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APPENDICES

Appendix A Scanning Electron Microscopy Micrographs

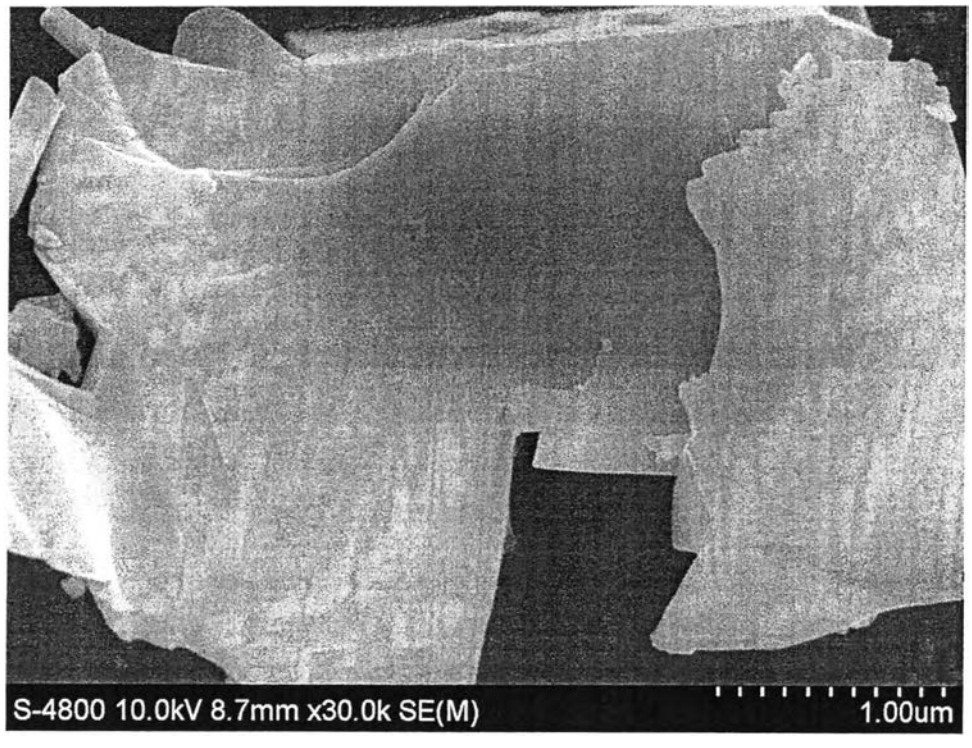

Figure A1 SEM image of HZ5 (10.0 kV 8.7mm ×30.0k).

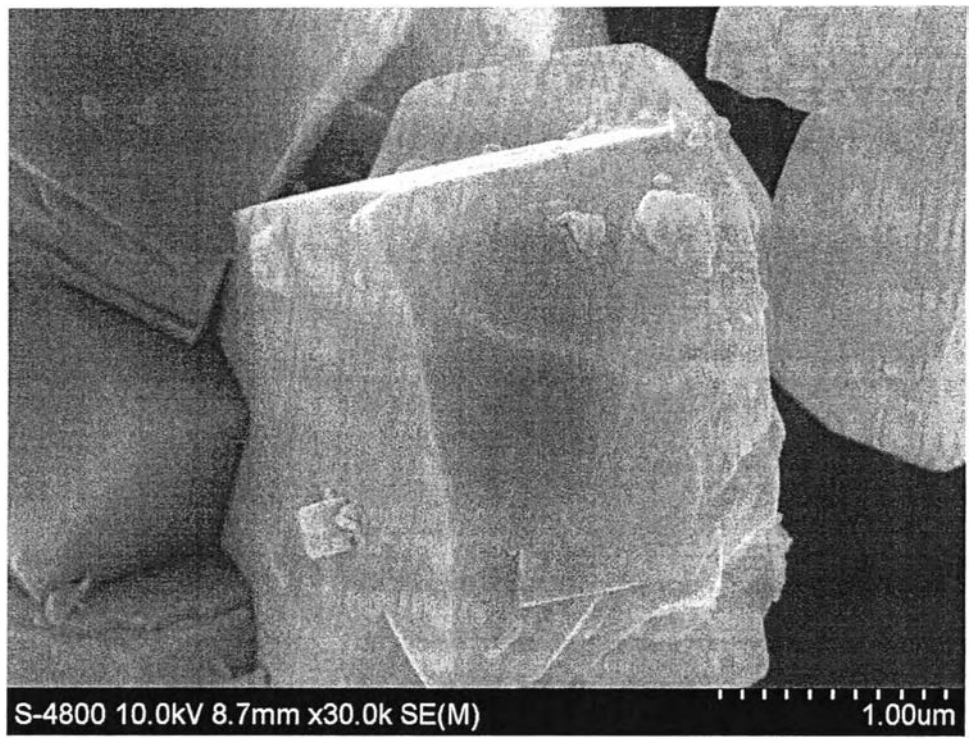

Figure A2 SEM image of 2PHZ5 (10.0 kV 8.7mm ×30.0k).

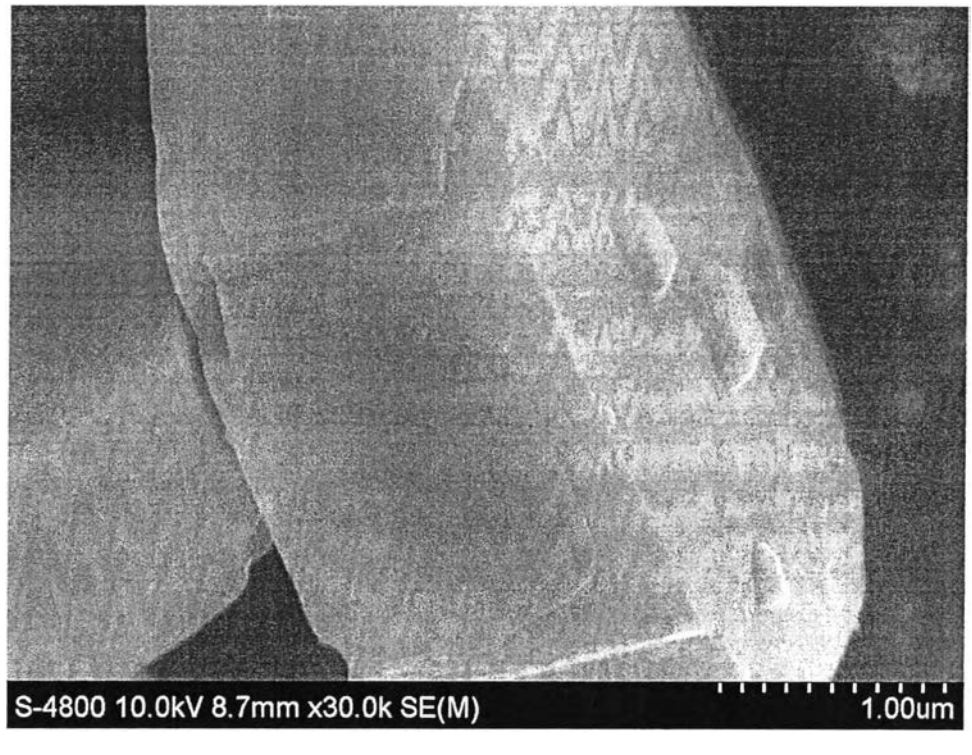

Figure A3 SEM image of 2SbHZ5 (10.0 kV 8.7mm ×30.0k).

