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APPENDICES

APPENDIX A

Table A1 Element concentration of catalysts from X-ray fluorescence

Catalyst	Element Concentration (% wt)																	
	F	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe	Sn	Ni	Sr	Co	Zn	Pb
Fe(5%)-Sn(5%)-F(2%)	2.124	13.138	2.349	24.411	35.294	0.388	0.177	9.746	0.213	1.005	0.095	4.963	4.889	-	-	-	-	-
Ni(5%)-Sn(5%)-F(2%)	2.175	12.713	2.288	24.611	35.016	0.383	0.214	9.992	0.217	0.98	0.098	0.855	5.159	5.176	0.122	-	-	-
Co(5%)-Sn(5%)-F(2%)	2.171	13.188	2.401	24.439	35.977	0.403	-	11.894	0.214	1.018	0.112	0.843	5.206	-	0.04	5.206	-	-
Fe(5%)-Zn(5%)-F(2%)	2.060	13.711	2.421	24.552	34.764	0.399	0.157	13.62	0.217	0.936	0.109	4.856	-	-	-	-	5.198	-
Fe(5%)-Pb(5%)-F(2%)	1.878	13.476	2.428	24.543	35.189	0.4	0.2	9.808	0.189	0.951	0.106	5.086	-	-	-	-	-	4.946
Fe(5%)-Al(2%)-F(2%)	1.913	12.915	2.292	26.66	35.314	0.38	6.3	8.505	0.156	0.898	0.115	5.152	-	-	-	-	-	-
Fe(5%)-Al(3%)-F(2%)	2.283	12.228	2.287	27.878	35.443	0.385	7.805	4.523	0.191	0.84	0.102	5.235	-	-	-	-	-	-
Fe(5%)-Al(5%)-F(2%)	2.202	11.056	1.894	29.544	31.172	0.328	15.51	1.753	0.175	0.75	0.082	5.133	-	-	-	-	-	-

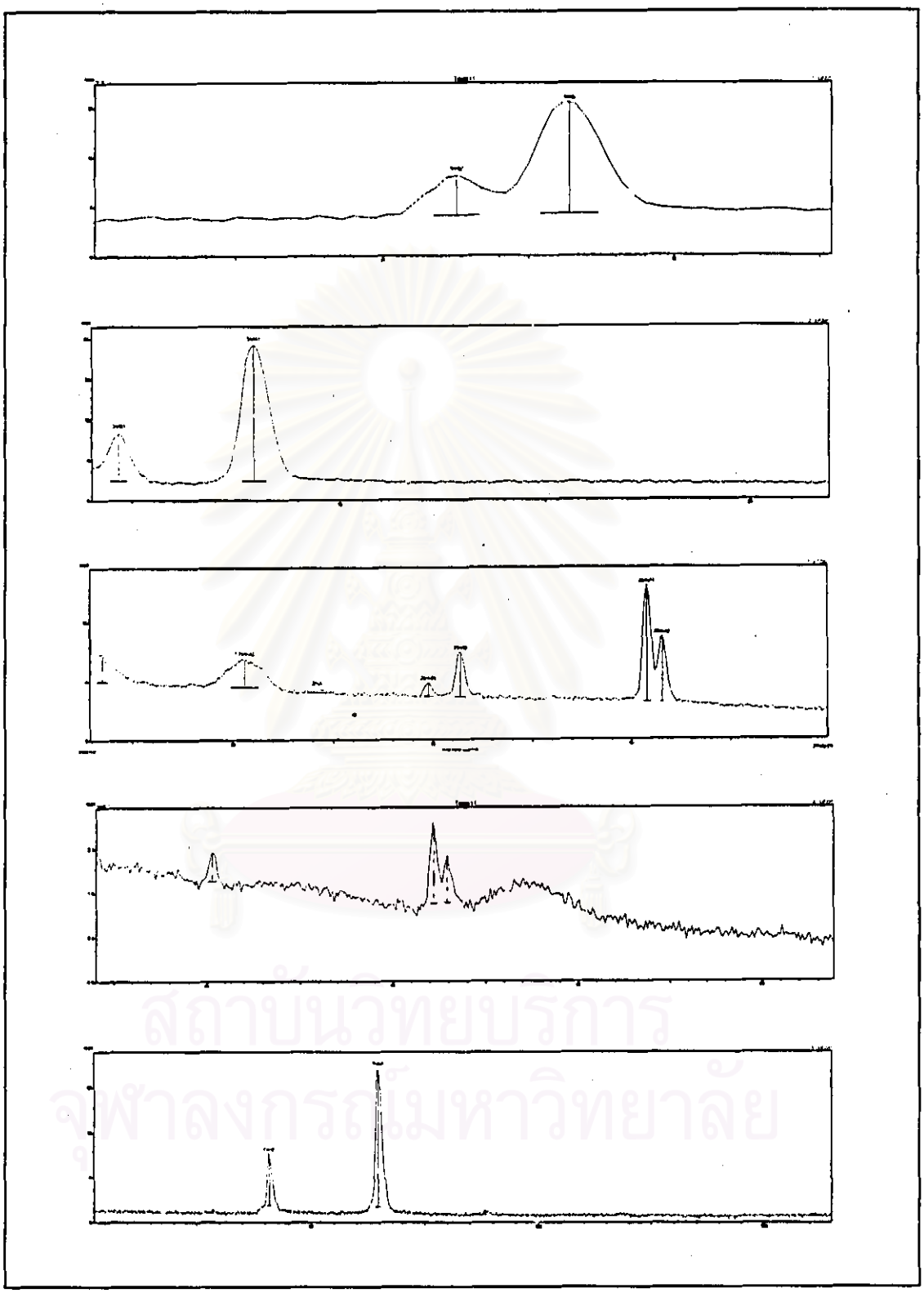

Figure A1 Plot of X-ray fluorescence data of Fe(5%)-Sn(5%)-F(2%) on molecular sieve catalyst

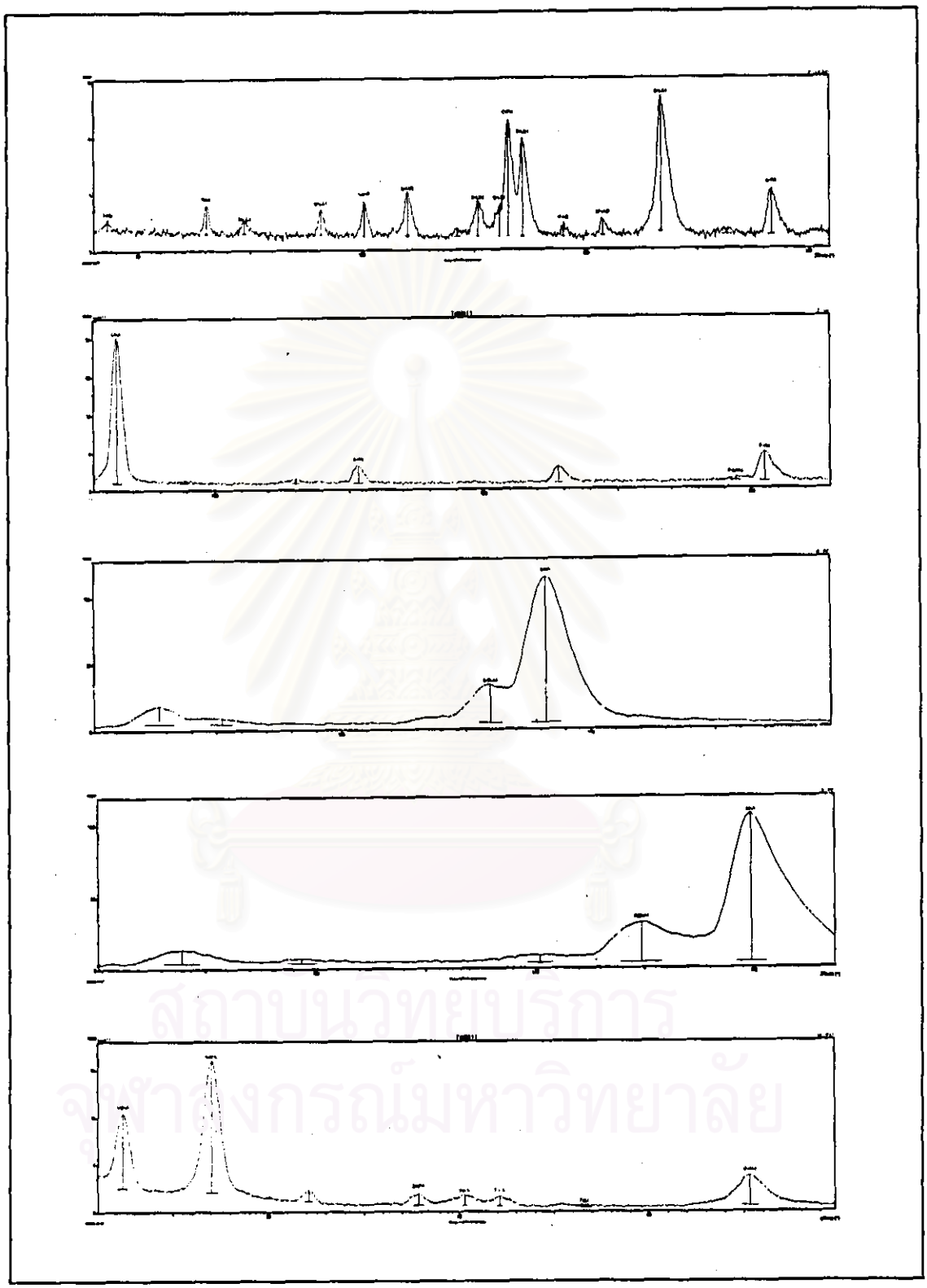

Figure A1 Plot of X-ray fluorescence data of Fe(5%)-Sn(5%)-F(2%) on molecular sieve catalyst (continued)

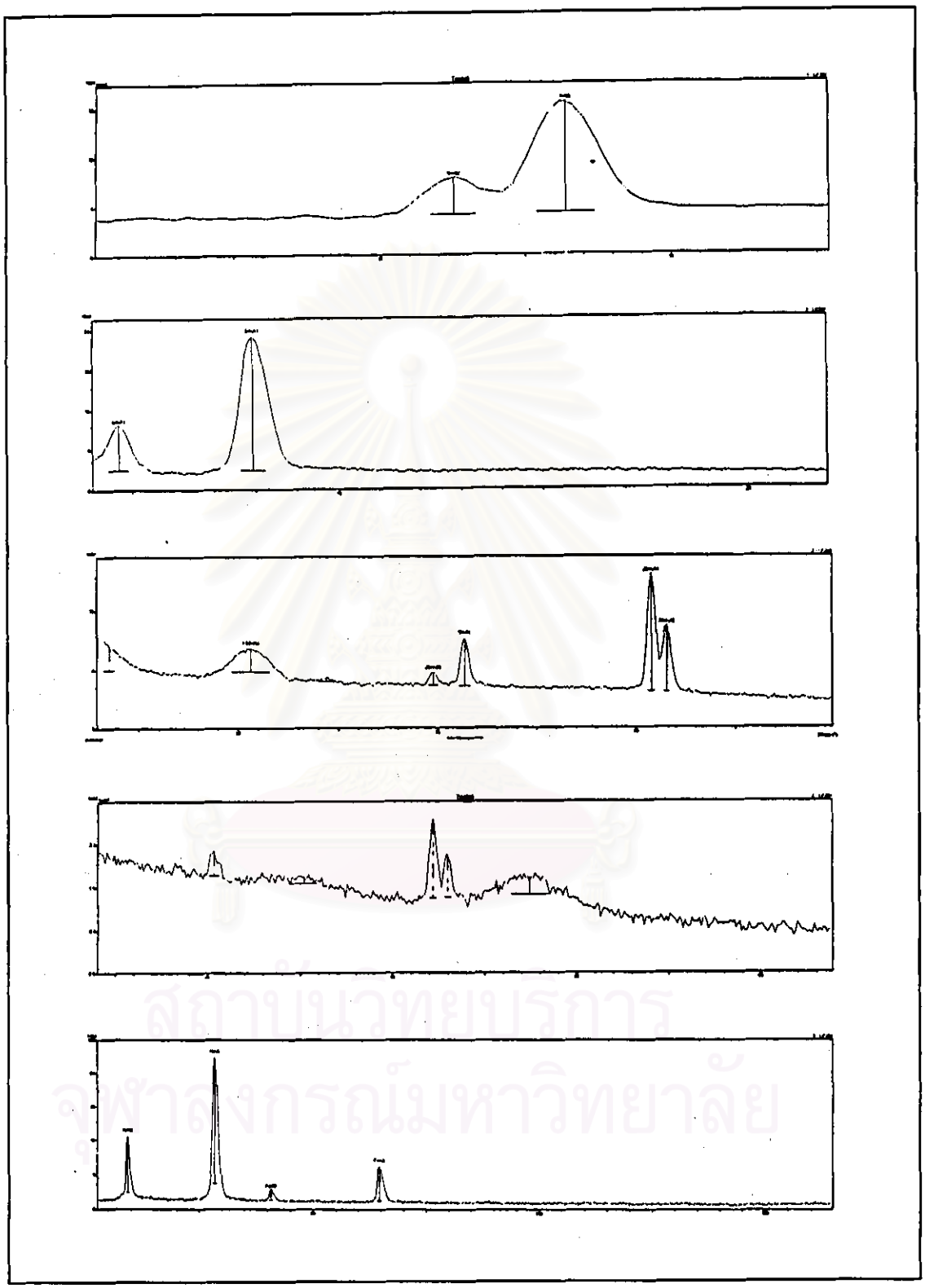

Figure A2 Plot of X-ray fluorescence data of Ni(5%)-Sn(5%)-F(2%) on molecular sieve catalyst

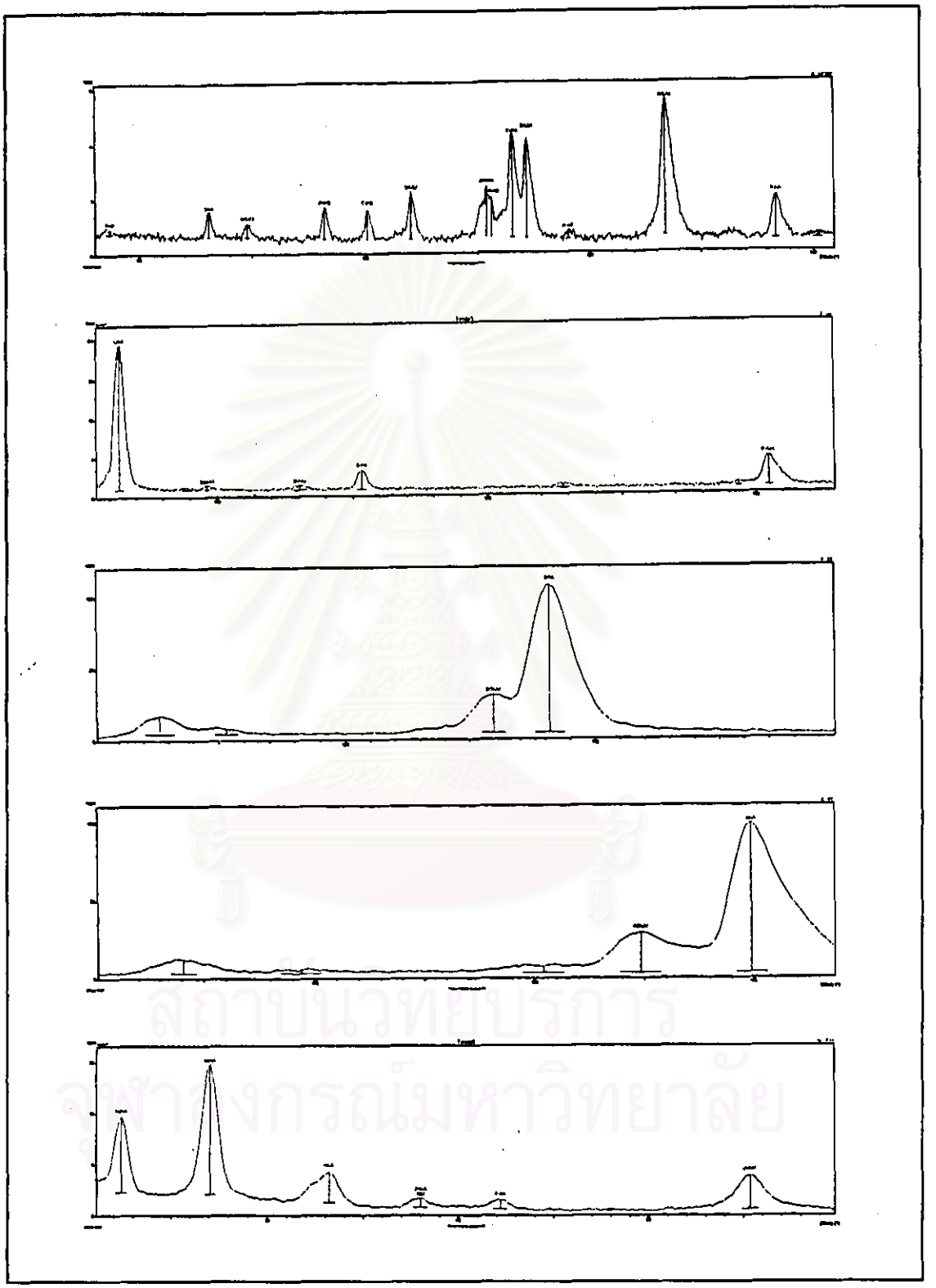

Figure A2 Plot of X-ray fluorescence data of Ni(5%)-Sn(5%)-F(2%) on molecular sieve catalyst (continued)

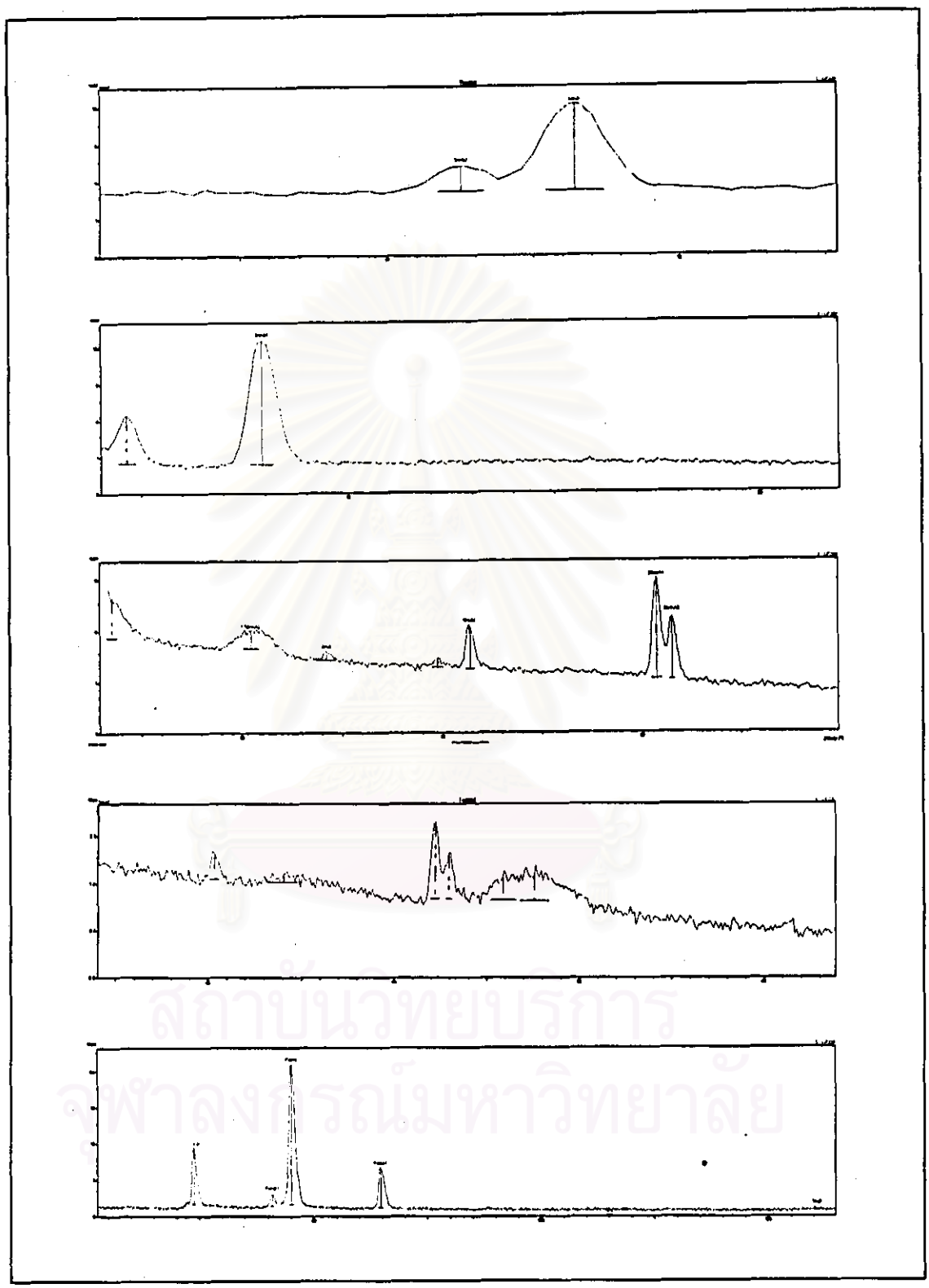

Figure A3 Plot of X-ray fluorescence data of Co(5%)-Sn(5%)-F(2%) on molecular sieve catalyst

