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APPENDICES

Appendix A Temperature Profiles

Table A1 Pyrolysis conditions: Non-catalyst, Tire = 30.006 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	26.4	25.0	32	387.6	578.2	62	335.5	501.2	92	335.7	499.4
4	36.1	36.7	34	399.0	565.0	64	336.7	499.7	94	335.4	498.8
6	52.8	57.9	36	402.9	556.1	66	335.9	502.0	96	335.1	501.1
8	76.1	86.8	38	400.1	538.1	68	336.6	500.7	98	334.5	500.2
10	106.6	124.8	40	395.1	524.5	70	337.1	501.5	100	334.0	500.0
12	143.4	169.3	42	381.8	504.1	72	336.7	499.3	102	333.3	499.7
14	185.4	218.6	44	356.3	501.9	74	337.8	498.4	104	333.1	499.6
16	230.2	273.4	46	355.2	502.6	76	337.8	500.2	106	332.8	500.5
18	279.9	337.4	48	351.8	501.8	78	337.8	500.9	108	332.4	499.2
20	307.2	409.2	50	346.3	497.7	80	337.1	500.6	110	331.6	500.8
22	277.6	421.3	52	341.0	490.2	82	336.5	498.9	112	330.4	500.1
24	268.5	354.8	54	334.9	500.7	84	336.1	500.0	114	330.1	500.1
26	298.1	388.6	56	337.4	501.1	86	336.8	499.3	116	329.7	499.9
28	312.7	407.6	58	336.9	497.7	88	336.5	500.5	118	329.2	500.2
30	339.7	570.0	60	335.7	499.6	90	335.6	499.4	120	328.8	500.4

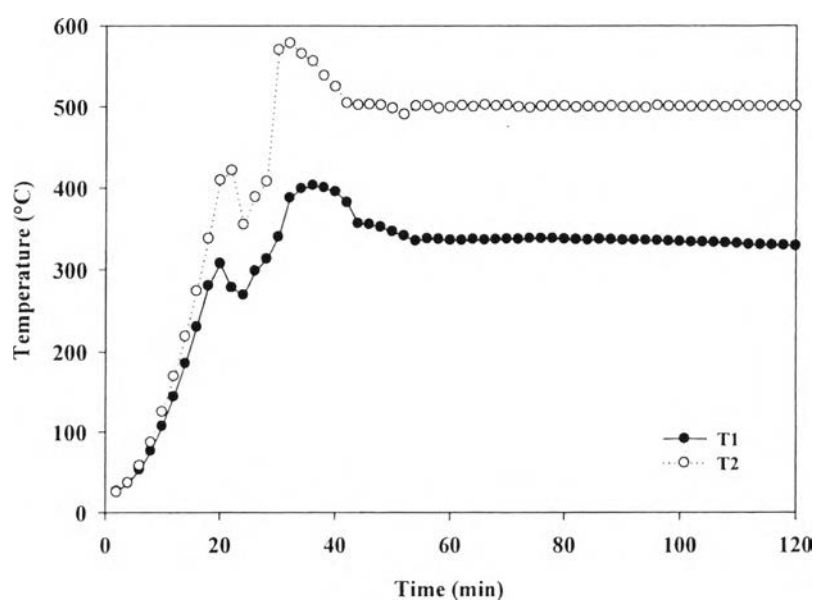


Figure A1 Temperature profiles of non-catalytic pyrolysis.

Table A2 Pyrolysis conditions: KL catalyst, Tire = 30.0005 g, KL = 7.5002 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	39.2	56.4	32	361.7	493.8	62	344.4	498.7	92	340.1	500.0
4	71.2	111.4	34	363.7	484.9	64	344.9	500.6	94	340.6	499.8
6	101.8	158.1	36	360.1	480.5	66	343.1	499.5	96	339.9	500.7
8	134.9	204.2	38	366.0	477.4	68	342.6	499.5	98	340.0	500.0
10	169.8	251.7	40	365.6	496.9	70	341.3	499.9	100	339.9	500.1
12	217.8	358.9	42	366.4	505.1	72	340.7	501.0	102	338.8	499.9
14	243.6	381.1	44	371.6	501.3	74	339.8	499.9	104	338.6	500.0
16	260.2	457.2	46	376.4	502.9	76	338.8	499.7	106	336.2	499.7
18	255.7	464.1	48	376.1	495.9	78	336.7	500.1	108	338.9	499.8
20	277.7	470.4	50	373.4	496.5	80	336.8	499.6	110	349.8	499.4
22	291.1	523.6	52	369.2	499.4	82	336.8	501.1	112	356.4	503.2
24	317.7	517.1	54	359.8	498.9	84	334.7	501.0	114	355.6	501.9
26	331.6	510.0	56	353.6	499.7	86	334.0	500.1	116	352.5	500.1
28	343.8	500.6	58	351.1	499.4	88	333.6	499.6	118	350.0	499.4
30	355.0	504.8	60	346.8	498.7	90	337.2	500.0	120	345.9	499.5

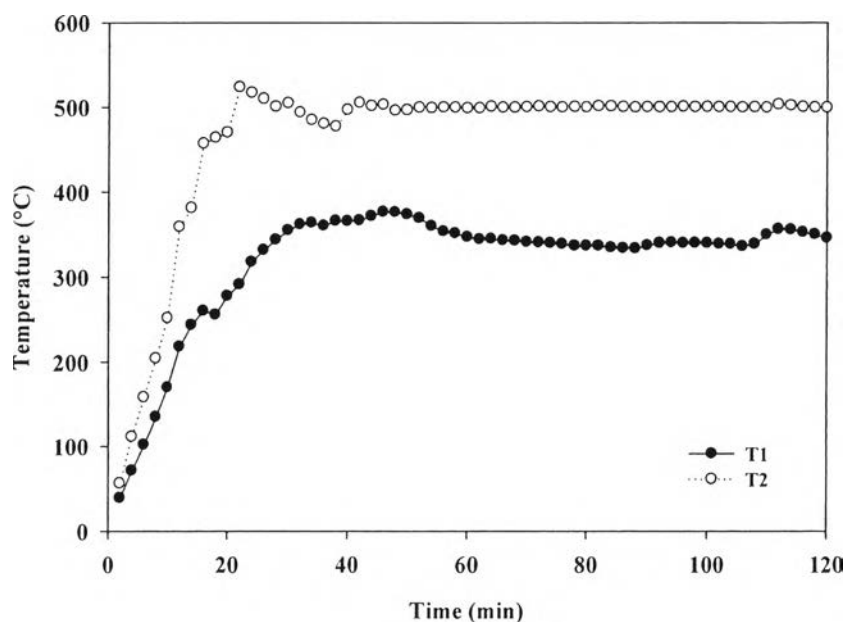


Figure A2 Temperature profiles of waste tire pyrolysis with using KL catalyst.

Table A3 Pyrolysis conditions: HY catalyst, Tire = 30.0015 g, HY = 7.5036 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	27.5	28.0	32	344.7	504.2	62	344.0	499.5	92	349.5	499.4
4	37.3	44.7	34	347.0	497.5	64	341.8	500.2	94	350.3	500.5
6	44.5	58.1	36	362.0	487.6	66	340.2	500.1	96	349.7	499.8
8	62.2	88.7	38	361.1	479.4	68	338.6	499.3	98	350.6	501.0
10	86.3	131.8	40	361.8	470.2	70	337.4	500.6	100	348.9	498.9
12	116.4	180.4	42	371.3	460.9	72	336.3	499.9	102	348.0	500.8
14	150.5	230.1	44	374.7	471.5	74	336.6	500.0	104	347.5	499.6
16	194.0	291.1	46	374.7	496.3	76	336.8	499.4	106	347.6	500.4
18	229.7	352.3	48	365.5	504.4	78	335.4	500.2	108	345.5	499.8
20	293.1	414.0	50	354.7	499.4	80	335.2	500.0	110	344.4	500.2
22	280.1	457.8	52	355.2	502.2	82	339.0	499.3	112	343.3	500.8
24	274.6	501.5	54	354.2	492.9	84	347.3	501.6	114	342.8	499.7
26	293.1	514.3	56	353.5	497.4	86	347.6	500.2	116	342.3	500.8
28	304.3	503.9	58	348.9	500.2	88	350.2	499.4	118	342.5	500.2
30	328.5	497.3	60	345.3	498.6	90	350.4	500.0	120	341.3	499.9

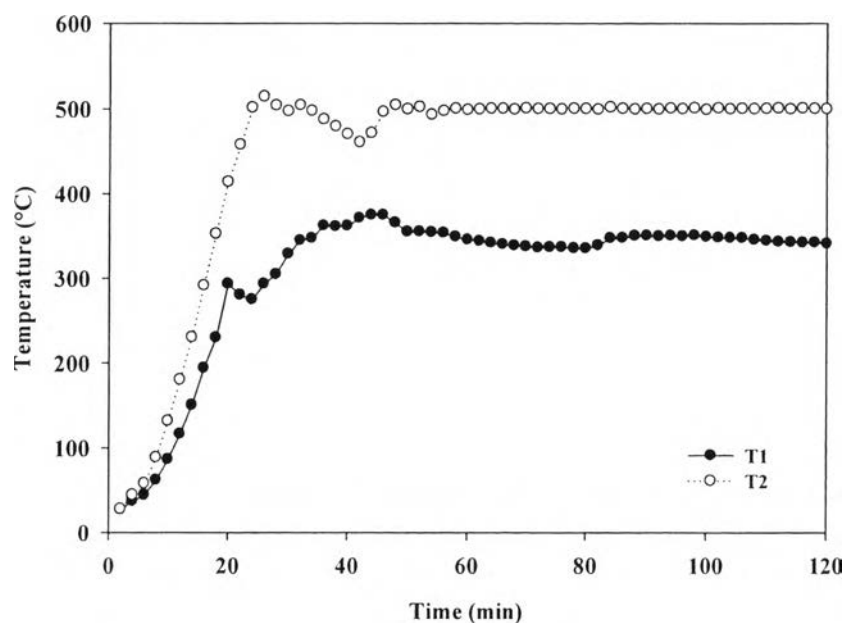


Figure A3 Temperature profiles of waste tire pyrolysis with using HY catalyst.

Table A4 Pyrolysis conditions: HBETA catalyst, Tire = 30.0003 g, HBETA = 7.5005 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	25.0	23.1	32	344.8	493.8	62	347.3	503.5	92	344.4	500.3
4	30.9	31.5	34	358.7	485.5	64	343.5	499.6	94	340.3	498.0
6	52.9	60.0	36	373.0	478.6	66	345.1	498.6	96	342.2	500.5
8	74.8	93.1	38	367.5	464.6	68	344.8	500.2	98	341.7	498.7
10	96.2	124.0	40	344.1	452.6	70	340.7	499.4	100	343.4	500.1
12	112.0	146.6	42	345.1	444.0	72	341.8	501.1	102	342.5	500.2
14	145.8	195.8	44	334.1	437.3	74	343.1	499.4	104	342.6	500.3
16	185.1	251.0	46	339.6	430.5	76	344.1	500.2	106	341.8	499.7
18	243.9	317.5	48	338.6	427.3	78	347.0	499.2	108	341.2	500.1
20	308.4	405.7	50	340.2	425.6	80	345.7	501.9	110	340.8	498.8
22	272.7	434.7	52	340.3	448.1	82	347.1	498.6	112	340.1	500.1
24	256.5	482.7	54	338.9	471.2	84	341.8	499.0	114	339.4	500.2
26	294.3	495.0	56	343.5	500.7	86	343.1	500.0	116	339.5	500.0
28	312.2	507.3	58	351.6	507.0	88	343.5	501.7	118	338.5	500.4
30	324.7	500.4	60	352.0	497.3	90	344.4	498.5	120	338.8	499.7

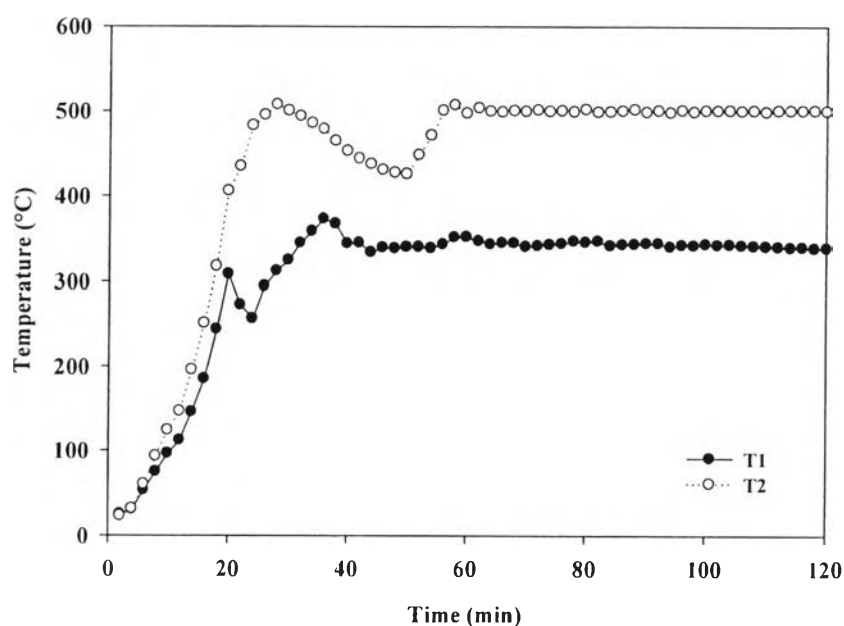


Figure A4 Temperature profiles of waste tire pyrolysis with using HBETA catalyst.

Table A5 Pyrolysis conditions: 0.25% Rh/KL catalyst, Tire = 30.0025 g, 0.25% Rh/KL = 7.5032 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	27.4	25.0	32	363.7	514.1	62	353.5	496.8	92	342.0	499.6
4	33.1	33.6	34	383.7	499.7	64	353.4	500.5	94	343.4	500.8
6	45.7	51.1	36	373.4	489.3	66	353.1	499.3	96	356.2	500.8
8	64.4	75.4	38	356.6	485.9	68	352.6	499.3	98	352.4	499.0
10	91.3	109.7	40	344.1	502.9	70	351.3	499.6	100	350.8	499.4
12	125.6	151.8	42	346.5	505.6	72	351.4	500.2	102	347.2	499.9
14	163.5	202.4	44	354.1	496.6	74	350.6	500.4	104	343.8	500.8
16	201.8	258.4	46	349.1	484.0	76	350.1	501.3	106	352.6	499.5
18	242.5	316.2	48	350.0	483.3	78	349.6	500.9	108	355.0	499.8
20	297.2	382.6	50	348.5	499.1	80	348.7	500.6	110	353.3	498.5
22	314.2	434.3	52	351.0	505.3	82	347.2	499.3	112	352.3	499.2
24	286.9	447.6	54	352.5	497.4	84	346.0	499.6	114	351.2	502.2
26	283.9	492.0	56	353.2	505.5	86	344.3	499.8	116	351.8	499.6
28	298.0	522.8	58	353.4	500.1	88	343.8	499.7	118	351.3	499.1
30	333.7	518.2	60	353.6	494.2	90	343.4	499.2	120	350.9	499.7

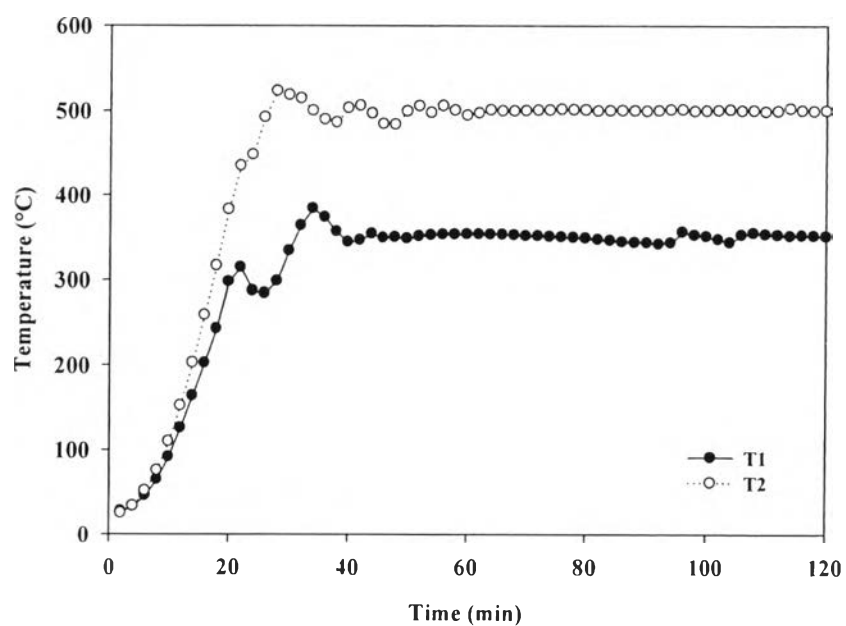


Figure A5 Temperature profiles of waste tire pyrolysis with using 0.25% Rh/KL catalyst.

