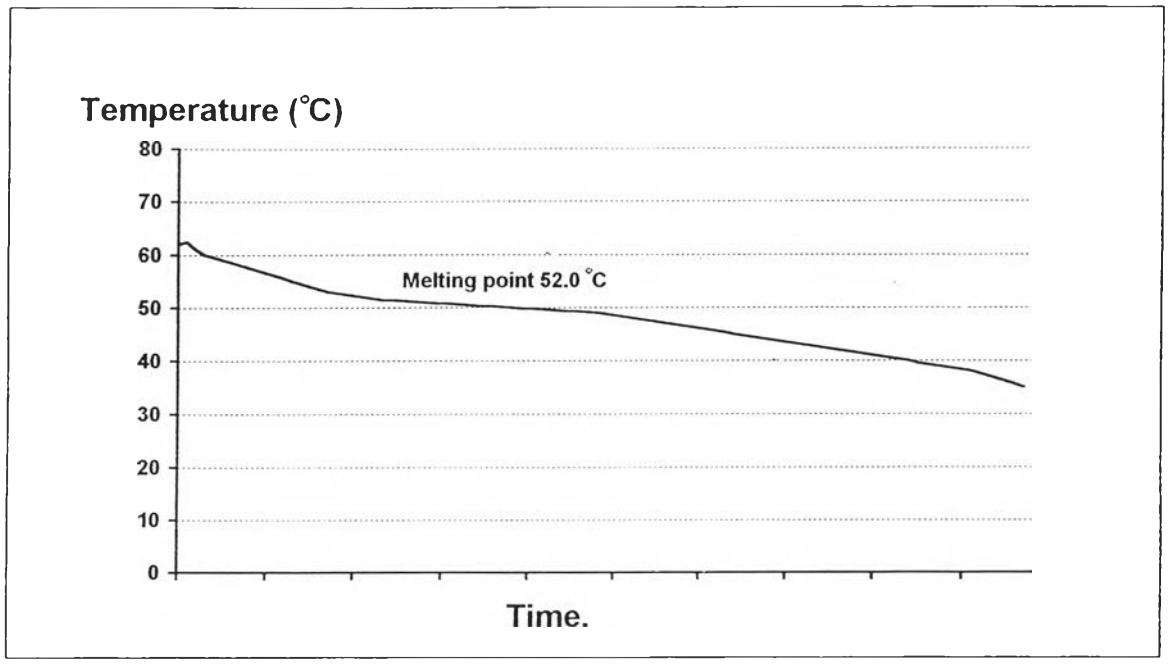


Figure A12 Melting point of slack wax by cooling curve method.