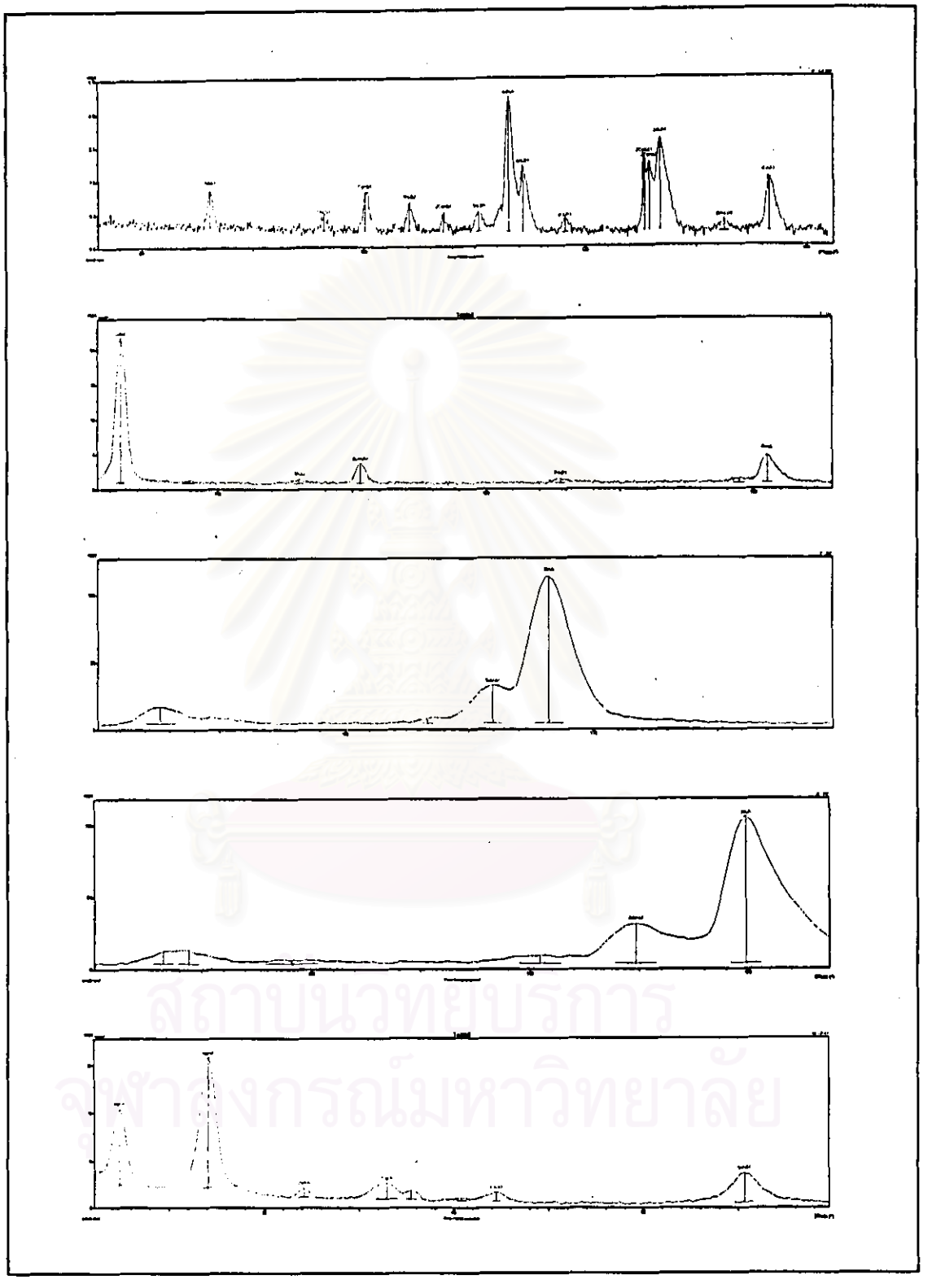

Figure A3 Plot of X-ray fluorescence data of Co(5%)-Sn(5%)-F(2%) on molecular sieve catalyst (continued)

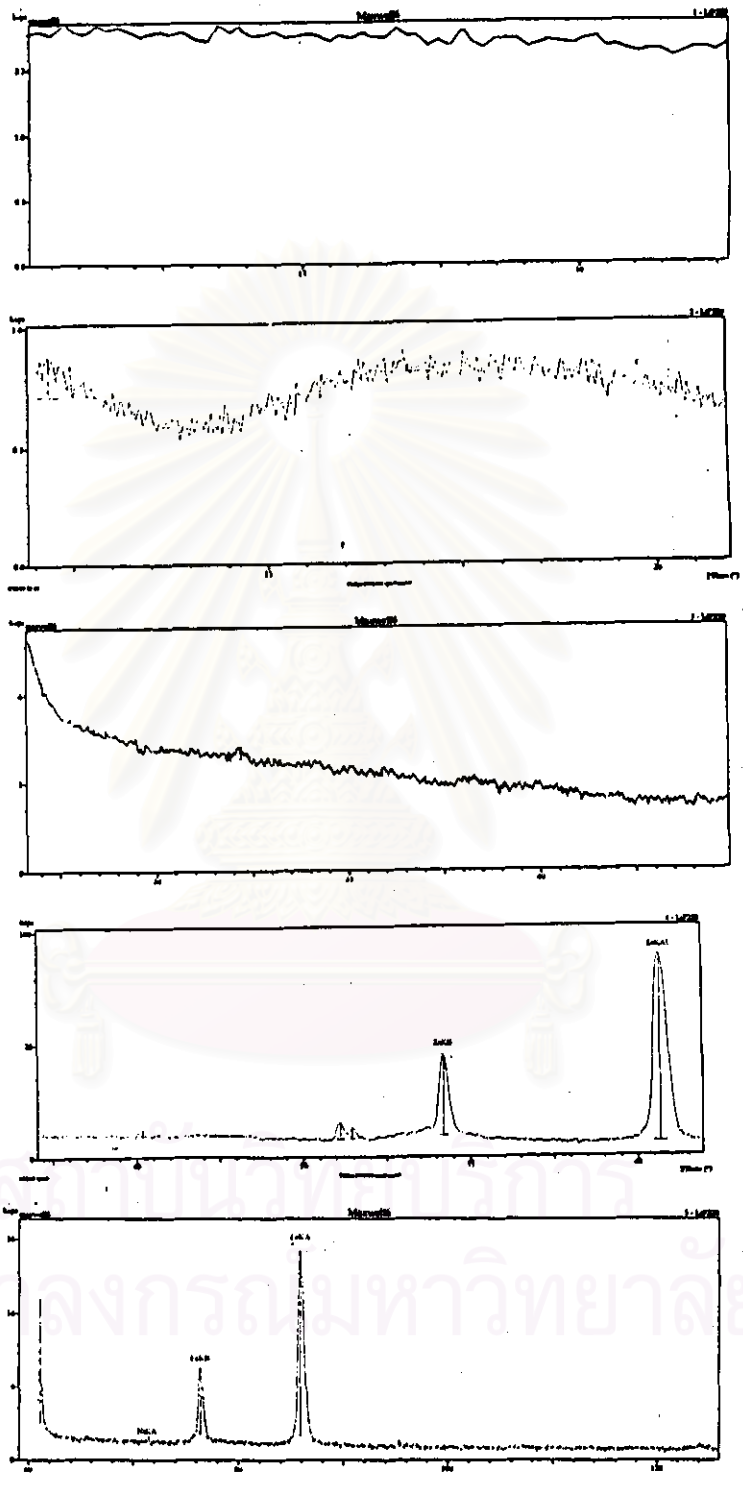

Figure A4 Plot of X-ray fluorescence data of Fe(5%)-Zn(5%)-F(2%) on molecular sieve catalyst

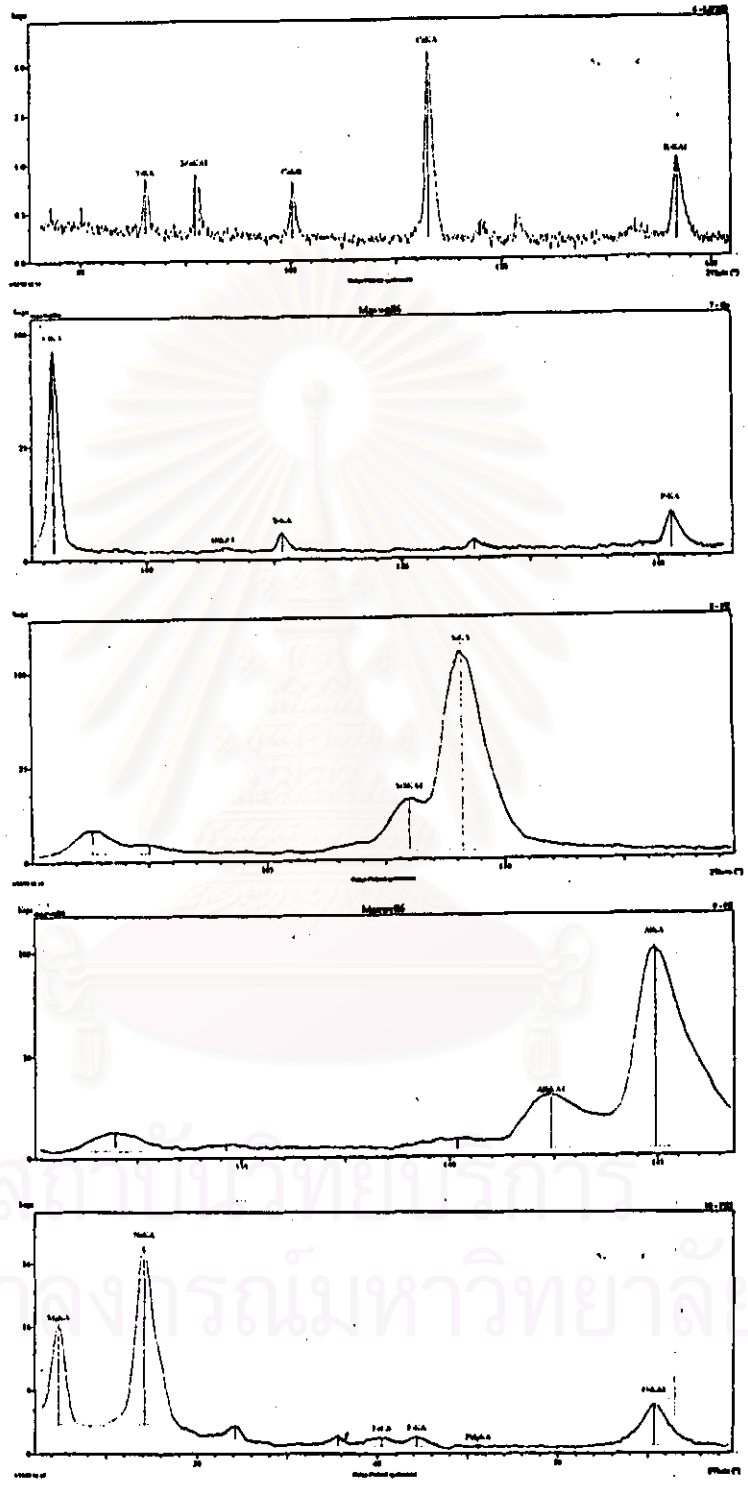

Figure A4 Plot of X-ray fluorescence data of Fe(5%)-Zn(5%)-F(2%) on molecular sieve catalyst (continued)

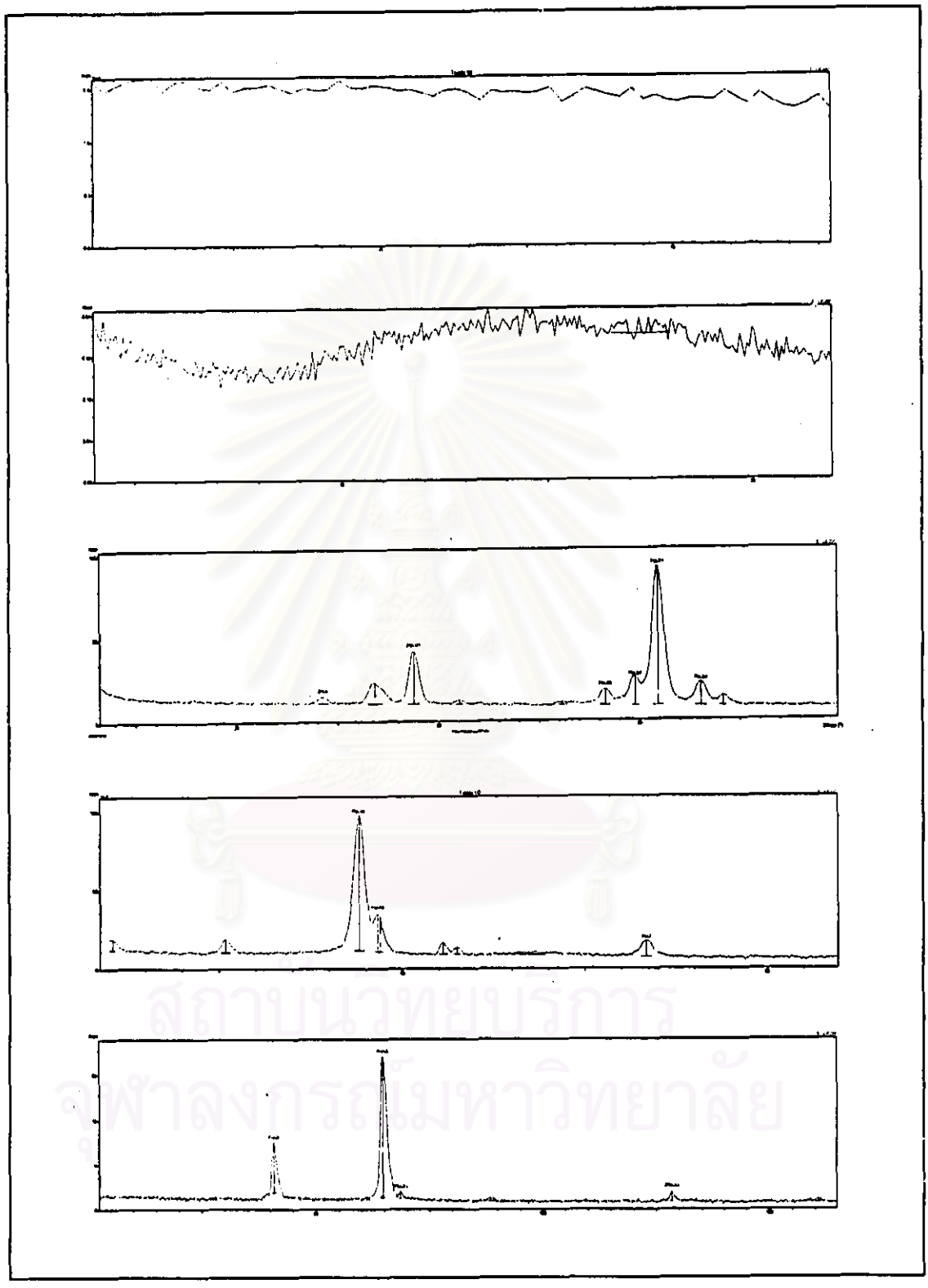

Figure A5 Plot of X-ray fluorescence data of Fe(5%)-Pb(5%)-F(2%) on molecular sieve catalyst

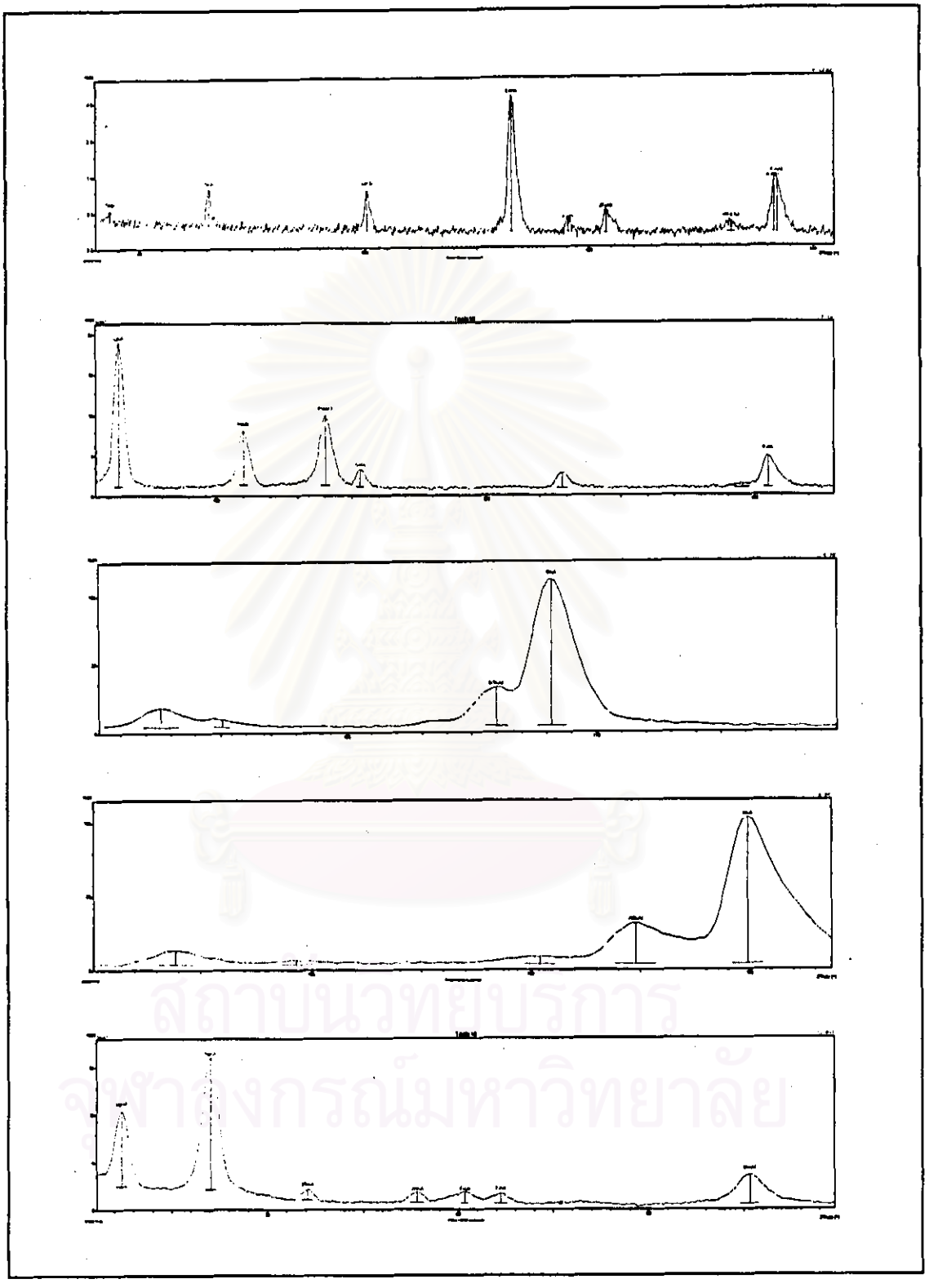

Figure A5 Plot of X-ray fluorescence data of Fe(5%)-Pb(5%)-F(2%) on molecular sieve catalyst (continued)

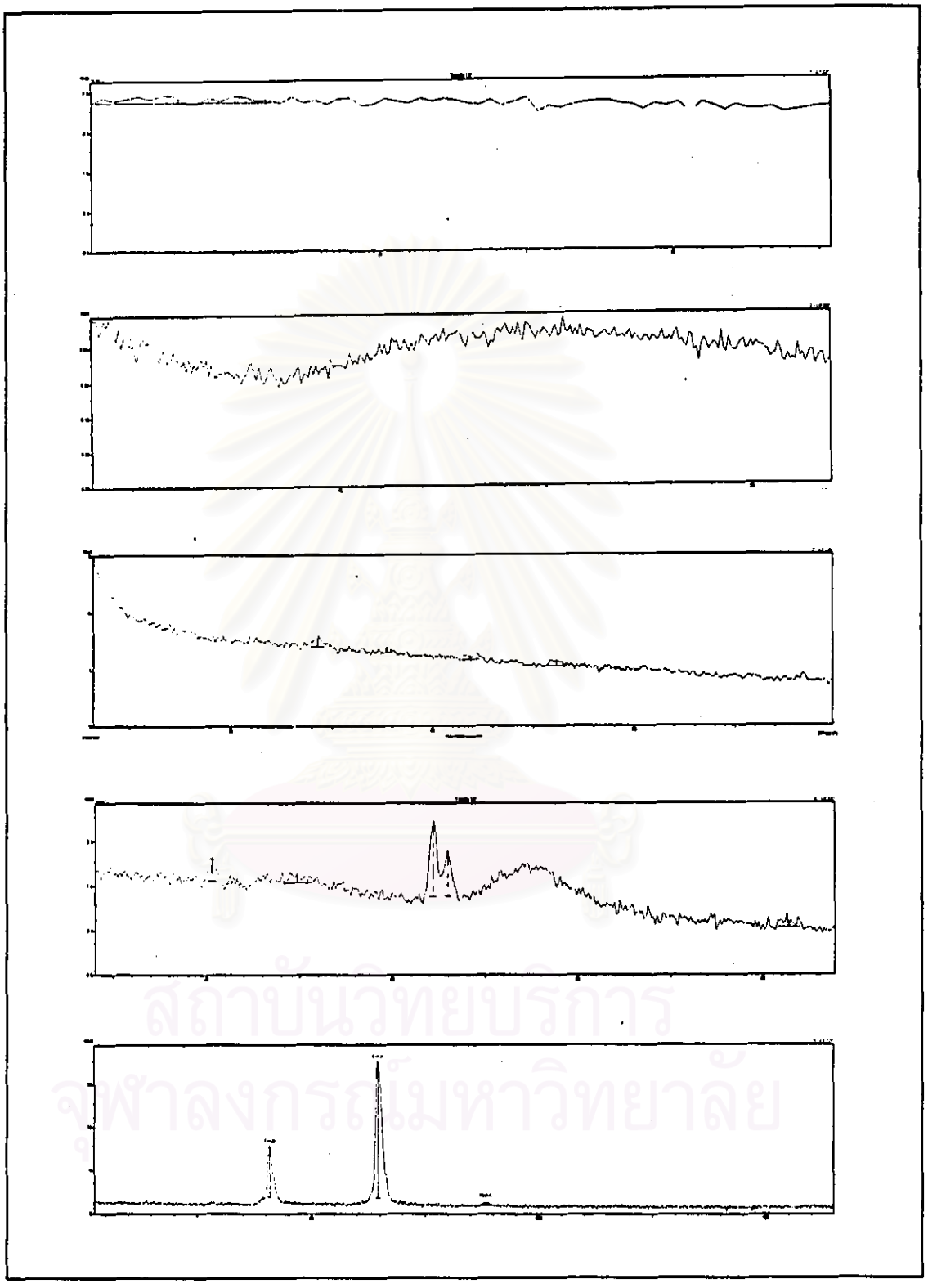

Figure A6 Plot of X-ray fluorescence data of Fe(5%)-Al(2%)-F(2%) on molecular sieve catalyst