Table A6 Pyrolysis conditions: 0.25% Rh/HY catalyst, Tire = 30.0002 g, 0.25% Rh/HY = 7.5025 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	27.4	26.9	32	355.3	499.5	62	353.4	500.7	92	354.5	498.4
4	33.5	39.7	34	365.9	492.1	64	352.7	498.5	94	349.2	500.2
6	45.7	61.8	36	379.6	497.8	66	351.8	499.5	96	346.3	499.3
8	63.8	92.8	38	384.9	506.7	68	351.0	500.6	98	348.2	499.9
10	87.6	133.0	40	374.4	496.1	70	350.3	500.9	100	354.5	502.1
12	117.5	178.9	42	355.2	502.3	72	348.5	500.2	102	355.4	498.4
14	153.7	229.8	44	349.9	496.4	74	347.8	499.7	104	352.5	498.9
16	176.9	282.7	46	350.0	499.9	76	347.2	499.9	106	348.2	501.1
18	211.1	342.2	48	350.7	500.1	78	346.1	500.8	108	344.9	500.7
20	292.1	411.0	50	352.5	500.0	80	345.2	500.0	110	344.8	500.1
22	251.6	458.9	52	353.6	500.0	82	344.4	500.3	112	352.9	500.8
24	260.3	492.1	54	353.6	500.2	84	342.7	499.4	114	357.0	499.3
26	294.7	509.3	56	353.8	499.8	86	343.7	500.2	116	355.5	499.7
28	314.4	497.6	58	353.6	500.7	88	351.3	499.1	118	352.5	500.6
30	333.8	506.2	60	353.9	500.0	90	355.3	501.8	120	349.4	501.7

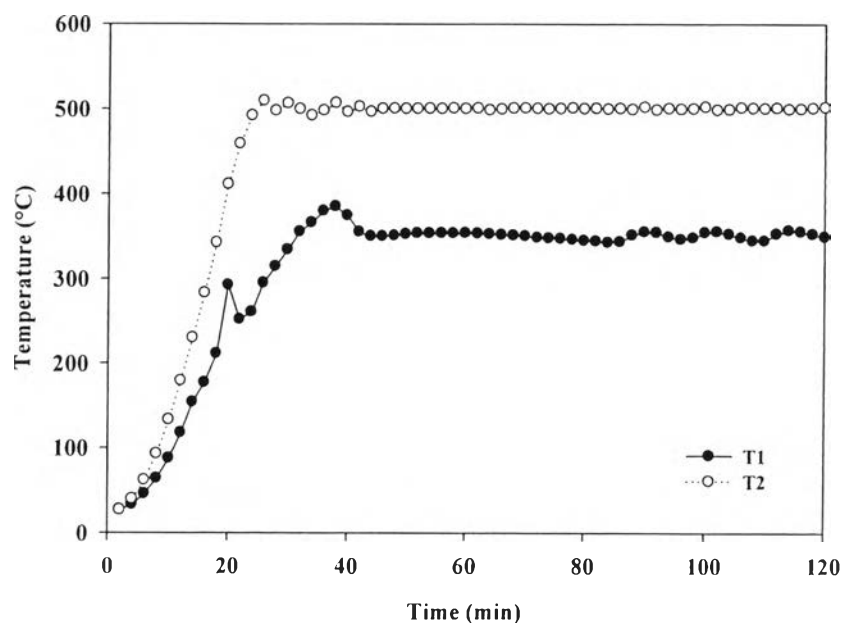


Figure A6 Temperature profiles of waste tire pyrolysis with using 0.25% Rh/HY catalyst.

Table A7 Pyrolysis conditions: 0.25% Rh/HBETA catalyst, Tire = 30.0131 g, 0.25% Rh/HBETA = 7.5018 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	26.0	26.4	32	350.0	494.5	62	363.7	500.3	92	346.1	501.2
4	32.9	41.1	34	351.0	505.8	64	354.5	499.8	94	346.1	499.6
6	45.9	65.7	36	343.8	497.4	66	361.9	500.9	96	344.3	499.2
8	65.1	100.6	38	350.1	502.9	68	361.8	501.0	98	343.5	500.5
10	92.4	145.5	40	348.3	495.4	70	361.0	500.7	100	343.2	500.4
12	128.0	204.6	42	353.4	497.7	72	360.5	501.0	102	342.2	499.2
14	157.5	251.6	44	344.8	499.0	74	359.2	500.0	104	341.1	501.4
16	196.5	316.1	46	345.4	499.9	76	357.5	500.3	106	340.3	500.4
18	249.3	414.0	48	347.0	499.3	78	356.7	499.9	108	345.5	499.7
20	308.7	455.4	50	344.4	499.7	80	354.8	500.4	110	353.3	500.9
22	339.2	508.5	52	348.8	499.7	82	353.9	500.7	112	357.3	502.2
24	335.2	501.1	54	349.1	500.9	84	352.9	500.7	114	355.9	499.4
26	338.9	497.9	56	359.5	501.5	86	351.1	500.8	116	352.2	497.9
28	335.5	499.9	58	354.0	500.6	88	349.7	501.1	118	348.8	499.8
30	345.3	488.0	60	356.1	500.8	90	348.8	498.7	120	346.1	499.5

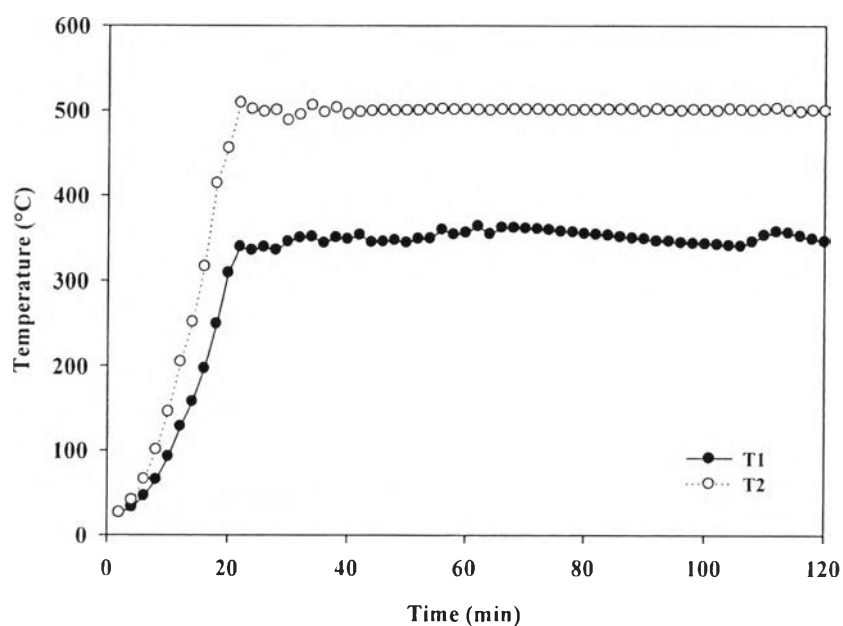


Figure A7 Temperature profiles of waste tire pyrolysis with using 0.25% Rh/HBETA catalyst.

Table A8 Pyrolysis conditions: 1% Rh/HBETA catalyst, Tire = 30.0008 g, 1% Rh/HBETA = 7.5012 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	24.1	25.1	32	365.6	502.5	62	353.7	499.7	92	345.2	498.2
4	30.7	40.1	34	370.0	494.0	64	352.7	499.3	94	345.9	502.4
6	42.5	63.1	36	364.7	483.7	66	352.8	500.2	96	345.4	498.7
8	62.4	95.7	38	345.0	468.0	68	352.5	499.8	98	345.1	501.8
10	88.2	136.2	40	342.6	485.2	70	352.1	501.1	100	344.7	500.8
12	120.1	182.9	42	343.3	497.2	72	352.4	500.7	102	344.0	502.0
14	156.5	238.0	44	346.2	502.6	74	351.6	501.3	104	342.9	496.2
16	193.1	293.4	46	347.4	504.5	76	351.5	500.9	106	341.2	499.9
18	237.4	349.9	48	348.5	494.3	78	350.4	500.5	108	340.9	500.2
20	298.6	428.4	50	349.6	499.9	80	350.1	501.7	110	340.6	499.8
22	329.7	450.7	52	351.0	500.2	82	348.6	499.8	112	340.1	499.6
24	278.7	466.8	54	352.2	501.4	84	348.2	500.5	114	339.2	498.2
26	292.3	507.3	56	353.2	500.0	86	347.2	500.7	116	338.7	502.5
28	307.4	492.2	58	353.7	500.0	88	347.7	500.0	118	336.8	502.3
30	341.4	511.3	60	353.5	500.0	90	346.5	500.1	120	335.5	502.1

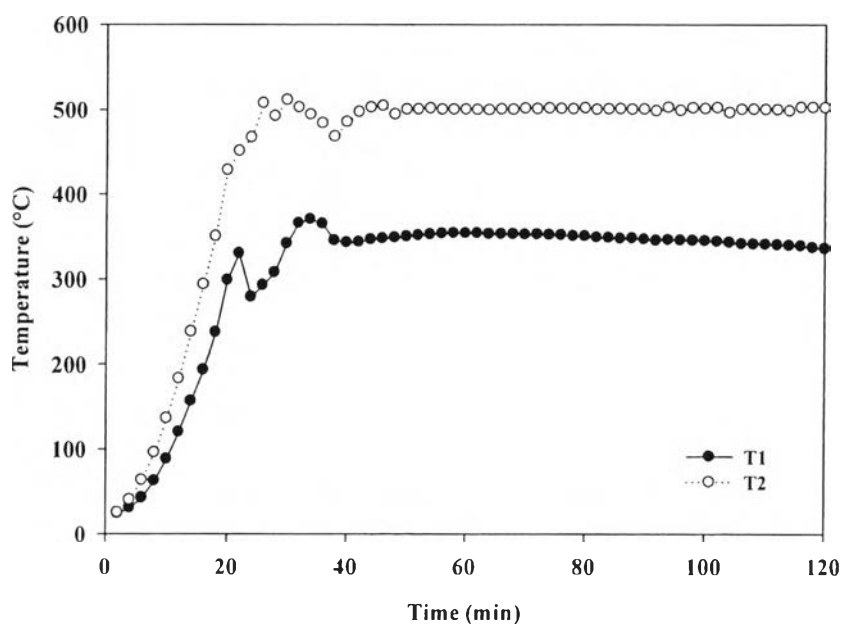


Figure A8 Temperature profiles of waste tire pyrolysis with using 1% Rh/HBETA catalyst.

Table A9 Pyrolysis conditions: Spent NiMoS/Al₂O₃ catalyst, Tire = 30.0024 g, Spent NiMoS/Al₂O₃ = 7.5040 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	25.0	24.9	32	365.0	495.1	62	354.0	499.2	92	342.0	499.3
4	32.2	38.7	34	362.9	482.9	64	355.3	500.9	94	339.2	499.1
6	47.5	65.5	36	320.7	486.9	66	355.1	499.3	96	338.1	500.6
8	63.2	89.9	38	351.2	502.2	68	352.5	501.1	98	336.7	501.7
10	103.5	152.4	40	343.7	498.8	70	354.0	500.2	100	334.8	499.7
12	145.6	214.2	42	356.1	503.8	72	352.1	500.6	102	336.1	501.2
14	189.6	278.8	44	370.4	498.1	74	350.2	501.1	104	335.7	500.0
16	212.8	310.9	46	369.2	494.9	76	350.4	499.5	106	333.7	499.6
18	239.1	348.5	48	379.1	496.3	78	349.6	499.9	108	333.7	501.2
20	287.3	423.5	50	338.1	500.4	80	348.5	500.2	110	332.8	499.7
22	283.7	459.8	52	348.5	497.6	82	346.4	500.9	112	331.9	498.2
24	256.4	485.6	54	361.9	500.8	84	346.3	499.8	114	330.6	499.3
26	294.4	510.2	56	367.0	500.1	86	345.5	499.2	116	329.3	499.8
28	333.1	501.2	58	346.5	500.3	88	342.7	498.2	118	327.1	500.0
30	354.1	502.7	60	351.4	499.6	90	342.4	500.8	120	325.9	500.2

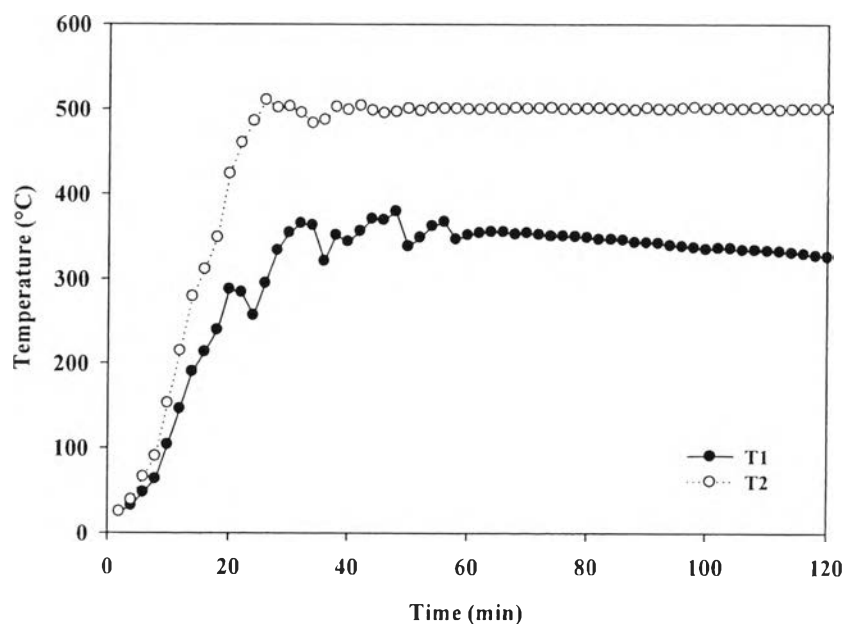


Figure A9 Temperature profiles of waste tire pyrolysis with using Spent NiMoS/Al₂O₃ catalyst.