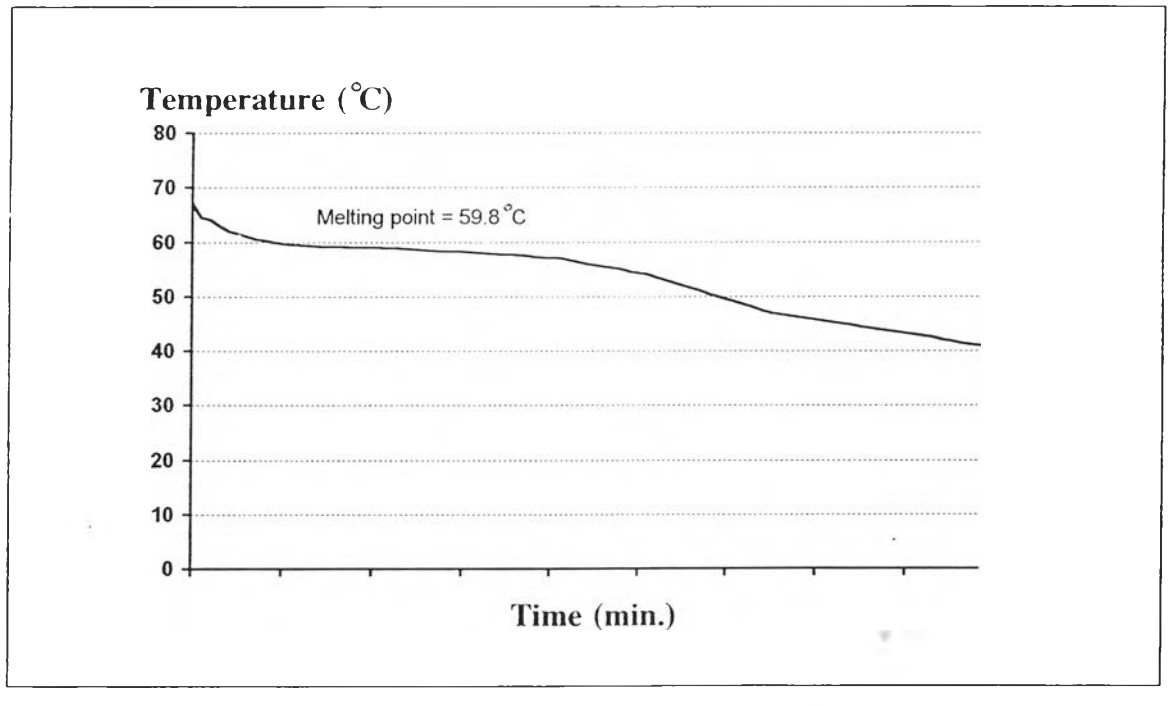


Figure A13 Melting point of hydrodesulfurized wax

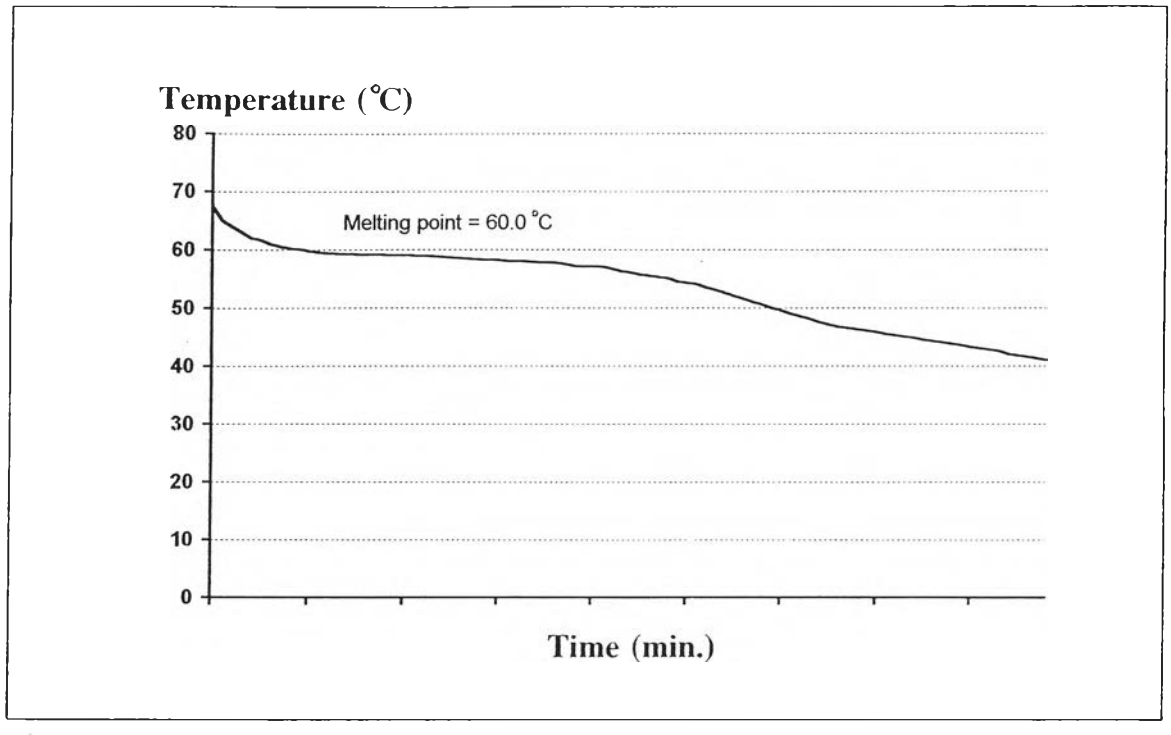


Figure A14 Melting point of hydroismerized wax

IPLE : Lube base oil from hydroisomerization process
TING RATE : 5 °C/min
RANGE : 20/650 °C
OSPHERE : AIR
W RATE : 4O ml/min
ERENCE : Al_2O_3
TRUMENT : NETZSCH STA 4O9 C
GHT : SAMPLE (24.9 mg), REFFERENCE (26.0 mg)