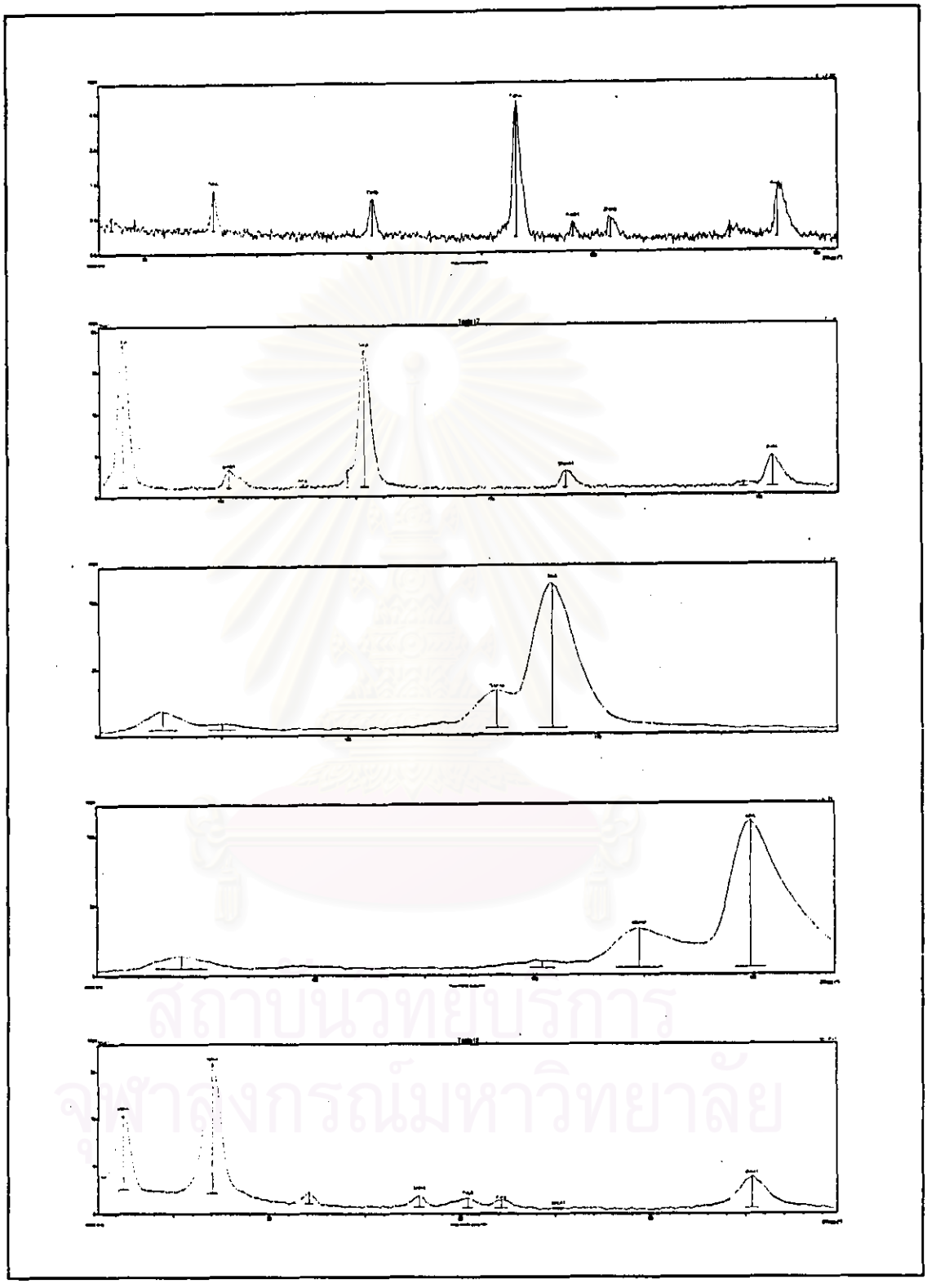

Figure A6 Plot of X-ray fluorescence data of Fe(5%)-Al(2%)-F(2%) on molecular sieve catalyst (continued)

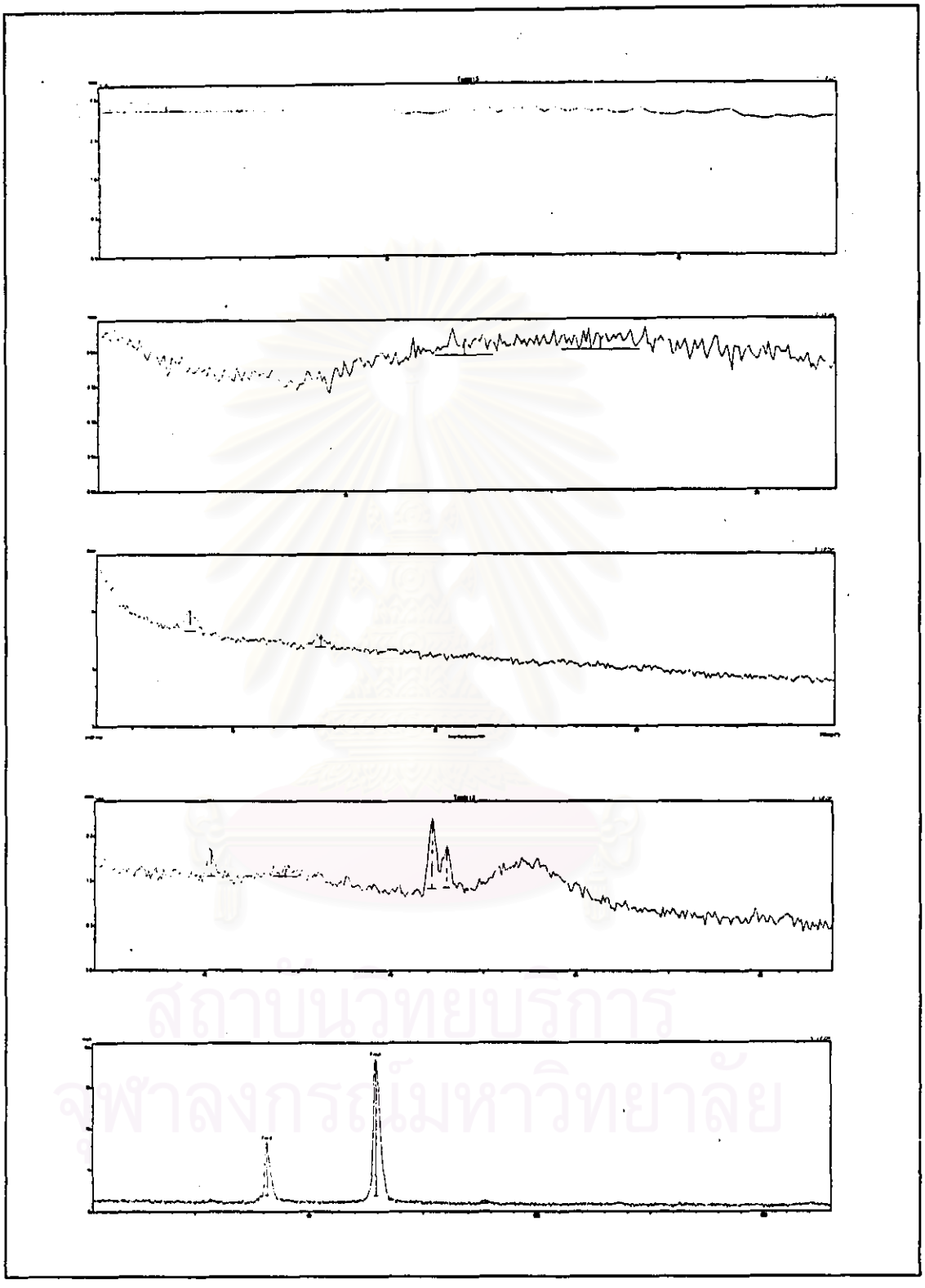

Figure A7 Plot of X-ray fluorescence data of Fe(5%)-Al(3%)-F(2%) on molecular sieve catalyst

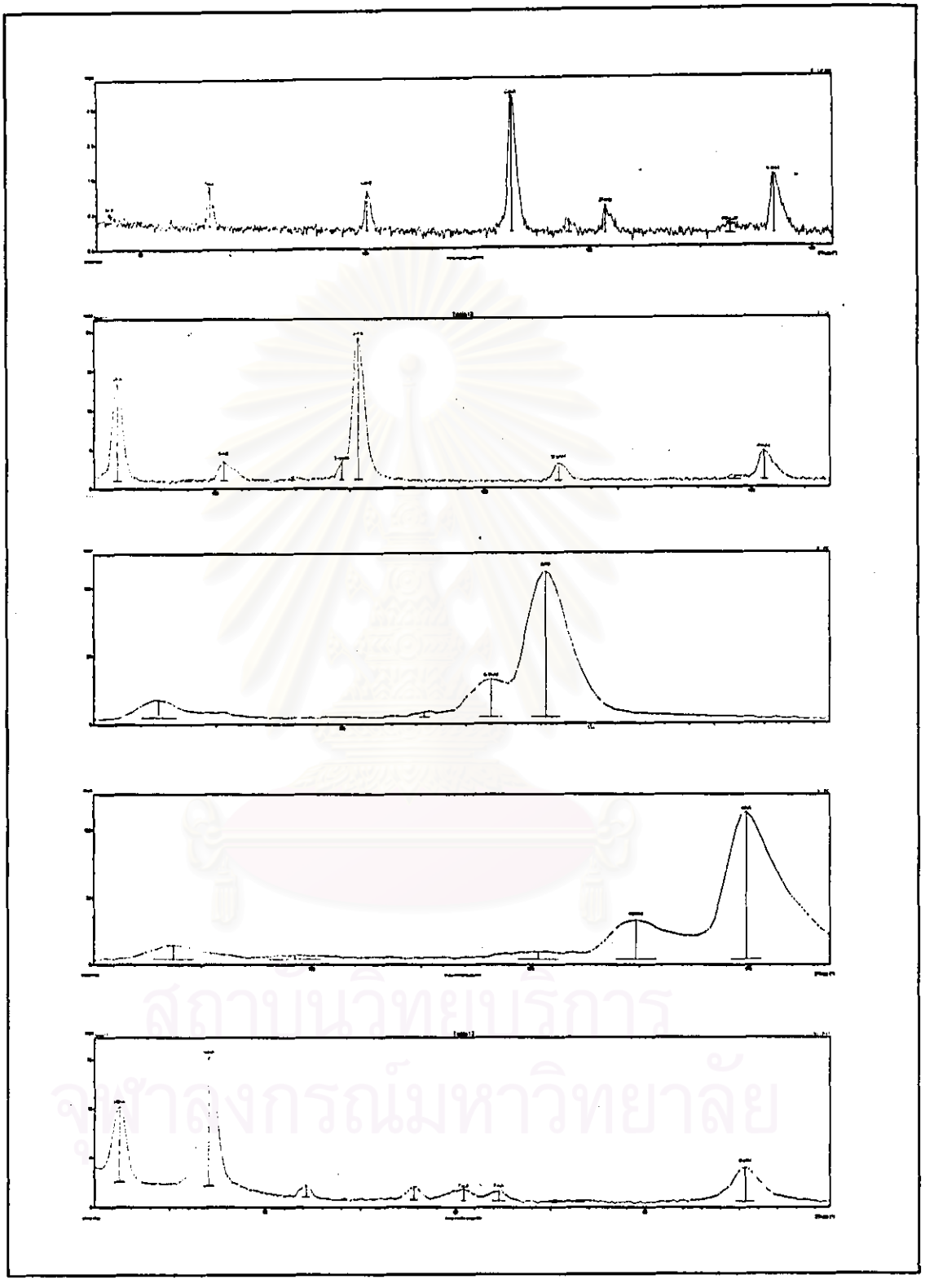

Figure A7 Plot of X-ray fluorescence data of Fe(5%)-Al(3%)-F(2%) on molecular sieve catalyst (continued)

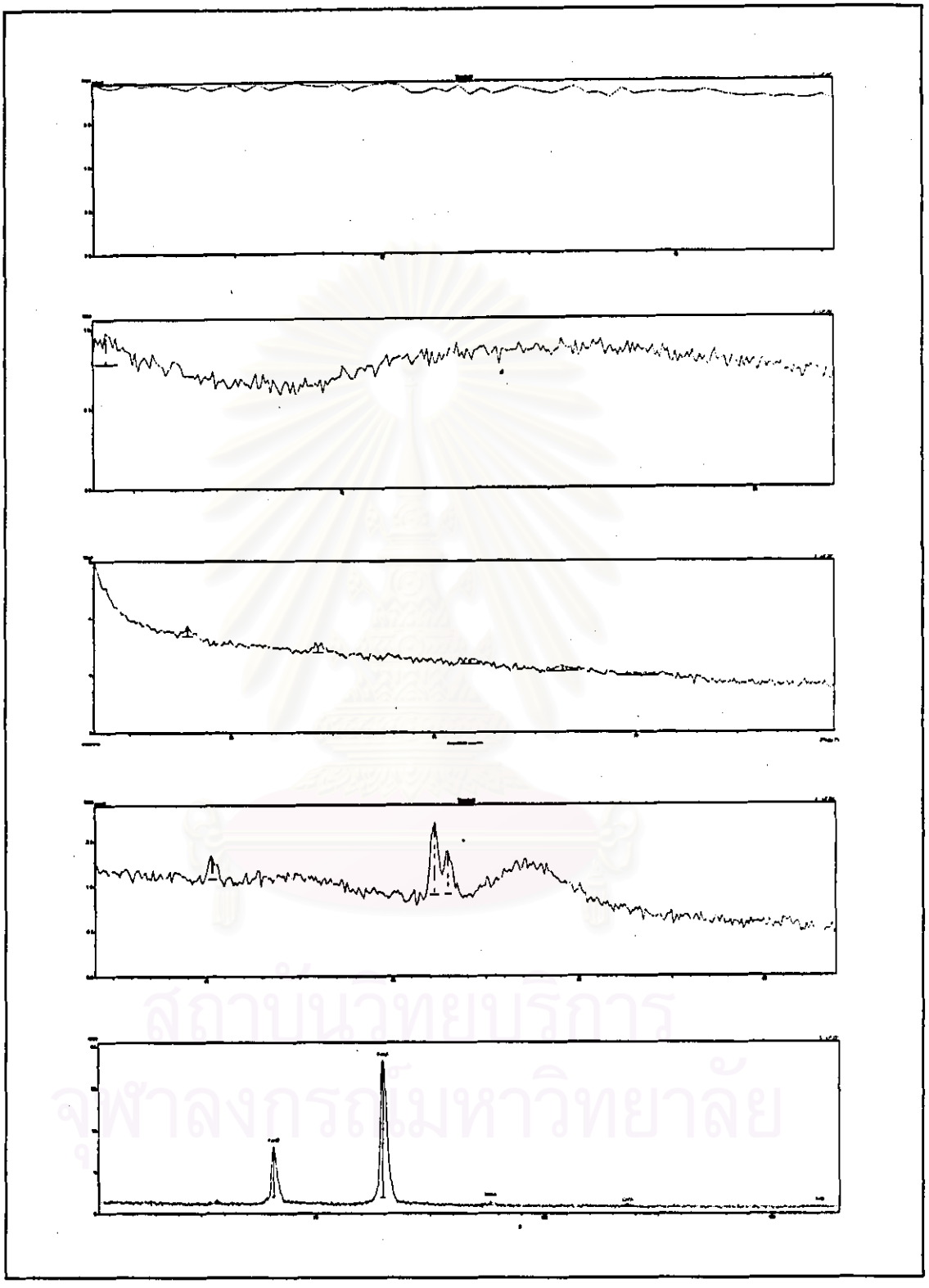

Figure A8 Plot of X-ray fluorescence data of Fe(5%)-Al(5%)-F(2%) on molecular sieve catalyst

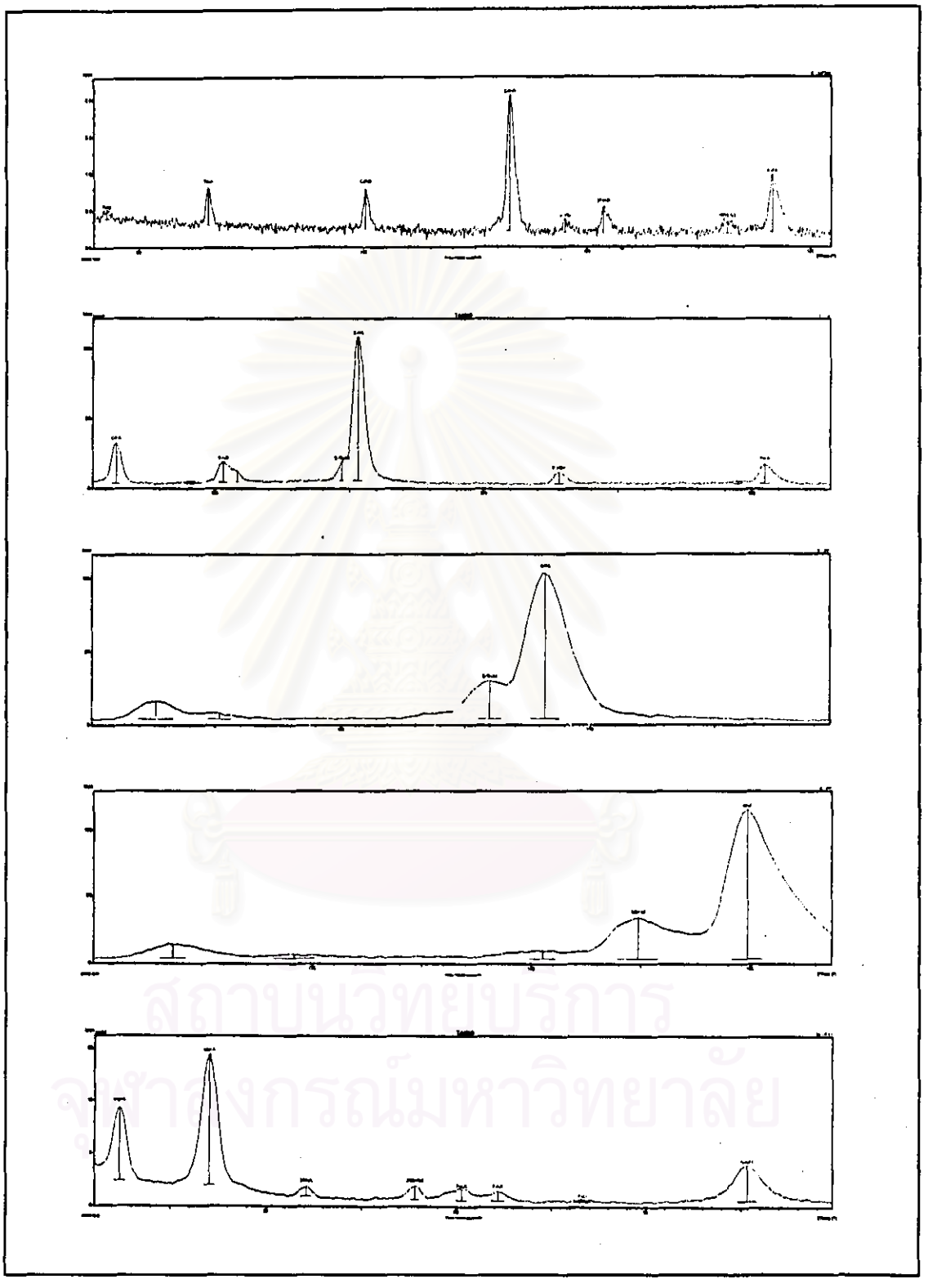

Figure A8 Plot of X-ray fluorescence data of Fe(5%)-Al(5%)-F(2%) on molecular sieve catalyst (continued)

APPENDIX B

Table B1 Hydrocarbon products from hydrocracking as a function of catalyst type

Catalyst Type	% by weight		
	1st experiment	2nd experiment	Average
Fe(5%)-Sn(5%)-F(2%)	76.51	76.21	76.36
Ni(5%)-Sn(5%)-F(2%)	77.18	77.74	77.46
Co(5%)-Sn(5%)-F(2%)	77.05	77.31	77.18
Fe(5%)-Zn(5%)-F(2%)	37.67	33.45	35.56
Fe(5%)-Pb(5%)-F(2%)	59.62	56.86	58.24
Fe(5%)-Al(2%)-F(2%)	67.50	67.66	67.58
Fe(5%)-Al(3%)-F(2%)	62.38	58.50	60.44
Fe(5%)-Al(5%)-F(2%)	42.74	41.26	42.00

Table B2 Hydrocarbon products from hydrocracking as a function of hydrogen pressure

Hydrogen Pressure (psig)	% by weight		
	1st experiment	2nd experiment	Average
300	65.55	63.77	64.66
400	76.51	76.21	76.36

Table B3 Hydrocarbon products from cracking under nitrogen pressure as a function of reaction time

Reaction Time (min.)	% by weight		
	1st experiment	2nd experiment	Average
180	83.68	79.84	81.76
90	79.33	76.91	78.12

Table B4 Hydrocarbon productS from cracking under nitrogen pressure as a function of nitrogen pressure

Nitrogen Pressure (psig)	% by weight		
	1st experiment	2nd experiment	Average
500	79.33	76.91	78.12
400	75.22	75.98	75.60
300	75.60	75.36	75.48
200	59.44	59.32	59.38

Table B5 Hydrocarbon products from cracking under nitrogen pressure as a function of catalyst type

Catalyst Type	% by weight		
	1st experiment	2nd experiment	Average
Fe(5%)-Sn(5%)-F(2%)	75.60	75.36	75.48
Ni(5%)-Sn(5%)-F(2%)	68.14	70.74	69.44
Co(5%)-Sn(5%)-F(2%)	69.96	67.16	68.56
Fe(5%)-Zn(5%)-F(2%)	73.70	75.46	74.58
Fe(5%)-Pb(5%)-F(2%)	69.78	72.66	71.22
Fe(5%)-Al(2%)-F(2%)	74.48	73.48	73.98

Table B6 Hydrocarbon products from cracking under nitrogen pressure as a function of catalyst concentration

Catalyst Concentration (% by weight)	% by weight		
	1st experiment	2nd experiment	Average
10	59.95	61.33	60.64
15	75.60	75.36	75.48

APPENDIX C

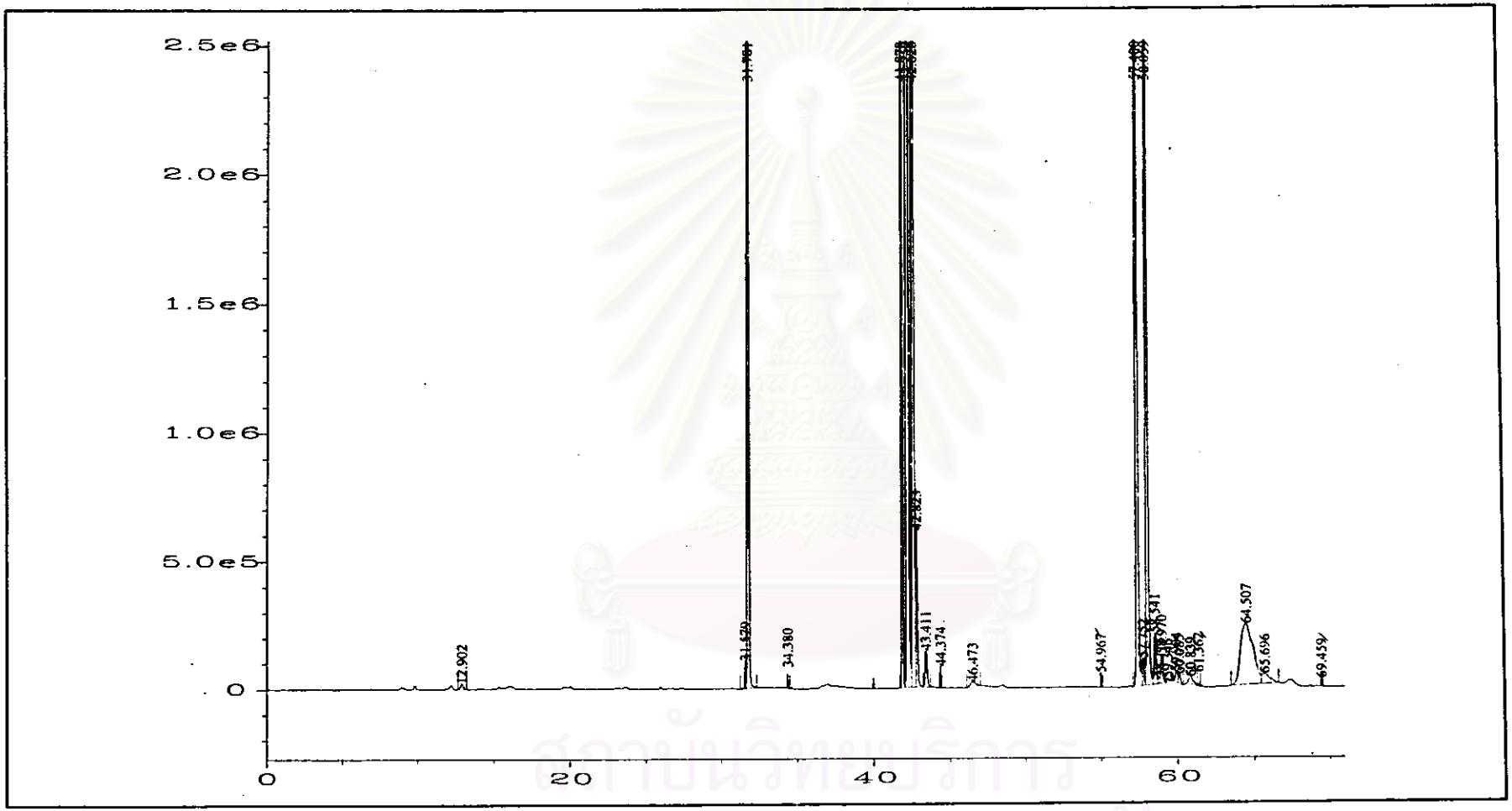

Figure C1 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C1 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	12.902	n-octane	0.0391
2	31.579	benzene	0.0664
3	31.781	toluene	12.4428
	41.878		3.2400
4	34.380	poly-naphthene	0.0090
5	42.257	ethylbenzene	46.6738
6	42.628	iso-propylbenzene	13.5401
7	42.823	C_8 aromatic	0.6007
8	43.411	C_9 aromatic	0.2000
9	46.473	C_9 aromatic	0.0679
10	57.400	xylenes	13.9076
11	57.752	n-propylbenzene	0.1169
12	58.059	1,2,4-trimethylbenzene	6.2343
13	58.541	1,2,3-trimethylbenzene	0.2532
14	58.970	C_9 aromatic	0.1737
15	59.904	C_9 aromatic	0.0677
16	60.085	1,2,4,5-tetramethylbenzene	0.0588
17	60.839	C_{10} aromatic	0.0818
18	64.507	pentamethylbenzene	2.0215
19	65.696	C_{11} aromatic	0.2047