Table A10 Pyrolysis conditions: CoMoS/Al₂O₃ catalyst, Tire = 30.0009 g, CoMoS/Al₂O₃ = 7.5021 g, N₂ flow = 30 ml/min, Catalytic Temperature (T1) = 350 °C, Pyrolysis Temperature (T2) = 500 °C

Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2	Time (min)	T1	T2
2	34.0	42.4	32	359.8	509.3	62	348.9	501.8	92	348.6	492.5
4	45.2	64.0	34	373.8	486.2	64	348.2	496.0	94	347.4	496.4
6	63.6	99.5	36	359.2	492.0	66	347.1	506.0	96	347.3	497.3
8	81.9	142.1	38	351.7	506.6	68	346.8	498.6	98	347.2	498.7
10	105.6	190.1	40	346.1	500.5	70	347.9	505.2	100	347.1	499.8
12	146.6	261.6	42	346.8	487.3	72	346.5	494.0	102	347.0	499.6
14	162.5	316.4	44	347.1	493.9	74	345.2	500.1	104	346.3	499.4
16	200.7	364.0	46	348.3	500.0	76	345.9	505.2	106	346.5	500.1
18	259.9	419.0	48	349.5	503.1	78	344.1	502.6	108	345.6	500.2
20	329.8	453.6	50	350.0	501.8	80	343.9	501.3	110	345.0	500.4
22	305.3	501.3	52	349.8	498.7	82	342.7	493.9	112	344.5	500.5
24	311.7	493.7	54	349.5	497.4	84	342.5	506.7	114	344.3	500.7
26	324.8	512.5	56	350.0	498.3	86	346.9	501.2	116	344.0	500.8
28	332.3	511.0	58	349.6	499.0	88	348.3	505.3	118	343.8	499.9
30	338.4	519.0	60	348.5	499.2	90	348.3	502.7	120	343.6	499.8

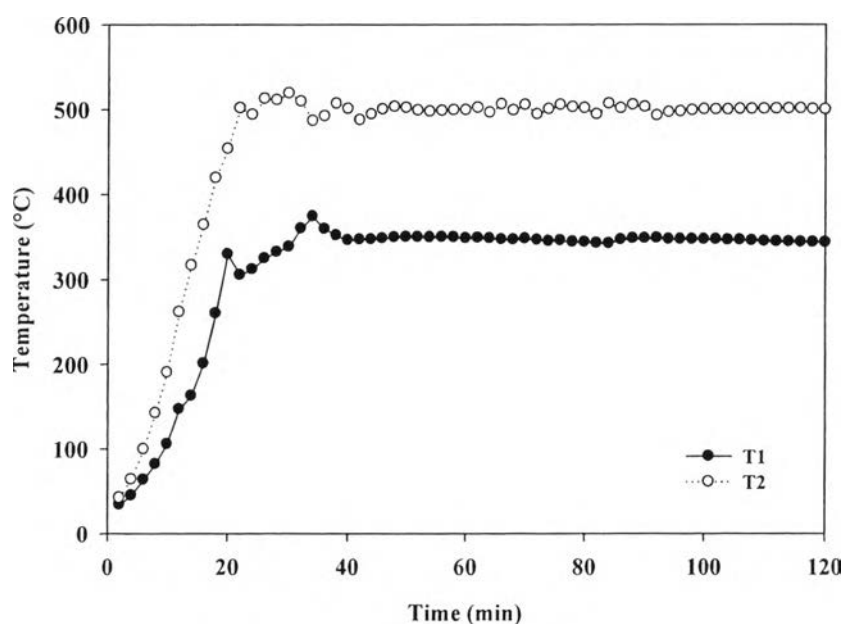


Figure A10 Temperature profiles of waste tire pyrolysis with using CoMoS/Al₂O₃ catalyst.

Appendix B Yields of Pyrolysis Products

Table B1 Product distribution obtained from pyrolysis

Effect	Catalyst	Yield (%)			
		Gas	Liquid	Solid	Coke
Non-catalyst	Non-catalyst	18.57	41.87	39.57	0.00
Support	KL	19.68	39.47	40.23	0.63
	HY	23.06	30.37	38.46	8.12
	HBETA	23.39	32.90	39.42	4.29
Metal loading	0.25% Rh/KL	18.66	36.13	39.87	5.34
	0.25% Rh/HY	17.98	33.47	38.85	9.71
	0.25% Rh/HBETA	24.86	23.96	38.57	12.61
	1% Rh/HBETA	19.39	30.90	38.82	10.89
Commercial catalyst	NiMoS/Al ₂ O ₃	21.42	32.70	38.90	6.98
	CoMoS/Al ₂ O ₃	22.55	36.07	39.84	1.54

Table B2 Amount of coke in spent catalysts obtained from TG/DTA

Spent catalyst	% Coke in spent catalyst	g coke/ g catalyst
Non-catalyst	0	0
KL	14.9	0.149
HY	27.0	0.270
HBETA	27.2	2.272
0.25% Rh/KL	19.7	0.197
0.25% Rh/HY	27.4	0.274
0.25% Rh/HBETA	34.5	0.345
1% Rh/HBETA	30.1	0.301
NiMoS/Al ₂ O ₃	35.6	0.356
CoMoS/Al ₂ O ₃	31.4	0.314

Table B3 Amount of asphaltene separated from maltenes

Spent catalyst	Asphaltene (g)
Non-catalyst	0.0105
KL	0.0042
HY	0.0069
HBETA	0.0052
0.25% Rh/KL	0.0037
0.25% Rh/HY	0.0064
0.25% Rh/HBETA	0.0046
1% Rh/HBETA	0.0037
NiMoS/Al ₂ O ₃	0.0053
CoMoS/Al ₂ O ₃	0.0039

Appendix C Gas Yield (%)

Table C1 Gas compositions obtained from waste tire pyrolysis

Catalysts	Component						
	Methane	Ethylene	Ethane	Propylene	Propane	C4	C5
Non- Catalyst	20.32	14.02	13.58	11.10	6.68	18.60	15.70
KL	18.86	11.60	14.14	9.89	7.75	18.59	19.17
HY	19.84	11.15	14.97	10.55	9.09	20.14	14.27
HB	14.81	8.05	10.82	8.88	8.64	29.84	18.97
0.25RhKL	20.00	12.17	14.92	10.30	8.05	18.83	15.73
0.25RhHY	19.58	11.04	14.80	10.28	8.90	20.23	15.17
0.25RhHB	16.91	8.47	12.84	8.73	9.12	27.14	16.80
1RhHB	16.52	8.73	12.67	9.04	8.92	26.84	17.27
NiMoS/Al ₂ O ₃	19.99	11.48	15.63	10.21	9.13	19.76	13.80
CoMoS/Al ₂ O ₃	20.47	13.61	15.32	10.00	8.35	18.07	14.19

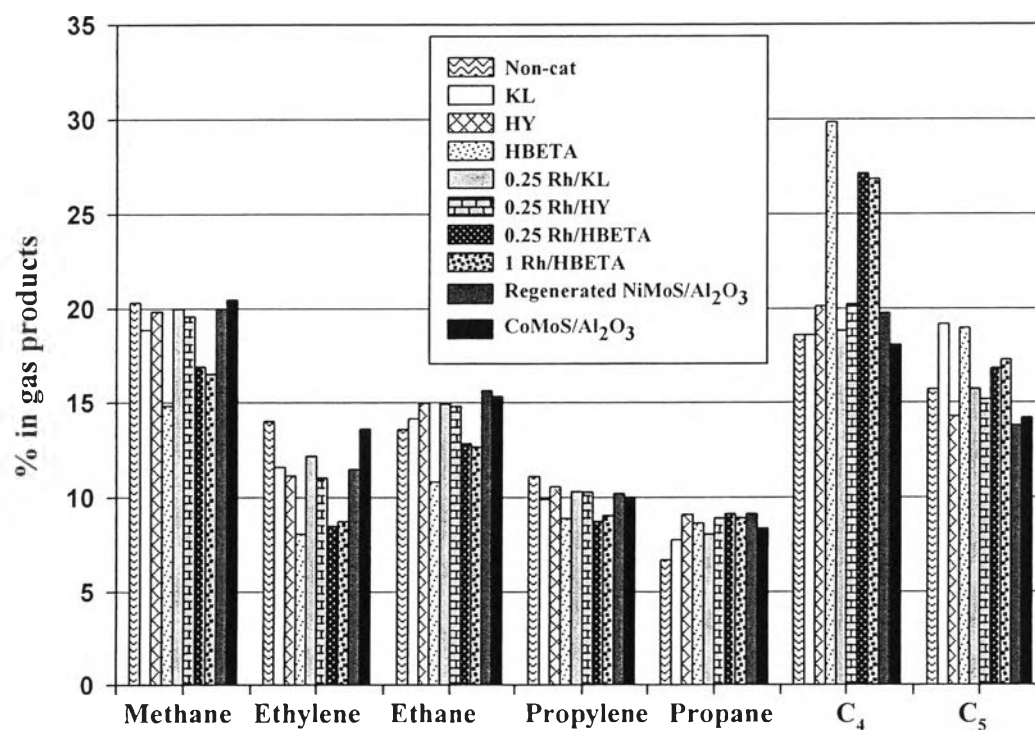


Figure C1 Gas compositions obtained from waste tire pyrolysis.

Appendix D Liquid Yield (%)

Table D1 Chemical composition of maltenes obtained from waste tire pyrolysis

Catalysts	Composition				
	Sat. HC	Mono-aro.	Di-aro.	Poly-aro.	Polar-aro.
Non- Catalyst	54.04	20.19	11.73	8.85	5.19
KL	35.83	21.89	12.56	22.82	6.90
HY	42.79	23.99	13.78	10.86	8.59
HB	50.62	14.14	16.13	5.96	13.15
0.25RhKL	35.75	27.62	14.77	15.21	6.65
0.25RhHY	36.53	27.40	14.22	13.92	7.93
0.25RhHB	37.54	17.80	13.95	22.85	7.86
1RhHB	29.29	25.83	15.44	18.76	10.68
NiMoS/Al ₂ O ₃	33.29	26.93	13.34	21.57	4.86
CoMoS/Al ₂ O ₃	41.05	27.17	11.57	15.73	4.48

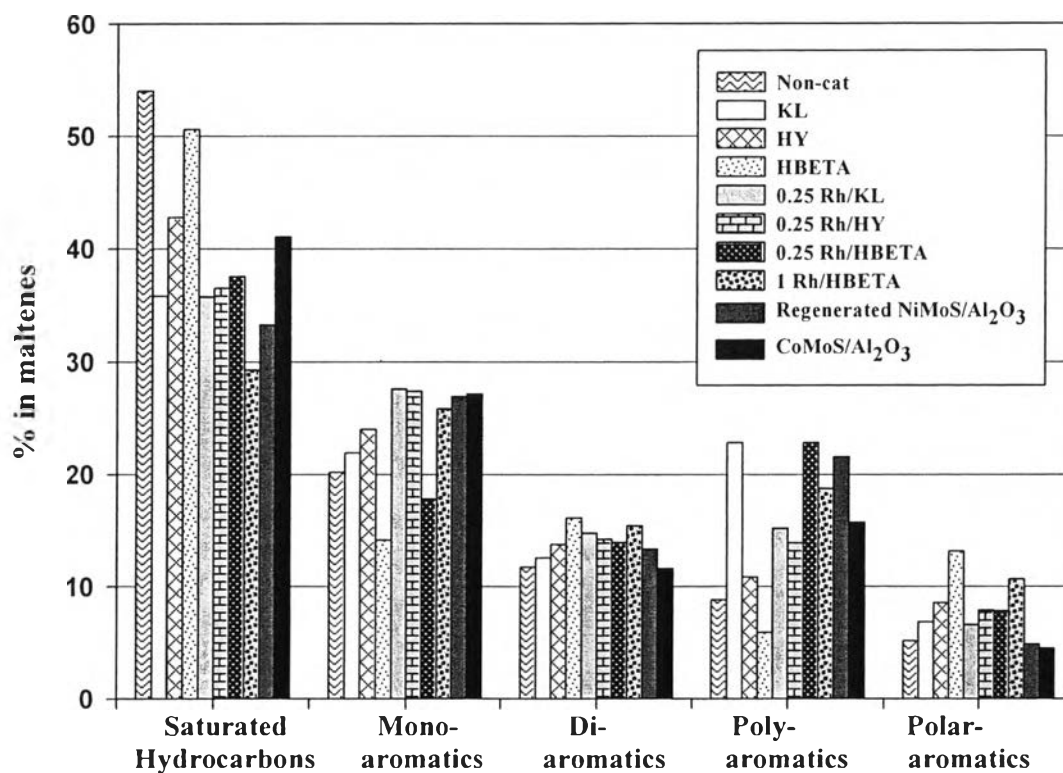


Figure D1 Chemical compositions of maltenes obtained from waste tire pyrolysis.

Table D2 Petroleum fractions of derived oils obtained from waste tire pyrolysis (1)

Catalysts	Fractions				
	Full range naphtha	Kerosene	Light gas oil	Heavy gas oil	Long Residue
Non-Catalyst	39.74	19.52	12.91	13.89	13.94
KL	39.65	19.18	13.10	13.15	14.92
HY	47.52	19.10	10.76	10.65	11.97
HB	45.26	20.41	14.90	9.41	10.01
0.25RhKL	40.49	19.24	13.81	14.28	12.18
0.25RhHY	42.40	17.30	12.67	13.25	14.38
0.25RhHB	50.83	15.99	10.26	11.63	11.28
1RhHB	41.59	20.60	13.18	12.25	12.38
NiMoS/Al ₂ O ₃	42.78	17.49	12.71	13.26	13.75
CoMoS/Al ₂ O ₃	38.23	20.96	14.51	14.30	12.00

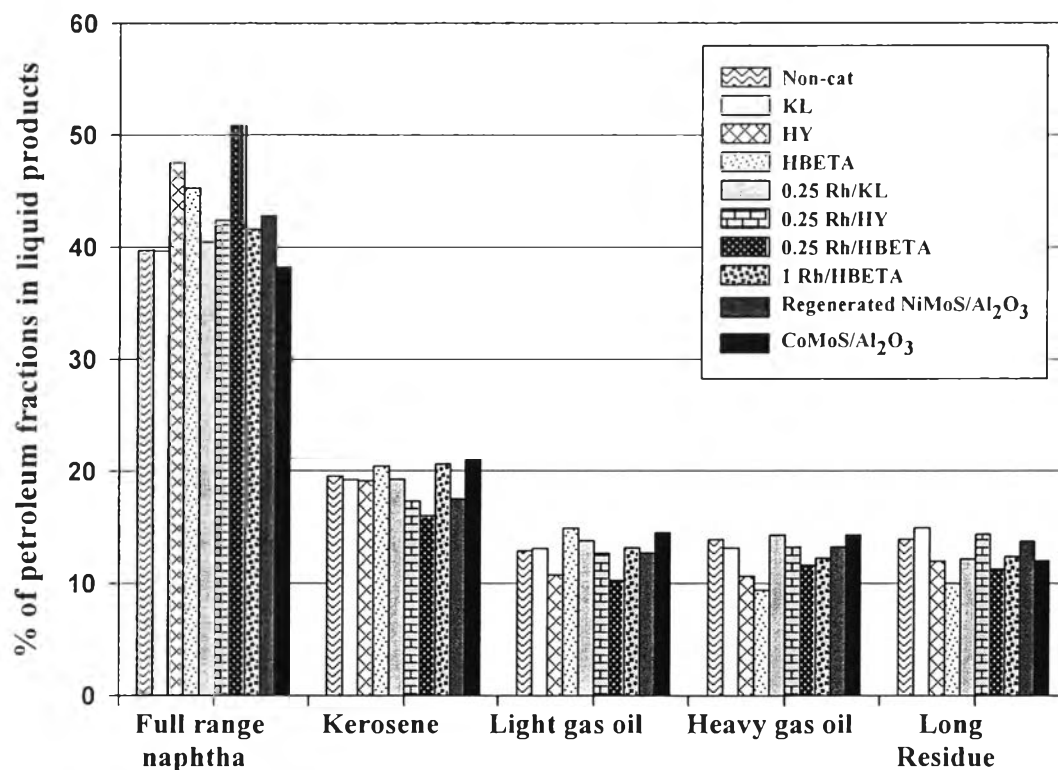
**Figure D2** Petroleum fractions of derived oils obtained from waste tire pyrolysis (1).