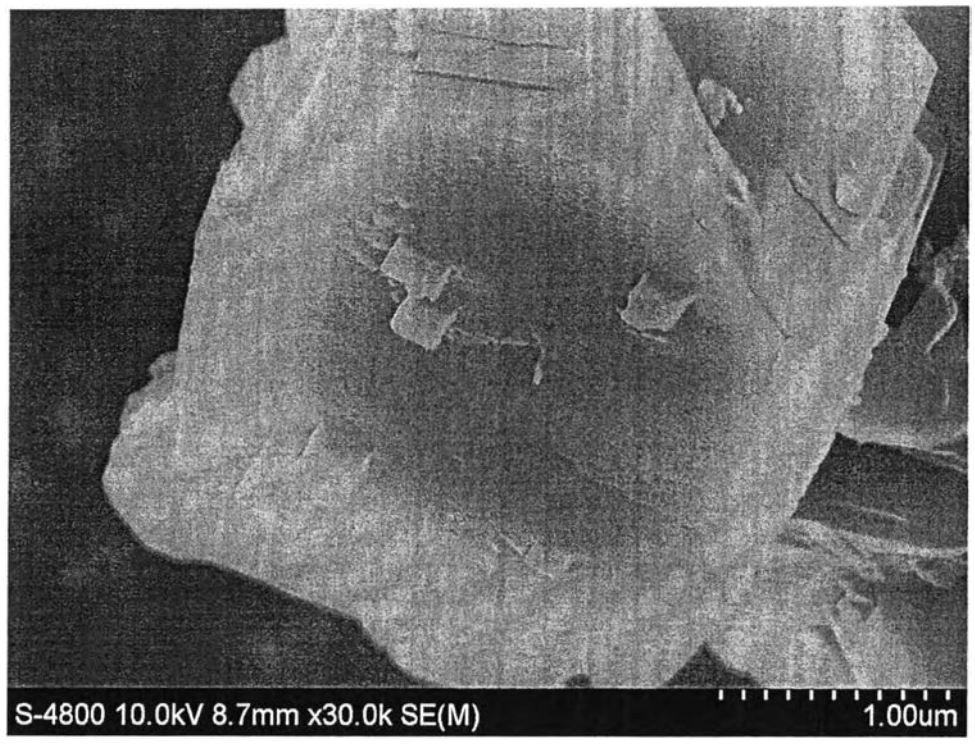

Figure A4 SEM image of 2BiHZ5 (10.0 kV 8.7mm ×30.0k).

Appendix B Raman Spectra

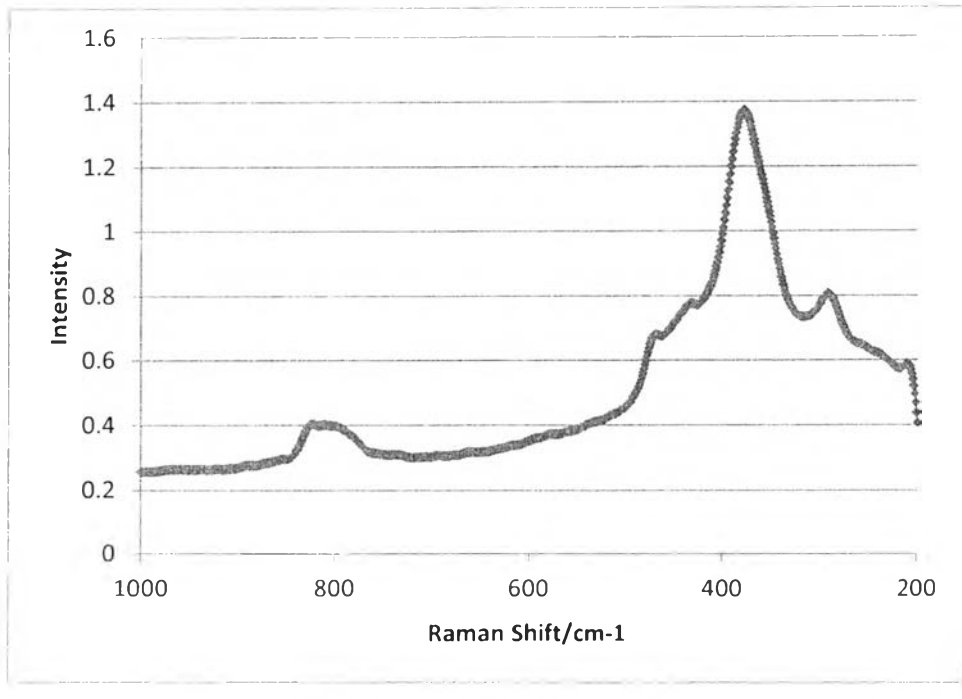

Figure B1 Raman spectrum of HZ5 catalyst in the 200-1000 cm^{-1}.

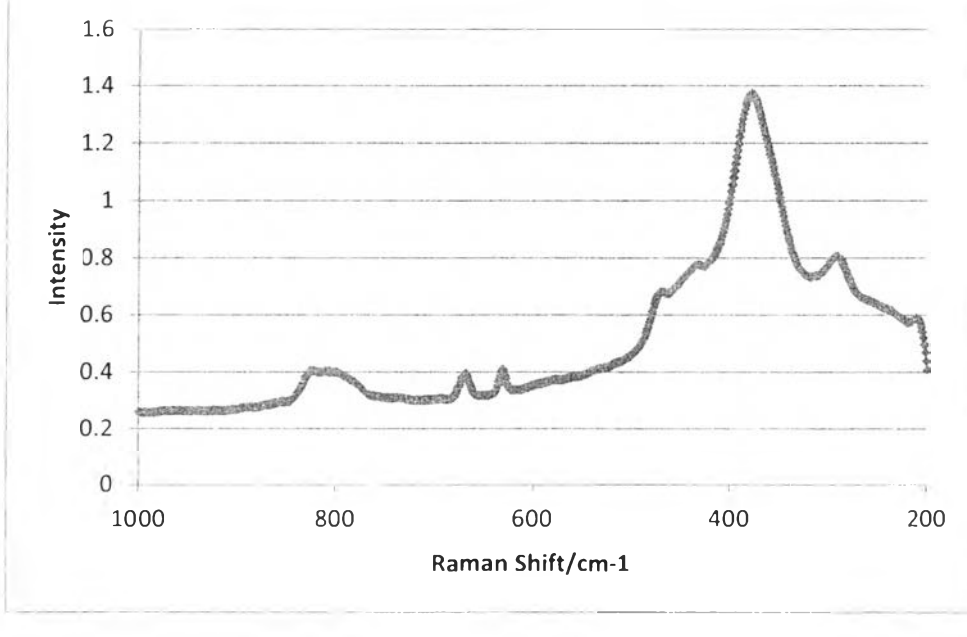

Figure B2 Raman spectrum of 2GaHZ5 catalyst in the 200-1000 cm^{-1}.

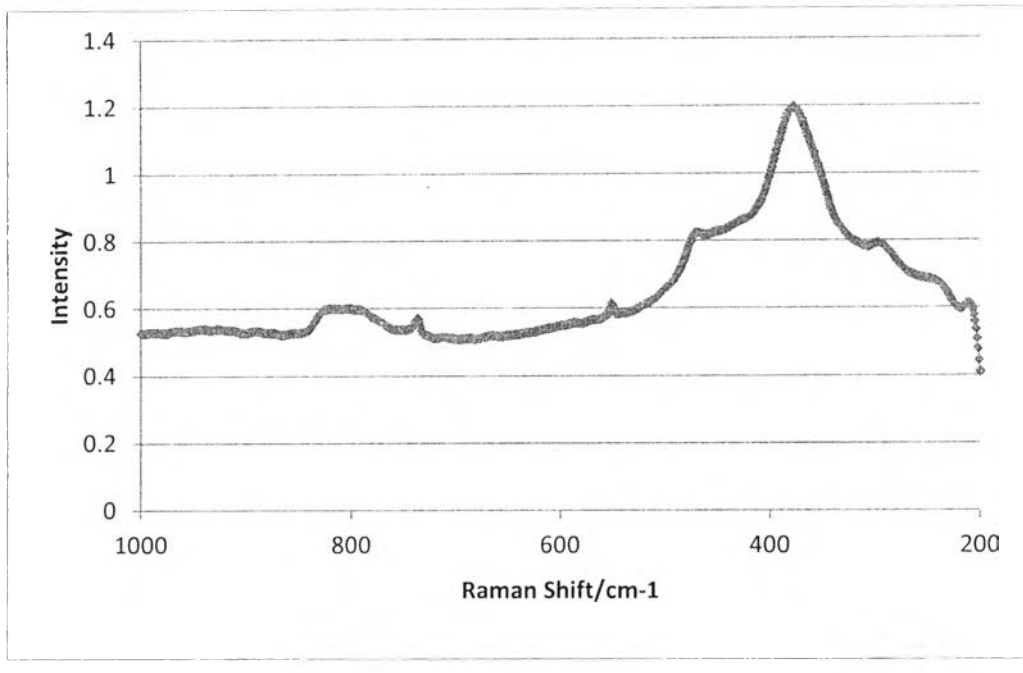

Figure B3 Raman spectrum of 1PHZ5 catalyst in the 200-1000 cm^{-1}.