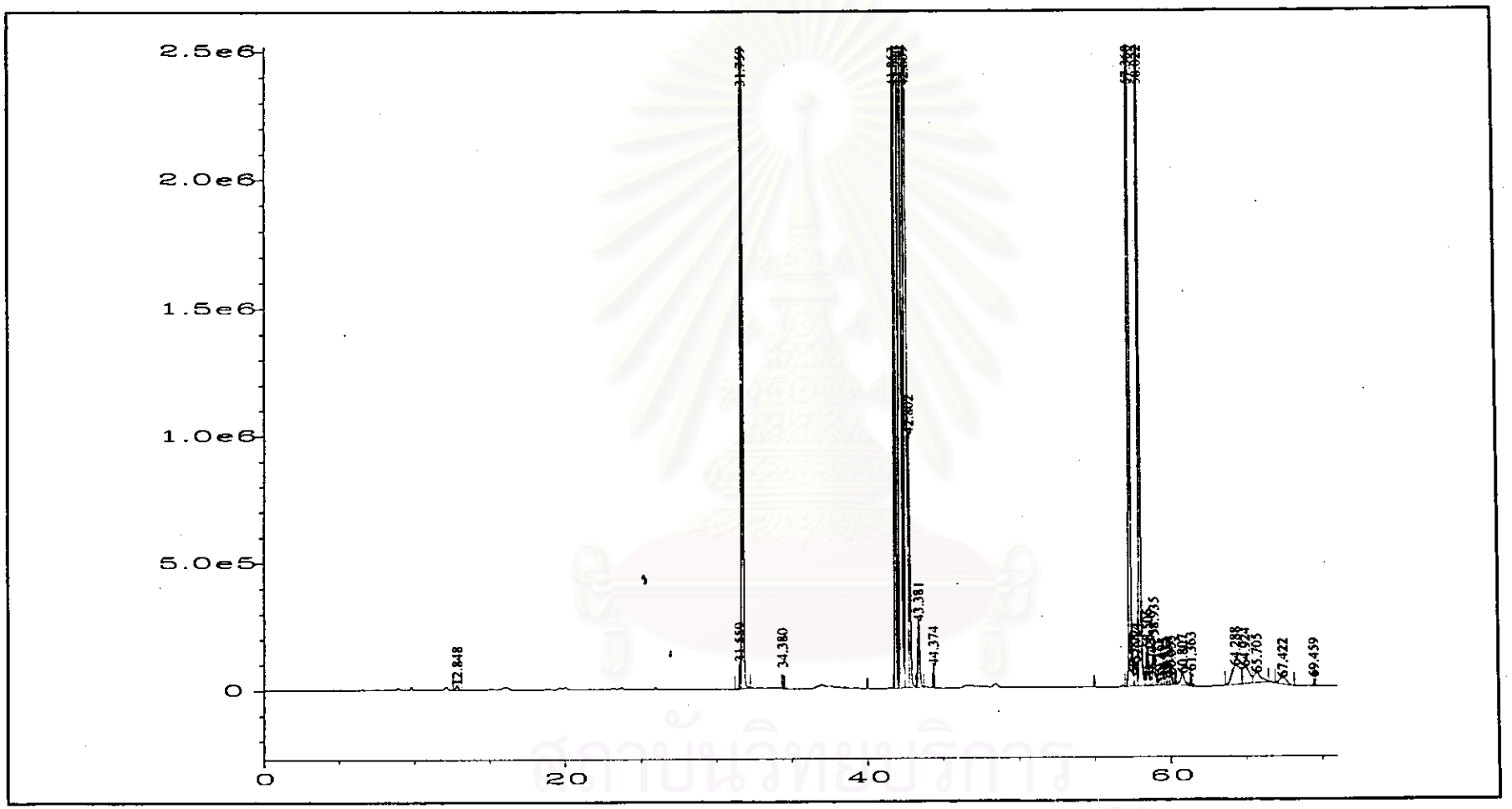

Figure C2 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Ni(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C2 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Ni(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	12.848	n-octane	0.0382
2	31.559	benzene	0.0661
3	31.759	toluene	11.8444
	41.863		5.3179
4	34.380	poly-naphthene	0.0092
5	42.240	ethylbenzene	51.4132
6	42.609	iso-propylbenzene	16.1328
7	42.802	C_8 aromatic	1.0116
8	43.381	C_9 aromatic	0.3531
9	57.368	xylenes	8.1940
10	57.724	n-propylbenzene	0.1074
11	58.022	1,2,4-trimethylbenzene	3.5718
12	58.506	1,2,3-trimethylbenzene	0.2082
13	58.935	C_9 aromatic	0.3019
14	59.493	C_9 aromatic	0.0494
15	59.853	C_9 aromatic	0.0549
16	60.055	1,2,4,5-tetramethylbenzene	0.0701
17	60.807	C_{10} aromatic	0.1428
18	64.288	pentamethylbenzene	0.4532
19	64.924	C_{11} aromatic	0.3345
20	65.705	C_{11} aromatic	0.1945
21	67.422	C_{11} aromatic	0.1308

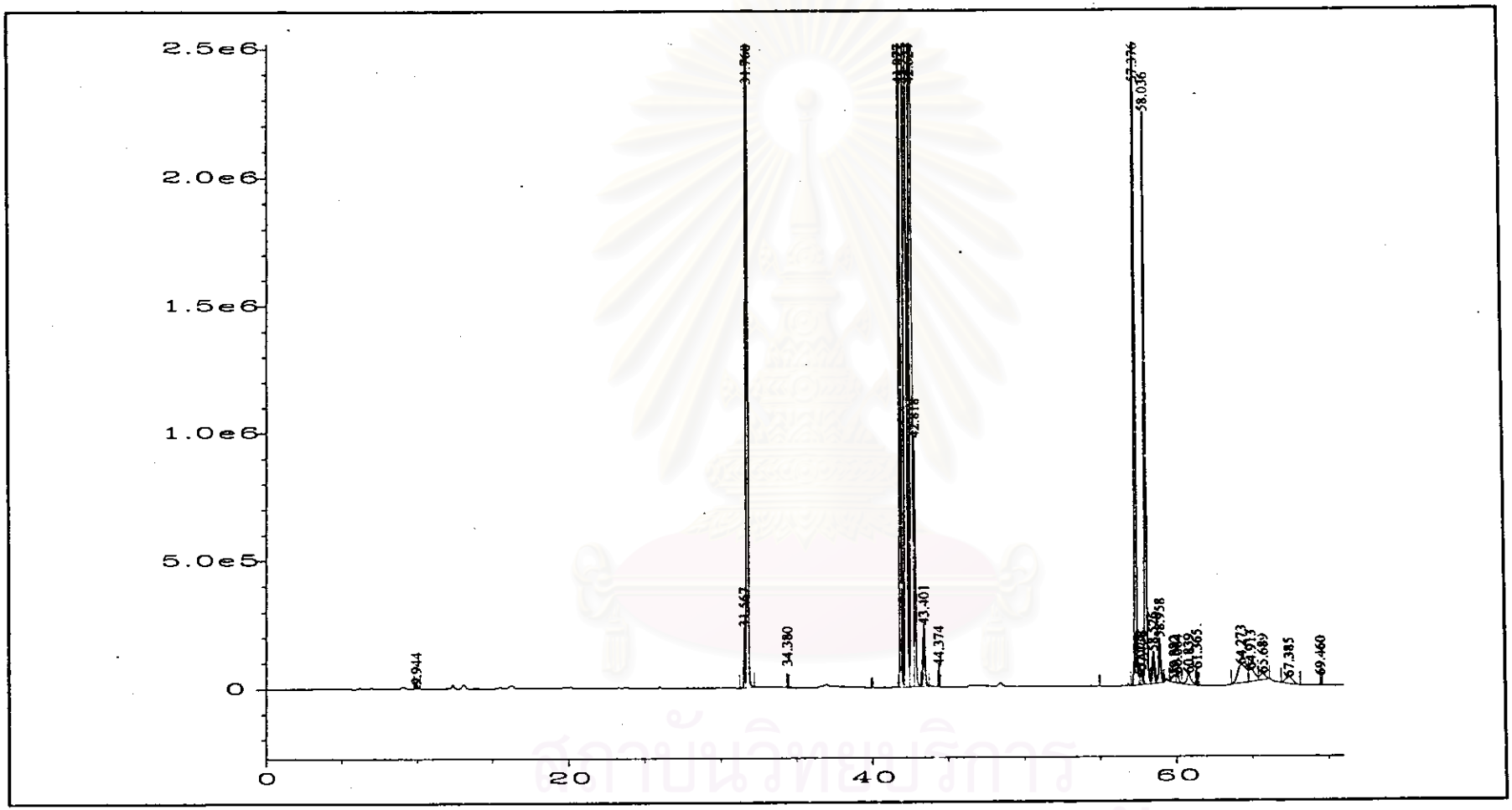

Figure C3 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Co(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C3 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Co(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	9.944	n-heptane	0.0262
2	31.567	benzene	0.1490
3	31.768	toluene	14.0701
	41.877		6.1589
4	34.380	poly-naphthene	0.0093
5	42.255	ethylbenzene	53.8722
6	42.624	iso-propylbenzene	15.3408
7	42.818	C_8 aromatic	1.0054
8	43.401	C_9 aromatic	0.3373
9	57.376	xylenes	4.7878
10	57.738	n-propybenzene	0.0667
11	58.036	1,2,4-trimethylbenzene	2.5660
12	58.526	1,2,3-trimethylbenzene	0.1685
13	58.958	C_9 aromatic	0.2774
14	59.882	C_9 aromatic	0.0683
15	60.084	1,2,4,5-tetramethylbenzene	0.0659
16	60.839	C_{10} aromatic	0.1349
17	64.273	pentamethylbenzene	0.4452
18	64.913	C_{11} aromatic	0.2169
19	65.689	C_{11} aromatic	0.0998
20	67.385	C_{11} aromatic	0.1334

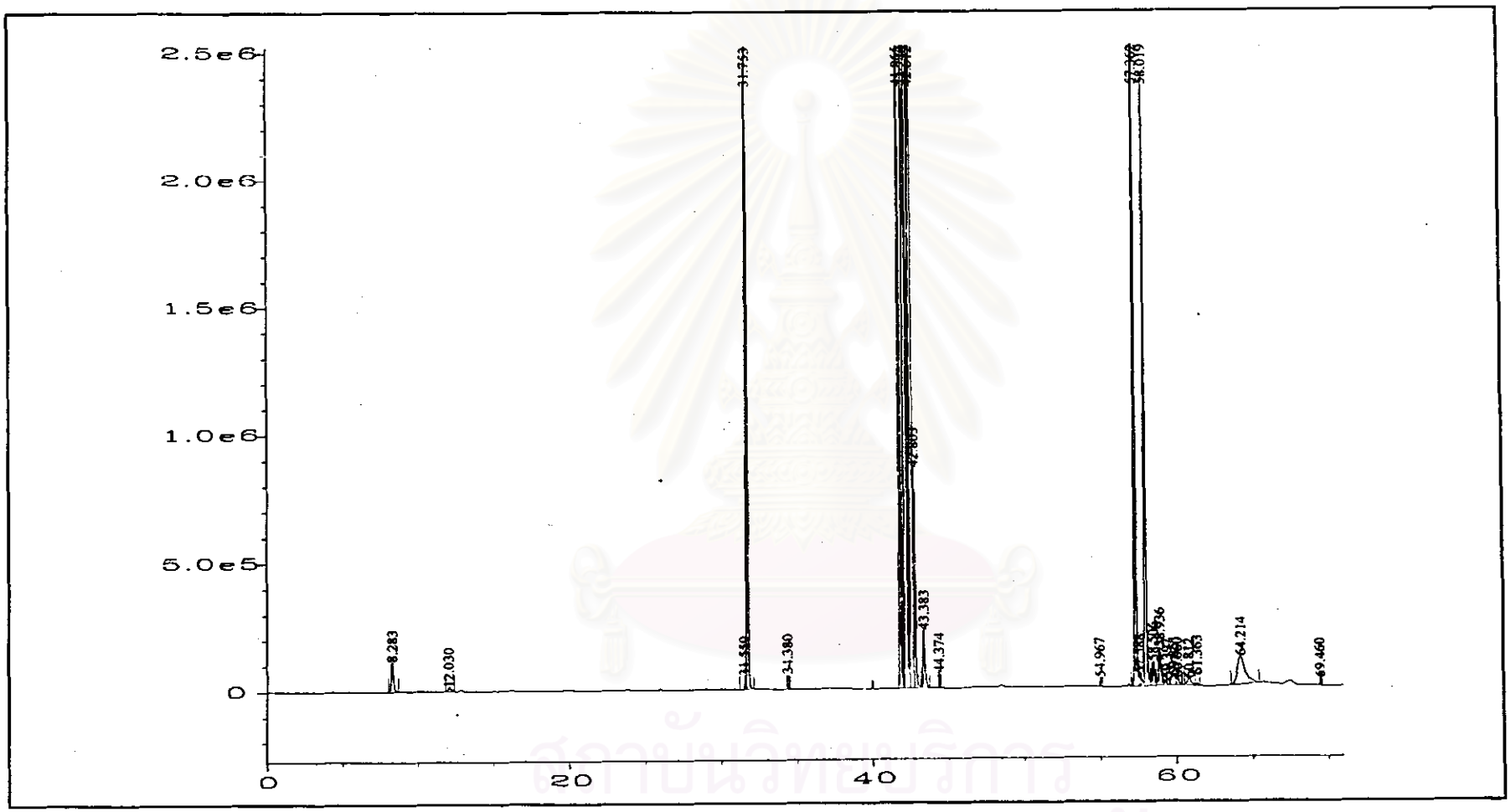

Figure C4 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Zn(5%)-F(2%) catalyst for 90 minutes

Table C4 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Zn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	8.283	methylcyclohexane	0.2199
2	12.030	1,2-dimethylcyclohexane	0.0400
3	31.559	benzene	0.0403
4	31.753	toluene	5.4274
	41.865		7.5536
5	34.380	poly-naphthene	0.0087
6	42.240	ethylbenzene	55.3882
7	42.612	iso-propylbenzene	20.2540
8	42.803	C_8 aromatic	0.9914
9	43.383	C_9 aromatic	0.3569
10	57.362	xylenes	5.1488
11	57.588	n-propybenzene	0.0610
12	58.019	1,2,4-trimethylbenzene	3.0759
13	58.506	1,2,3-trimethylbenzene	0.1600
14	58.936	C_9 aromatic	0.2738
15	59.851	C_9 aromatic	0.1348
16	60.060	1,2,4,5-tetramethylbenzene	0.0610
17	60.812	C_{10} aromatic	0.0812
18	64.214	pentamethylbenzene	0.7231

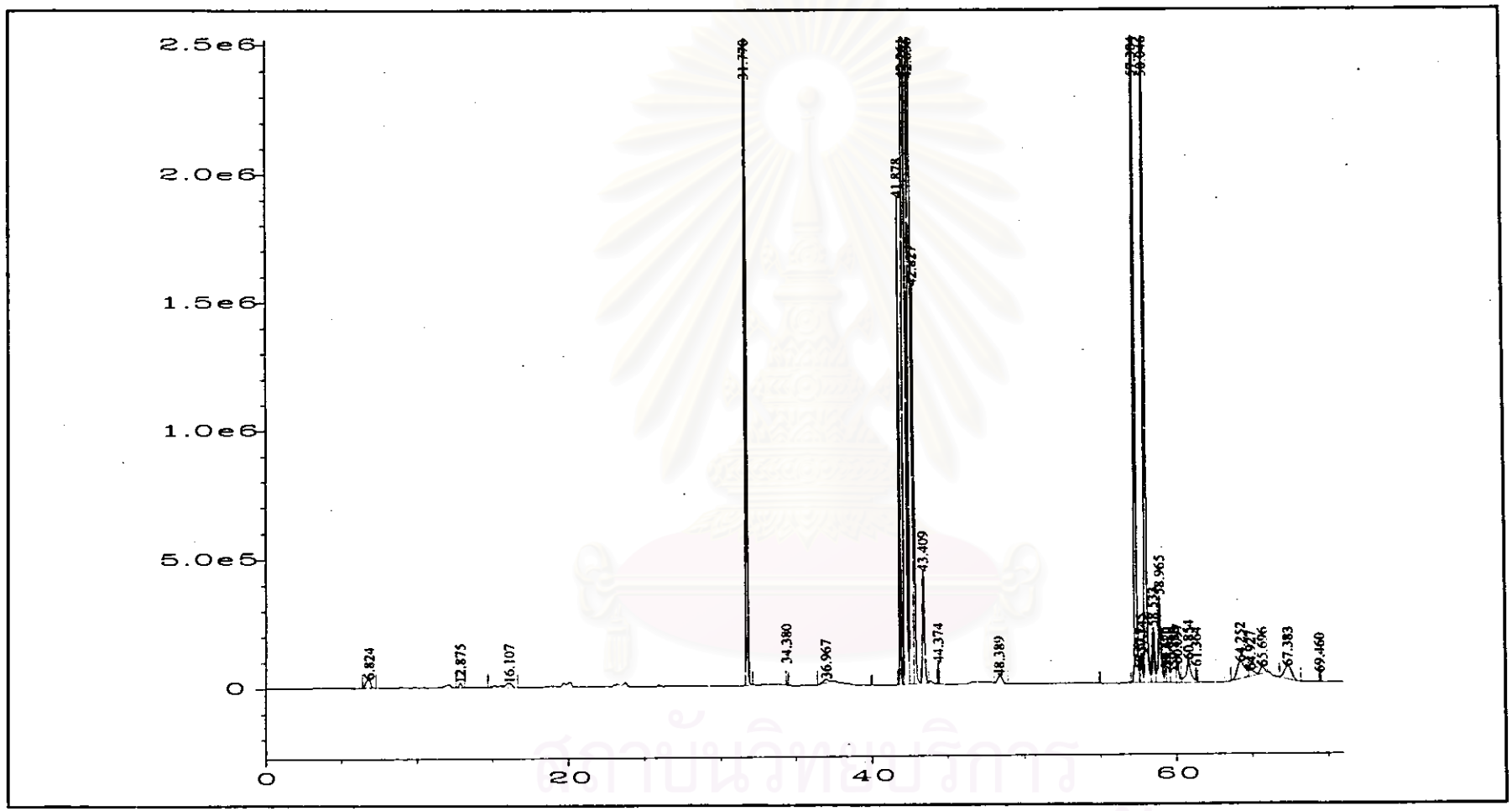

Figure C5 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Pb(5%)-F(2%) catalyst for 90 minutes

Table C5 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Pb(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	6.824	n-hexane	0.1140
2	12.875	n-octane	0.0344
3	16.107	n-nonane	0.1228
4	31.770	toluene	5.2607
	41.878	*	1.2894
5	34.380	poly-naphthene	0.0086
6	36.967	n-tetradecane	0.0552
7	42.261	ethylbenzene	55.1475
7	42.636	iso-propylbenzene	22.7036
8	42.827	C_8 aromatic	1.5486
9	43.409	C_9 aromatic	0.5891
10	48.389	C_9 aromatic	0.0921
11	57.384	xylenes	6.5547
12	57.745	n-propylbenzene	0.1336
13	58.046	1,2,4-trimethylbenzene	3.9144
14	58.533	1,2,3-trimethylbenzene	0.3078
15	58.965	C_9 aromatic	0.5859
16	59.429	C_9 aromatic	0.1256
17	59.888	C_9 aromatic	0.1752
18	60.097	1,2,4,5-tetramethylbenzene	0.1498
19	60.854	C_{10} aromatic	0.2943
20	64.252	pentamethylbenzene	0.3630
21	64.927	C_{11} aromatic	0.0926
22	65.696	C_{11} aromatic	0.0821
23	67.383	C_{11} aromatic	0.2550