Table D3 Petroleum fractions of derived oils obtained from waste tire pyrolysis (2)

Catalysts	Fractions				
	Gasoline	Kerosene	Gas oil	LVGO	HVGO
Non-Catalyst	15.19	38.45	27.56	5.02	13.78
KL	17.25	35.64	27.56	4.80	14.75
HY	22.76	38.46	23.14	3.81	11.84
HB	22.89	35.82	28.43	2.90	9.97
0.25RhKL	16.77	36.87	29.26	5.10	12.00
0.25RhHY	20.14	34.17	26.66	4.80	14.22
0.25RhHB	24.21	38.27	22.03	4.36	11.13
1RhHB	19.13	36.79	27.59	4.26	12.23
NiMoS/Al ₂ O ₃	22.20	32.36	27.13	4.73	13.59
CoMoS/Al ₂ O ₃	15.92	36.88	30.44	4.93	11.83

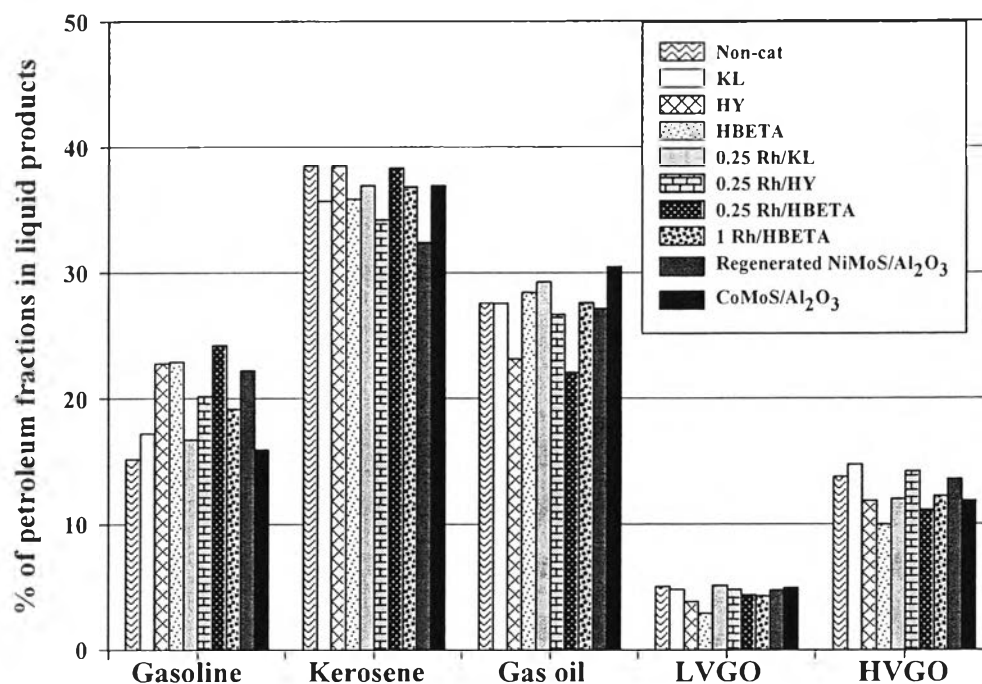
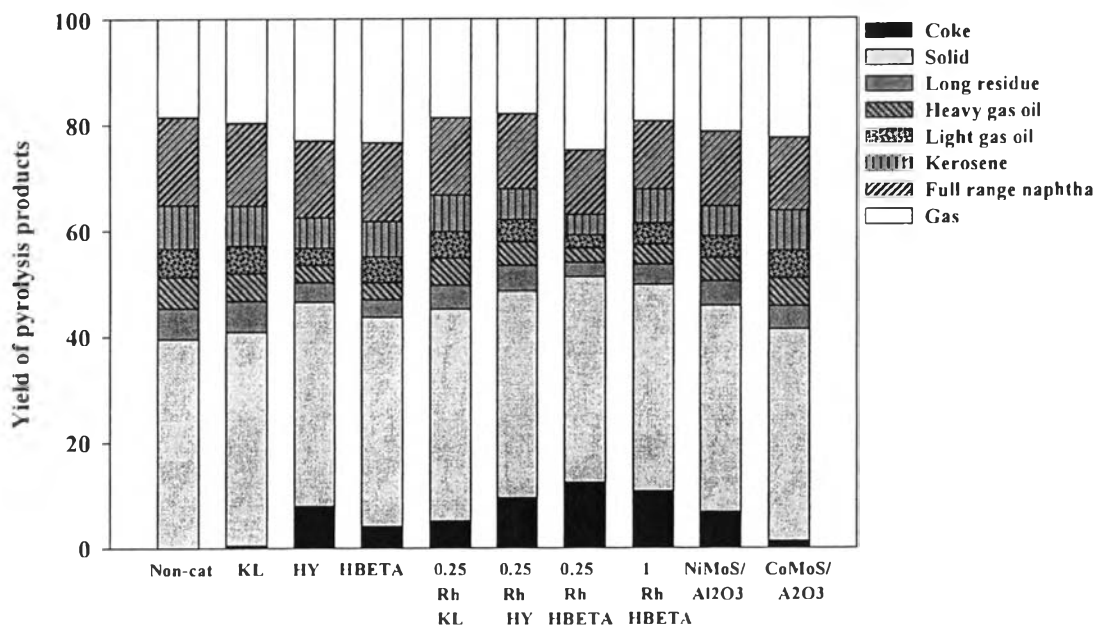
**Figure D3** Petroleum fractions of derived oils obtained from waste tire pyrolysis (2).

Table D4 Yield of pyrolysis products (The weight of asphaltenes is neglected)

Composition	Non-Catalyst	KL	HY	HB	0.25RhKL	0.25RhHY	0.25RhHB	1RhHB	NiMoS/ Al ₂ O ₃	CoMoS/ Al ₂ O ₃
Gas	18.57	19.68	23.06	23.39	18.66	17.98	24.86	19.39	21.42	22.55
Liquid	41.87	39.47	30.37	32.90	36.13	33.47	23.96	30.90	32.70	36.07
Full range naphtha	16.64	15.65	14.43	14.89	14.63	14.19	12.18	12.85	13.99	13.79
Kerosene	8.17	7.57	5.80	6.72	6.95	5.79	3.83	6.37	5.72	7.56
Light gas oil	5.41	5.17	3.27	4.90	4.99	4.24	2.46	4.07	4.16	5.23
Heavy gas oil	5.81	5.19	3.23	3.10	5.16	4.43	2.79	3.79	4.34	5.16
Residue	5.83	5.89	3.63	3.29	4.40	4.81	2.70	3.83	4.49	4.33
Solid	39.57	40.23	38.46	39.42	39.87	38.85	38.57	38.82	38.90	39.84
Coke	0.00	0.63	8.12	4.29	5.34	9.71	12.61	10.89	6.98	1.54

**Figure D4** Distribution of sulfur compounds in petroleum fractions.

Appendix E Mono-Aromatics Found in Pyrolysis Oils

Table E1 The prominent mono-aromatics molecules in pyrolysis oils from using Rh supported catalysts

Name	% Area			
	0.25RhKL	0.25RhHY	0.25RhHB	1RhHB
Benzene, 1-methyl-2-(1-methylethyl)-	2.1113	2.9286	0.0949	1.6508
Benzene, 1-methyl-3-(1-methylethyl)-	0.3300	0.3261	1.5219	0.2774
Benzene, 1-methyl-3-(1-methyl-2-propenyl)-	0.8585	-	0.1835	1.4096
Benzene, 1-butynyl-	1.9496	1.3074	-	2.1876
Benzene, (2-cyclopropylethenyl)-	1.6455	0.5205	-	-
Benzocycloheptatriene	-	-	3.8273	-
Bicyclo[4.2.0]octa-1,3,5-triene, 7-isopropyl-	0.4026	1.1504	1.1372	0.1567
Ethylbenzene	2.0462	1.9314	1.0494	1.1010
Styrene	1.5713	1.0625	0.5080	0.9502
m-Xylene	1.5584	1.6993	0.7481	1.1741
Naphthalene, 1,2-dihydro-	1.0914	0.0712	0.0332	1.4032
1H-Indene, 1-ethylidene-	1.2542	1.7358	2.1059	3.0318
1H-Indene, 2,3-dihydro-4-methyl-	-	1.4481	1.4824	-

Table E2 The top 15 mono-aromatics species of 0.25% Rh/KL experiment rearranged by area percentage

Peak #	Name	Formula	Area	Area %
205	Benzene, 1-methyl-2-(1-methylethyl)-	C10H14	32784450	2.1113
65	Ethylbenzene	C8H10	31772844	2.0462
300	Benzene, 1-butynyl-	C10H10	30272452	1.9496
411	Benzene, (2-cyclopropylethenyl)-	C11H12	25550620	1.6455
89	Styrene	C8H8	24399312	1.5713
71	m-Xylene	C8H10	24198757	1.5584
420	1H-Indene, 1-ethylidene-	C11H10	19474853	1.2542
307	Naphthalene, 1,2-dihydro-	C10H10	16946633	1.0914
215	Indane	C9H10	15180229	0.97762
291	1H-Indene, 2,3-dihydro-5-methyl-	C10H12	14186980	0.91365
251	Benzene, 1-butenyl-, (E)-	C10H12	14061213	0.90556
459	Benzene, (1,2,3-trimethyl-2-cyclopropen-1-yl)-	C12H14	13693619	0.88188
327	Benzene, 1-methyl-3-(1-methyl-2-propenyl)-	C11H14	13329833	0.85845
299	Benzene, 1-methyl-2-(2-propenyl)-	C10H12	13181317	0.84889
181	Benzene, 1,2,3-trimethyl-	C9H12	13081893	0.84249

Table E3 The top 15 mono-aromatics species of 0.25% Rh/HY experiment rearranged by area percentage

Peak #	Name	Formula	Area	Area %
202	Benzene, 1-methyl-2-(1-methylethyl)-	C10H11	49269754	2.9286
60	Ethylbenzene	C8H10	32493617	1.9314
407	1H-Indene, 1-ethylidene-	C11H10	29202422	1.7358
66	m-Xylene	C8H10	28589424	1.6993
295	1H-Indene, 2,3-dihydro-4-methyl-	C10H12	24363002	1.4481
296	Benzene, 1-butynyl-	C10H10	21994760	1.3074
248	Benzene, 1-butenyl-, (E)-	C10H12	20052260	1.1919
175	Benzene, 1,2,3-trimethyl-	C9H12	19390021	1.1525
322	Bicyclo[4.2.0]octa-1,3,5-triene, 7-isopropyl-	C11H14	19353718	1.1504
81	Styrene	C8H8	17875721	1.0625
289	1H-Indene, 2,3-dihydro-5-methyl-	C10H12	16938583	1.0068
211	Indane	C9H10	16471248	0.97905
356	Benzene, (1-ethyl-1-propenyl)-	C11H14	15756845	0.93658
330	1H-Indene, 2,3-dihydro-1,6-dimethyl-	C11H14	14934413	0.88770
227	Benzene, (2-methylpropyl)-	C10H14	13511115	0.80310

Table E4 The top 15 mono-aromatics species of 0.25% Rh/HBETA experiment rearranged by area percentage

Peak #	Name	Formula	Area	Area %
241	Benzocycloheptatriene	C11H10	25531199	3.8273
249	1H-Indene, 1-ethylidene-	C11H10	14048227	2.1059
100	Benzene, 1-methyl-3-(1-methylethyl)-	C10H14	10152493	1.5219
156	1H-Indene, 2,3-dihydro-4-methyl-	C10H12	9888809	1.4824
176	Bicyclo[4.2.0]octa-1,3,5-triene, 7-isopropyl-	C11H14	7586077	1.1372
183	1H-Indene, 2,3-dihydro-1,6-dimethyl-	C11H14	7434015	1.1144
127	Benzene, 1-butenyl-, (E)-	C10H12	7081419	1.0615
30	Ethylbenzene	C8H10	7000281	1.0494
157	Cycloprop[a]indene, 1,1a,6,6a-tetrahydro-	C10H10	6593980	0.98847
151	1H-Indene, 2,3-dihydro-5-methyl-	C10H12	6252401	0.93727
200	Benzene, (1-ethyl-1-propenyl)-	C11H14	6121777	0.91769
34	m-Xylene	C8H10	4990592	0.74812
163	Benzene, (1-methylene-2-propenyl)-	C10H10	4724343	0.70820
83	Benzene, 1,2,3-trimethyl-	C9H12	4624050	0.69317
106	Indane	C9H10	4399652	0.65953

Table E5 The top 15 mono-aromatics species of 1% Rh/KL experiment rearranged by area percentage

Peak #	Name	Formula	Area	Area %
385	1H-Indene, 1-ethylidene-	C11H10	67911254	3.0318
253	Benzene, 1-butyryl-	C10H10	49001707	2.1876
163	Benzene, 1-methyl-2-(1-methylethyl)-	C10H14	36977470	1.6508
282	Benzene, 1-methyl-3-(1-methyl-2-propenyl)-	C11H14	31574054	1.4096
260	Naphthalene, 1,2-dihydro-	C10H10	31432296	1.4032
48	m-Xylene	C8H10	26299225	1.1741
138	Benzene, 1,2,3-trimethyl-	C9H12	25008526	1.1165
44	Ethylbenzene	C8H10	24661247	1.1010
322	Benzene, (1-ethyl-1-propenyl)-	C11H14	23894282	1.0667
60	Styrene	C8H8	21284353	0.95020
341	1H-Indene, 1,3-dimethyl-	C11H12	20807475	0.92891
290	1H-Indene, 2,3-dihydro-1,6-dimethyl-	C11H14	20527485	0.91641
350	1H-Indene, 2,3-dimethyl-	C11H12	20232029	0.90322
245	1H-Indene, 2,3-dihydro-5-methyl-	C10H12	20083481	0.89659
205	Benzene, 1-butenyl-, (E)-	C10H12	19058440	0.85083

Appendix F Sulfur Contents in Pyrolysis Products

Table F1 The weight of sulfur in the products

Experiments	weight of sulfur (W_S)				
	Tire	Char	Oil	Gas	Spent catalysts
Non- Catalyst	45.9	28.5	17.0	0.37	0
KL	45.9	22.4	11.5	10.6	1.31
HY	45.9	21.0	7.87	12.8	4.27
HB	45.9	21.2	8.11	11.0	5.62
0.25RhKL	45.9	21.8	9.25	10.8	4.10
0.25RhHY	45.9	17.9	8.68	10.0	9.27
0.25RhHB	45.9	18.4	5.41	13.9	8.24
1RhHB	45.9	22.5	7.00	9.43	7.00
NiMoS/Al ₂ O ₃	45.9	21.7	5.91	10.4	7.91
CoMoS/Al ₂ O ₃	45.9	19.5	5.98	13.4	7.06

Table F2 The weight of the products recorded from waste tire pyrolysis

Experiments	weight of product (W_P)				
	Tire	Char	Oil	Gas	Spent catalysts
Non- Catalyst	30.0	11.9	12.6	5.57	0
KL	30.0	12.1	11.8	5.90	7.69
HY	30.0	11.5	9.11	6.92	9.94
HB	30.0	11.8	9.87	7.02	8.79
0.25RhKL	30.0	12.0	10.8	5.60	9.11
0.25RhHY	30.0	11.7	10.0	5.39	10.4
0.25RhHB	30.0	11.6	7.19	7.46	11.3
1RhHB	30.0	11.6	9.27	5.82	10.8
NiMoS/Al ₂ O ₃	30.0	11.7	9.81	6.43	9.60
CoMoS/Al ₂ O ₃	30.0	12.0	10.82	6.77	7.96

Table F3 Distribution of sulfur in the products

Experiments	% weight of sulfur in product (S _p)				
	Tire	Char	Oil	Gas	Spent catalysts
Non- Catalyst	1.53	2.40	1.36	0.07	0
KL	1.53	1.86	0.98	1.80	0.17
HY	1.53	1.82	0.86	1.84	0.43
HB	1.53	1.79	0.82	1.57	0.64
0.25RhKL	1.53	1.82	0.85	1.93	0.45
0.25RhHY	1.53	1.54	0.86	1.85	0.89
0.25RhHB	1.53	1.59	0.75	1.86	0.73
1RhHB	1.53	1.93	0.76	1.62	0.65
NiMoS/Al ₂ O ₃	1.53	1.86	0.60	1.62	0.82*
CoMoS/Al ₂ O ₃	1.53	1.63	0.55	1.98	0.89*