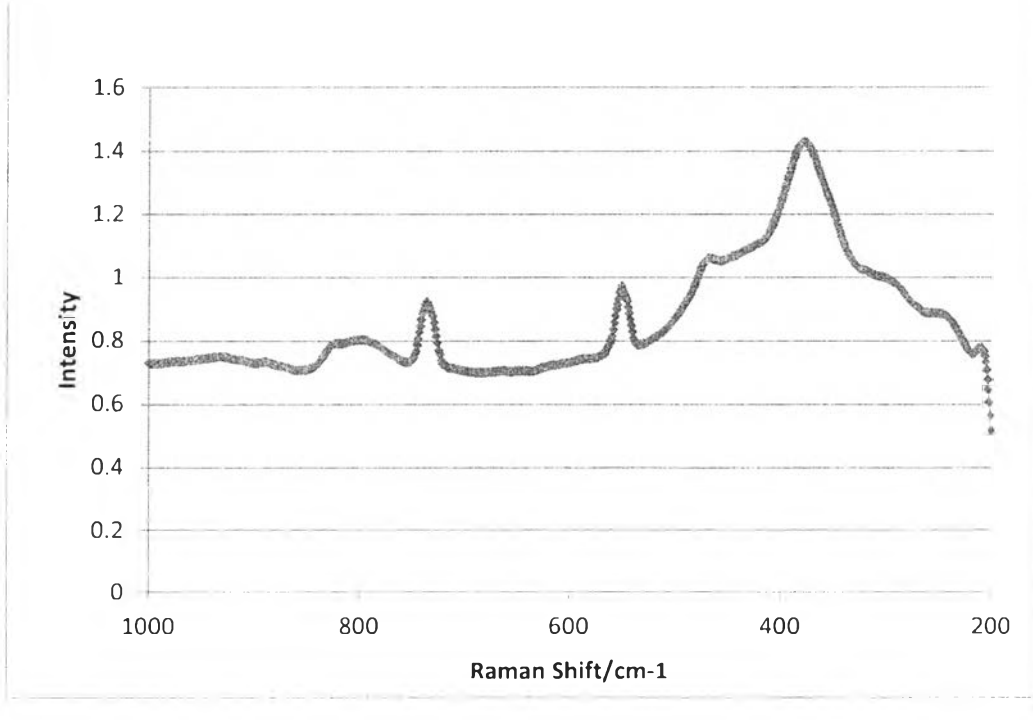

Figure B4 Raman spectrum of 4PHZ5 catalyst in the 200-1000 cm^{-1}.

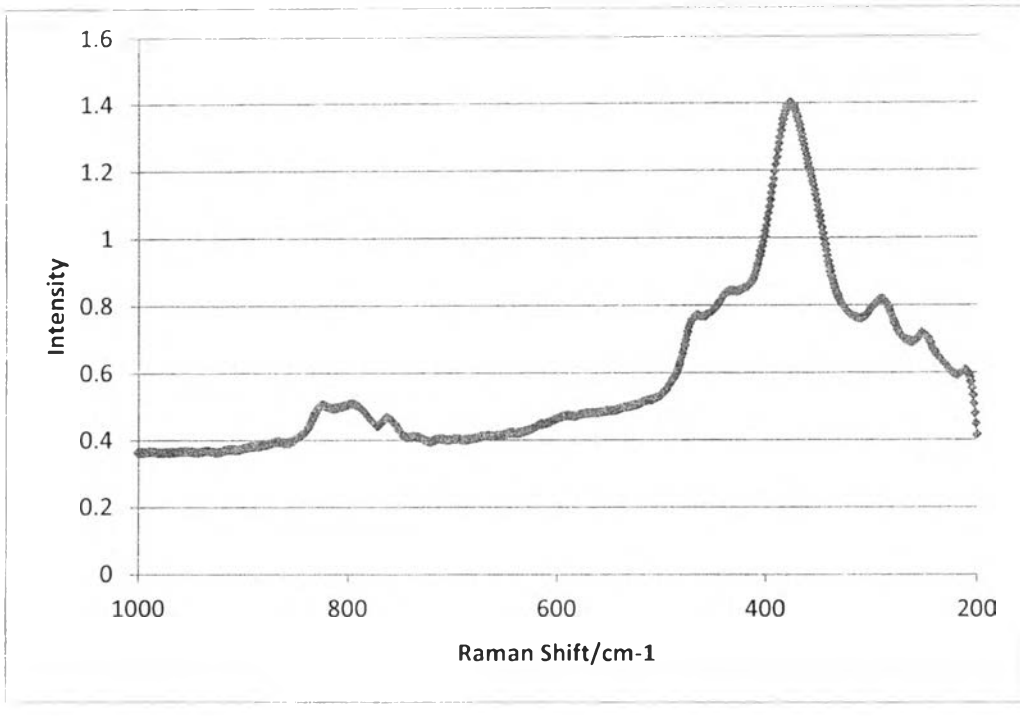

Figure B5 Raman spectrum of 1SbHZ5 catalyst in the 200-1000 cm^{-1}.

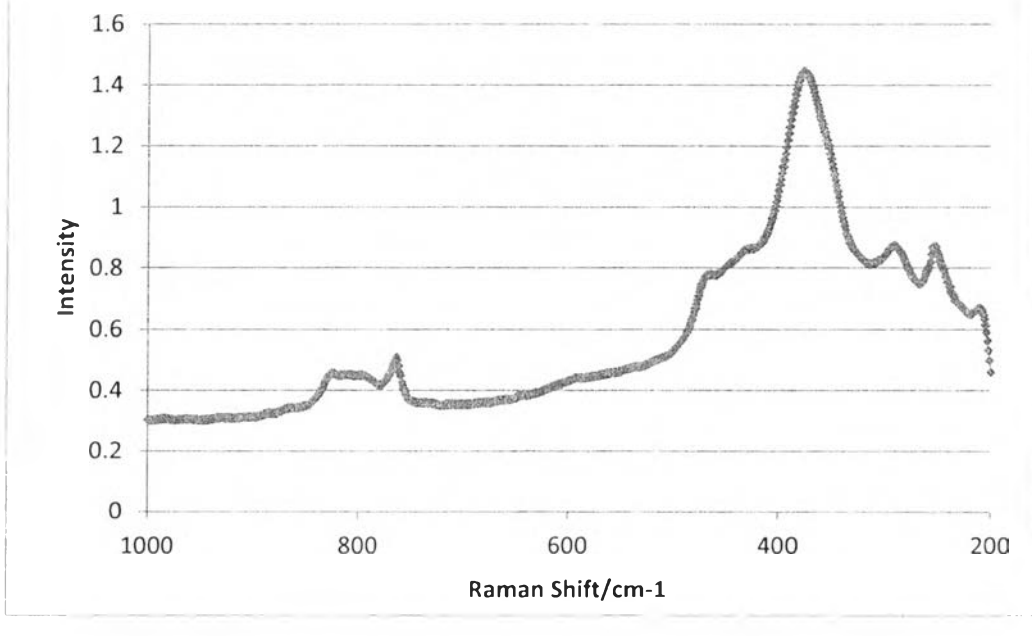

Figure B6 Raman spectrum of 4SbHZ5 catalyst in the 200-1000 cm^{-1}.