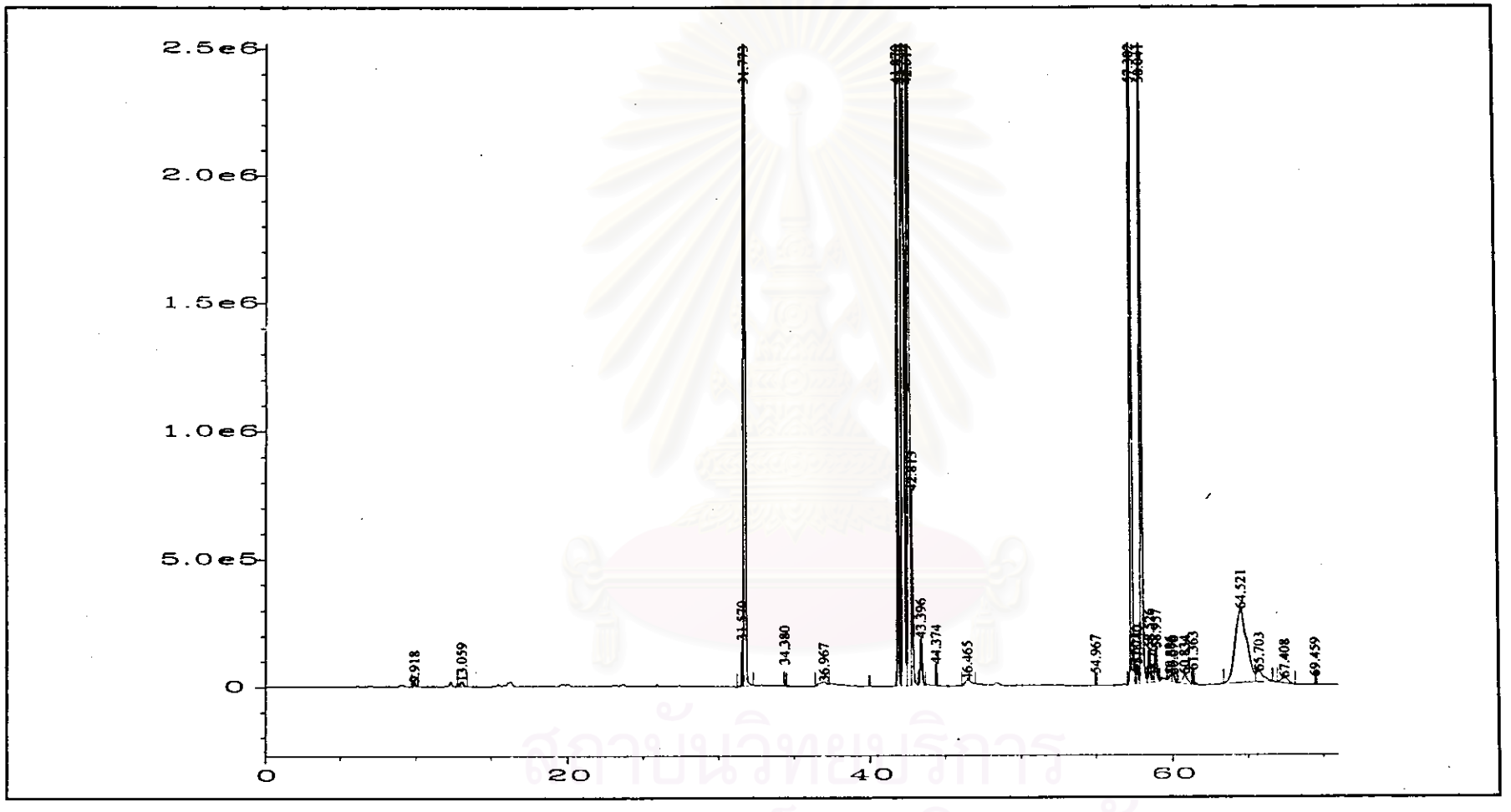

Figure C6 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Al(2%)-F(2%) catalyst for 90 minutes

Table C6 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Al(2%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	9.918	n-heptane	0.0255
2	13.059	n-octane	0.0491
3	31.570	benzene	0.1104
4	31.773	toluene	14.1438
	41.870		2.6720
5	34.380	poly-naphthene	0.0096
6	36.967	n-tetradecane	0.0529
7	42.249	ethylbenzene	50.8164
8	42.619	iso-propylbenzene	15.3207
9	42.813	C_8 aromatic	0.7828
10	43.396	C_9 aromatic	0.2589
11	46.465	C_9 aromatic	0.0715
12	57.382	xylenes	8.2788
13	57.740	n-propylbenzene	0.0848
14	58.041	1,2,4-trimethylbenzene	4.0118
15	58.526	1,2,3-trimethylbenzene	0.1772
16	58.957	C_9 aromatic	0.1963
17	59.886	C_9 aromatic	0.0444
18	60.076	1,2,4,5-tetramethylbenzene	0.0483
19	60.834	C_{10} aromatic	0.1252
20	64.521	pentamethylbenzene	2.3994
21	65.703	C_{11} aromatic	0.2181
22	67.408	C_{11} aromatic	0.1021

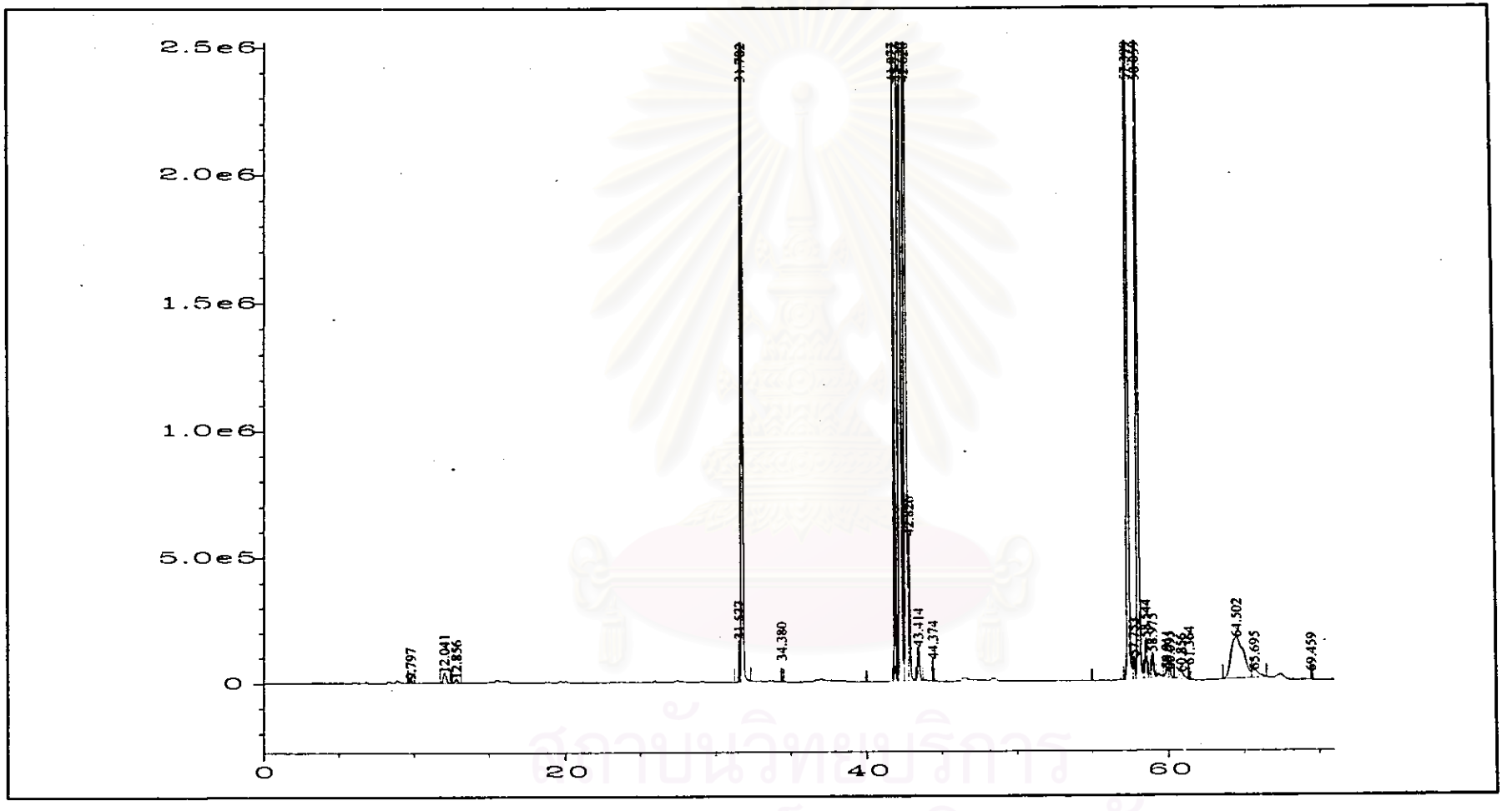

Figure C7 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Al(3%)-F(2%) catalyst for 90 minutes

Table C7 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Al(3%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	9.797	n-heptane	0.0233
2	12.041	1,2-dimethylcyclohexane	0.0892
3	12.856	n-octane	0.0367
4	31.577	benzene	0.1107
5	31.782	toluene	16.0368
	41.877		2.3393
6	34.380	poly-naphthene	0.0100
7	42.256	ethylbenzene	45.5052
8	42.628	iso-propylbenzene	12.7275
9	42.826	C_8 aromatic	0.6294
10	43.414	C_9 aromatic	0.2089
11	57.399	xylenes	14.0743
12	57.753	n-propylbenzene	0.1052
13	58.059	1,2,4-trimethylbenzene	5.8179
14	58.544	1,2,3-trimethylbenzene	0.2193
15	58.975	C_9 aromatic	0.1625
16	59.911	C_9 aromatic	0.0621
17	60.095	1,2,4,5-tetramethylbenzene	0.0558
18	60.856	C_{10} aromatic	0.1063
19	64.502	pentamethylbenzene	1.5274
20	65.695	C_{11} aromatic	0.1522

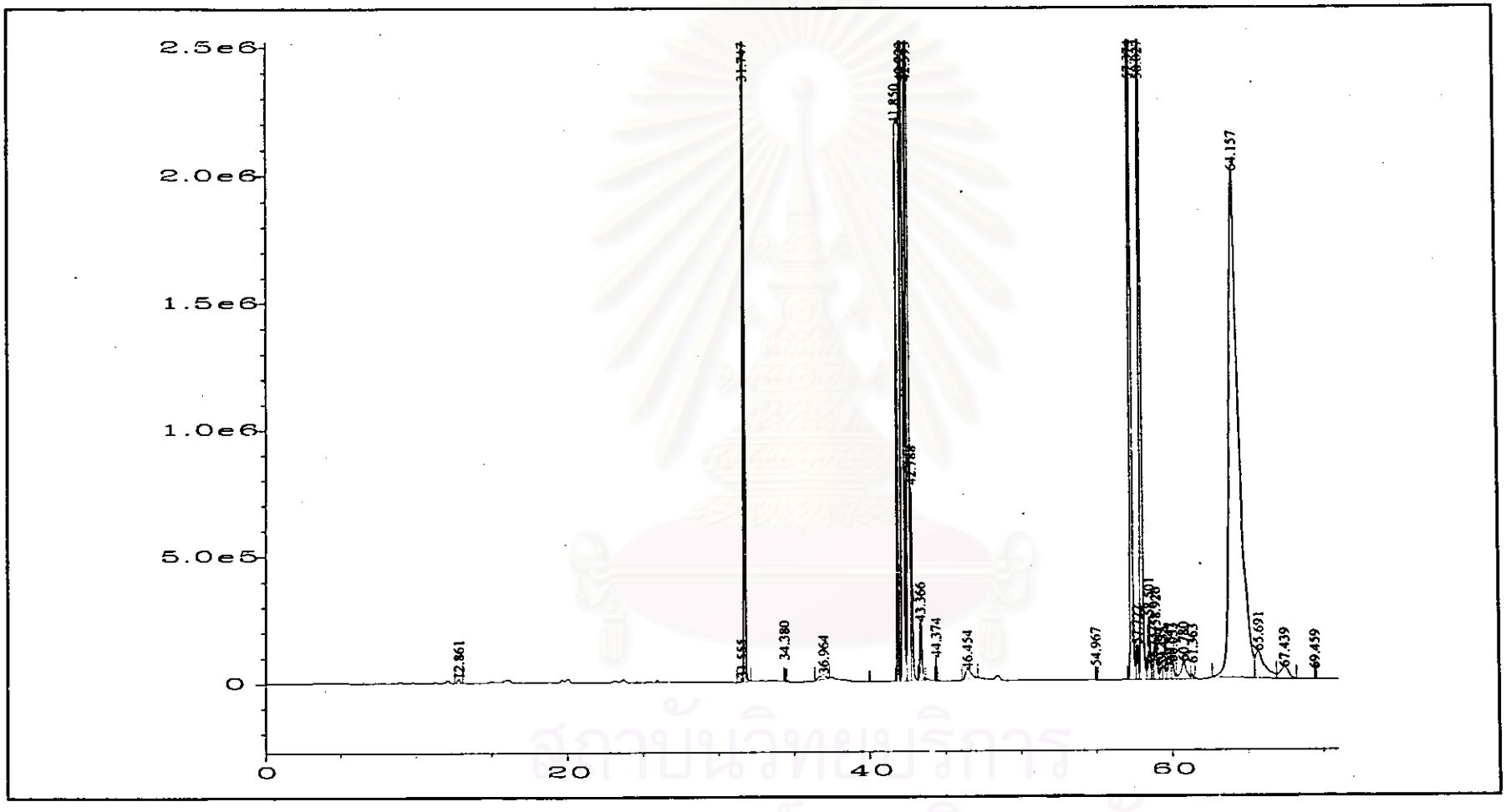

Figure C8 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Al(5%)-F(2%) catalyst for 90 minutes

Table C8 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Al(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	12.861	n-octane	0.0331
2	31.555	benzene	0.0129
3	31.747	toluene	5.7015
	41.850		1.5209
4	34.380	poly-naphthene	0.0098
5	36.964	n-tetradecane	0.0853
6	42.223	ethylbenzene	35.3364
7	42.593	iso-propylbenzene	13.1968
8	42.788	C_8 aromatic	0.8325
9	43.366	C_9 aromatic	0.3417
10	46.454	C_9 aromatic	0.1635
11	57.374	xylenes	18.1100
12	57.722	n-propylbenzene	0.1632
13	58.027	1,2,4-trimethylbenzene	7.7057
14	58.501	1,2,3-trimethylbenzene	0.3513
15	58.926	C_9 aromatic	0.3613
16	59.435	C_9 aromatic	0.1078
17	59.847	C_9 aromatic	0.1593
18	60.035	1,2,4,5-tetramethylbenzene	0.1367
19	60.780	C_{10} aromatic	0.2843
20	64.157	pentamethylbenzene	14.3668
21	65.691	C_{11} aromatic	0.7353
22	67.439	C_{11} aromatic	0.2839

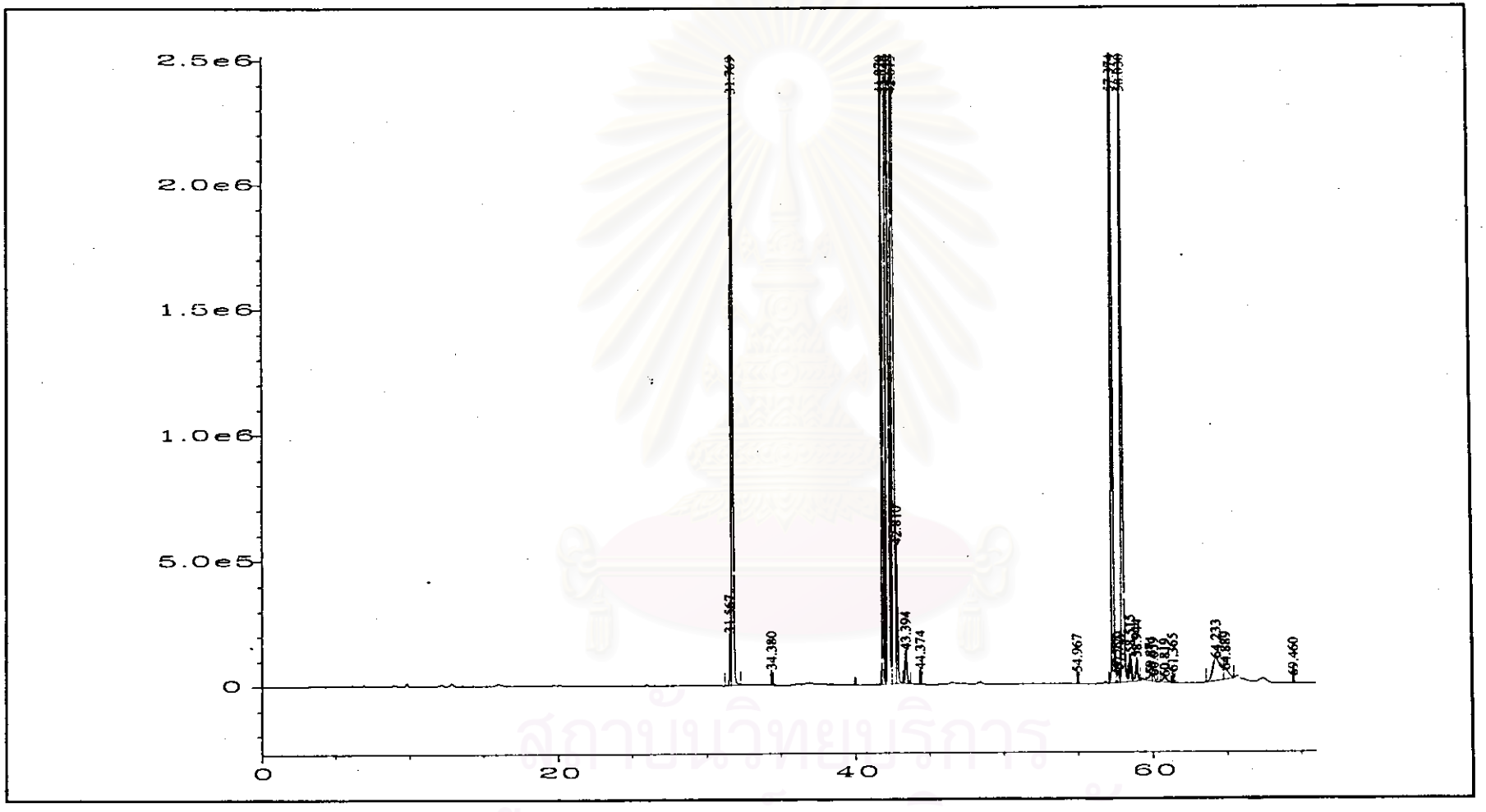

Figure C9 GC chromatogram of product from hydrocracking at H_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C9 Composition and % peak area of product from hydrocracking at H_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	31.567	benzene	0.1530
2	31.769	toluene	14.3834
	41.870		4.6678
3	34.380	poly-naphthene	0.0085
4	42.246	ethylbenzene	49.9597
5	42.615	iso-propylbenzene	14.6393
6	42.810	C_8 aromatic	0.6596
7	43.394	C_9 aromatic	0.2244
8	57.374	xylenes	9.4288
9	57.729	n-propylbenzene	0.0673
10	58.030	1,2,4-trimethylbenzene	4.5012
11	58.515	1,2,3-trimethylbenzene	0.1750
12	58.944	C_9 aromatic	0.1804
13	59.871	C_9 aromatic	0.0663
14	60.059	1,2,4,5-tetramethylbenzene	0.0475
15	60.819	C_{10} aromatic	0.0732
16	64.233	pentamethylbenzene	0.6052
17	64.889	C_{11} aromatic	0.1594

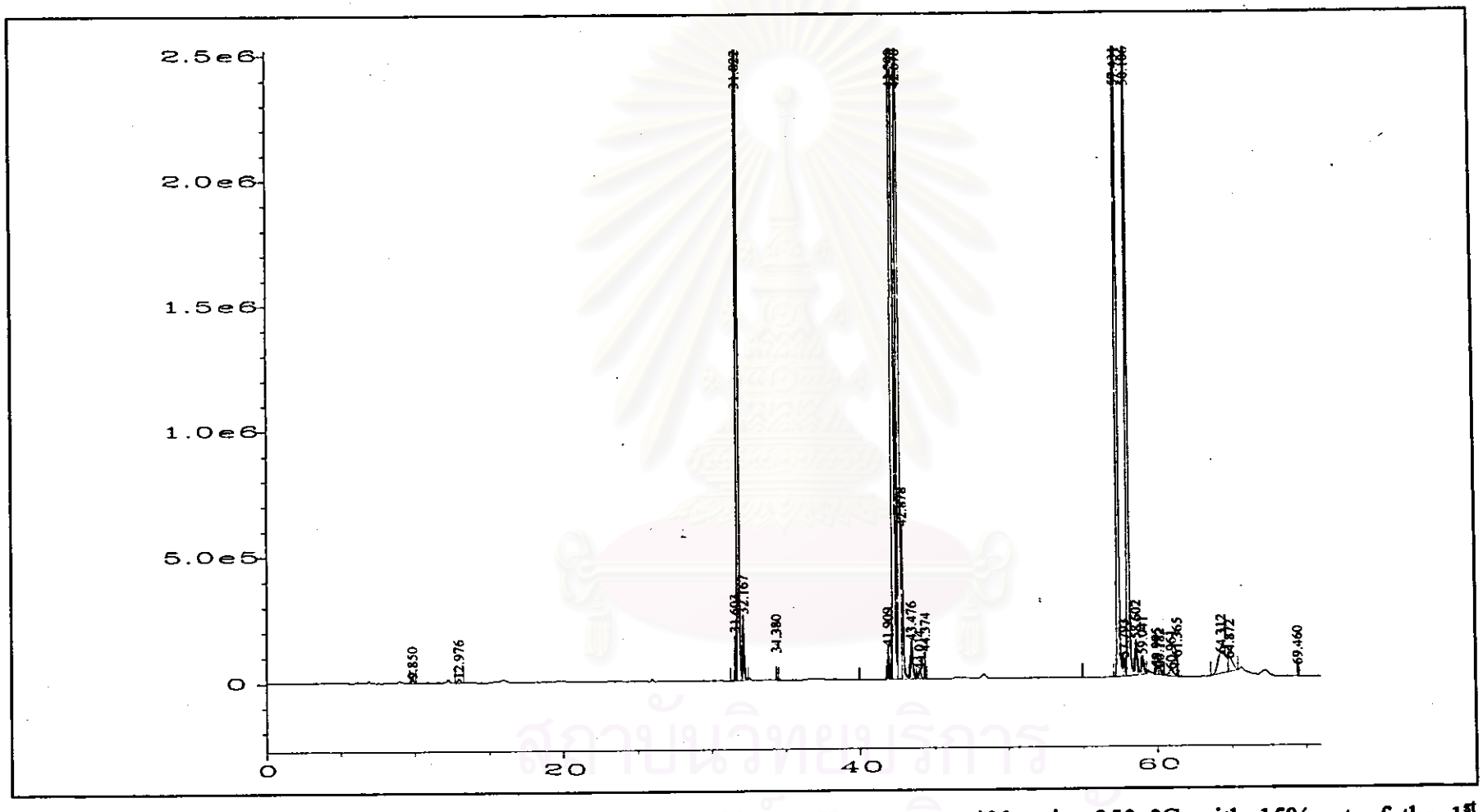

Figure C10 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of the 1st regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C10 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of the 1st regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	9.850	n-heptane	0.0264
2	12.976	n-octane	0.0364
3	31.603	benzene	0.1388
4	31.822	toluene	20.0462
	41.909		0.1045
5	32.167	C_8 aromatic	0.2816
6	34.380	poly-naphthene	0.0133
7	42.298	ethylbenzene	42.0322
8	42.676	iso-propylbenzene	13.5868
9	42.878	C_8 aromatic	0.7289
10	43.476	C_9 aromatic	0.2562
11	44.014	C_9 aromatic	0.0656
12	57.431	xylenes	15.1823
13	57.793	n-propylbenzene	0.0923
14	58.106	1,2,4-trimethylbenzene	6.1025
15	58.602	1,2,3-trimethylbenzene	0.2085
16	59.041	C_9 aromatic	0.1346
17	59.995	C_9 aromatic	0.0540
18	60.182	1,2,4,5-tetramethylbenzene	0.0552
19	60.961	C_{10} aromatic	0.1028
20	64.312	pentamethylbenzene	0.5419
21	64.872	C_{11} aromatic	0.2090