* Sulfur from tire (not including sulfur in catalyst structure)

The amount of sulfur in gas product can be calculated as the following equations;

$$W_{S_{Tire}} = W_{S_{Char}} + W_{S_{Oil}} + W_{S_{Gas}} + W_{S_{Spent\ cat}}$$

$$S_{p_{Tire}} W_{p_{Tire}} = S_{p_{Char}} W_{p_{Char}} + S_{p_{Oil}} W_{p_{Oil}} + S_{p_{Gas}} W_{p_{Gas}} + S_{p_{Spent\ cat}} W_{p_{Spent\ cat}}$$

W_s = The mass weight (g) of sulfur in products represented the sulfur distribution

W_p = The mass weight (g) of pyrolysis product

S_p = The weight percent (%) of sulfur in products obtained from S-Analyzer

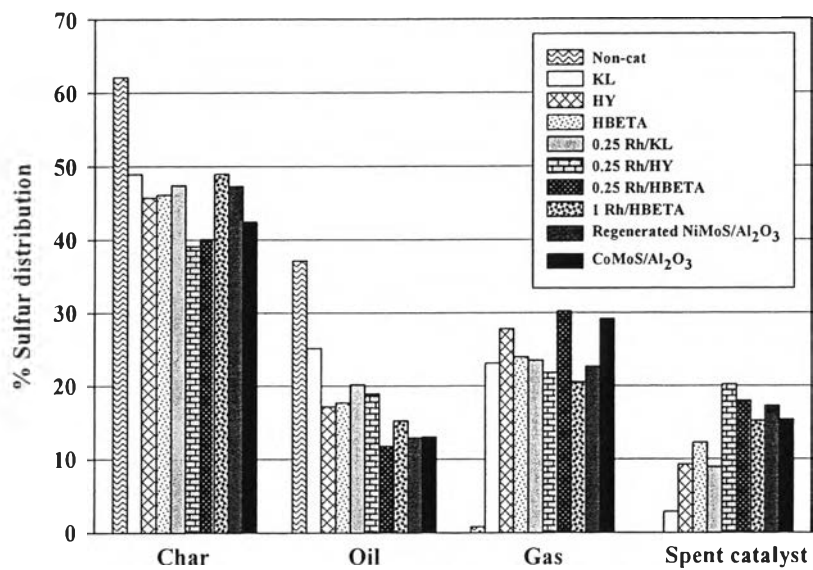


Figure F1 The sulfur distribution in pyrolysis products.

Appendix G Sulfur Species Found in Pyrolysis Oils

Table G1 Sulfur species found in oil obtained from non-catalytic pyrolysis

Peak	Name	Formula	Area %
980	1,3,5-Trithiane	C3H6S3	0.0016119
Total	(< C5)		0.0016119
71	Thiophene, 2-(1-methylethyl)-	C7H10S	0.011716
88	Benzenethiol	C6H6S	0.0025789
160	Thiophene, 2-(1,1-dimethylethyl)-	C8H12S	0.0061606
219	Thiophene, 2-methyl-5-propyl-	C8H12S	0.0055909
242	Thiophene, 2-butyl-	C8H12S	0.015180
252	Thiophene, 3,4-diethyl-	C8H12S	0.0073008
272	Thiophene, 2,5-diethyl-	C8H12S	0.0063879
285	Benzenethiol, 3-methyl-	C7H8S	0.0040783
416	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0087985
620	Benzo[b]thiophene	C8H6S	0.028329
670	4-Isopropylthiophenol	C9H12S	0.0053093
680	2-Benzothiophene #	C8H6S	0.00074027
915	3-Methylbenzothiophene	C9H8S	0.049942
945	Benzo[b]thiophene, 2-methyl-	C9H8S	0.018674
959	Benzo[b]thiophene, 4-methyl-	C9H8S	0.051471
Total	(C5-C9)		0.22225747
812	Thiophene, 2-hexyl-	C10H16S	0.010468
1195	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.040856
1218	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.045433
1250	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.11377
1282	Benzo[b]thiophene, 3,6-dimethyl-	C10H10S	0.030021
1283	5-Ethylbenzo[b]thiophene	C10H10S	0.013698
1298	Sulfide, 1-butylnyl phenyl	C10H10S	0.022664
1373	Benzene, 1-methyl-4-[(methylthio)ethynyl]-	C10H10S	0.0020109
1402	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.0024295
1491	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.060590
1509	Thiophene, 2-(phenylmethyl)-	C11H10S	0.017022
1520	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.044587
1558	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.0077268
1596	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.0044348
1650	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.0079043
1668	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.046307
1845	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0020273
1932	Benzo[b]thiophene, 7-ethyl-2-propyl-	C13H16S	0.0068293
2063	Dibenzothiophene	C12H8S	0.014380
2120	Naphtho[2,1-b]thiophene	C12H8S	0.0062062
2303	4-Methylnaphtho[1,2-b]thiophene	C13H10S	0.012603
2317	Thioxanthene	C13H10S	0.0043904
2334	1-Methyldibenzothiophene	C13H10S	0.0078652
2390	Dibenzothiophene, 4-methyl-	C13H10S	0.0023694

Table G1 Sulfur species found in oil obtained from non-catalytic pyrolysis (cont.)

Total	(C10-C13)		0.5265931
2418	3-Ethyl dibenzothiophene	C14H12S	0.0017200
2432	2,8-Dimethylbenzo(b,d)thiophene	C14H12S	0.0061634
2473	2,7-Dimethyl dibenzothiophene	C14H12S	0.022206
2504	2,6-Dimethyl dibenzothiophene	C14H12S	0.0056863
2520	1,7-Dimethyl dibenzothiophene	C14H12S	0.014453
2545	3,7-Dimethyl dibenzothiophene	C14H12S	0.0091192
2655	1-Propene-2-thiol, 1,1-diphenyl-	C15H14S	0.0059792
2669	Phenaleno[1,9-bc]thiophene	C14H8S	0.0061401
2680	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0092741
2828	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.0015694
2949	Benzo[b]naphtho[2,1-d]thiophene	C16H10S	0.0034527
2982	Benzo[b]naphtho[2,3-d]thiophene, 9,10-dihydro-7-methyl-	C17H14S	0.0015665
3033	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.0033094
3050	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.0020993
3069	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.0044326
3137	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0026595
3146	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0037599
Total	(C14-C20)		0.1035906

Table G2 Sulfur species found in oil obtained from using KL catalyst

Peak	Name	Formula	Area %
63	Thiophene, tetrahydro-2-methyl-	C5H10S	0.00048985
89	Thiophene, 2-ethyl-	C6H8S	0.0090244
93	Thiophene, 3-ethyl-	C6H8S	0.0055931
99	3,4-Dimethylthiophene	C6H8S	0.0049335
128	Thiophene, 2,3-dimethyl-	C6H8S	0.0023223
129	Thiophene, 2,5-dimethyl-	C6H8S	0.0011656
141	Benzenethiol	C6H6S	0.0051256
253	Thiophene, 2-propyl-	C7H10S	0.0035987
265	Thiophene, 2-(1-methylethyl)-	C7H10S	0.018176
277	Thiophene, 2-ethyl-5-methyl-	C7H10S	0.0098584
279	Thiophene, 2-ethenyl-	C6H6S	0.0029190
372	Thiophene, 2,3,4-trimethyl-	C7H10S	0.0051387
384	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.013367
451	Thiophene, 2-methyl-5-propyl-	C8H12S	0.043583
452	Thiophene, 2,5-diethyl-	C8H12S	0.021283
475	Thiophene, 2-butyl-	C8H12S	0.035905
483	Thiophene, 2-(1,1-dimethylethyl)-	C8H12S	0.0060715
506	Thiophene, 3,4-diethyl-	C8H12S	0.0057938
510	Benzenethiol, 2-methyl-	C7H8S	0.0025848
571	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.0066159
572	2H-Cyclopenta[b]thiophene, hexahydro-, cis-	C7H12S	0.0027332
579	Thioxyleneol	C8H10S	0.0040666

Table G2 Sulfur species found in oil obtained from using KL catalyst (cont.)

625	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.0069665
626	Thiophene, 2,4-dimethyl-	C6H8S	0.0047780
647	Thiophene, 2-ethyl-5-propyl-	C9H14S	0.024730
804	Benzo[b]thiophene	C8H6S	0.055129
879	Benzene, (propylthio)-	C9H12S	0.0048486
936	2,6-Dimethylbenzenethiol, S-methyl-	C9H12S	0.0037586
1059	Benzo[b]thiophene, 2-methyl-	C9H8S	0.071946
1084	3-Methylbenzothiophene	C9H8S	0.030650
1097	Benzo[b]thiophene, 6-methyl-	C9H8S	0.041395
1127	Benzo[b]thiophene, 5-methyl-	C9H8S	0.00091237
1307	2,2'-Bithiophene	C8H6S2	0.00090036
Total	(C5-C9)		0.45636338
301	Thiophene, 2-ethyl-5-isopentyl-	C11H18S	0.026722
354	2-Undecanethiol, 2-methyl-	C12H26S	0.013071
570	Thiophene, 2-ethyl-5-(2-methylpropyl)-	C10H16S	0.010413
641	Thiophene, 2-heptyl-	C11H18S	0.0059661
918	Thiophene, 2-butyl-5-ethyl-	C10H16S	0.0039495
974	Thiophene, 2-hexyl-	C10H16S	0.010695
1288	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.040077
1306	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.020945
1320	Thiophene, 2-phenyl-	C10H8S	0.011815
1332	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.11891
1344	Thiophene, 3-phenyl-	C10H8S	0.0033953
1359	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.012769
1432	5-Ethylbenzo[b]thiophene	C10H10S	0.0040644
1463	Benzo[b]thiophene, 3,6-dimethyl-	C10H10S	0.0015873
1477	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.0021847
1569	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.026022
1606	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.018199
1638	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.0033936
1695	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.0050901
1710	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.030456
1864	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0015121
2039	Dibenzothiophene	C12H8S	0.0051813
2094	Naphtho[2,3-b]thiophene	C12H8S	0.0017855
2206	Thioxanthene	C13H10S	0.0063909
2245	1-Methyldibenzothiophene	C13H10S	0.0062673
2270	Thioxanthene	C13H10S	0.0065318
2316	Methanethione, diphenyl-	C13H10S	0.00074412
Total	(C10-C13)		0.39813802
2350	2,7-Dimethyldibenzothiophene	C14H12S	0.0023445
2374	Benzenemethanethiol, à-methyl-à-phenyl-	C14H14S	0.0036311
2396	Dibenzothiophene, 4,6-dimethyl-	C14H12S	0.0078017
2416	Naphtho[2,3-b]thiophene, 4,9-dimethyl-	C14H12S	0.0090683
2435	1,7-Dimethyldibenzothiophene	C14H12S	0.0079922
2488	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0032320
2535	1-Propene-2-thiol, 1,1-diphenyl-	C15H14S	0.0029598

Table G2 Sulfur species found in oil obtained from using KL catalyst (cont.)

2539	Phenaleno[1,9-bc]thiophene	C14H8S	0.0015082
2803	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.00040563
2813	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.00047492
2827	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.0010737
2859	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0010480
Total	(C14-C20)		0.04154005

Table G3 Sulfur species found in oil obtained from using HY catalyst

Peak	Name	Formula	Area %
471	Thiophene, tetrahydro-	C4H8S	0.00073330
910	1,3,5-Trithiane	C3H6S3	0.00046622
Total	(< C5)		0.00119952
20	Thiophene, 3-ethyl-	C6H8S	0.00049990
134	Thiophene, 2-propyl-	C7H10S	0.0019829
151	Thiophene, 2-(1-methylethyl)-	C7H10S	0.0046090
160	Benzenethiol	C6H6S	0.0017023
220	2-Cyclopropylthiophene	C7H8S	0.0012452
224	Thiophene, 2,3,4-trimethyl-	C7H10S	0.00056514
231	Thiophene, 3,4-diethyl-	C8H12S	0.013389
249	Benzenethiol, 3-methyl-	C7H8S	0.014920
308	Thiophene, 2-butyl-	C8H12S	0.010554
312	2-(2-Methylvinyl)thiophene	C7H8S	0.0028009
317	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.013930
329	Thiophene, 2,5-diethyl-	C8H12S	0.018993
344	Benzenethiol, 4-methyl-	C7H8S	0.0026684
385	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.0027198
395	Thiophene, 2-ethyl-5-propyl-	C9H14S	0.0095149
399	2H-Cyclopenta[b]thiophene, hexahydro-, cis-	C7H12S	0.0015350
451	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0044262
542	Thioxlenol	C8H10S	0.0070459
554	Thiophene, 2-ethenyl-	C6H6S	0.0046618
555	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00069038
575	4-Isopropylthiophenol	C9H12S	0.0029158
607	Thiophene, tetrahydro-2-methyl-	C5H10S	0.0034519
620	Benzo[b]thiophene	C8H6S	0.075462
650	Thieno[3,2-b]thiophene	C6H4S2	0.00022772
668	Cyclopenta[b]thiapyran	C8H6S	0.00055360
757	Benzo[b]thiophene, 2,3-dihydro-	C8H8S	0.0019478
831	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00041837
843	Benzo[b]thiophene, 6-methyl-	C9H8S	0.077343
871	Benzo[b]thiophene, 2,3-dihydro-3-methyl-	C9H10S	0.0019817
883	3-Methylbenzothiophene	C9H8S	0.10428
896	Benzo[b]thiophene, 2-methyl-	C9H8S	0.011367
919	Benzo[b]thiophene, 4-methyl-	C9H8S	0.0012562
956	2H-1-Benzothiopyran, 3,4-dihydro-	C9H10S	0.00072266

Table G3 Sulfur species found in oil obtained from using HY catalyst (cont.)

1061	3,3'-Bithiophene	C8H6S2	0.00092918
1272	2,2'-Methylenedithiophene	C9H8S2	0.00075790
1319	Thiophene, 2-pentyl-	C9H14S	0.0010858
Total	(C5-C9)		0.40315435
295	Thiophene, 2-ethyl-5-heptyl-	C13H22S	0.0096098
626	Thiophene, 2-ethyl-5-(2-methylpropyl)-	C10H16S	0.0075091
685	Thiophene, 2,5-dipropyl-	C10H16S	0.0045706
766	Thiophene, 2-hexyl-	C10H16S	0.0039433
839	Benzenethiol, 4-(1,1-dimethylethyl)-	C10H14S	0.0017288
917	Benzene, (butylthio)-	C10H14S	0.0042190
1018	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.0038139
1042	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.034918
1060	5-Ethylbenzo[b]thiophene	C10H10S	0.044560
1088	Thiophene, 2-phenyl-	C10H8S	0.012752
1097	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.13416
1100	Thiophene, 3-phenyl-	C10H8S	0.0075414
1139	Thiophene, 2-(phenylmethyl)-	C11H10S	0.00083958
1191	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.0046058
1205	Benzo[b]thiophene, 2-propyl-	C11H12S	0.0010950
1207	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.0022159
1226	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.0064300
1284	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.089212
1347	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.0048064
1361	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.0056873
1410	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.012261
1439	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.013034
1465	1-(3'-Isopropylphenylthio)prop-1-yne	C12H14S	0.018948
1506	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0041627
1552	Benzo[b]thiophene, 7-ethyl-2-propyl-	C13H16S	0.0048066
1703	Dibenzothiophene	C12H8S	0.0072771
1737	Naphtho[2,3-b]thiophene	C12H8S	0.0032640
1779	Naphtho[1,2-b]thiophene	C12H8S	0.00051829
1839	Dibenzothiophene, 4-methyl-	C13H10S	0.010789
1924	1-Methyldibenzothiophene	C13H10S	0.0023582
2625	2,2':4',2''-Terthiophene	C12H8S3	0.00044182
Total	(C10-C13)		0.46207859
1986	2,6-Dimethyldibenzothiophene	C14H12S	0.018225
2009	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.028249
2045	1,7-Dimethyldibenzothiophene	C14H12S	0.0031824
2121	1-Propene-2-thiol, 1,1-diphenyl-	C15H14S	0.0058743
2128	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0018974
2132	Phenaleno[1,9-bc]thiophene	C14H8S	0.0019687
2209	Dibenzo[b,d]thiophene, 1,3,6,7-tetramethyl-	C16H16S	0.0021032
2234	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.0011154
2491	Benzo[b]naphtho[2,3-d]thiophene, 9,10-dihydro-7-methyl-	C17H14S	0.00064047
2551	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.0010208
2576	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.0014042

Table G3 Sulfur species found in oil obtained from using HY catalyst (cont.)