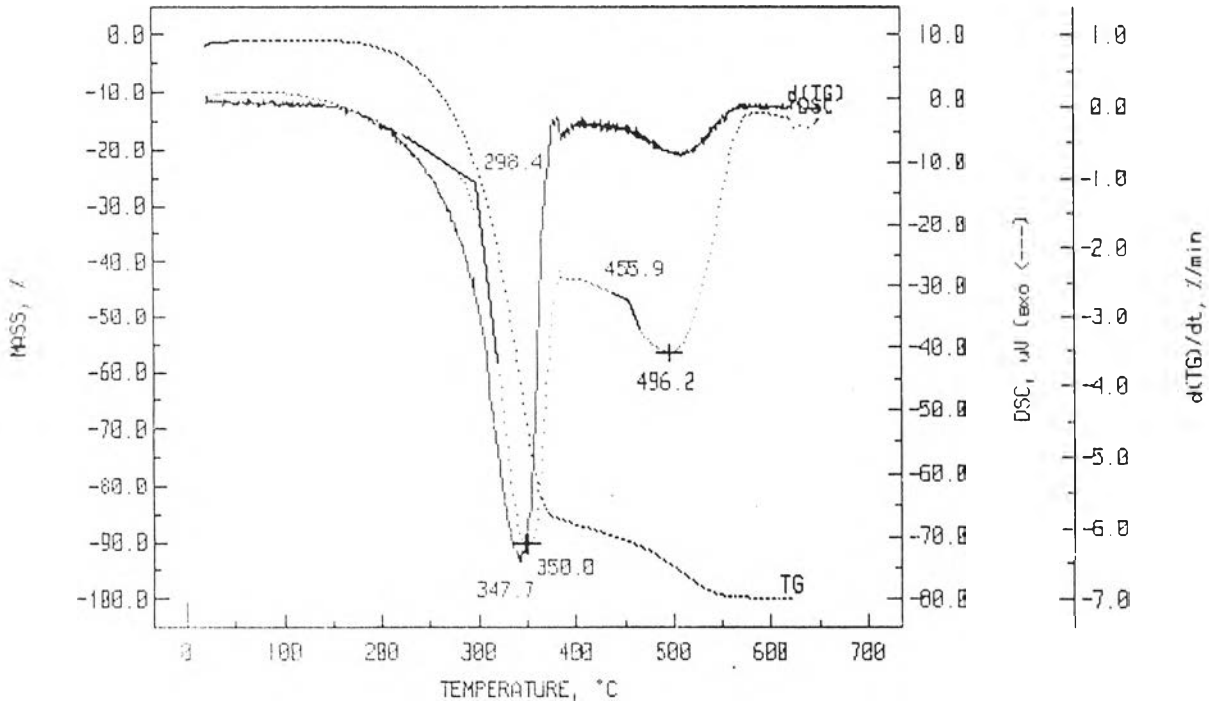


Figure A15 Thermogram of lube base oil from hydroisomerization process