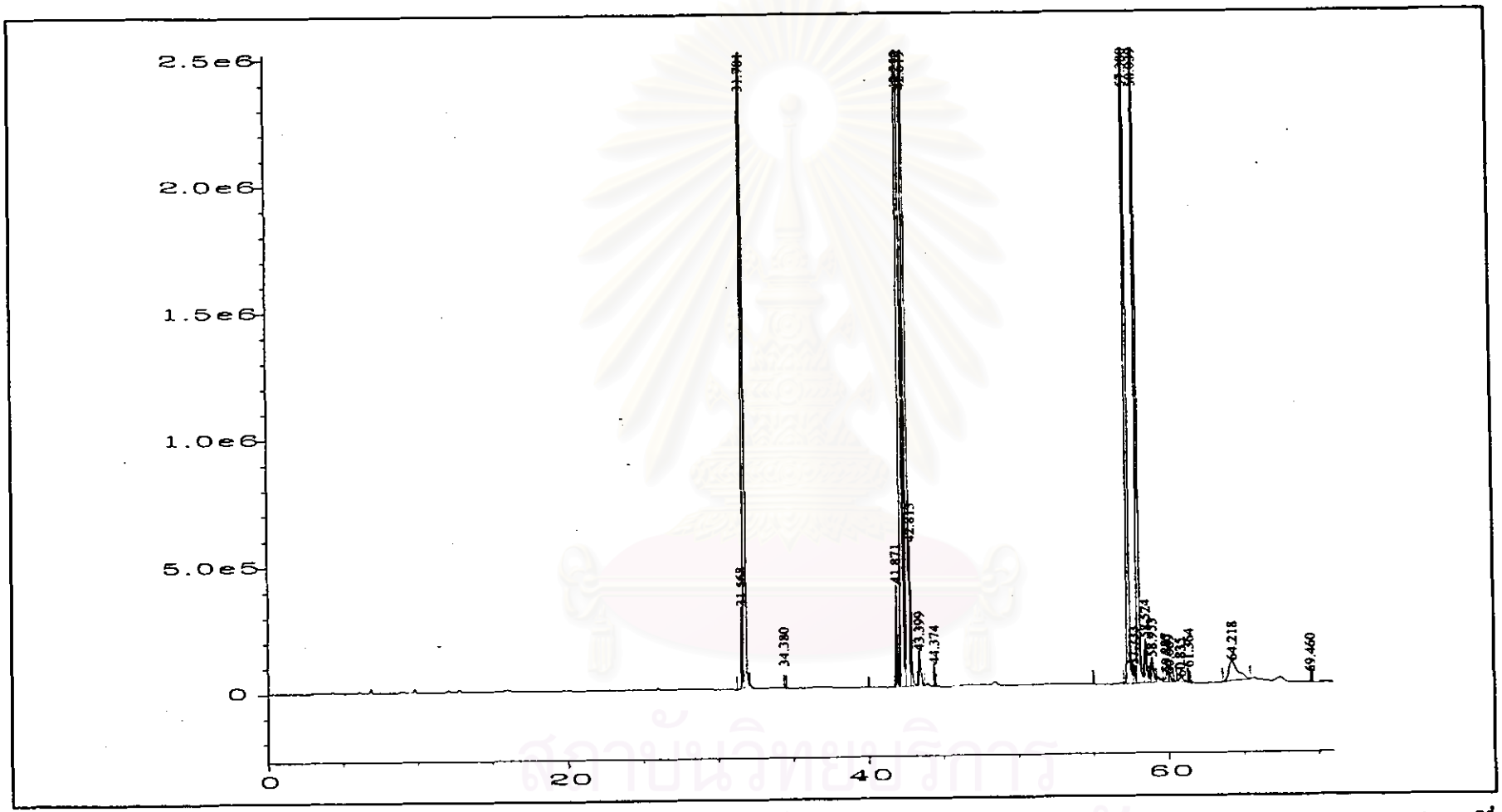

Figure C11 GC chromatogram of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of the 2nd regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C11 Composition and % peak area of product from hydrocracking at H_2 pressure 400 psig, 350 °C with 15% wt of the 2nd regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	31.568	benzene	0.1932
2	31.781	toluene	22.6707
	41.871		0.2783
3	34.380	poly-naphthene	0.0103
4	42.252	ethylbenzene	46.2447
5	42.619	iso-propylbenzene	13.1694
6	42.813	C_8 aromatic	0.5710
7	43.399	C_9 aromatic	0.2052
8	57.380	xylenes	10.4777
9	57.733	n-propylbenzene	0.0842
10	58.039	1,2,4-trimethylbenzene	4.9966
11	58.524	1,2,3-trimethylbenzene	0.2327
12	58.953	C_9 aromatic	0.1659
13	59.887	C_9 aromatic	0.0281
14	60.069	1,2,4,5-tetramethylbenzene	0.0562
15	60.835	C_{10} aromatic	0.0558
16	64.218	pentamethylbenzene	0.5100

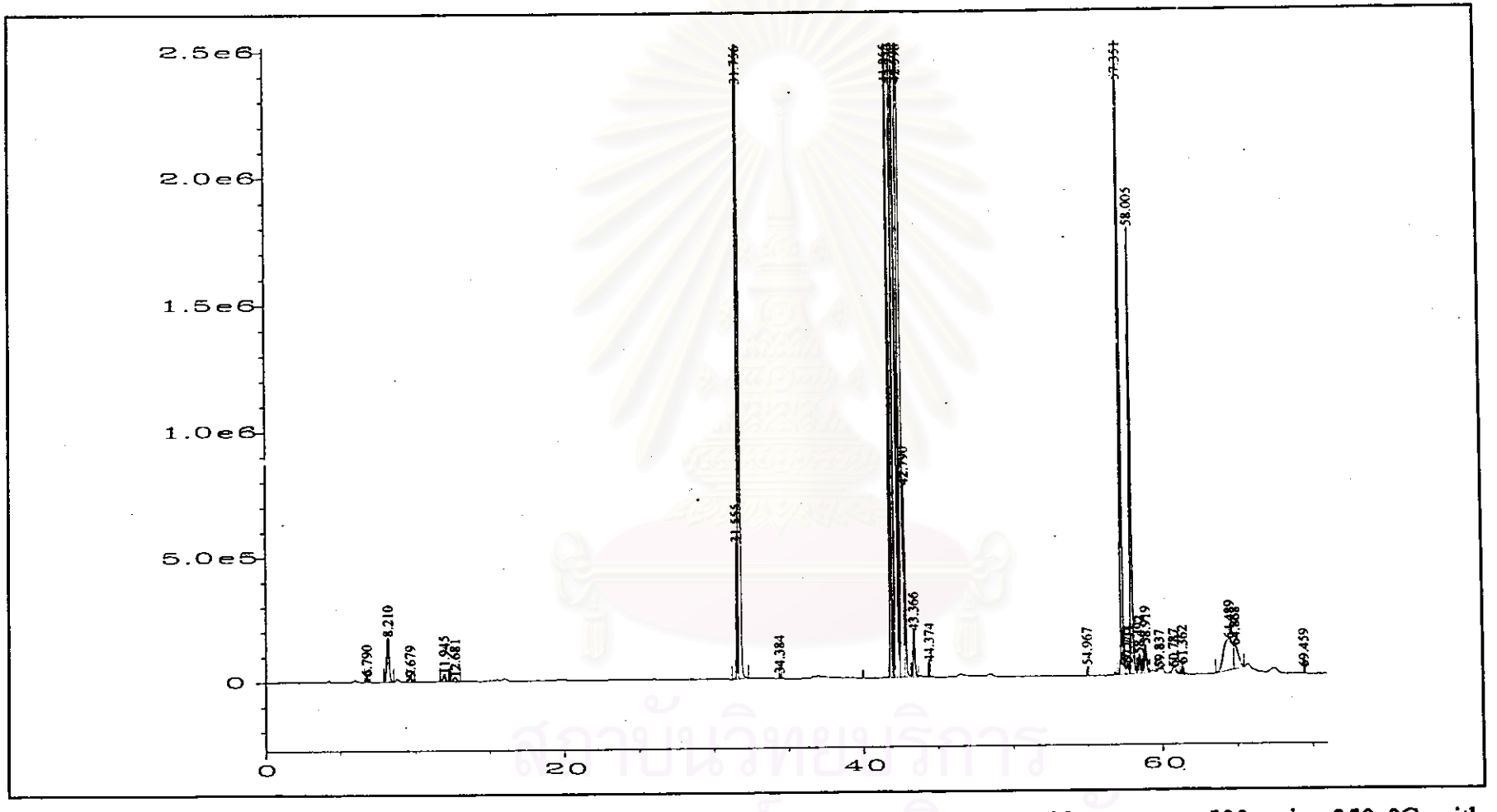

Figure C12 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 500 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 180 minutes

Table C12 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 500 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 180 minutes

No.	Retention Time (min.)	Component	% peak area
1	6.790	n-hexane	0.0289
2	8.210	methylcyclohexane	0.3607
3	9.679	n-heptane	0.0419
4	11.945	1,2-dimethylcyclohexane	0.0549
5	12.681	n-octane	0.0452
6	31.555	benzene	0.3851
7	31.756	toluene	18.1530
	41.855		3.9060
8	34.384	poly-naphthene	0.0059
9	42.230	ethylbenzene	52.8556
10	42.596	iso-propylbenzene	14.7610
11	42.790	C_8 aromatic	0.9036
12	43.366	C_9 aromatic	0.2881
13	57.351	xylenes	4.2185
14	57.711	n-propylbenzene	0.0565
15	58.005	1,2,4-trimethylbenzene	2.2651
16	58.492	1,2,3-trimethylbenzene	0.1176
17	58.919	C_9 aromatic	0.1922
18	60.787	C_{10} aromatic	0.0748
19	64.489	pentamethylbenzene	0.9261
20	64.868	C_{11} aromatic	0.3593

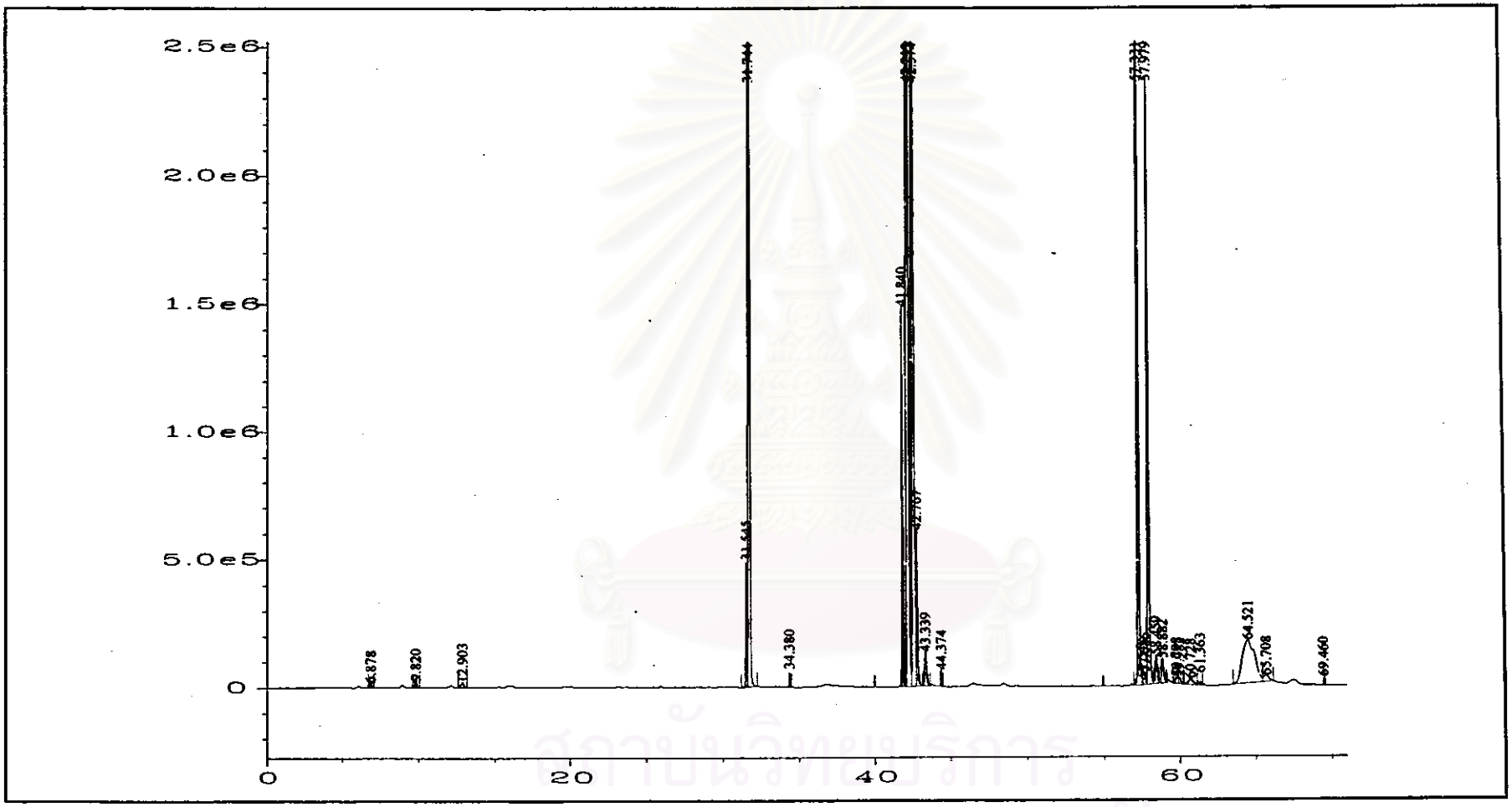

Figure C13 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 500 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C13 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 500 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	6.878	n-hexane	0.0244
2	9.820	n-heptane	0.0427
3	12.903	n-octane	0.0507
4	31.545	benzene	0.3670
5	31.744	toluene	20.3970
	41.840		1.2063
6	34.380	poly-naphthene	0.0098
7	42.213	ethylbenzene	52.1503
8	42.574	iso-propylbenzene	13.7555
9	42.767	C_8 aromatic	0.7623
10	43.339	C_9 aromatic	0.2314
11	57.331	xylenes	5.4154
12	57.686	n-propylbenzene	0.0645
13	57.979	1,2,4-trimethylbenzene	3.1636
14	58.459	1,2,3-trimethylbenzene	0.1726
15	58.882	C_9 aromatic	0.1728
16	60.728	C_{10} aromatic	0.0974
17	64.521	pentamethylbenzene	1.8079
18	65.708	C_{11} aromatic	0.1084

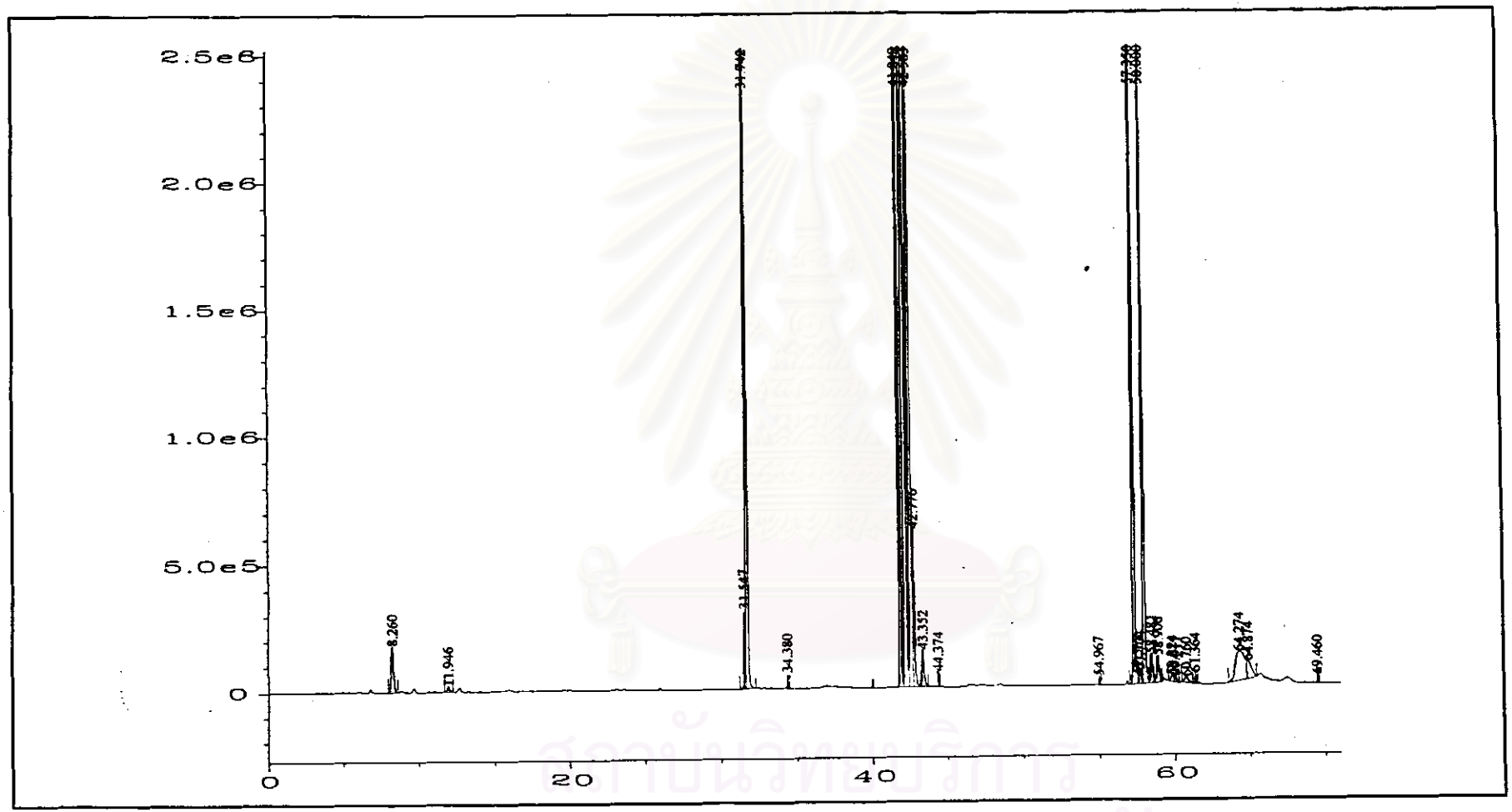

Figure C14 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C14 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 400 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	8.260	methylcyclohexane	0.3481
2	11.946	1,2-dimethylcyclohexane	0.0433
3	31.547	benzene	0.2192
4	31.742	toluene	12.0028
	41.849		8.1958
5	34.380	poly-naphthene	0.0085
6	42.219	ethylbenzene	51.4520
7	42.583	iso-propylbenzene	13.9991
8	42.776	C_8 aromatic	0.7334
9	43.352	C_9 aromatic	0.2362
10	57.350	xylenes	7.2959
11	57.704	n-propylbenzene	0.0712
12	58.000	1,2,4-trimethylbenzene	3.6968
13	58.481	1,2,3-trimethylbenzene	0.1722
14	58.906	C_9 aromatic	0.1950
15	59.824	C_9 aromatic	0.0606
16	60.011	1,2,4,5-tetramethylbenzene	0.0495
17	60.760	C_{10} aromatic	0.0808
18	64.274	pentamethylbenzene	0.8651
19	64.874	C_{11} aromatic	0.2745

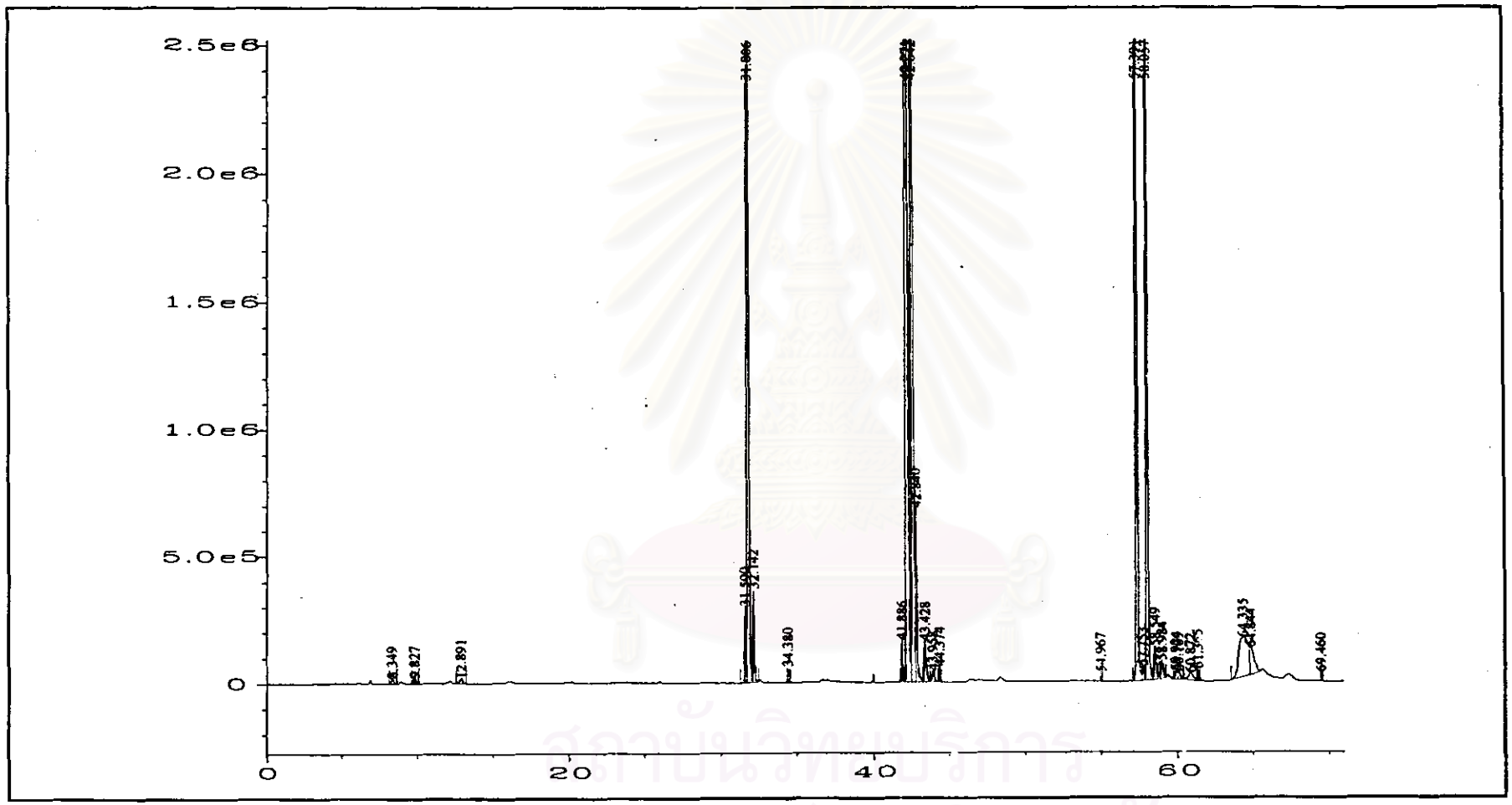

Figure C15 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C15 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	8.349	methylcyclohexane	0.0383
2	9.827	n-heptane	0.0332
3	12.891	n-octane	0.0448
4	31.590	benzene	0.2044
5	31.806	toluene	21.8266
	41.886		0.1252
6	32.142	C_8 aromatic	0.3710
7	34.380	poly-naphthene	0.0079
8	42.271	ethylbenzene	47.9717
9	42.642	iso-propylbenzene	14.0278
10	42.840	C_8 aromatic	0.7678
11	43.428	C_9 aromatic	0.2499
12	43.958	C_9 aromatic	0.0755
13	57.391	xylenes	8.1930
14	57.753	n-propylbenzene	0.0660
15	58.057	1,2,4-trimethylbenzene	4.0453
16	58.549	1,2,3-trimethylbenzene	0.1776
17	58.984	C_9 aromatic	0.1156
18	59.924	C_9 aromatic	0.0562
19	60.109	1,2,4,5-tetramethylbenzene	0.0566
20	60.872	C_{10} aromatic	0.1077
21	64.335	pentamethylbenzene	1.0727
22	64.844	C_{11} aromatic	0.3644