2604	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.0017395
2682	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0029553
2701	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0015544
Total	(C14-C20)		0.07193007
2080	Cyclic octaatomic sulfur	S8	0.00030531
Total			0.00030531

Table G4 Sulfur species found in oil obtained from using HBETA catalyst

Peak	Name	Formula	Area %
1060	1,3,5-Trithiane	C3H6S3	0.0027381
Total	(< C5)		0.0027381
91	Thiophene, 2-ethyl-	C6H8S	0.012716
101	3,4-Dimethylthiophene	C6H8S	0.0080170
116	Thiophene, 2,4-dimethyl-	C6H8S	0.0023787
126	Thiophene, 2,3-dimethyl-	C6H8S	0.0054539
135	Thiophene, 2-ethenyl-	C6H6S	0.0044256
240	Thiophene, 2-propyl-	C7H10S	0.0039405
251	Thiophene, 2-(1-methylethyl)-	C7H10S	0.049342
256	Thiophene, 2-pentyl-	C9H14S	0.0053315
257	Benzenethiol	C6H6S	0.0044748
265	Thiophene, 2-ethyl-5-methyl-	C7H10S	0.012579
343	Thiophene, 2,3,4-trimethyl-	C7H10S	0.010750
356	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.025020
373	2-(2-Methylvinyl)thiophene	C7H8S	0.0034195
419	Thiophene, 2-methyl-3-propyl-	C8H12S	0.033711
420	Thiophene, 2,5-diethyl-	C8H12S	0.017426
421	Thiophene, propyl-	C7H14S	0.0071590
446	Thiophene, 2-butyl-	C8H12S	0.030194
447	2-Cyclopropylthiophene	C7H8S	0.0041617
469	Thiophene, 3,4-diethyl-	C8H12S	0.026250
471	Benzenethiol, 3-methyl-	C7H8S	0.0046252
522	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0033356
575	2-(2,2-Dimethylvinyl)thiophene	C8H10S	0.0021867
592	Thiophene, 2-ethyl-5-propyl-	C9H14S	0.018466
739	Benzo[b]thiophene	C8H6S	0.043175
755	Cyclopenta[b]thiapyran	C8H6S	0.0031897
900	Benzo[b]thiophene, 2,3-dihydro-	C8H8S	0.0015737
971	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00085762
999	Benzo[b]thiophene, 2-methyl-	C9H8S	0.058915
1012	Benzo[b]thiophene, 2,3-dihydro-3-methyl-	C9H10S	0.0047485
1027	3-Methylbenzothiophene	C9H8S	0.024682
1043	Benzo[b]thiophene, 6-methyl-	C9H8S	0.044245
1071	Benzo[b]thiophene, 4-methyl-	C9H8S	0.00095164
Total	(C5-C9)		0.47770186

Table G4 Sulfur species found in oil obtained from using HBETA catalyst (cont.)

281	Thiophene, 2-ethyl-5-isopentyl-	C11H18S	0.039525
764	Thiophene, 2-butyl-5-ethyl-	C10H16S	0.0036725
909	Thiophene, 2-hexyl-	C10H16S	0.0099726
1173	Benzo[b]thiophene, 7-ethyl-2-propyl-	C13H16S	0.0031399
1221	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.031603
1255	Thiophene, 3-phenyl-	C10H8S	0.010813
1267	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.10680
1282	2-Naphthalenethiol	C10H8S	0.0021027
1296	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.015232
1297	Sulfide, 1-butynyl phenyl	C10H10S	0.035761
1311	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.013031
1318	Thiophene, 2-ethyl-5-hexyl-	C12H20S	0.0042235
1401	Benzene, 1-methyl-4-[(methylthio)ethynyl]-	C10H10S	0.0012650
1412	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.0028931
1477	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.042507
1489	Thiophene, 2-(phenylmethyl)-	C11H10S	0.014262
1499	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.029751
1526	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.020354
1620	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.055646
1657	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0057359
1672	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.0076745
1698	1-(3'-Isopropylphenylthio)prop-1-yne	C12H14S	0.012398
1940	Dibenzothiophene	C12H8S	0.0096580
1989	Naphtho[2,1-b]thiophene	C12H8S	0.0036283
2096	Dibenzothiophene, 4-methyl-	C13H10S	0.0086052
2132	Thioxanthene	C13H10S	0.0089542
2153	Dibenzothiophene, 3-methyl-	C13H10S	0.0083817
Total	(C10-C13)		0.5075901
2221	3,7-Dimethyldibenzothiophene	C14H12S	0.0027703
2241	Naphtho[2,3-b]thiophene, 4,9-dimethyl-	C14H12S	0.0056184
2276	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.012896
2339	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0025056
2378	Phenaleno[1,9-bc]thiophene	C14H8S	0.0015415
2450	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.00051996
2524	Benzo[b]naphtho[2,1-d]thiophene	C16H10S	0.0015195
Total	(C14-C20)		0.02737126

Table G5 Sulfur species found in oil obtained from using 0.25% Rh/KL catalyst

Peak	Name	Formula	Area %
963	1,3,5-Trithiane	C3H6S3	0.00050389
Total	(< C5)		0.00050389
9	Thiophene, 2-methyl-	C5H6S	0.0013520
96	Thiophene, 2-ethyl-	C6H8S	0.029699
100	Thiophene, 3-ethyl-	C6H8S	0.0025502

Table G5 Sulfur species found in oil obtained from using 0.25% Rh/KL catalyst (cont.)

115	3,4-Dimethylthiophene	C6H8S	0.0081883
133	Thiophene, 2,5-dimethyl-	C6H8S	0.0063260
136	Thiophene, 2,3-dimethyl-	C6H8S	0.0013898
250	Thiophene, 2-propyl-	C7H10S	0.0071621
277	Thiophene, 2-(1-methylethyl)-	C7H10S	0.0029625
278	Benzenethiol	C6H6S	0.00091029
299	Thiophene, 2-ethyl-5-methyl-	C7H10S	0.017273
335	Thiophene, 2,3,4-trimethyl-	C7H10S	0.0027246
336	2-Cyclopropylthiophene	C7H8S	0.0036207
346	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.038757
407	Thiophene, 2-methyl-5-propyl-	C8H12S	0.026253
408	Thiophene, 2,5-diethyl-	C8H12S	0.023398
429	Thiophene, 2-(1,1-dimethylethyl)-	C8H12S	0.010436
442	Thiophene, 3,4-diethyl-	C8H12S	0.012419
443	Benzenemethanethiol	C7H8S	0.00060168
450	Benzenethiol, 4-methyl-	C7H8S	0.0010747
487	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0060693
532	2-(2-Methylcyclopropyl)thiophene	C8H10S	0.00046041
545	4-Ethylthiophenol	C8H10S	0.0025807
553	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.010301
617	Thiophene, 2-pentyl-	C9H14S	0.019144
662	4-Isopropylthiophenol	C9H12S	0.0026498
702	Benzo[b]thiophene	C8H6S	0.053948
752	2-Benzothiophene #	C8H6S	0.00070931
919	3-Methylbenzothiophene	C9H8S	0.061760
937	Benzo[b]thiophene, 2-methyl-	C9H8S	0.060195
975	3-Methylbenzothiophene	C9H8S	0.00064230
1292	2,2'-Methylenedithiophene	C9H8S2	0.00064161
Total	(C5-C9)		0.4161993
496	Thiophene, 2-ethyl-5-(2-methylpropyl)-	C10H16S	0.0075485
840	Thiophene, 2-hexyl-	C10H16S	0.0066033
972	Benzene, (butylthio)-	C10H14S	0.0058670
1062	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.0029057
1085	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.019280
1096	Benzene, 1-methyl-4-[(methylthio)ethynyl]-	C10H10S	0.035018
1116	Thiophene, 3-phenyl-	C10H8S	0.016825
1126	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.10185
1129	Thiophene, 2-phenyl-	C10H8S	0.0049920
1165	Thiophene, 2-(phenylmethyl)-	C11H10S	0.00068426
1210	5-Ethylbenzo[b]thiophene	C10H10S	0.0028487
1220	Benzo[b]thiophene, 2-propyl-	C11H12S	0.0014503
1222	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.0011137
1240	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.0021940
1291	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.063685
1309	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.0072260
1355	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.0030222

Table G5 Sulfur species found in oil obtained from using 0.25% Rh/KL catalyst (cont.)

1361	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.0010464
1388	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.0042822
1428	1-(3'-Isopropylphenylthio)prop-1-yne	C12H14S	0.0033693
1477	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0016809
1644	Dibenzothiophene	C12H8S	0.0040904
1674	Azuleno(2,1-b)thiophene	C12H8S	0.00088637
1685	Naphtho[2,1-b]thiophene	C12H8S	0.00076133
1774	Dibenzothiophene, 4-methyl-	C13H10S	0.0049930
1798	1-Methyldibenzothiophene	C13H10S	0.0040784
1837	Thioxanthene	C13H10S	0.0050974
Total	(C10-C13)		0.31339936
151	Bicyclo[3.2.1]octa-2,6-diene, 4-(phenylthio)-	C14H14S	0.015297
1922	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.0036548
1950	3,7-Dimethyldibenzothiophene	C14H12S	0.0030142
1986	1,7-Dimethyldibenzothiophene	C14H12S	0.0065117
2006	2,6-Dimethyldibenzothiophene	C14H12S	0.0037906
2099	Phenaleno[1,9-bc]thiophene	C14H8S	0.0010189
2109	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0041993
2184	Dibenzo[b,d]thiophene, 1,3,6,7-tetramethyl-	C16H16S	0.0012296
2249	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.00010117
2395	Benzo[b]naphtho[2,1-d]thiophene	C16H10S	0.00069041
2422	Benzo[b]naphtho[2,3-d]thiophene, 9,10-dihydro-7-methyl-	C17H14S	0.00043289
2460	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.00061597
2474	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.00057586
2494	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.00076031
2539	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0023255
2549	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0011820
Total	(C14-C20)		0.04540021

Table G6 Sulfur species found in oil obtained from using 0.25% Rh/HY catalyst

Peak	Name	Formula	Area %
726	1,3,5-Trithiane	C3H6S3	0.0011334
Total	(< C5)		0.0011334
62	Thiophene, 2-propyl-	C7H10S	0.0013428
68	Thiophene, 2-(1-methylethyl)-	C7H10S	0.011476
80	Benzenethiol	C6H6S	0.00082151
91	Thiophene, 2,3,4-trimethyl-	C7H10S	0.0022958
145	Thiophene, 3,4-diethyl-	C8H12S	0.0056809
180	Thiophene, 2-methyl-5-propyl-	C8H12S	0.0029964
191	Thiophene, 2,5-diethyl-	C8H12S	0.0081112
204	Thiophene, 2-butyl-	C8H12S	0.011712
209	Thiophene, 3,4-diethyl-	C8H12S	0.0077375
232	Benzenethiol, 4-methyl-	C7H8S	0.0018191

Table G6 Sulfur species found in oil obtained from using 0.25% Rh/HY catalyst (cont.)

257	4-Ethylthiophenol	C8H10S	0.0032001
277	Benzene, 1-methyl-4-(methylthio)-	C8H10S	0.0014388
313	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0028040
373	Thiophene, 2-pentyl-	C9H14S	0.014914
466	Benzo[b]thiophene	C8H6S	0.062111
509	Cyclopenta[b]thiapyran	C8H6S	0.00053795
585	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00069540
663	Benzo[b]thiophene, 4-methyl-	C9H8S	0.030196
700	3-Methylbenzothiophene	C9H8S	0.13815
734	3-Methylbenzothiophene	C9H8S	0.00056777
1090	2,2'-Methylenedithiophene	C9H8S2	0.00043539
1631	Thiophene, 2-methyl-5-propyl-	C8H12S	0.0031199
Total	(C5-C9)		0.31216352
443	Thiophene, 2-ethyl-5-(2-methylpropyl)-	C10H16S	0.0015366
513	Thiophene, 2,5-dipropyl-	C10H16S	0.0022327
573	Thiophene, 2-heptyl-	C11H18S	0.0020496
592	Thiophene, 2-hexyl-	C10H16S	0.0072400
732	Benzene, (butylthio)-	C10H14S	0.0045066
824	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.0039734
852	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.034172
869	5-Ethylbenzo[b]thiophene	C10H10S	0.037314
896	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.21525
897	Thiophene, 2-phenyl-	C10H8S	0.042007
949	Thiophene, 2-(phenylmethyl)-	C11H10S	0.00055470
951	Thiophene, 2-ethyl-5-hexyl-	C12H20S	0.0032240
1008	Benzene, 1-methyl-4-[(methylthio)ethynyl]-	C10H10S	0.0031539
1020	Benzo[b]thiophene, 2-propyl-	C11H12S	0.0013090
1022	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.0015471
1043	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.0037615
1059	Benzo[b]thiophene, 2-propyl-	C11H12S	0.0047587
1069	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.055208
1089	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.091683
1114	Thiophene, 2-(phenylmethyl)-	C11H10S	0.018431
1170	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.0082647
1215	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.014855
1233	Thiophene, 2-(phenylmethyl)-	C11H10S	0.0014412
1241	1-(3'-Isopropylphenylthio)prop-1-yne	C12H14S	0.029044
1248	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.021326
1316	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0066367
1512	Dibenzothiophene	C12H8S	0.0080299
1541	Naphtho[2,1-b]thiophene	C12H8S	0.0033658
1647	4-Methylnaphtho[1,2-b]thiophene	C13H10S	0.0073697
1669	Dibenzothiophene, 4-methyl-	C13H10S	0.0066267
1705	Dibenzothiophene, 3-methyl-	C13H10S	0.0095659
1735	1-Methyldibenzothiophene	C13H10S	0.0014541

Table G6 Sulfur species found in oil obtained from using 0.25% Rh/HY catalyst (cont.)