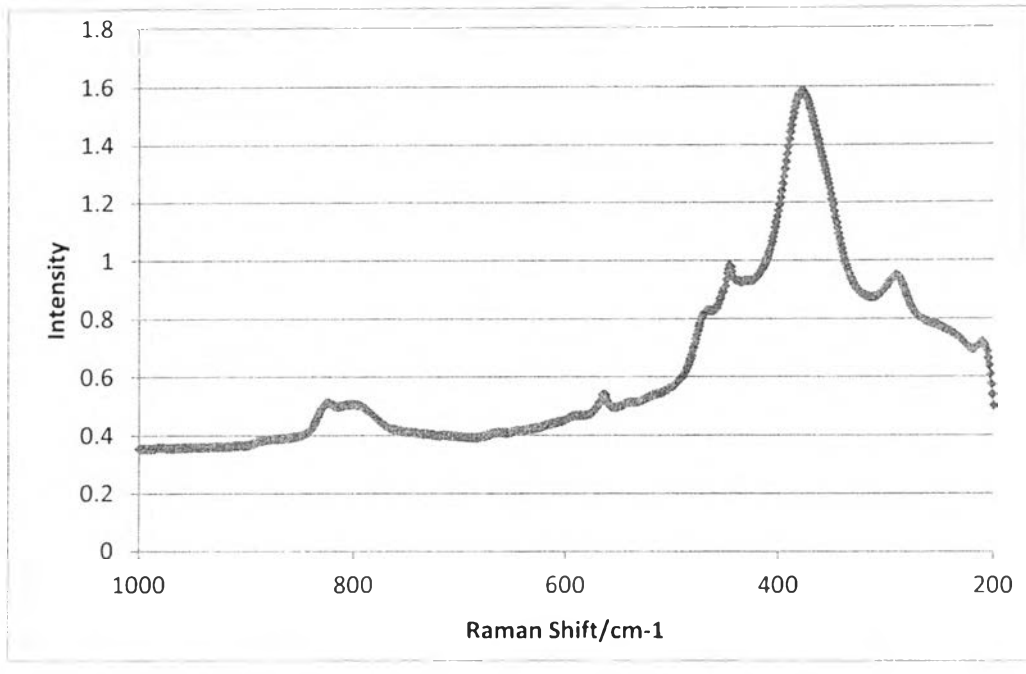

Figure B7 Raman spectrum of 1BiHZ5 catalyst in the 200-1000 cm^{-1}.

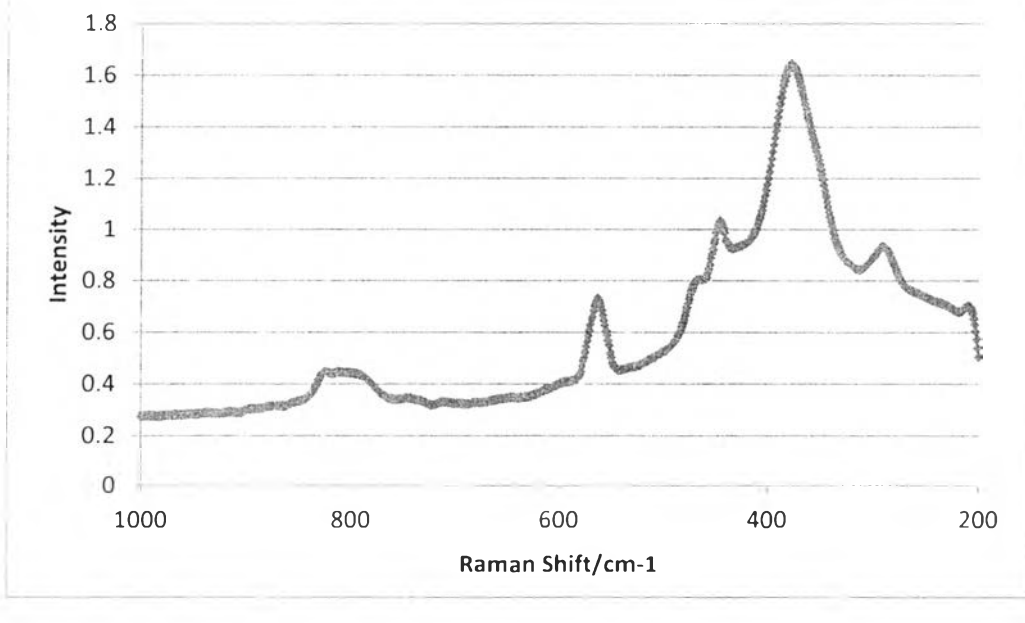

Figure B8 Raman spectrum of 4BiHZ5 catalyst in the 200-1000 cm^{-1}.

Appendix C Product Distribution and Product Yield Calculation

$$\text{Yield (wt \%)} = \frac{\text{Total weight of any products}}{\text{Total weight of converted bioethanol}} \times 100$$

Table C1 Product distribution and product yields from the two consecutive layers of catalysts

Catalyst	2GaHZ5	2GaHZ5:X	2GaHZ5:Y	2GaHZ5:β
Ethanol conversion (wt %)	96.5	96.0	96.1	96.1
Feed ethanol (ml/h)	2.00	4.00	4.00	4.00
Feed ethanol (ml)	16.0	32.0	32.0	32.0
Feed ethanol (g)*	12.6	25.2	25.2	25.2
Converted ethanol (g)	12.2	24.2	24.3	24.3
Product distribution (g)				
Oil	0.85	1.26	1.48	1.15
Gas	6.48	13.0	12.9	13.3
Water	4.86	9.94	9.85	9.83
Other**	0.45	1.02	0.98	0.98
Product yield (wt %)				
Oil	6.95	5.19	6.09	4.76
Gas	53.2	53.8	53.3	54.8
Water	39.9	41.0	40.6	40.5

*Ethanol concentration is 99.5 v/v %

**Unconverted bio-ethanol

Table C2 Product distribution and product yields from HZ5, 1PHZ5, 2PHZ5, 3PHZ5, and 4PHZ5 catalysts

Catalyst	HZ5	1PHZ5	2PHZ5	3PHZ5	4PHZ5
Ethanol conversion (wt %)	97.0	97.0	97.0	96.9	96.9
Feed ethanol (ml/h)	2.00	2.00	2.00	2.00	2.00
Feed ethanol (ml)	16.0	16.0	16.0	16.0	16.0
Feed ethanol (g)*	12.6	12.6	12.6	12.6	12.6
Converted ethanol (g)	12.2	12.2	12.2	12.2	12.2
Product distribution (g)					
Oil	0.75	0.87	0.71	0.53	0.35
Gas	6.41	6.55	6.64	6.82	7.27
Water	5.08	4.82	4.88	4.88	4.61
Other**	0.38	0.38	0.38	0.39	0.39
Product yield (wt %)					
Oil	6.13	7.07	5.80	4.35	2.88
Gas	52.4	53.5	54.3	55.8	59.5
Water	41.5	39.4	39.9	39.9	37.7

*Ethanol concentration is 99.5 v/v %

**Unconverted bio-ethanol

Table C3 Product distribution and product yields from HZ5, 1SbHZ5, 2SbHZ5, 3SbHZ5, and 4SbHZ5 catalysts

Catalyst	HZ5	1SbHZ5	2SbHZ5	3SbHZ5	4SbHZ5
Ethanol conversion (wt %)	97.0	96.2	96.2	96.1	96.2
Feed ethanol (ml/h)	2.00	2.00	2.00	2.00	2.00
Feed ethanol (ml)	16.0	16.0	16.0	16.0	16.0
Feed ethanol (g)*	12.6	12.6	12.6	12.6	12.6
Converted ethanol (g)	12.2	12.1	12.1	12.1	12.1
Product distribution (g)					
Oil	0.75	0.84	0.95	0.79	0.74
Gas	6.41	6.54	6.41	6.55	6.70
Water	5.08	4.76	4.78	4.80	4.70
Other**	0.38	0.47	0.48	0.49	0.48
Product yield (wt %)					
Oil	6.13	6.94	7.87	6.48	6.06
Gas	52.4	53.9	52.8	54.0	55.2
Water	41.5	39.2	39.3	39.6	38.7

*Ethanol concentration is 99.5 v/v %

**Unconverted bio-ethanol

Table C4 Product distribution and product yields from HZ5, 1BiHZ5, 2BiHZ5, 3BiHZ5, and 4BiHZ5 catalysts