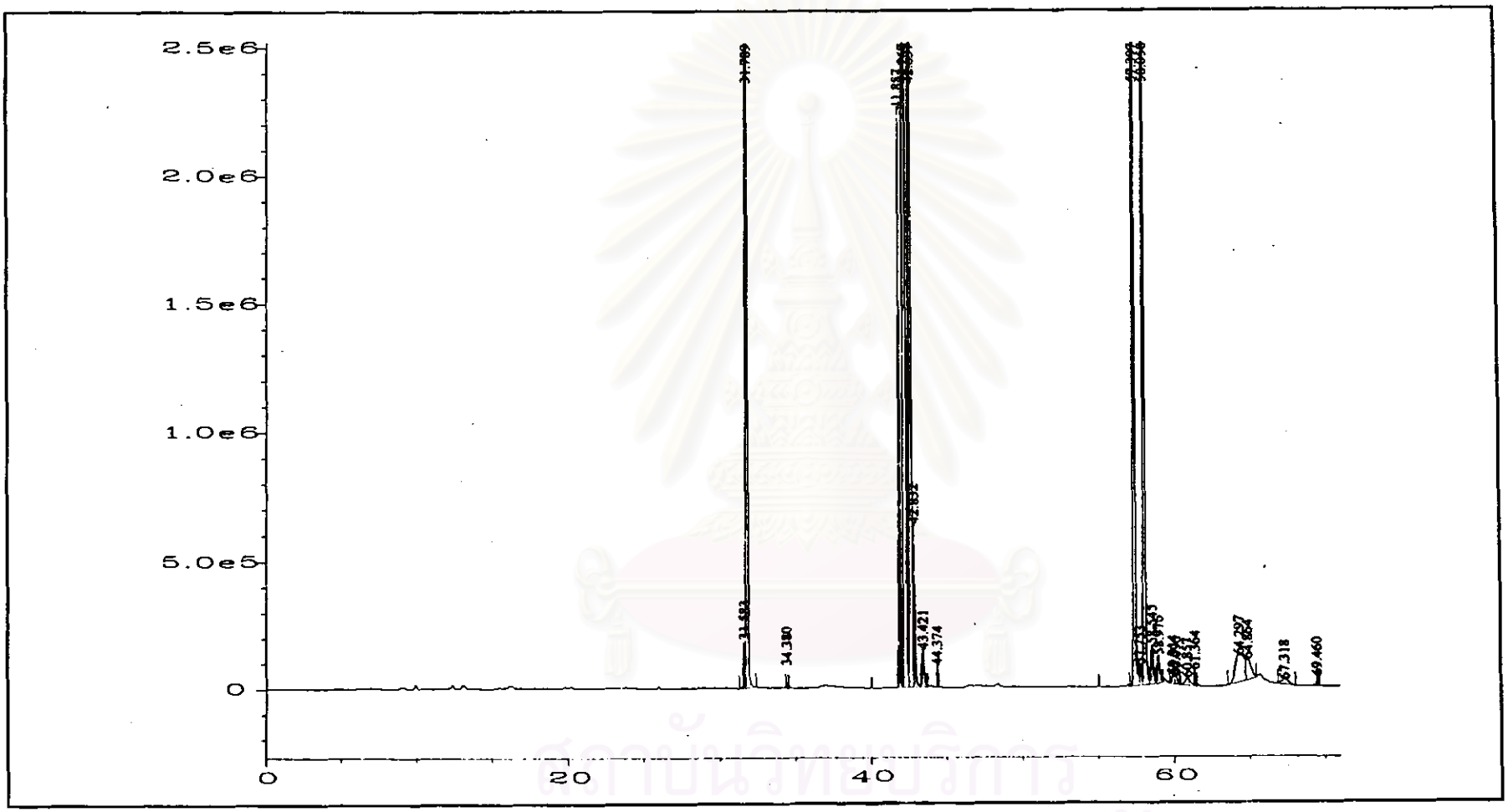

Figure C16 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 200 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C16 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 200 psig, 350 °C with 15% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	31.583	benzene	0.1245
2	31.789	toluene	17.1164
	41.887		1.5909
3	34.380	poly-naphthene	0.0103
4	42.267	ethylbenzene	49.5944
5	42.637	iso-propylbenzene	13.3465
6	42.832	C_8 aromatic	0.6582
7	43.421	C_9 aromatic	0.2185
8	57.397	xylenes	10.7195
9	57.753	n-propylbenzene	0.0934
10	58.058	1,2,4-trimethylbenzene	4.8596
11	58.545	1,2,3-trimethylbenzene	0.2096
12	58.976	C_9 aromatic	0.1716
13	59.914	C_9 aromatic	0.0600
14	60.096	1,2,4,5-tetramethylbenzene	0.0554
15	60.857	C_{10} aromatic	0.1108
16	64.297	pentamethylbenzene	0.6792
17	64.864	C_{11} aromatic	0.3093
18	67.318	C_{11} aromatic	0.1019

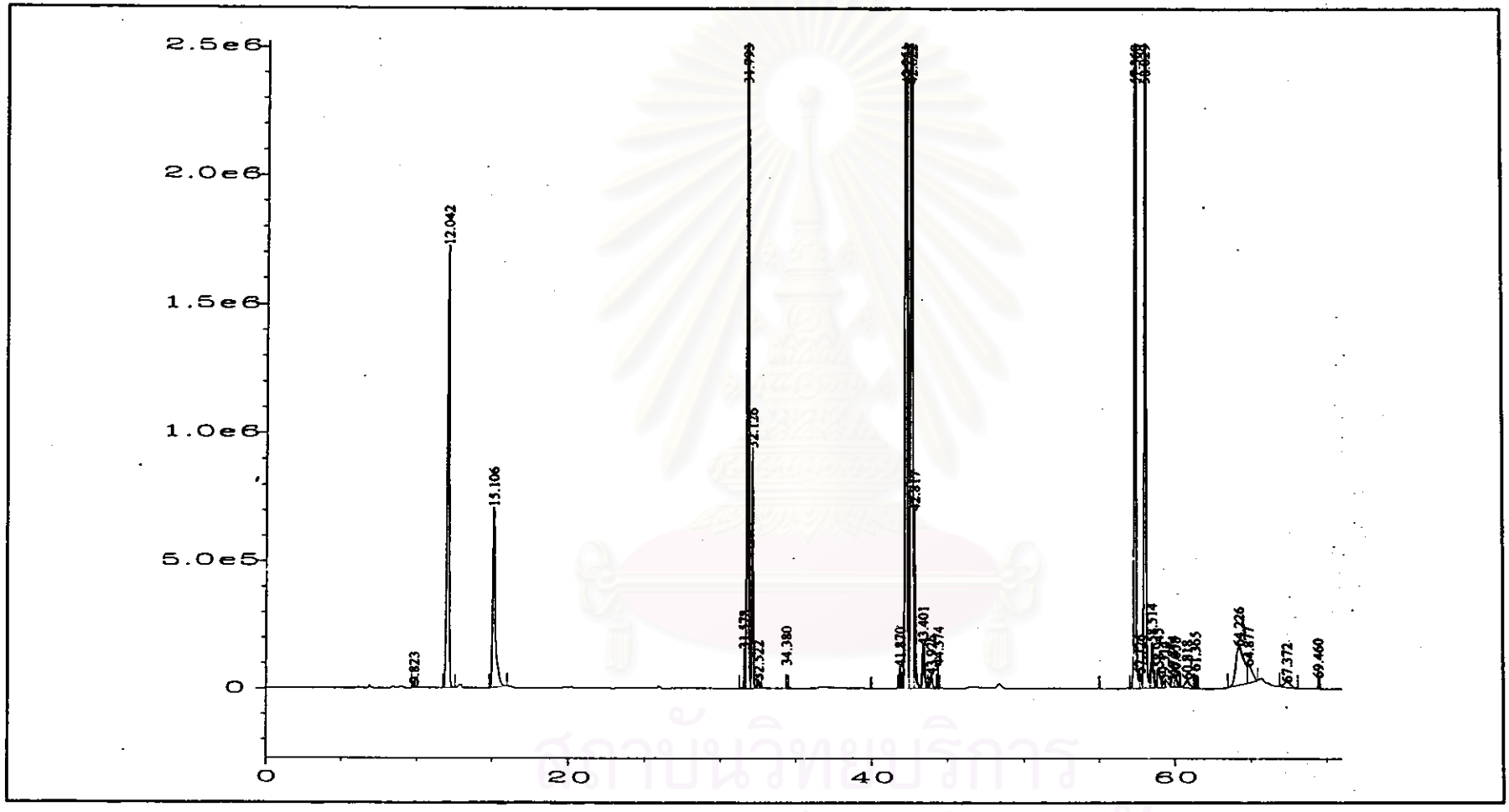

Figure C17 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Ni(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C17 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Ni(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	9.823	n-heptane	0.0227
2	12.042	1,2-dimethylcyclohexane	2.7837
3	15.106	1,2,3-trimethylcyclohexane	1.4779
4	31.578	benzene	0.1129
5	31.793	toluene	19.8603
	41.870		0.0703
6	32.126	C_8 aromatic	0.9689
7	32.522	C_8 aromatic	0.0419
8	34.380	poly-naphthene	0.0115
9	42.251	ethylbenzene	42.1608
10	42.622	iso-propylbenzene	15.1110
11	42.817	C_8 aromatic	0.8058
12	43.401	C_9 aromatic	0.2760
13	43.926	C_9 aromatic	0.0913
14	57.368	xylenes	9.2187
15	57.726	n-propylbenzene	0.0729
16	58.029	1,2,4-trimethylbenzene	4.8579
17	58.514	1,2,3-trimethylbenzene	0.2656
18	58.945	C_9 aromatic	0.1556
19	59.874	C_9 aromatic	0.0919
20	60.058	1,2,4,5-tetramethylbenzene	0.0777
21	60.818	C_{10} aromatic	0.1191
22	64.226	pentamethylbenzene	0.9673
23	64.877	C_{11} aromatic	0.2640
24	67.372	C_{11} aromatic	0.1143

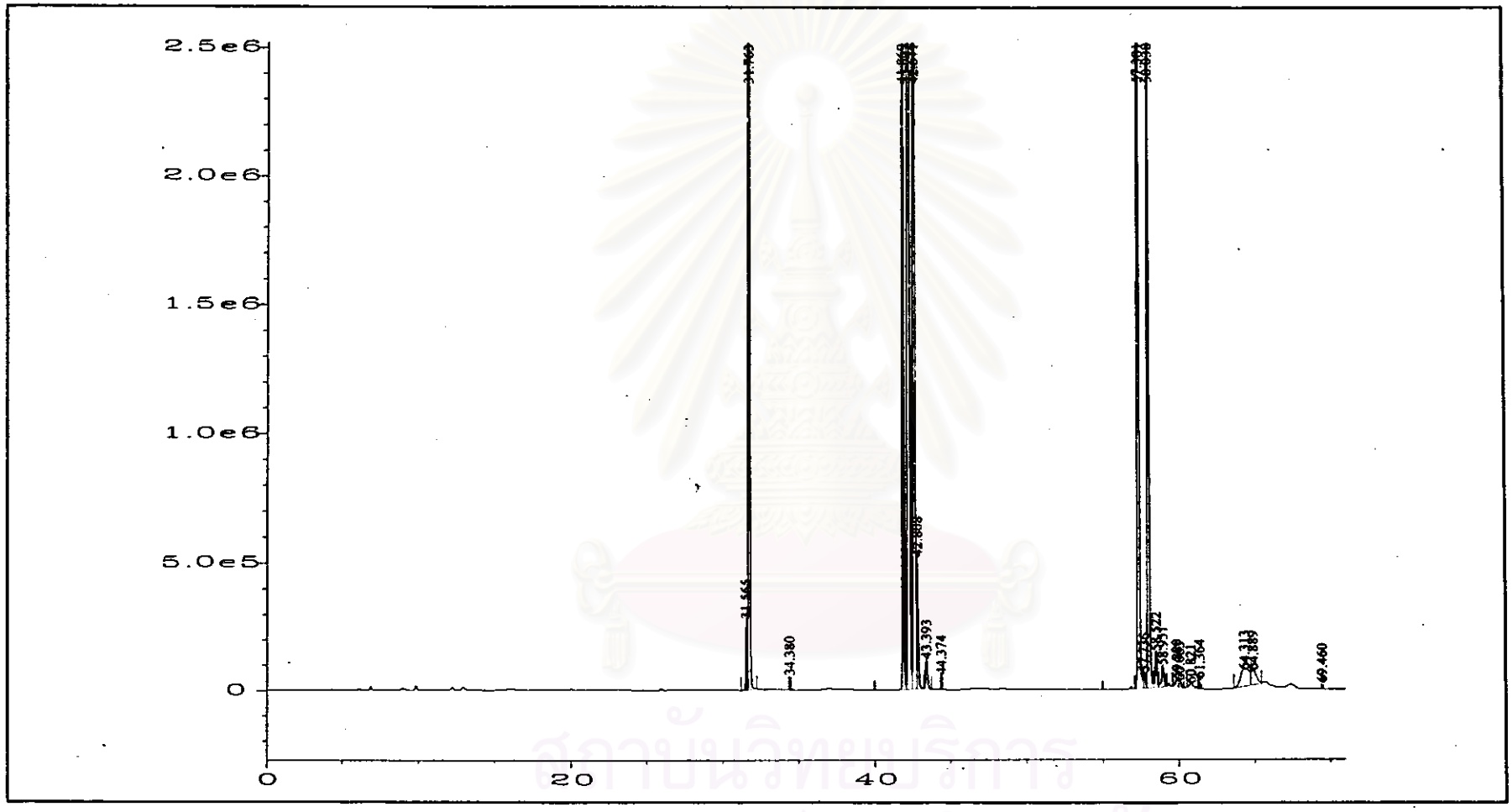

Figure C18 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Co(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C18 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Co(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	31.565	benzene	0.2046
2	31.763	toluene	12.2757
	41.869		8.8078
3	34.380	poly-naphthene	0.0083
4	42.242	ethylbenzene	47.1469
5	42.611	iso-propylbenzene	12.7567
6	42.808	C_8 aromatic	0.6284
7	43.393	C_9 aromatic	0.2030
8	57.381	xylenes	11.3046
9	57.736	n-propylbenzene	0.0842
10	58.038	1,2,4-trimethylbenzene	5.2079
11	58.522	1,2,3-trimethylbenzene	0.2259
12	58.951	C_9 aromatic	0.1720
13	59.880	C_9 aromatic	0.0738
14	60.063	1,2,4,5-tetramethylbenzene	0.0544
15	60.821	C_{10} aromatic	0.0677
16	64.313	pentamethylbenzene	0.5055
17	64.889	C_{11} aromatic	0.2726

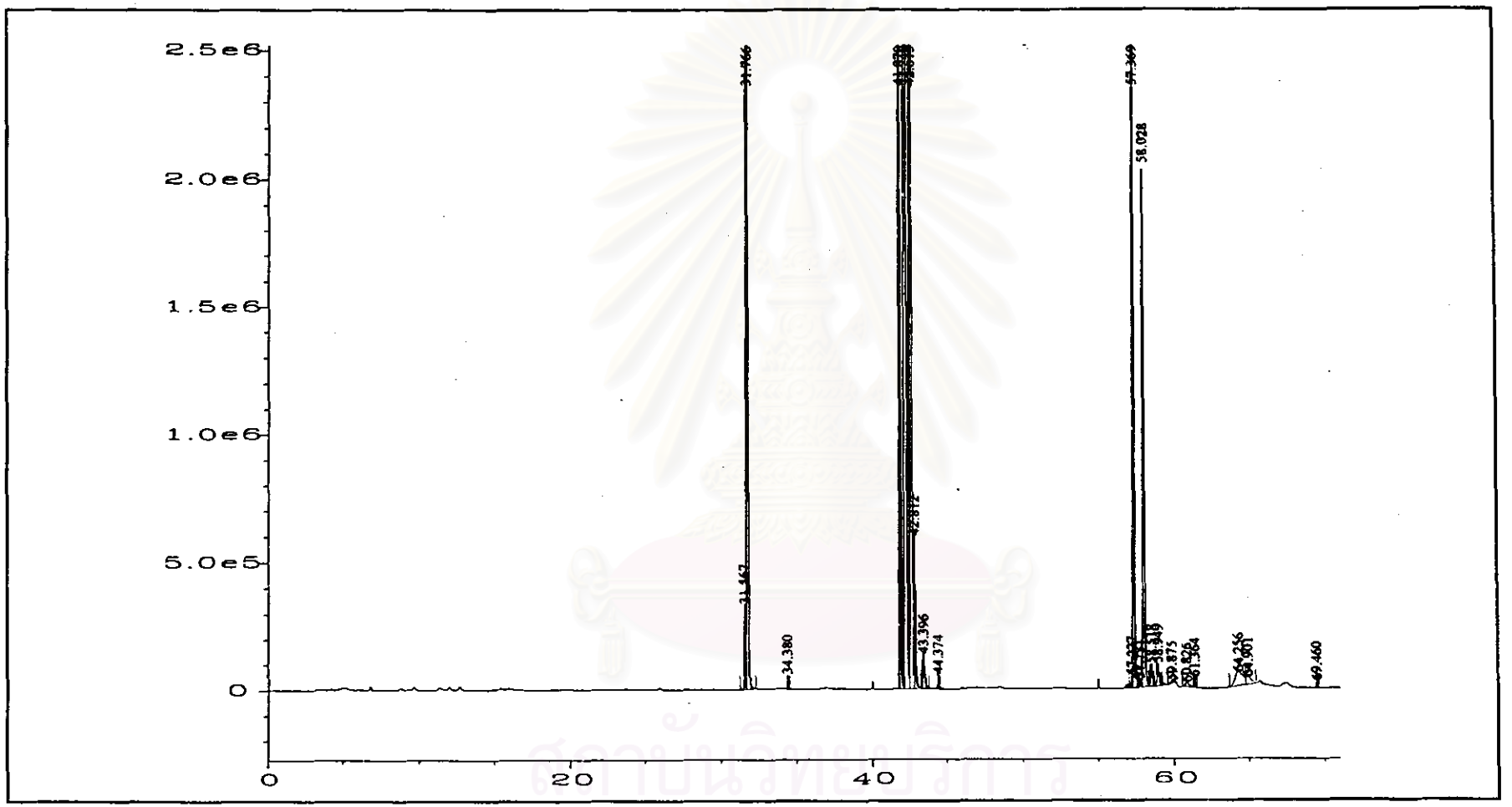

Figure C19 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Zn(5%)-F(2%) catalyst for 90 minutes

Table C19 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Zn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	31.567	benzene	0.2673
2	31.766	toluene	13.7856
	41.870		7.2320
3	34.380	poly-naphthene	0.0096
4	42.246	ethylbenzene	54.3773
5	42.615	iso-propylbenzene	14.4892
6	42.812	C_8 aromatic	0.8028
7	43.396	C_9 aromatic	0.2525
8	57.369	xylenes	4.7498
9	57.731	n-propylbenzene	0.0506
10	58.028	1,2,4-trimethylbenzene	2.9772
11	58.518	1,2,3-trimethylbenzene	0.1562
12	58.949	C_9 aromatic	0.1854
13	59.875	C_9 aromatic	0.0254
14	60.826	C_{10} aromatic	0.0625
15	64.256	pentamethylbenzene	0.4187
16	64.901	C_{11} aromatic	0.1579

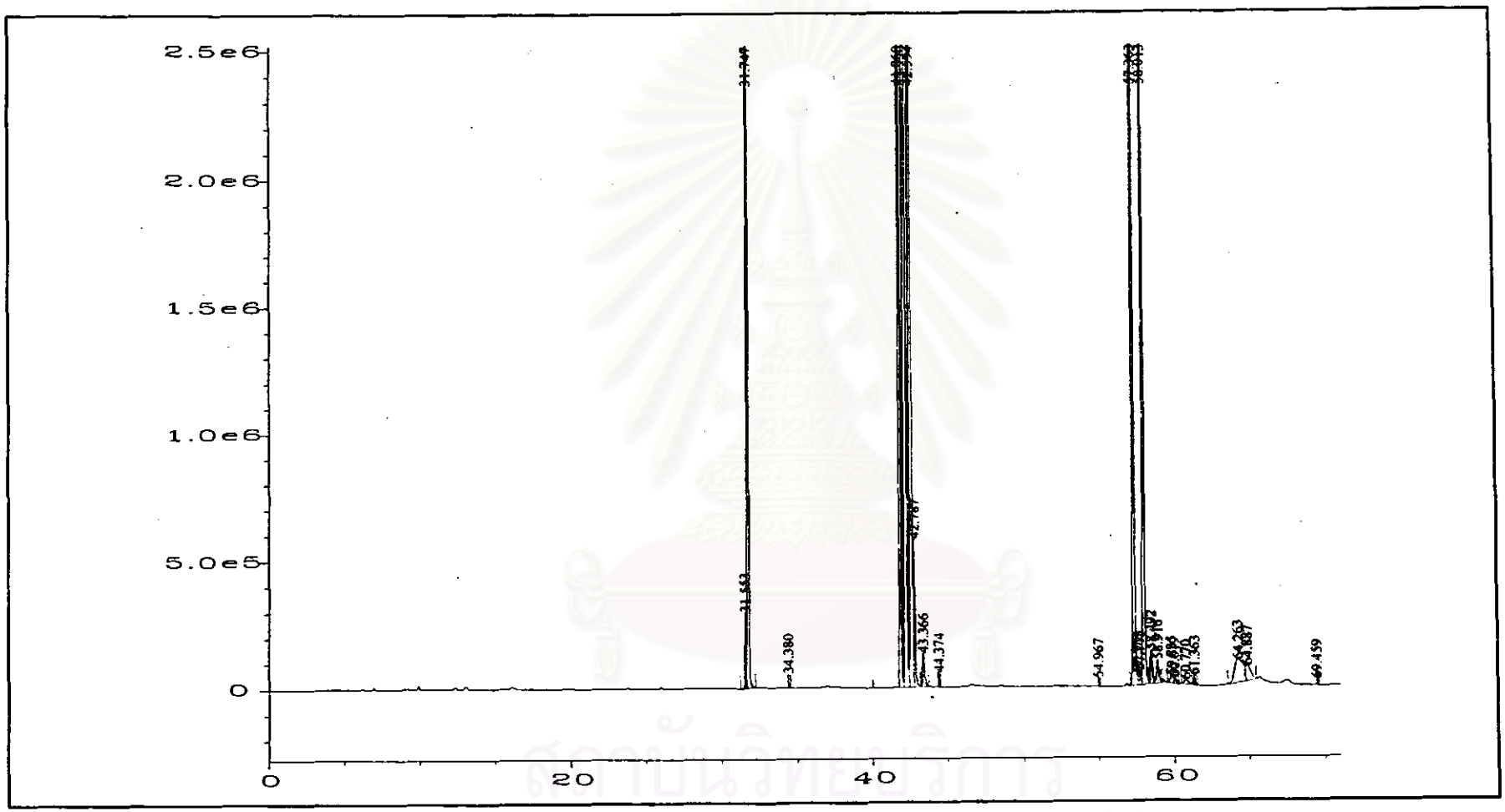

Figure C20 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Pb(5%)-F(2%) catalyst for 90 minutes