Total	(C10-C13)		0.6518925
1776	Naphtho[2,3-b]thiophene, 4,9-dimethyl-	C14H12S	0.0023822
1796	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.0068633
1822	2,6-Dimethyldibenzothiophene	C14H12S	0.0039804
1832	2,7-Dimethyldibenzothiophene	C14H12S	0.012663
1852	1,7-Dimethyldibenzothiophene	C14H12S	0.0031237
1868	Dibenzothiophene, 4,6-dimethyl-	C14H12S	0.0012737
1951	Phenaleno[1,9-bc]thiophene	C14H8S	0.0014812
1977	Benzene, 1,1'-[1-(ethylthio)propylidene]bis-	C17H20S	0.024890
2051	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.00086601
2251	Benzo[b]naphtho[2,1-d]thiophene	C16H10S	0.00074251
2320	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.00068877
2337	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.00092599
2361	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.0010729
2406	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0023108
2414	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0012334
Total	(C14-C20)		0.06449788
1902	Cyclic octaatomic sulfur	S8	0.00065033
Total			0.00065033

Table G7 Sulfur species found in oil obtained from using 0.25% Rh/HBETA catalyst

Peak	Name	Formula	Area %
656	Thiophene, tetrahydro-	C4H8S	0.0010106
Total	(< C5)		0.0010106
13	Thiophene, 2-methyl-	C5H6S	0.0014495
101	Thiophene, 3-ethyl-	C6H8S	0.0078633
109	Thiophene, 2-ethyl-	C6H8S	0.0019187
112	Thiophene, 2,4-dimethyl-	C6H8S	0.0046985
129	Thiophene, 2,3-dimethyl-	C6H8S	0.0047059
145	3,4-Dimethylthiophene	C6H8S	0.015712
149	Thiophene, 2,5-dimethyl-	C6H8S	0.0022654
266	Thiophene, 2-ethyltetrahydro-	C6H12S	0.0015029
277	Thiophene, 2-propyl-	C7H10S	0.019221
305	Thiophene, 2-(1-methylethyl)-	C7H10S	0.031416
307	Benzenethiol	C6H6S	0.0022259
332	Thiophene, 2-ethyl-5-methyl-	C7H10S	0.018097
346	2-Cyclopropylthiophene	C7H8S	0.0041188
382	Thiophene, 2,3,4-trimethyl-	C7H10S	0.0098761
390	Thiophene, 2-(1,1-dimethylethyl)-	C8H12S	0.017068
417	2-(2-Methylvinyl)thiophene	C7H8S	0.0043632
471	Thiophene, 3,4-diethyl-	C8H12S	0.024753
491	Thiophene, 2,5-diethyl-	C8H12S	0.035053

Table G7 Sulfur species found in oil obtained from using 0.25% Rh/HBETA catalyst (cont.)

509	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.023773
510	Benzenemethanethiol	C7H8S	0.00020734
521	Benzenethiol, 4-methyl-	C7H8S	0.0036078
565	4-Ethylthiophenol	C8H10S	0.0062068
572	Thiophene, 2-ethyl-5-propyl-	C9H14S	0.0044231
579	2H-Cyclopenta[b]thiophene, hexahydro-, cis-	C7H12S	0.0025290
633	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.0052603
634	Thiophene, 2-methyl-5-propyl-	C8H12S	0.0041648
649	2-(1-Methylcyclopropyl)thiophene	C8H10S	0.00067880
717	Thiophene, 2-pentyl-	C9H14S	0.011906
742	4-Ethylthiophenol	C8H10S	0.0054749
743	Benzenethiol	C6H6S	0.0084982
744	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00091953
765	4-Isopropylthiophenol	C9H12S	0.0018747
796	Thiophene, tetrahydro-2-methyl-	C5H10S	0.0016523
811	Benzo[b]thiophene	C8H6S	0.091141
836	Thieno[3,2-b]thiophene	C6H4S2	0.00024306
861	Cyclopenta[b]thiapyran	C8H6S	0.00036434
873	Benzene, 1-(ethylthio)-4-methyl-	C9H12S	0.0022094
961	Benzo[b]thiophene, 2,3-dihydro-	C8H8S	0.0017967
1030	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00031090
1042	Benzo[b]thiophene, 6-methyl-	C9H8S	0.045739
1043	Thieno[2,3-b]thiophene, 2-methyl-	C7H6S2	0.00007590
1044	Thiophene, 2-ethyltetrahydro-	C6H12S	0.0015694
1079	3-Methylbenzothiophene	C9H8S	0.13605
1109	Benzo[b]thiophene, 5-methyl-	C9H8S	0.0011389
1122	Benzo[b]thiophene, 2-methyl-	C9H8S	0.00053387
1159	Benzo[b]thiophene, 2,3-dihydro-3-methyl-	C9H10S	0.00045029
1250	Thiophane, propyl-	C7H14S	0.00086579
1266	2,2'-Bithiophene	C8H6S2	0.00072728
1490	2,2'-Methylenedithiophene	C9H8S2	0.00055403
2072	Thiophene, 2-methyl-5-propyl-	C8H12S	0.0032446
Total	(C5-C9)		0.57449923
752	Thiophene, 2,5-dipropyl-	C10H16S	0.0038817
756	1,3-Dithiolane, 2-benzyl-2-methyl-	C11H14S2	0.0019625
789	Thiophene, 2-butyl-5-ethyl-	C10H16S	0.0016642
906	Thiophene, 2-butyl-5-ethyl-	C10H16S	0.0040333
967	Thiophene, 2-hexyl-	C10H16S	0.0028360
1140	Thiophene, 2-ethyl-5-isopentyl-	C11H18S	0.0021790
1222	5-Ethylbenzo[b]thiophene	C10H10S	0.0034359
1235	Benzo[b]thiophene, 2-ethyl-	C10H10S	0.0018584
1247	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.024912
1275	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.028855
1292	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.093898
1327	5-Ethylbenzo[b]thiophene	C10H10S	0.030412
1340	Thiophene, 2-(phenylmethyl)-	C11H10S	0.00075454

Table G7 Sulfur species found in oil obtained from using 0.25% Rh/HBETA catalyst (cont.)

1392	Benzene, 1-methyl-4-[(methylthio)ethynyl]-	C10H10S	0.0046673
1405	Benzo[b]thiophene, 2-propyl-	C11H12S	0.00092803
1407	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.0015093
1416	2-Benzothiophene, 1,3-dihydro-5,6-dimethyl-	C10H12S	0.00021995
1430	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.0046443
1465	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.025079
1500	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.10010
1558	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.0055760
1569	2-Naphthalenethiol	C10H8S	0.014152
1612	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.0095115
1646	Cyclohepta[cd][2]benzothiophene, 2,6,7,8,9,9a-hexahydro-	C12H14S	0.0049666
1659	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.0032632
1721	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0053950
1921	Benzene, 1,1'-[1-(methylthio)ethylidene]bis-	C15H16S	0.013513
1929	Dibenzothiophene	C12H8S	0.0084890
2088	Dibenzothiophene, 4-methyl-	C13H10S	0.0094307
2109	Dibenzothiophene, 3-methyl-	C13H10S	0.0082955
2146	4-Methylnaphtho[1,2-b]thiophene	C13H10S	0.013291
2181	Thioxanthene	C13H10S	0.0028213
2972	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.0017131
Total	(C10-C13)		0.43824832
2203	3-Ethylidibenzothiophene	C14H12S	0.0032692
2213	2,6-Dimethyldibenzothiophene	C14H12S	0.0082641
2238	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.015547
2268	1,7-Dimethyldibenzothiophene	C14H12S	0.014950
2289	Naphtho[2,3-b]thiophene, 4,9-dimethyl-	C14H12S	0.0065817
2367	1-Propene-2-thiol, 1,1-diphenyl-	C15H14S	0.0014999
2400	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0073539
2403	Phenaleno[1,9-bc]thiophene	C14H8S	0.0021943
2499	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.0014277
2522	Dibenzo[b,d]thiophene, 1,3,6,7-tetramethyl-	C16H16S	0.0030919
2540	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.00040602
2619	4,4'-Bis(methylsulfanyl)biphenyl	C14H14S2	0.0010071
2661	Naphthalene, 1-(phenylthio)-	C16H12S	0.0019449
2712	Benzo[b]naphtho[2,1-d]thiophene	C16H10S	0.0018097
2734	Benzo[b]naphtho[1,2-d]thiophene	C16H10S	0.00060635
2754	2-Naphthyl-p-tolyl sulfide	C17H14S	0.00054223
2770	Anthra(1,2-b)thiophene	C16H10S	0.00028546
2785	Benzo[b]naphtho[2,3-d]thiophene, 9,10-dihydro-7-methyl-	C17H14S	0.0019299
2821	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.00098286
2848	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.0014616
2882	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.0039154
2965	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0029492
2986	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0029170
Total	(C14-C20)		0.08493742

Table G7 Sulfur species found in oil obtained from using 0.25% Rh/HBETA catalyst (cont.)

2342	Cyclic octaatomic sulfur	S8	0.00040684
Total			0.00040684

Table G8 Sulfur species found in oil obtained from using 1% Rh/HBETA catalyst

Peak	Name	Formula	Area %
68	Thiophene, 3-ethyl-	C6H8S	0.0076001
74	Thiophene, 2-ethyl-	C6H8S	0.0014866
79	3,4-Dimethylthiophene	C6H8S	0.010514
94	Thiophene, 2,5-dimethyl-	C6H8S	0.0032606
104	Thiophene, 2,4-dimethyl-	C6H8S	0.0095144
107	Thiophene, 2,3-dimethyl-	C6H8S	0.0015371
215	Thiophene, 2-propyl-	C7H10S	0.011137
223	Thiophene, 2-ethyl-5-methyl-	C7H10S	0.030429
234	Thiophene, 2-(1-methylethyl)-	C7H10S	0.018865
236	Benzenethiol	C6H6S	0.0013923
300	Thiophene, 2,3,4-trimethyl-	C7H10S	0.0045145
309	Thiophene, 2-(1,1-dimethylethyl)-	C8H12S	0.013268
330	Benzenethiol, 3-methyl-	C7H8S	0.0092073
372	Thiophene, 2-methyl-5-propyl-	C8H12S	0.036300
373	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.016232
390	2-(2-Methylvinyl)thiophene	C7H8S	0.0049352
396	Thiophene, 3,4-diethyl-	C8H12S	0.019142
414	Thiophene, 2,5-diethyl-	C8H12S	0.017250
425	Benzenethiol, 4-methyl-	C7H8S	0.0027992
461	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.0033409
485	Benzene, 1-methyl-4-(methylthio)-	C8H10S	0.0011176
526	4-Ethylthiophenol	C8H10S	0.0018080
534	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0044590
558	Thiophene, 2-ethyl-5-propyl-	C9H14S	0.033829
616	Thiophene, 2-pentyl-	C9H14S	0.018016
649	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.0024850
723	Benzo[b]thiophene	C8H6S	0.088800
740	Cyclopenta[c]thiapyran	C8H6S	0.0027099
747	4-Isopropylthiophenol	C9H12S	0.0012742
754	Thieno[3,2-b]thiophene	C6H4S2	0.00030561
776	2-Benzothiophene #	C8H6S	0.00065366
874	Benzo[b]thiophene, 2,3-dihydro-	C8H8S	0.00076793
946	Benzo[b]thiophene, 6-methyl-	C9H8S	0.045817
988	3-Methylbenzothiophene	C9H8S	0.16140
1029	Benzo[b]thiophene, 2-methyl-	C9H8S	0.0010169
1380	2,2'-Methylenedithiophene	C9H8S2	0.00052267
1418	Thiophene, 2-pentyl-	C9H14S	0.0018376
1942	Thiophene, 2-methyl-5-propyl-	C8H12S	0.0029890

Table G8 Sulfur species found in oil obtained from using 1% Rh/HBETA catalyst (cont.)

Total	(C5-C9)		0.59253427
341	1,3-Dithiolane, 2-benzyl-2-methyl-	C11H14S2	0.010235
465	2-Undecanethiol, 2-methyl-	C12H26S	0.00094813
699	Thiophene, 2-ethyl-5-(2-methylpropyl)-	C10H16S	0.0020257
829	Thiophene, 2-butyl-5-ethyl-	C10H16S	0.0025498
879	Thiophene, 2-hexyl-	C10H16S	0.0038007
1025	Benzene, (butylthio)-	C10H14S	0.0044051
1135	5-Ethylbenzo[b]thiophene	C10H10S	0.0032337
1160	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.048742
1176	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.038799
1205	Thiophene, 2-phenyl-	C10H8S	0.013181
1212	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.16646
1214	Thiophene, 3-phenyl-	C10H8S	0.0074257
1309	Benzo[b]thiophene, 2-propyl-	C11H12S	0.0019249
1311	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.0021848
1331	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.0055025
1356	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.031885
1378	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.13786
1399	Thiophene, 2-(phenylmethyl)-	C11H10S	0.017380
1443	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.0025434
1503	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.013734
1504	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.010081
1539	1-(3'-Isopropylphenylthio)prop-1-yne	C12H14S	0.018085
1555	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.0042168
1618	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0067195
1739	2H-Naphtho[1,8-bc]thiophene, 2-methyl-	C12H10S	0.0010617
1812	Dibenzothiophene	C12H8S	0.010325
1843	Naphtho[2,3-b]thiophene	C12H8S	0.0040239
1890	Naphtho[2,1-b]thiophene	C12H8S	0.00071242
1955	Dibenzothiophene, 4-methyl-	C13H10S	0.010701
1982	Dibenzothiophene, 3-methyl-	C13H10S	0.0094569
2017	Thioxanthene	C13H10S	0.013769
2035	Thiophene, 2,5-bis(1,1-dimethylethyl)-	C12H20S	0.0028836
2052	1-Methyldibenzothiophene	C13H10S	0.0018328
Total	(C10-C13)		0.60868905
2092	2,6-Dimethyldibenzothiophene	C14H12S	0.010047
2100	3-Ethyldibenzothiophene	C14H12S	0.0018369
2117	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.0092224
2146	1,7-Dimethyldibenzothiophene	C14H12S	0.022702
2167	2,7-Dimethyldibenzothiophene	C14H12S	0.0041371
2186	2,6-Dimethyldibenzothiophene	C14H12S	0.0040686
2195	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0049470
2219	1-Propene-2-thiol, 1,1-diphenyl-	C15H14S	0.0096336
2267	Phenaleno[1,9-bc]thiophene	C14H8S	0.0023052
2281	Benzene, 1,1'-[1-(ethylthio)propylidene]bis-	C17H20S	0.0094948

Table G8 Sulfur species found in oil obtained from using 1% Rh/HBETA catalyst (cont.)

2374	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.0019142
2379	Dibenzo[b,d]thiophene, 1,3,6,7-tetramethyl-	C16H16S	0.0036062
2583	Benzo[b]naphtho[2,1-d]thiophene	C16H10S	0.0014415
2622	Benzo[b]naphtho[2,3-d]thiophene, 9,10-dihydro-7-methyl-	C17H14S	0.0013997
2674	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.0012728
2686	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.0017403
2704	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.0024965
2763	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0029622
2776	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0033053
Total	(C14-C20)		0.0985333

Table G9 Sulfur species found in oil obtained from using spent NiMoS/Al₂O₃ catalyst

Peak	Name	Formula	Area %
1058	1,3,5-Trithiane	C3H6S3	0.00036912
Total	(< C5)		0.00036912
5	Thiophene, 2-methyl-	C5H6S	0.00026255
11	Thiophene, 3-methyl-	C5H6S	0.0021406
79	Thiophene, 2,3-dihydro-5-methyl-	C5H8S	0.00059785
110	Thiophene, 3-ethyl-	C6H8S	0.015507
119	Thiophene, 2-ethyl-	C6H8S	0.0091499
123	Thiophene, 2,4-dimethyl-	C6H8S	0.012101
136	3,4-Dimethylthiophene	C6H8S	0.015392
140	Thiophene, 2,5-dimethyl-	C6H8S	0.0052375
147	5-Thiatricyclo[4.1.0.0(2,4)]heptanes	C6H8S	0.0018686
163	Thiophene, 2,3-dimethyl-	C6H8S	0.0034859
260	Benzenemethanethiol	C7H8S	0.010932
276	Thiophene, 2-propyl-	C7H10S	0.022722
285	Thiophene, 2-ethyl-5-methyl-	C7H10S	0.052295
303	Thiophene, 2-(1-methylethyl)-	C7H10S	0.020632
305	Benzenethiol	C6H6S	0.00092222
372	Thiophene, 2,3,4-trimethyl-	C7H10S	0.0044642
381	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.047018
434	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0031416
445	Thioxyleneol	C8H10S	0.0026377
457	Thiophene, 2-methyl-5-propyl-	C8H12S	0.039406
458	Thiophene, 3,4-diethyl-	C8H12S	0.045056
470	Thiophene, 2-butyl-	C8H12S	0.011558
479	Thiophene, 2-(1,1-dimethylethyl)-	C8H12S	0.013464
501	Thiophene, 2,5-diethyl-	C8H12S	0.014356
510	Benzenethiol, 4-methyl-	C7H8S	0.0022952
556	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.0035176
578	2-(1-Methylcyclopropyl)thiophene	C8H10S	0.0011100

Table G9 Sulfur species found in oil obtained from using spent NiMoS/Al₂O₃ catalyst (cont.)