Catalyst	HZ5	1BiHZ5	2BiHZ5	3BiHZ5	4BiHZ5
Ethanol conversion (wt %)	97.0	96.2	96.1	96.2	96.2
Feed ethanol (ml/h)	2.00	2.00	2.00	2.00	2.00
Feed ethanol (ml)	16.0	16.0	16.0	16.0	16.0
Feed ethanol (g)*	12.6	12.6	12.6	12.6	12.6
Converted ethanol (g)	12.2	12.1	12.1	12.1	12.1
Product distribution (g)					
Oil	0.75	0.79	0.81	0.76	0.76
Gas	6.41	6.55	6.54	6.60	6.63
Water	5.08	4.80	4.79	4.78	4.76
Other**	0.38	0.49	0.49	0.49	0.47
Product yield (wt %)					
Oil	6.13	6.50	6.66	6.29	6.23
Gas	52.4	54.0	53.9	54.3	54.6
Water	41.5	39.5	39.4	39.4	39.2

*Ethanol concentration is 99.5 v/v %

**Unconverted bio-ethanol

Appendix D Compositions in Gas Products

Table D1 Gas composition as a function of time on stream for 2GaHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	46.1	44.5	43.0	48.3	40.1	35.5	33.9	34.5
CO2	12.4	12.7	13.5	16.5	14.2	12.0	12.0	21.2
Ethylene	4.86	4.92	5.32	5.61	6.03	6.84	7.37	8.49
Ethane	15.2	15.1	14.9	14.1	14.6	14.1	14.0	12.2
Propylene	0.00	0.00	0.00	0.00	0.00	2.70	3.02	3.51
Propane	21.5	22.7	23.3	15.5	25.1	28.9	29.7	20.1
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D2 Gas composition as a function of time on stream for 2GaHZ5:X catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	39.3	37.0	33.0	30.0	30.2	26.0	27.0	25.2
CO2	10.3	9.55	8.37	7.75	7.82	7.69	7.55	7.65
Ethylene	0.00	0.00	2.21	2.98	3.58	3.87	3.92	4.21
Ethane	15.2	15.3	14.6	14.6	15.1	15.1	14.4	15.9
Propylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Propane	35.1	38.1	41.8	44.7	43.2	47.3	47.1	47.0
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D3 Gas composition as a function of time on stream for 2GaHZ5:Y catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300- min	@360 min	@420 min	@480 min
CH4	35.1	35.2	32.8	33.1	32.2	32.5	29.9	29.9
CO2	10.1	9.97	10.2	9.84	9.65	10.3	9.24	9.87
Ethylene	5.44	5.95	5.44	5.92	6.86	7.39	7.32	7.73
Ethane	14.5	15.0	14.1	13.5	14.7	14.4	14.2	14.5
Propylene	0.00	0.00	0.00	0.00	0.00	2.86	3.07	3.59
Propane	34.8	33.8	37.4	37.7	36.6	32.6	36.3	34.5
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D4 Gas composition as a function of time on stream for 2GaHZ5:β catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	36.5	36.2	35.8	35.6	35.5	33.2	30.4	31.0
CO2	7.96	8.01	8.24	8.17	8.10	8.00	8.85	9.08
Ethylene	2.93	3.05	3.14	3.23	3.45	4.06	4.86	5.29
Ethane	14.1	14.1	14.1	14.1	14.1	14.0	13.9	14.3
Propylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Propane	38.5	38.6	38.7	38.9	38.9	40.8	41.9	40.4
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D5 Gas composition as a function of time on stream for HZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	4.72	3.47	3.17	3.23	3.63	2.89	2.65	2.48
CO2	2.21	1.43	1.41	1.47	1.71	1.42	1.36	1.32
Ethylene	12.3	13.6	14.6	15.6	16.3	17.3	18.1	20.5
Ethane	4.09	3.38	3.30	3.45	3.82	3.32	3.24	3.16
Propylene	65.9	66.2	65.0	64.2	62.2	62.7	62.3	60.1
Propane	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butylene	5.66	6.65	7.05	6.97	7.13	7.21	7.19	7.26
Butane	4.42	5.23	5.52	5.08	5.19	5.14	5.22	5.22
Σ	100	100	100	100	100	100	100	100

Table D6 Gas composition as a function of time on stream for 1PHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	18.3	18.9	14.7	13.9	13.4	13.6	13.5	13.7
CO2	4.40	4.51	3.85	3.90	4.32	4.40	3.80	4.33
Ethylene	17.5	17.2	17.0	16.7	16.8	17.7	17.9	19.4
Ethane	2.06	1.69	1.96	1.99	2.08	2.25	2.08	1.27
Propylene	55.6	56.7	60.3	61.0	60.8	59.9	60.9	59.4
Propane	1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butylene	0.70	1.02	2.19	2.48	2.59	2.10	1.80	1.97
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D7 Gas composition as a function of time on stream for 2PHZ5catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	25.7	30.6	25.8	21.9	19.0	19.0	16.0	15.1
CO2	13.8	13.6	12.6	11.6	10.9	10.8	10.1	9.67
Ethylene	20.9	22.4	22.6	23.2	23.6	24.7	23.6	23.4
Ethane	4.65	4.62	4.64	4.70	4.78	5.05	4.89	4.90
Propylene	27.9	24.6	28.7	32.5	35.0	34.2	37.1	38.0
Propane	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butylene	3.33	1.85	3.60	3.92	4.33	4.09	4.52	4.80
Butane	2.01	2.24	2.00	2.16	2.41	2.19	3.78	4.20
Σ	100	100	100	100	100	100	100	100

Table D8 Gas composition as a function of time on stream for 3PHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	1.64	1.60	2.91	4.41	4.95	9.72	15.38	12.13
CO2	1.57	1.39	1.67	2.36	2.60	2.17	3.10	2.71
Ethylene	52.7	53.3	53.7	52.9	54.9	52.2	49.2	50.1
Ethane	1.90	1.14	0.88	1.01	0.92	0.72	0.00	0.71
Propylene	39.7	36.4	34.0	35.1	32.0	30.3	31.5	30.4
Propane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butylene	2.45	3.50	3.58	3.12	3.47	3.48	0.85	2.84
Butane	0.00	2.66	3.23	1.11	1.25	1.32	0.00	1.04
Σ	100	100	100	100	100	100	100	100