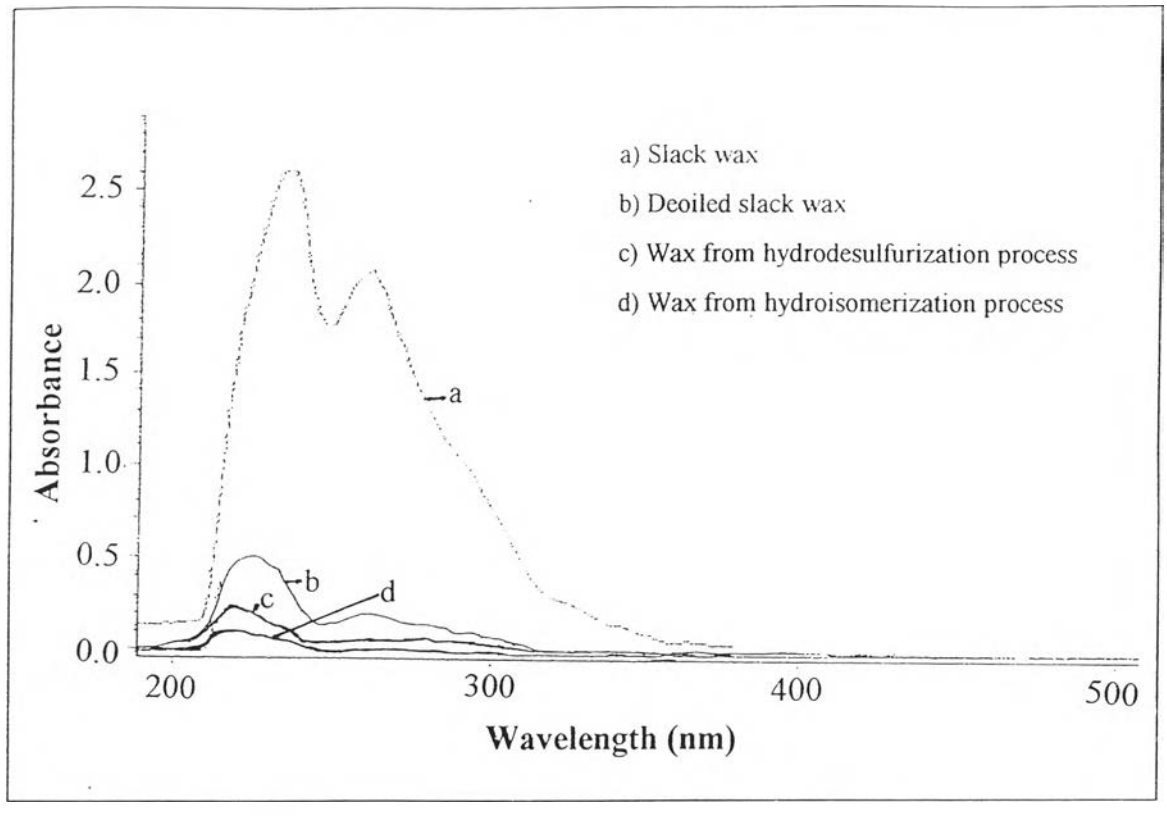


Figure A16 UV absorption of slack wax, deoiled wax, hydrodesulfurized wax, and hydroisomerized wax.