590	3,4-Dimethylthiophenol	C8H10S	0.0014157
601	2-(2-Methylcyclopropyl)thiophene	C8H10S	0.00085993
620	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0050317
631	2-(2,2-Dimethylvinyl)thiophene	C8H10S	0.0015881
641	Thiophene, 2-ethyl-5-propyl-	C9H14S	0.011516
692	Thiophene, 2-pentyl-	C9H14S	0.013716
722	Benzenethiol	C6H6S	0.0041541
723	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00068167
779	Benzo[b]thiophene	C8H6S	0.061265
805	Thieno[3,2-b]thiophene	C6H4S2	0.00025804
830	2-Benzothiophene #	C8H6S	0.00031846
887	2-(2,2-Dimethylcyclopropyl)thiophene	C9H12S	0.0025871
915	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00051360
994	3-Methylbenzothiophene	C9H8S	0.038682
1018	Benzo[b]thiophene, 2,3-dihydro-3-methyl-	C9H10S	0.0014785
1033	3-Methylbenzothiophene	C9H8S	0.16573
1071	Benzo[b]thiophene, 2-methyl-	C9H8S	0.0013909
1199	3,3'-Bithiophene	C8H6S2	0.0014933
1420	2,2'-Methylenedithiophene	C9H8S2	0.00079150
Total	(C5-C9)		0.67474202
334	3-(Benzylthio)propene	C10H12S	0.0078844
564	2-(1,4,4-Trimethylcyclohex-2-enyl)[1,3]dithiane	C13H22S2	0.0024387
637	2-Undecanethiol, 2-methyl-	C12H26S	0.019935
849	Thiophene, 2,5-dipropyl-	C10H16S	0.0015770
920	Thiophene, 2-hexyl-	C10H16S	0.0032480
1154	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.0042320
1180	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.027853
1213	5-Ethylbenzo[b]thiophene	C10H10S	0.052867
1229	Thiophene, 3-phenyl-	C10H8S	0.014374
1240	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.089749
1255	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.016679
1272	Benzo[b]thiophene, 2-ethyl-	C10H10S	0.025324
1282	Thiophene, 2-(phenylmethyl)-	C11H10S	0.00079000
1333	Benzene, 1-methyl-4-[(methylthio)ethynyl]-	C10H10S	0.0041025
1344	Benzo[b]thiophene, 2-propyl-	C11H12S	0.00099795
1346	Benzo[b]thiophene, 3,6-dimethyl-	C10H10S	0.0024473
1368	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.0039013
1391	2-(2-Methyl-propenyl)-indan-1-thiol	C13H16S	0.0069641
1406	Benzo[b]thiophene, 2-ethyl-5-methyl-	C11H12S	0.020435
1432	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.054737
1495	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.011644
1535	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.0074629
1580	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.0070633
1630	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0040792
1672	Benzo[b]thiophene, 7-ethyl-2-propyl-	C13H16S	0.0023731
1685	1-(3'-Isopropylphenylthio)prop-1-yne	C12H14S	0.0090654

Table G9 Sulfur species found in oil obtained from using spent NiMoS/Al₂O₃ catalyst (cont.)

1747	2H-Naphtho[1,8-bc]thiophene, 2-methyl-	C12H10S	0.00079436
1834	Dibenzothiophene	C12H8S	0.0086282
1875	Naphtho[2,3-b]thiophene	C12H8S	0.0027125
1914	Naphtho[1,2-b]thiophene	C12H8S	0.00035304
1987	Dibenzothiophene, 4-methyl-	C13H10S	0.0075697
2010	4-Methylnaphtho[1,2-b]thiophene	C13H10S	0.0080582
2052	Thioxanthene	C13H10S	0.010969
Total	(C10-C13)		0.44130915
2121	3-Ethylidibenzothiophene	C14H12S	0.0033243
2134	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.0058773
2151	3,7-Dimethyldibenzothiophene	C14H12S	0.0066894
2186	Naphtho[2,3-b]thiophene, 4,9-dimethyl-	C14H12S	0.014013
2208	1,7-Dimethyldibenzothiophene	C14H12S	0.0044250
2234	Dibenzothiophene, 4,6-dimethyl-	C14H12S	0.0025535
2245	1-Propene-2-thiol, 1,1-diphenyl-	C15H14S	0.0030275
2326	Phenaleno[1,9-bc]thiophene	C14H8S	0.0024647
2355	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0050820
2435	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.0013908
2442	Dibenzo[b,d]thiophene, 1,3,6,7-tetramethyl-	C16H16S	0.0017610
2612	Naphthalene, 1-(phenylthio)-	C16H12S	0.0013844
2673	Benzo[b]naphtho[2,3-d]thiophene	C16H10S	0.0011965
2694	Benzo[b]naphtho[1,2-d]thiophene	C16H10S	0.00027566
2714	Benzo[b]naphtho[2,3-d]thiophene, 9,10-dihydro-7-methyl-	C17H14S	0.0010293
2721	Benzo[b]thiophene, 3,5-dimethyl-	C10H10S	0.00096558
2782	Benzo[b]naphtho[2,3-d]thiophene, 6-methyl-	C17H12S	0.00099009
2803	5-Methylbenzo[b]naphtho[2,1-d]thiophene	C17H12S	0.0017905
2834	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.0027645
2859	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.00048610
2909	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.00050048
2943	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0031860
Total	(C14-C20)		0.06517761
2255	Cyclic octaatomic sulfur	S8	0.017949
Total			0.017949

Table G10 Sulfur species found in oil obtained from using CoMoS/Al₂O₃ catalyst

Peak	Name	Formula	Area %
69	Thiophene, 2-ethyl-	C6H8S	0.025016
77	Thiophene, 3-ethyl-	C6H8S	0.0016959
82	3,4-Dimethylthiophene	C6H8S	0.014243
97	Thiophene, 2,5-dimethyl-	C6H8S	0.0054216
110	Thiophene, 2,3-dimethyl-	C6H8S	0.0015300
236	Thiophene, 2-(1-methylethyl)-	C7H10S	0.069501
252	Thiophene, 2-ethyl-5-methyl-	C7H10S	0.0031885

Table G10 Sulfur species found in oil obtained from using CoMoS/Al₂O₃ catalyst (cont.)

253	Benzenethiol	C6H6S	0.010266
278	Benzenethiol	C6H6S	0.0035736
286	Thiophene, 2-ethenyl-	C6H6S	0.0014479
318	Thiophene, 2,3,4-trimethyl-	C7H10S	0.0028056
356	Benzenethiol, 3-methyl-	C7H8S	0.015210
393	Thiophene, 2-(1,1-dimethylethyl)-	C8H12S	0.0027680
403	Thiophene, 2,5-diethyl-	C8H12S	0.027372
418	2-(2-Methylvinyl)thiophene	C7H8S	0.0044115
427	Thiophene, 3-(1,1-dimethylethyl)-	C8H12S	0.017941
447	Thiophene, 3,4-diethyl-	C8H12S	0.018003
459	Benzenethiol, 4-methyl-	C7H8S	0.0014085
465	Thiophene, 2-(2-butenyl)-, (E)-	C8H10S	0.0016297
500	2-(2,2-Dimethylvinyl)thiophene	C8H10S	0.0023489
510	Thiophene, 3,4-diethyl-	C8H12S	0.0021920
513	2H-Cyclopenta[b]thiophene, hexahydro-, cis-	C7H12S	0.0056000
567	Thiophene, 3-(2-butenyl)-, (E)-	C8H10S	0.0044401
587	Thiophene, 2-ethyl-5-propyl-	C9H14S	0.012661
633	Thiophene, 2-pentyl-	C9H14S	0.017720
724	Benzo[b]thiophene	C8H6S	0.047997
744	Thieno[2,3-b]thiophene	C6H4S2	0.00022913
765	Benzene, (propylthio)-	C9H12S	0.0035759
767	Cyclopenta[b]thiapyran	C8H6S	0.00025088
805	4-Isopropylthiophenol	C9H12S	0.0026528
839	Benzo[c]thiophene, 1,3-dihydro-	C8H8S	0.00063746
899	Benzo[b]thiophene, 2-methyl-	C9H8S	0.020220
919	2-(Cyclopent-1-enyl)-thiophene	C9H10S	0.00049472
940	3-Methylbenzothiophene	C9H8S	0.091271
971	Benzo[b]thiophene, 5-methyl-	C9H8S	0.00061746
1110	3,3'-Bithiophene	C8H6S2	0.00047170
Total	(C5-C9)		0.44081285
274	Thiophene, 2-ethyl-5-isopentyl-	C11H18S	0.015376
707	Thiophene, 2-ethyl-5-(2-methylpropyl)-	C10H16S	0.0015467
728	Thiophene, 2-butyl-5-ethyl-	C10H16S	0.0058117
783	Thiophene, 2,5-dipropyl-	C10H16S	0.0039738
831	Thiophene, 2-hexyl-	C10H16S	0.0079479
847	Thiophene, 2-isohexyl-	C10H16S	0.0034042
1067	5-Ethylbenzo[b]thiophene	C10H10S	0.0011077
1093	Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.040087
1109	Benzo[b]thiophene, 7-ethyl-	C10H10S	0.027976
1131	Thiophene, 2-phenyl-	C10H8S	0.016243
1138	Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.14519
1140	Thiophene, 3-phenyl-	C10H8S	0.0047805
1174	Thiophene, 2-(phenylmethyl)-	C11H10S	0.00065949
1181	Thiophene, 2-ethyl-5-hexyl-	C12H20S	0.0019716
1242	Benzo[b]thiophene, 3,6-dimethyl-	C10H10S	0.0017664
1257	Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.0025090

1304	Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.050937
1328	Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.047366
1425	Benzo[b]thiophene, 2-ethyl-5,7-dimethyl-	C12H14S	0.0074716
1465	Benzo[b]thiophene, 2,3-diethyl-	C12H14S	0.013164
1477	Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.0032058
1668	2H-Naphtho[1,8-bc]thiophene, 2-methyl-	C12H10S	0.00074066
1748	Dibenzothiophene	C12H8S	0.0077977
1779	Naphtho[2,3-b]thiophene	C12H8S	0.0020111
1892	Dibenzothiophene, 4-methyl-	C13H10S	0.0056251
1912	4-Methylnaphtho[1,2-b]thiophene	C13H10S	0.0044778
1945	1-Methyldibenzothiophene	C13H10S	0.0080392
1981	Dibenzothiophene, 3-methyl-	C13H10S	0.0018329
Total	(C10-C13)		0.43301985
1985	Thiophene, 2-ethyl-5-octyl-	C14H24S	0.00082828
2016	2,7-Dimethyldibenzothiophene	C14H12S	0.0081014
2050	2,8-Dimethyldibenzo(b,d)thiophene	C14H12S	0.0067739
2079	1,7-Dimethyldibenzothiophene	C14H12S	0.013286
2102	Naphtho[2,3-b]thiophene, 4,9-dimethyl-	C14H12S	0.0056672
2120	3,7-Dimethyldibenzothiophene	C14H12S	0.0011464
2155	Benzenemethanethiol, à-methyl-à-phenyl-	C14H14S	0.0044283
2193	1-Propene-2-thiol, 1,1-diphenyl-	C15H14S	0.0035467
2202	Phenaleno[1,9-bc]thiophene	C14H8S	0.0021408
2206	Benzene, 1,1'-[(methylthio)ethenylidene]bis-	C15H14S	0.0057052
2289	1-Methylphenanthro[4,5-bcd]thiophene	C15H10S	0.0010500
2459	Benzo[b]naphtho[1,2-d]thiophene	C16H10S	0.0010516
2525	Benzo[b]naphtho[2,3-d]thiophene, 8-methyl-	C17H12S	0.00084435
2541	Benzo[b]naphtho[2,3-d]thiophene, 7-methyl-	C17H12S	0.0014087
2606	Benzo[b]naphtho[2,3-d]thiophene, 6,8-dimethyl-	C18H14S	0.0017825
2613	Benzo[b]naphtho[2,3-d]thiophene, 7,8-dimethyl-	C18H14S	0.0016566
Total	(C14-C20)		0.0594179

Table G11 Sulfur species found in oil from all experiments

Compounds	Formula	Area (%)									
		Non-Catalyst	KL	HY	HB	0.25RhKL	0.25RhHY	0.25RhHB	1RhHB	NiMoS/ Al ₂ O ₃	CoMoS/ Al ₂ O ₃
Thiophene, 2-(1-methylethyl)-	C7H10S	0.0117	0.0182	0.0046	0.0493	0.003	0.0115	0.0314	0.0189	0.0206	0.0695
Benzo[b]thiophene	C8H6S	0.0283	0.0551	0.0755	0.0432	0.0539	0.0621	0.0911	0.0888	0.0613	0.048
Benzo[b]thiophene, 2-methyl-	C9H8S	0.0187	0.0719	0.0114	0.0589	0.0602	-	0.0005	0.001	0.0014	0.0202
Benzo[b]thiophene, 6-methyl-	C9H8S	-	0.0414	0.0773	0.0442	-	-	0.0457	0.0458	-	-
3-Methylbenzothiophene	C9H8S	0.0499	0.0307	0.1043*	0.0247	0.0618	0.1382*	0.1361*	0.1614*	0.16573*	0.0913
Benzo[b]thiophene, 2,5-dimethyl-	C10H10S	0.0409	0.1189*	0.1342*	0.1068*	0.0193	0.0342	0.0249	0.0487	0.0897	0.0401
Benzo[b]thiophene, 2,7-dimethyl-	C10H10S	0.1138*	0.0401	0.0349	0.0316	0.1019*	0.2153*	0.0939	0.1665*	0.0279	0.1452*
Benzo[b]thiophene, 2-ethyl-7-methyl-	C11H12S	0.0606	0.026	0.0892	0.0425	0.0022	0.0038	0.1001*	0.0025	0.0039	0.0025
Benzo[b]thiophene, 2,5,7-trimethyl-	C11H12S	0.0446	0.0034	0.0057	0.0029	0.003	0.0917	0.0056	0.1379*	0.0116	0.0474
Benzo[b]thiophene, 7-ethyl-2-methyl-	C11H12S	0.0077	0.0022	0.0064	0.0298	0.0637	0.0552	0.0046	0.0055	0.0547	0.0509
Benzo[b]thiophene, 2,7-diethyl-	C12H14S	0.0463	0.0305	0.013	0.0556	0.001	0.0213	0.0033	0.0042	0.0071	0.0032

Appendix H Physical Properties of Catalysts

Table H1 Catalyst properties obtained from surface area analyzer

Sample	Sample mass (g)	Specific surface area (m ² /g)	Pore specific volume (cm ³ /g)	Median pore width (Å)	Maximum pore width (Å)
KL	0.2729	239.9368	0.2672	6.677	6.67
HY	0.2790	547.6857	0.4376	7.788	7.656
HBETA	0.2564	525.7468	1.0115	8.040	8.100
0.25RhKL	0.2546	209.2667	0.1902	7.219	8.069
0.25RhHY	0.2824	531.0768	0.4151	7.927	7.795
0.25RhHB	0.2645	518.1262	0.5646	7.969	7.978
1RhHB	0.1114	500.0587	0.9308	7.705	7.095
NiMoS/Al ₂ O ₃	0.2685	198.7473	0.4224	8.855	7.961
CoMoS/Al ₂ O ₃	0.2417	213.8820	0.4339	8.107	5.067