Table D9 Gas composition as a function of time on stream for 4PHZ5catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	16.8	16.7	17.7	16.2	17.3	16.9	18.0	19.1
CO2	4.81	5.47	5.72	4.96	8.64	7.76	7.77	7.00
Ethylene	52.3	51.4	47.4	47.7	45.3	45.0	43.6	42.0
Ethane	1.56	1.46	1.51	1.35	1.66	1.73	1.68	1.69
Propylene	24.5	24.9	27.6	29.8	27.1	28.6	29.0	30.1
Propane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D10 Gas composition as a function of time on stream for 1SbHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	27.2	28.0	26.9	25.1	19.4	18.3	17.7	16.3
CO2	7.16	6.44	6.42	7.93	6.70	7.00	7.22	6.94
Ethylene	7.74	8.94	9.07	9.29	10.6	12.4	12.7	14.2
Ethane	17.2	17.2	16.0	16.0	15.0	15.6	15.2	15.1
Propylene	3.59	3.27	3.81	4.01	3.53	4.21	4.61	4.34
Propane	37.2	36.1	37.8	37.7	44.8	42.5	42.6	43.2
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D11 Gas composition as a function of time on stream for 2SbHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	30.0	24.1	24.2	23.8	21.4	22.6	23.2	26.4
CO2	13.1	8.78	9.91	9.14	8.67	8.86	9.35	12.1
Ethylene	9.18	9.53	8.87	10.3	11.0	11.4	11.3	11.5
Ethane	21.2	17.6	17.6	17.3	16.4	16.5	19.2	18.2
Propylene	3.65	3.63	4.23	4.27	4.36	4.56	4.94	5.08
Propane	22.8	36.4	35.1	35.2	38.2	36.0	32.0	26.7
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D12 Gas composition as a function of time on stream for 3SbHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	28.6	29.4	30.2	32.4	31.6	29.7	29.2	25.8
CO2	10.8	10.5	10.0	9.1	12.5	11.8	11.1	13.0
Ethylene	8.02	7.88	7.76	8.04	7.89	8.46	8.68	9.24
Ethnae	20.6	20.0	19.7	18.6	20.8	20.1	18.9	19.6
Propylene	3.09	3.04	2.91	3.19	3.28	3.49	3.80	4.24
Propane	28.9	29.1	29.4	28.8	23.9	26.4	28.3	28.1
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D13 Gas composition as a function of time on stream for 4SbHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	29.4	29.6	30.2	28.7	28.2	30.5	31.0	31.0
CO2	11.1	10.9	10.6	10.6	10.7	10.3	10.4	10.6
Ethylene	5.73	5.70	5.86	5.96	5.97	6.24	6.33	6.16
Ethane	21.2	21.1	19.2	18.3	18.2	17.8	18.1	17.7
Propylene	2.98	3.11	3.40	3.20	3.22	3.41	3.37	3.41
Propane	29.6	29.6	30.7	33.2	33.7	31.7	30.8	31.2
Butylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D14 Gas composition as a function of time on stream for 1BiHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	35.5	23.9	19.1	23.3	22.7	20.9	21.2	20.2
CO2	29.3	11.1	8.2	12.3	12.4	11.2	10.8	10.4
Ethylene	12.4	11.6	9.37	9.40	9.85	9.75	7.84	8.39
Ethane	9.70	10.9	15.9	12.9	12.6	12.6	13.8	12.8
Propylene	5.75	3.98	4.89	3.92	5.41	5.76	3.59	3.81
Propane	0.00	24.0	38.9	34.5	32.5	35.9	38.6	43.5
Butylene	7.32	14.6	3.60	3.59	4.64	3.97	4.28	0.95
Buthane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D15 Gas composition as a function of time on stream for 2BiHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	38.8	28.9	24.2	22.3	18.4	17.0	13.5	11.6
CO2	10.7	10.2	8.50	9.38	8.28	7.37	6.57	5.92
Ethylene	7.03	9.33	11.2	11.7	13.9	16.2	18.6	20.0
Ethnae	17.6	16.6	15.7	16.7	16.1	15.8	15.1	14.2
Propylene	3.81	3.54	4.29	4.44	5.39	6.32	7.38	8.96
Propane	22.0	31.5	34.4	33.9	35.3	34.1	35.0	34.5
Butylene	0.00	0.00	1.69	1.59	2.56	3.24	3.98	4.76
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D16 Gas composition as a function of time on stream for 3BiHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	28.6	21.3	17.7	14.7	11.7	10.8	10.0	10.0
CO2	9.97	7.91	7.30	6.43	5.63	5.38	4.86	6.19
Ethylene	10.0	12.0	14.0	16.0	18.5	20.2	22.6	23.1
Ethane	16.9	15.6	15.2	14.7	13.9	14.0	13.5	13.5
Propylene	4.19	5.12	6.05	6.76	7.68	9.08	11.38	14.64
Propane	30.2	35.9	36.7	37.6	37.8	35.5	32.5	27.6
Butylene	0.00	2.12	2.96	3.82	4.81	5.03	5.18	5.01
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Table D17 Gas composition as a function of time on stream for 4BiHZ5 catalyst

Component	Composition (mol %)							
	@60 min	@120 min	@180 min	@240 min	@300 min	@360 min	@420 min	@480 min
CH4	40.6	33.1	27.8	18.3	12.6	8.08	6.00	6.13
CO2	16.7	14.2	14.4	11.5	9.52	7.24	6.04	5.99
Ethylene	6.18	9.36	13.3	19.8	26.5	32.9	38.0	41.6
Ethane	22.3	19.6	17.2	13.5	10.8	8.57	7.29	7.19
Propylene	4.24	4.70	4.89	8.61	13.3	17.9	21.3	22.3
Propane	10.0	19.0	22.4	25.9	24.1	21.7	17.9	13.9
Butylene	0.00	0.00	0.00	2.38	3.18	3.62	3.43	2.92
Butane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	100	100	100	100	100	100	100	100

Appendix E Compositions in Liquid Products

Table E1 Oil composition from the two consecutive layers of catalysts

Component	Composition (wt%)			
	2GaHZ5	2GaHZ5:X	2GaHZ5:Y	2GaHZ5:β
Non-aromatic	0.94	1.97	2.08	2.01
Benzene	14.79	8.04	11.75	9.49
Toluene	19.78	15.68	17.65	14.62
o-Xylene	0.00	0.00	0.00	0.00
m-Xylene	28.49	14.93	24.22	20.11
p-Xylene	11.82	7.07	12.59	9.35
Ethylbenzene	1.92	4.73	3.44	1.70
C9	5.45	9.08	9.07	8.73
C10+	16.82	38.49	19.20	33.99
	100	*100*	*100*	*100*
BTEX/total aromatics	0.77	0.50	0.70	0.55
p-Xylene/total aromatics	0.12	0.07	0.13	0.09

Table E2 Oil composition from HZ5, 1PHZ5, 2PHZ5, 3PHZ5, and 4PHZ5 catalysts

Component	Composition (wt %)				
	HZ5	1PHZ5	2PHZ5	3PHZ5	4PHZ5
Non-aromatic	1.92	1.37	1.15	0.96	1.22
Benzene	14.26	7.46	9.46	8.15	6.55
Toluene	28.19	9.87	12.82	16.88	13.04
o-Xylene	0.00	0.00	0.00	0.00	0.00
m-Xylene	25.01	13.46	16.53	21.56	15.33
p-Xylene	10.84	11.37	13.38	13.39	11.81
Ethylbenzene	2.11	5.27	4.68	3.84	3.77
C9	5.15	19.56	16.76	12.30	12.78
C10+	12.52	31.64	25.22	22.90	35.50
	100	*100*	*100*	*100*	*100*
BTEX/total aromatics	0.80	0.47	0.57	0.64	0.51
p-Xylene/total aromatics	0.11	0.11	0.13	0.13	0.12

Table E3 Oil composition from HZ5, 1SbHZ5, 2SbHZ5, 3SbHZ5, and 4SbHZ5 catalysts

Component	Composition (wt%)				
	HZ5	**1SbHZ5**	**2SbHZ5**	**3SbHZ5**	**4SbHZ5**
Non-aromatic	1.92	1.44	0.93	1.17	0.97
Benzene	14.26	6.16	8.54	7.63	8.08
Toluene	28.19	20.86	15.61	12.82	14.44
o-Xylene	0.00	0.00	0.00	0.00	0.00
m-Xylene	25.01	26.00	16.34	18.53	17.49
p-Xylene	10.84	7.96	10.64	10.11	9.85
Ethylbenzene	2.11	4.25	2.75	2.84	2.09
C9	5.15	13.23	10.34	9.95	6.99
C10+	12.52	20.10	34.85	36.95	40.07
	100	*100*	*100*	*100*	*100*
BTEX/total aromatics	0.80	0.65	0.54	0.52	0.52
p-Xylene/total aromatics	0.11	0.08	0.11	0.10	0.10

Table E4 Oil composition from HZ5, 1BiHZ5, 2BiHZ5, 3BiHZ5, and 4BiHZ5 catalysts

Component	Composition (wt%)				
	HZ5	**1BiHZ5**	**2BiHZ5**	**3BiHZ5**	**4BiHZ5**
Non-aromatic	1.92	0.98	1.12	0.86	0.94
Benzene	14.26	8.38	8.46	11.55	7.36
Toluene	28.19	19.93	13.07	16.93	14.33
o-Xylene	0.00	0.00	0.00	0.00	0.00
m-Xylene	25.01	22.43	16.86	17.18	21.88
p-Xylene	10.84	9.20	7.56	6.57	7.75
Ethylbenzene	2.11	4.00	1.49	1.04	1.29
C9	5.15	8.92	5.90	6.00	6.08
C10+	12.52	26.16	45.54	39.88	40.37
	100	*100*	*100*	*100*	*100*
BTEX/total aromatics	0.80	0.64	0.47	0.53	0.53
p-Xylene/total aromatics	0.11	0.09	0.08	0.07	0.08