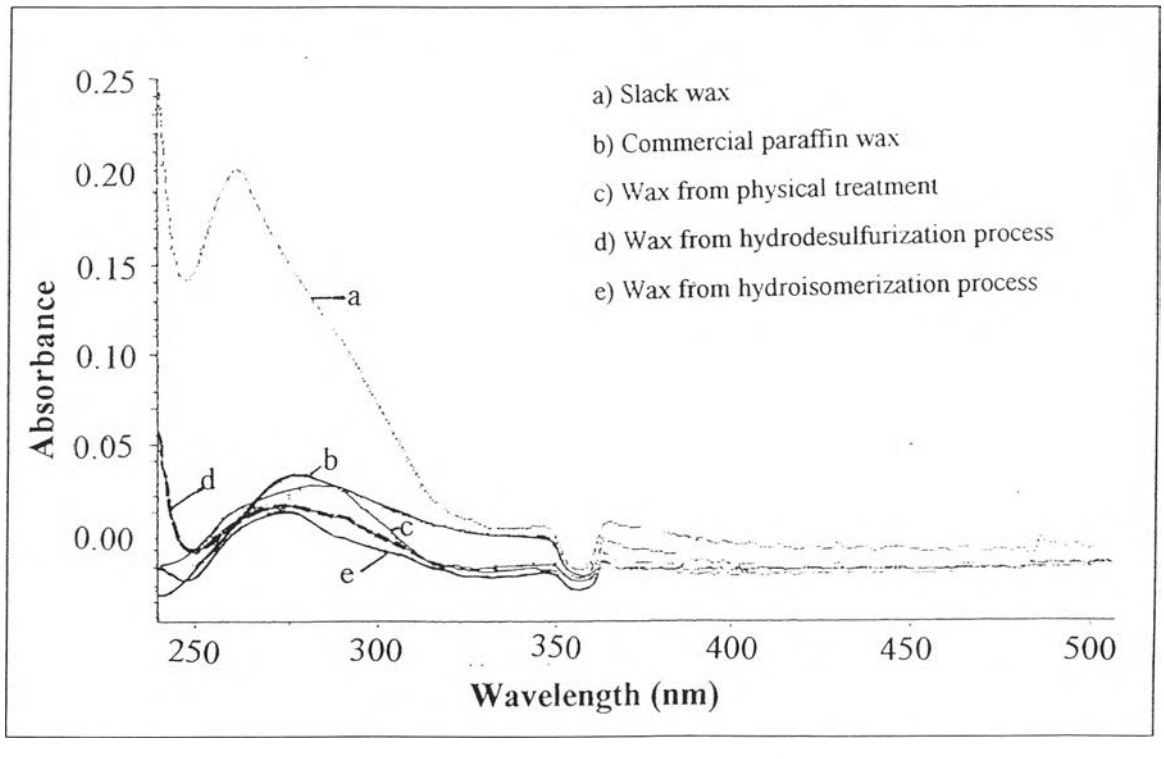


Figure A17 UV absorption of deoiled wax, commercial paraffin wax, physical treated wax, hydrodesulfurized wax, and hydroisomerized wax.