Table C20 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Pb(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	31.553	benzene	0.2019
2	31.747	toluene	7.8894
	41.860		12.7091
3	34.380	poly-naphthene	0.0081
4	42.229	ethylbenzene	49.4066
5	42.594	iso-propylbenzene	13.3934
6	42.787	C_8 aromatic	0.6541
7	43.366	C_9 aromatic	0.2120
8	57.363	xylenes	9.4239
9	57.715	n-propylbenzene	0.0734
10	58.013	1,2,4-trimethylbenzene	4.5980
11	58.492	1,2,3-trimethylbenzene	0.1925
12	58.916	C_9 aromatic	0.1670
13	59.835	C_9 aromatic	0.0741
14	60.019	1,2,4,5-tetramethylbenzene	0.0485
15	60.770	C_{10} aromatic	0.0673
16	64.263	pentamethylbenzene	0.6236
17	64.887	C_{11} aromatic	0.2598

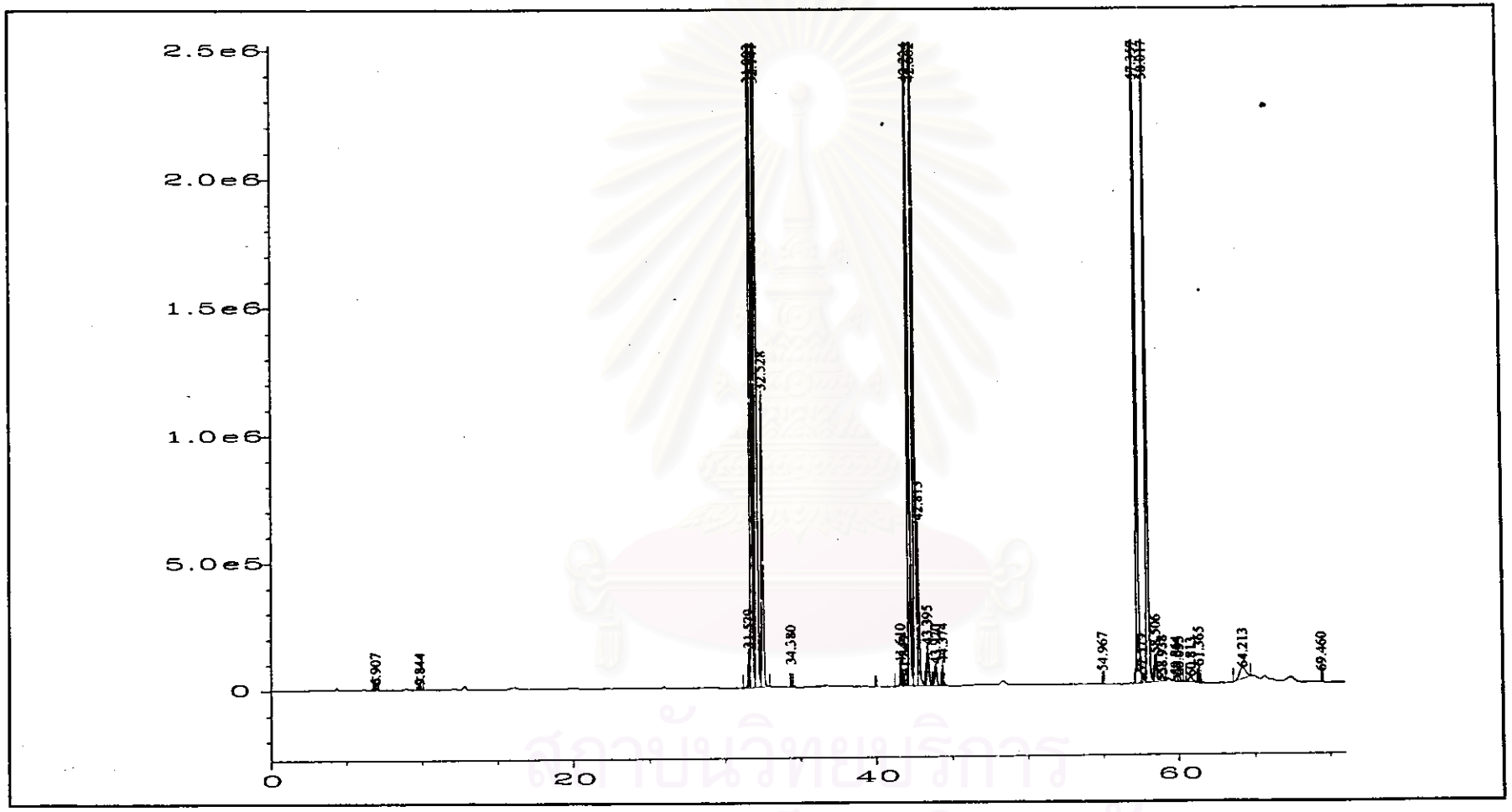

Figure C21 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Al(2%)-F(2%) catalyst for 90 minutes

Table C21 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of Fe(5%)-Al(2%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	6.907	n-hexane	0.0373
2	9.844	n-heptane	0.0420
3	31.579	benzene	0.1569
4	31.803	toluene	37.2429
	41.849		0.0480
5	32.141	C_8 aromatic	24.5208
6	32.528	C_8 aromatic	2.0505
7	34.380	poly-naphthene	0.0162
8	41.610	C_8 aromatic	0.0872
9	42.224	ethylbenzene	8.9752
10	42.602	iso-propylbenzene	7.8579
11	42.813	C_8 aromatic	1.1316
12	43.395	C_9 aromatic	0.3742
13	43.920	C_9 aromatic	0.1955
14	57.357	xylenes	11.0623
15	58.017	1,2,4-trimethylbenzene	5.3835
16	58.506	1,2,3-trimethylbenzene	0.2224
17	58.938	C_9 aromatic	0.0721
18	59.864	C_9 aromatic	0.0575
19	60.053	1,2,4,5-tetramethylbenzene	0.0626
20	60.813	C_{10} aromatic	0.0968
21	64.213	pentamethylbenzene	0.3066

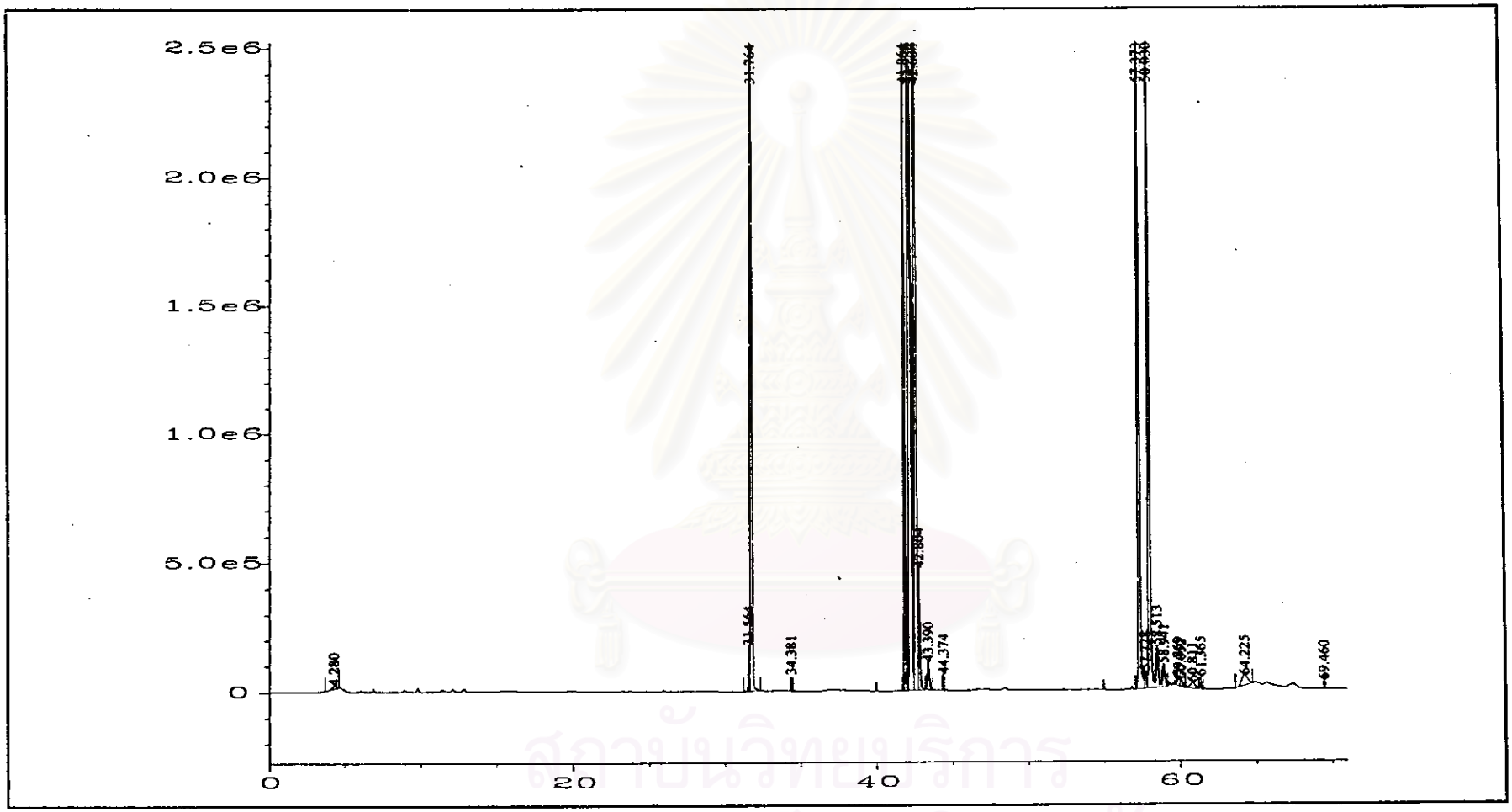

Figure C22 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 10% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C22 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 10% wt of Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	4.280	n-pentane	0.0395
2	31.564	benzene	0.1357
3	31.764	toluene	14.5748
	41.864		4.1344
4	34.381	poly-naphthene	0.0091
5	42.239	ethylbenzene	47.9334
6	42.608	iso-propylbenzene	13.1743
7	42.804	C_8 aromatic	0.5864
8	43.390	C_9 aromatic	0.1936
9	57.373	xylenes	12.2810
10	57.728	n-propylbenzene	0.0906
11	58.030	1,2,4-trimethylbenzene	5.9799
12	58.513	1,2,3-trimethylbenzene	0.2550
13	58.941	C_9 aromatic	0.1669
14	59.869	C_9 aromatic	0.0692
15	60.052	1,2,4,5-tetramethylbenzene	0.0585
16	60.811	C_{10} aromatic	0.1062
17	64.225	pentamethylbenzene	0.2115

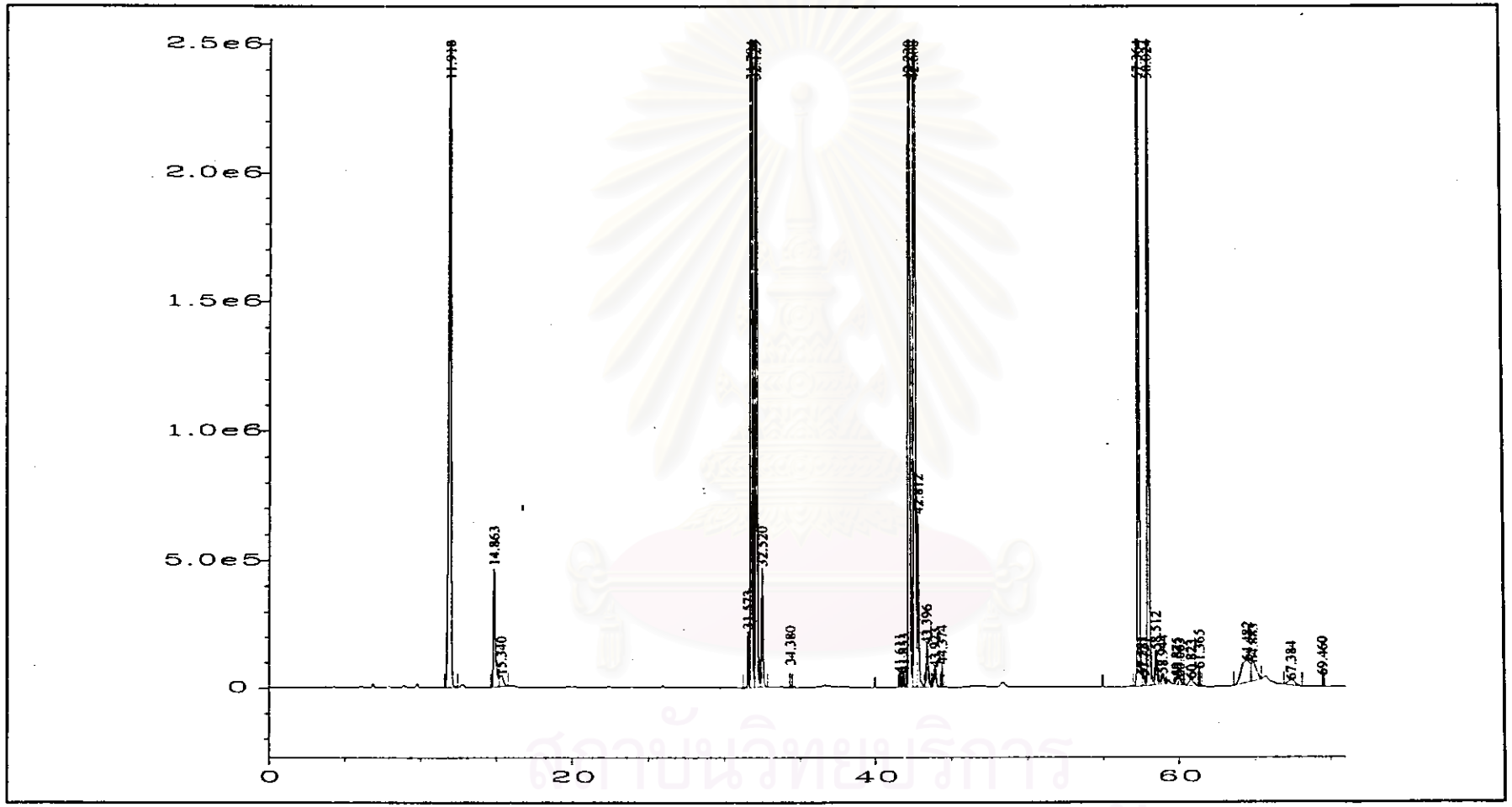

Figure C23 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of the 1st regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C23 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of the 1st regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	11.918	1,2-dimethylcyclohexane	6.1352
2	14.863	1,2,4-trimethylcyclohexane	0.8550
3	15.340	n-nonane	0.1723
4	31.573	benzene	0.2008
5	31.794	toluene	32.3114
	41.853		0.0563
6	32.129	C_8 aromatic	9.7265
7	32.520	C_8 aromatic	0.7093
8	34.380	poly-naphthene	0.0144
9	41.611	C_8 aromatic	0.0443
10	42.230	ethylbenzene	16.4149
11	42.608	iso-propylbenzene	11.1835
12	42.812	C_8 aromatic	0.9909
13	43.396	C_9 aromatic	0.3428
14	43.923	C_9 aromatic	0.1560
15	57.364	xylenes	13.0632
16	57.721	n-propylbenzene	0.0537
17	58.024	1,2,4-trimethylbenzene	5.7107
18	58.512	1,2,3-trimethylbenzene	0.2385
19	58.944	C_9 aromatic	0.0939
20	59.875	C_9 aromatic	0.0659
21	60.063	1,2,4,5-tetramethylbenzene	0.0711
22	60.823	C_{10} aromatic	0.1259
23	64.482	pentamethylbenzene	0.7284
24	64.883	C_{11} aromatic	0.3861
25	67.384	C_{11} aromatic	0.1490

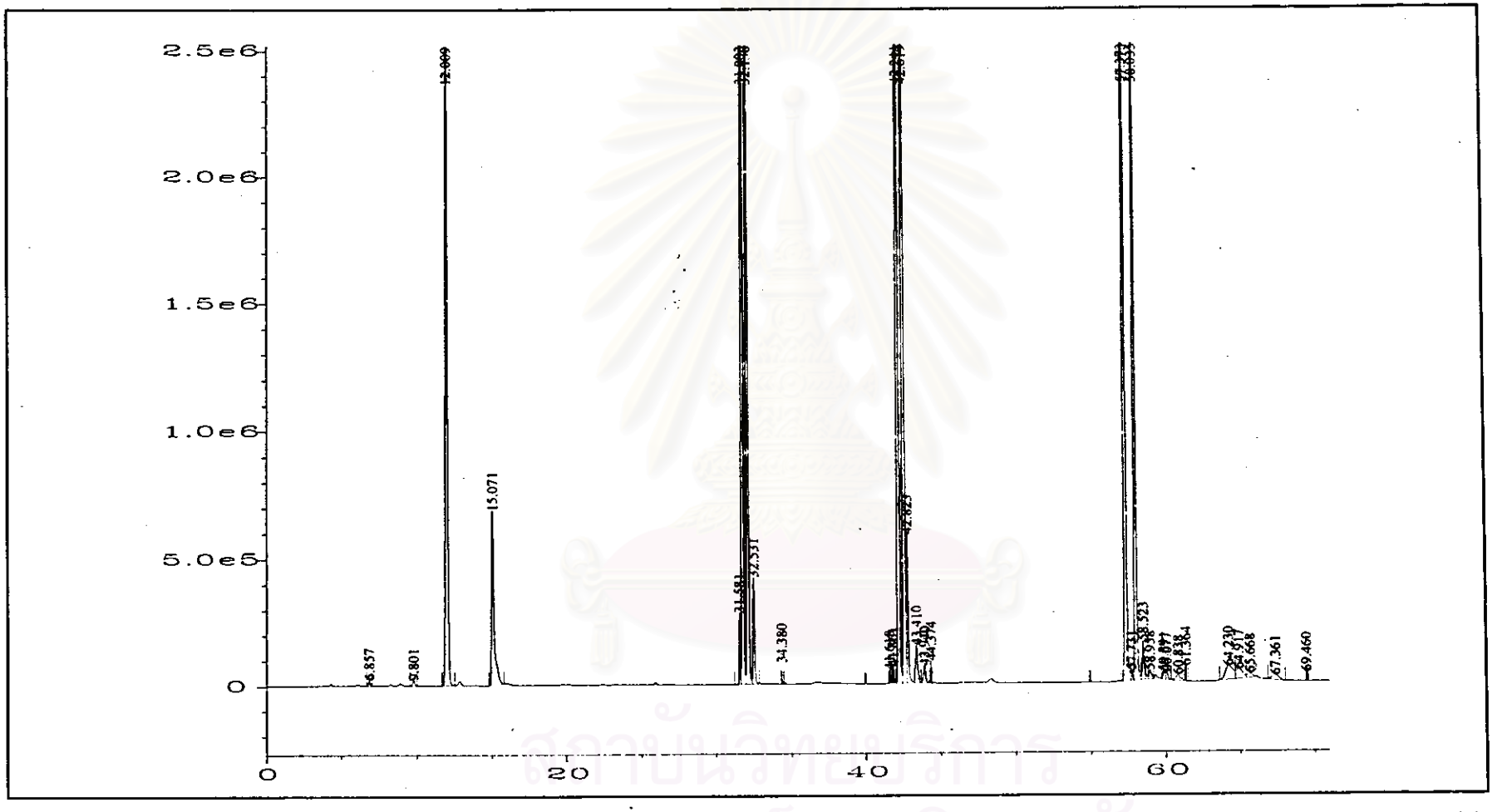

Figure C24 GC chromatogram of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of the 2nd regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

Table C24 Composition and % peak area of product from cracking under nitrogen pressure at N_2 pressure 300 psig, 350 °C with 15% wt of the 2nd regenerated Fe(5%)-Sn(5%)-F(2%) catalyst for 90 minutes

No.	Retention Time (min.)	Component	% peak area
1	6.857	n-hexane	0.0316
2	9.801	n-heptane	0.0388
3	12.009	1,2-dimethylcyclohexane	4.8945
4	15.071	1,2,4-trimethylcyclohexane	1.6282
5	31.581	benzene	0.2337
6	31.803	toluene	32.1547
	41.861		0.0613
7	32.138	C_8 aromatic	8.4876
8	32.531	C_8 aromatic	0.6007
9	34.380	poly-naphthene	0.0133
10	41.618	C_8 aromatic	0.0416
11	42.241	ethylbenzene	17.9069
12	42.619	iso-propylbenzene	10.8123
13	42.823	C_8 aromatic	0.8250
14	43.410	C_9 aromatic	0.2931
15	43.940	C_9 aromatic	0.1334
16	57.373	xylenes	14.2887
17	57.731	n-propylbenzene	0.0616
18	58.035	1,2,4-trimethylbenzene	6.0423
19	58.523	1,2,3-trimethylbenzene	0.2558
20	58.958	C_9 aromatic	0.0836
21	59.891	C_9 aromatic	0.0652
22	60.077	1,2,4,5-tetramethylbenzene	0.0728
23	60.838	C_{10} aromatic	0.1137
24	64.230	pentamethylbenzene	0.3983
25	64.917	C_{11} aromatic	0.2458
26	65.668	C_{11} aromatic	0.0893
27	67.361	C_{11} aromatic	0.1262

VITA

Miss Panatta Methakunvudhi was born on November 18, 1975 in Surin, Thailand. She received her Bachelor of Science degree in Chemistry, Kasetsart University in 1995. She continued her studies toward her Master' s degree at Chulalongkorn University, Program of Chemistry and Polymer Science, Graduate School, in 1996 and completed the program in 1998.