Appendix F True Boiling Point Curves

Table F1 True boiling point curves from the two consecutive layers of catalysts

% OFF	Boiling point (°C)			
	2GaHZ5	2GaHZ5:X	2GaHZ5:Y	2GaHZ5:β
0	62.8	61.3	61.2	61.0
5	71.3	72.0	71.6	71.1
10	71.8	72.6	72.1	71.6
15	72.3	73.6	72.7	72.1
20	76.2	98.5	74.8	72.7
25	98.7	98.8	98.5	75.4
30	99.0	99.0	98.7	98.1
35	99.2	99.2	98.9	98.3
40	99.4	99.4	99.1	98.7
45	99.6	99.6	99.5	99.1
50	99.8	99.8	100.1	99.3
55	100.0	100.2	122.4	99.5
60	122.3	124.0	125.1	123.5
65	126.1	127.2	125.7	124.5
70	126.4	145.4	128.5	128.3
75	145.3	148.3	145.8	190.5
80	148.9	169.3	163.8	191.6
85	179.3	173.6	191.4	210.7
90	220.8	210.0	213.0	233.1
95	342.2	228.9	233.0	269.4
100	411.0	390.5	372.3	377.3

Table F1 True boiling point curves from the two consecutive layers of catalysts (Continue)

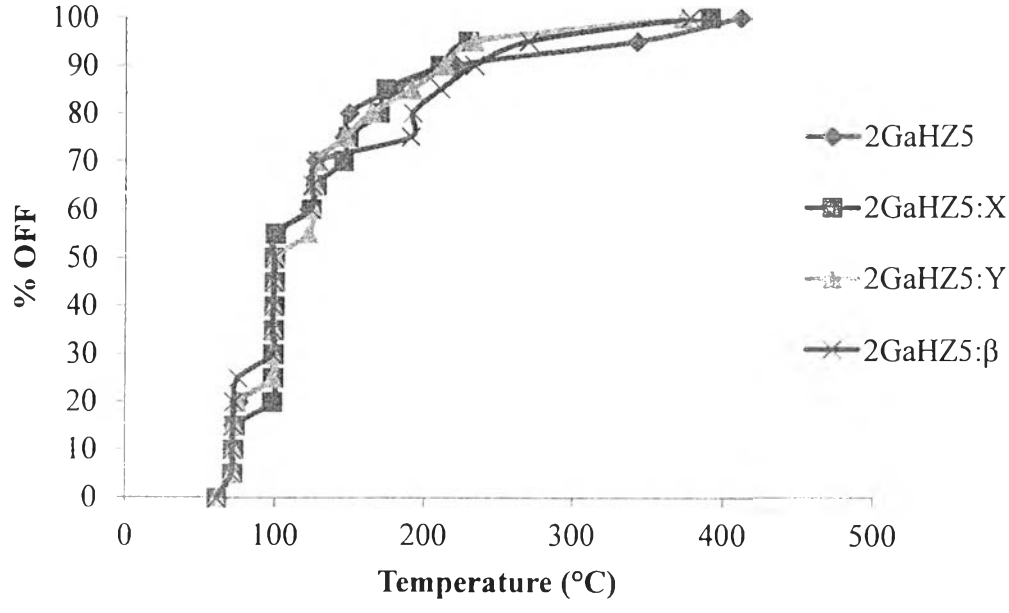

Table F2 Petroleum cuts obtained from the two consecutive layers catalytic systems

Fraction	Boiling point (°C)	wt %			
		2GaHZ5	2GaHZ5:X	2GaHZ5:Y	2GaHZ5:β
Gasoline	<149	80.0	75.2	75.9	71.7
Kerosene	149-232	10.4	19.9	18.9	18.1
Gas oil	232-343	4.60	3.43	4.20	8.66
LVGO	343-371	2.03	0.87	1.01	1.30
HVGO	>371	2.91	0.60	0.05	0.29

Table F3 True boiling point curves from HZ5, 1PHZ5, 2PHZ5, 3PHZ5, and 4PHZ5 catalysts

% OFF	Boiling point (°C)				
	HZ5	1PHZ	2PHZ5	3PHZ5	4PHZ5
0	59.1	77.5	58.1	55.0	52.8
5	78.5	78.5	71.9	55.8	53.3
10	83.1	79.2	76.8	56.7	53.8
15	107.5	107.1	99.4	57.9	54.4
20	107.8	107.7	99.7	59.7	54.9
25	108.1	108.0	99.5	61.2	55.4
30	108.3	108.1	100.1	63.1	55.9
35	108.5	108.3	100.3	73.0	56.5
40	108.6	108.5	100.5	75.0	57.0
45	108.8	108.7	111.0	95.3	58.7
50	132.9	108.9	116.7	96.4	60.5
55	134.9	133.0	124.2	101.4	63.9
60	135.2	135.0	127.4	101.5	69.1
65	135.5	135.3	127.5	101.7	74.6
70	135.7	135.5	130.5	102.0	92.7
75	135.9	139.2	137.2	107.3	100.7
80	140.4	140.7	138.8	130.4	102.3
85	150.8	168.3	148.7	147.7	133.5
90	168.3	204.2	212.4	231.4	176.6
95	206.8	226.0	366.2	356.2	524.3
100	527.9	505.5	533.1	543.1	564.4

Table F3 True boiling point curves from HZ5, 1PHZ5, 2PHZ5, 3PHZ5, and 4PHZ5 catalysts (Continue)

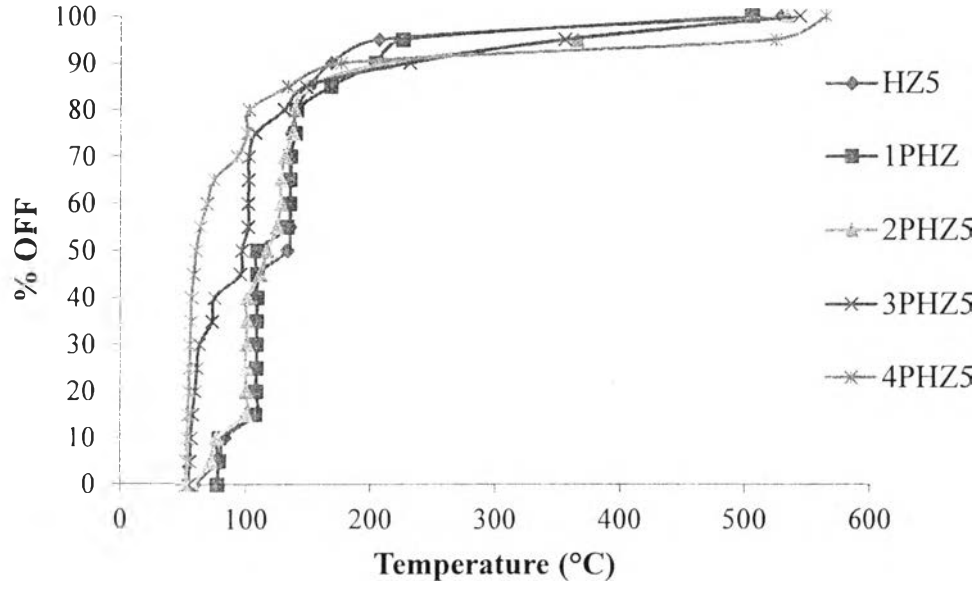

Table F4 Petroleum cuts obtained from HZ5, 1PHZ5, 2PHZ5, 3PHZ5, and 4PHZ5 catalysts

Fraction	Boiling point (°C)	wt %				
		HZ5	1PHZ5	2PHZ5	3PHZ5	4PHZ5
Gasoline	<149	84.1	81.5	85.0	85.1	86.8
Kerosene	149-232	11.3	13.6	5.61	4.95	4.00
Gas oil	232-343	1.73	1.99	3.61	4.45	1.60
LVGO	343-371	0.44	0.50	0.90	0.92	0.40
HVGO	>371	2.44	2.41	4.86	4.60	7.20

Table F5 True boiling point curves from HZ5, 1SbHZ5, 2SbHZ5, 3SbHZ5, and 4SbHZ5 catalysts