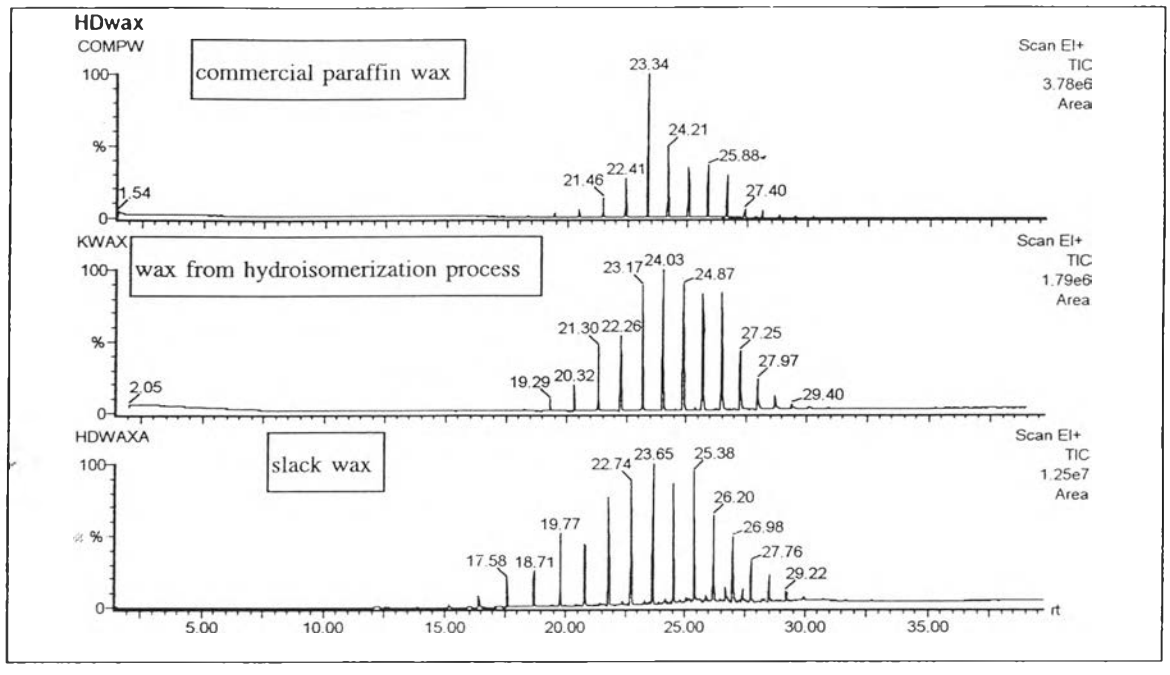


Figure A18 GC/MS Chromatograms of slack wax, wax from hydroisomerization process

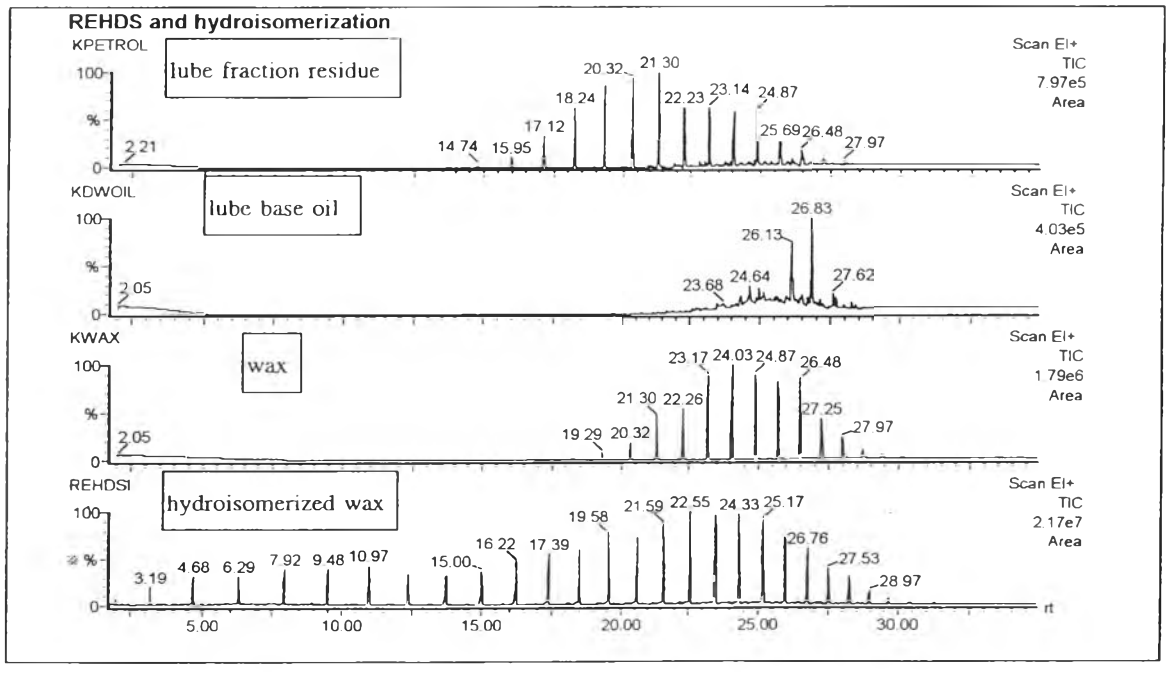


Figure A19 GC/MS Chromatograms of hydroisomerization products

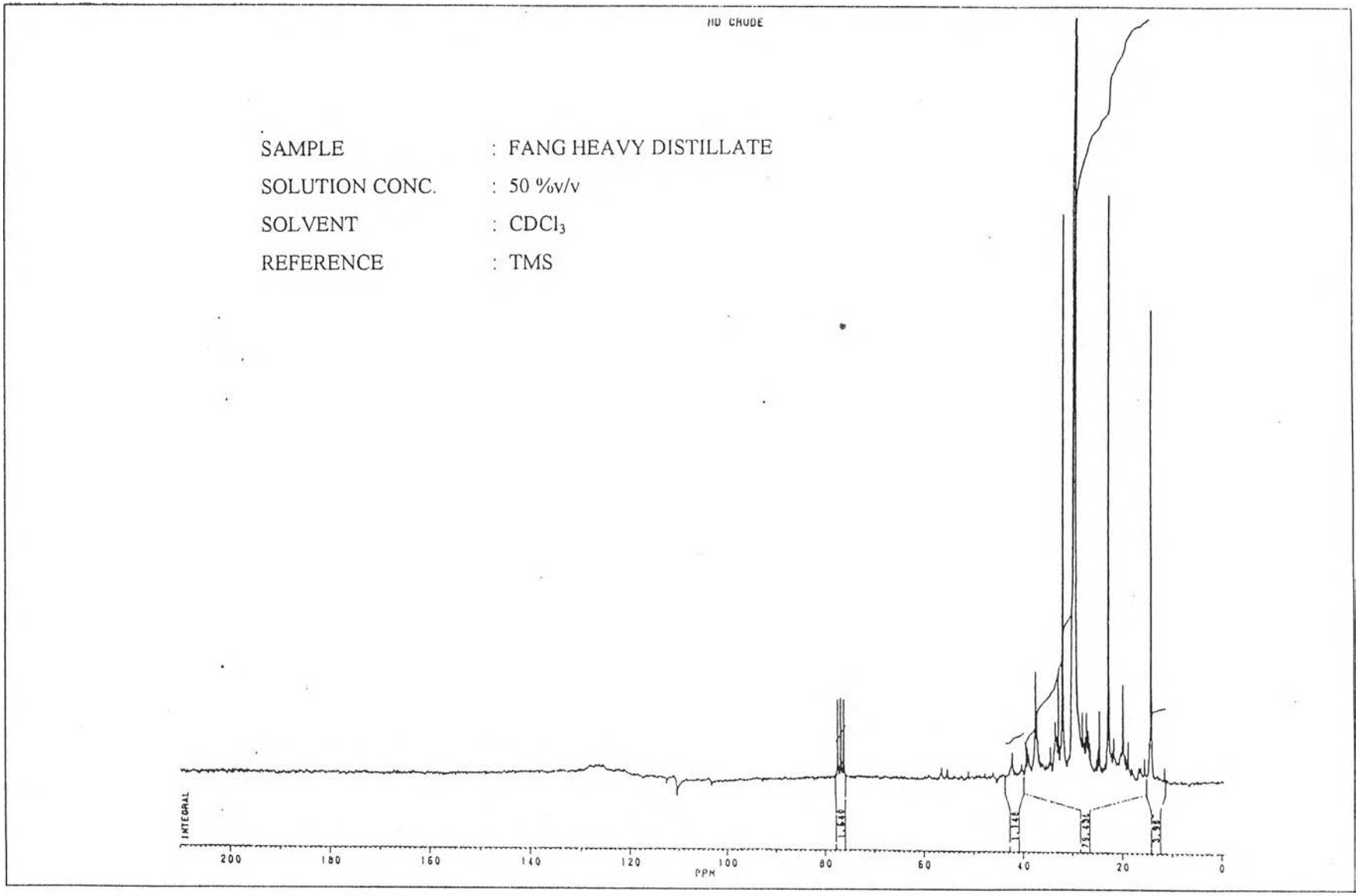


Figure A20 ^{13}C-NMR Spectrum of Fang heavy distillate