% OFF	Boiling point (°C)				
	HZ5	**1SbHZ5**	**2SbHZ5**	**3SbHZ5**	**4SbHZ5**
0	59.1	61.0	57.4	59.9	60.1
5	78.5	74.4	59.5	74.0	71.7
10	83.1	75.5	61.9	74.7	72.2
15	107.5	101.3	72.6	75.2	76.3
20	107.8	101.6	73.2	101.1	98.8
25	108.1	101.8	100.4	101.4	99.1
30	108.3	102.0	100.7	101.6	99.3
35	108.5	102.2	100.9	101.8	99.5
40	108.6	102.4	101.0	102.0	99.7
45	108.8	102.6	101.2	102.2	99.9
50	132.9	102.7	101.4	102.4	100.0
55	134.9	127.1	102.0	102.6	125.3
60	135.2	128.5	127.7	128.2	126.1
65	135.5	128.7	128.0	128.5	126.3
70	135.7	128.9	128.1	128.7	129.2
75	135.9	129.1	128.6	132.1	148.9
80	140.4	132.4	132.0	152.7	192.0
85	150.8	154.5	157.5	195.9	211.0
90	168.3	195.6	185.6	214.9	211.9
95	206.8	214.8	217.4	217.9	234.4
100	527.9	502.3	501.8	529.8	512.6

Table F5 True boiling point curves from HZ5, 1SbHZ5, 2SbHZ5, 3SbHZ5, and 4SbHZ5 catalysts (Continue)

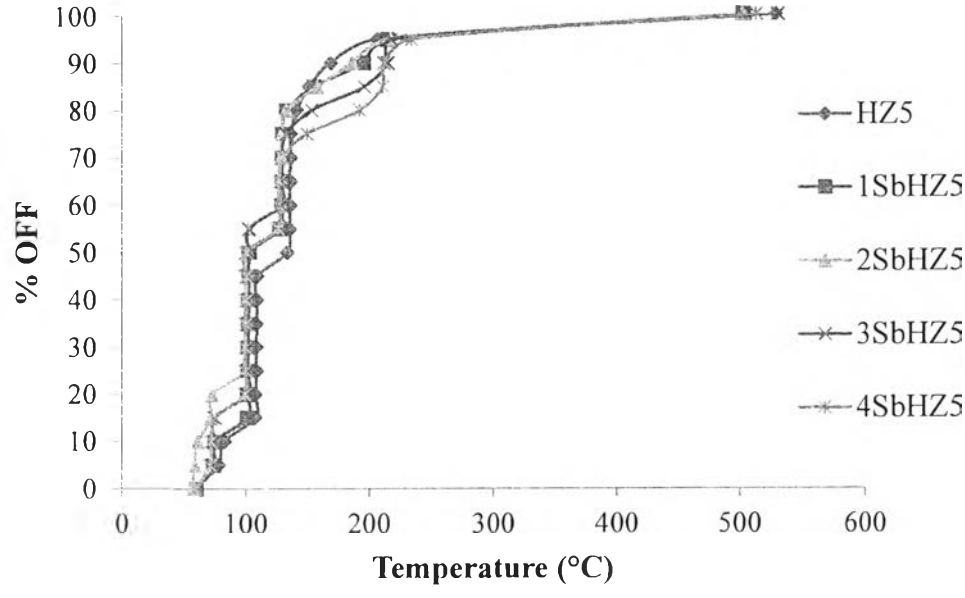

Table F6 Petroleum cuts obtained from HZ5, 1SbHZ5, 2SbHZ5, 3SbHZ5, and 4SbHZ5 catalysts

Fraction	Boiling point (°C)	wt %				
		HZ5	1SbHZ5	2SbHZ5	3SbHZ5	4SbHZ5
Gasoline	<149	84.1	83.8	83.3	79.1	75.0
Kerosene	149-232	11.3	11.5	11.9	16.1	19.5
Gas oil	232-343	1.73	1.93	1.95	1.78	2.49
LVGO	343-371	0.44	0.49	0.49	0.45	0.50
HVGO	>371	2.44	2.28	2.30	2.55	2.54

Table F7 True boiling point curves from HZ5, 1BiHZ5, 2BiHZ5, 3BiHZ5, and 4BiHZ5 catalysts

% OFF	Boiling point (°C)				
	HZ5	**1BiHZ5**	**2BiHZ5**	**3BiHZ5**	**4BiHZ5**
0	59.1	56.8	71.8	71.6	70.9
5	78.5	59.4	72.9	72.7	72.1
10	83.1	60.2	74.3	73.2	99.1
15	107.5	61.1	100.1	78.4	99.7
20	107.8	61.9	100.4	80.0	99.9
25	108.1	63.4	100.6	90.2	100.0
30	108.3	66.3	100.8	100.4	100.2
35	108.5	73.8	101.0	100.6	100.4
40	108.6	100.5	101.2	100.8	100.6
45	108.8	100.9	101.4	101.0	100.8
50	132.9	101.4	127.1	108.4	125.0
55	134.9	127.6	127.5	117.6	126.9
60	135.2	128.1	127.7	128.1	127.2
65	135.5	132.4	130.7	132.4	127.4
70	135.7	153.3	149.6	149.3	130.6
75	135.9	164.3	176.9	178.6	158.1
80	140.4	178.3	194.7	184.9	188.8
85	150.8	196.2	205.5	215.7	194.2
90	168.3	219.9	213.9	218.4	213.1
95	206.8	246.7	234.7	244.6	215.3
100	527.9	423.9	440.2	444.3	448.4

Table F7 True boiling point curves from HZ5, 1BiHZ5, 2BiHZ5, 3BiHZ5, and 4BiHZ5 catalysts (Continue)

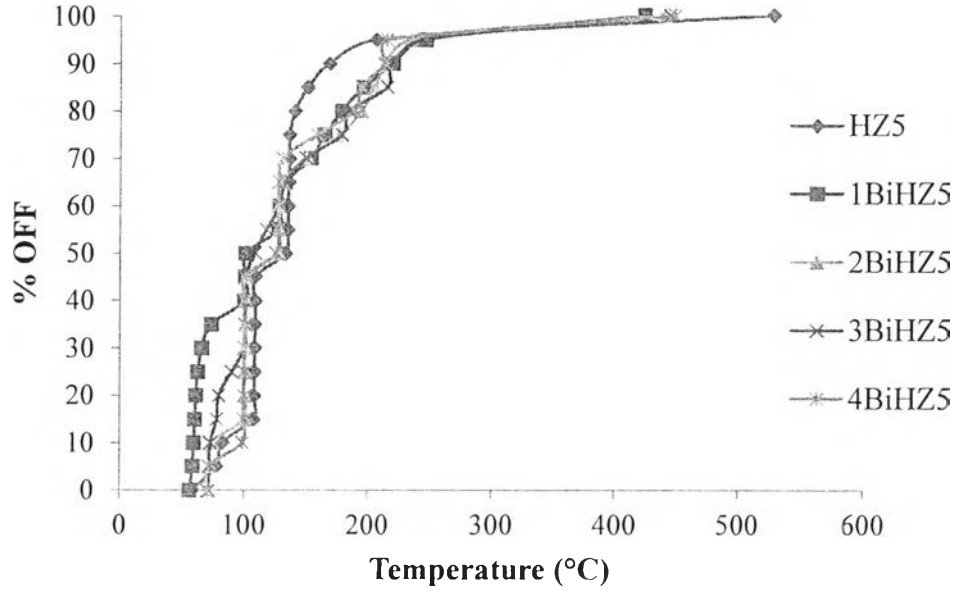

Table F8 Petroleum cuts obtained from HZ5, 1BiHZ5, 2BiHZ5, 3BiHZ5, and 4BiHZ5 catalysts

Fraction	Boiling point (°C)	wt %				
		HZ5	1BiHZ5	2BiHZ5	3BiHZ5	4BiHZ5
Gasoline	<149	84.1	69.0	69.8	69.9	73.3
Kerosene	149-232	11.3	23.3	24.5	22.7	22.0
Gas oil	232-343	1.73	5.46	3.28	4.87	2.38
LVGO	343-371	0.44	0.79	0.68	0.70	0.60
HVGO	>371	2.44	1.49	1.68	1.84	1.66

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