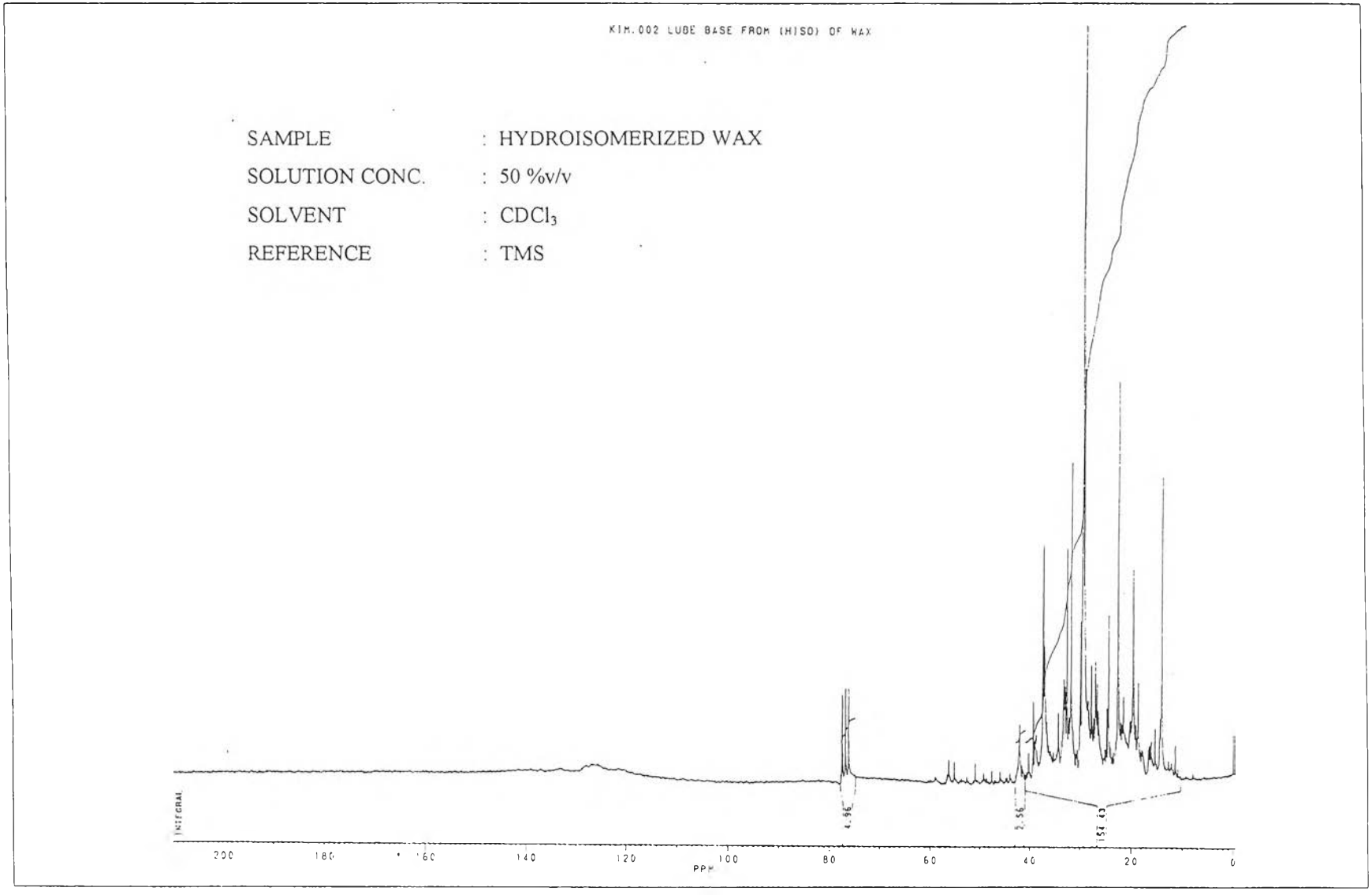


Figure A21 ^{13}C-NMR Spectrum of hydroisomerized wax

VITA

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