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APPENDICES

Appendix A Product Distribution

Table A1 Product distribution over metallic Co and Co_3O_4-modified Al_2O_3

Catalyst	Non-catalysts	Al_2O_3	Co	Co_3O_4
Ethanol conversion (%)				
	99.2	98.7	99.1	98.9
Product yield (wt%)				
Gas yield	82.6	76.3	86.8	82.0
liquid yield	6.20	3.10	2.20	2.70
water	11.2	20.6	11.0	15.3
Gas composition (wt%)				
Methane	0.00	0.00	5.50	3.20
Ethylene	99.1	96.0	64.5	81.3
Ethane	0.60	0.50	2.30	1.20
Propylene	0.20	1.00	3.20	2.20
propane	0.00	0.00	0.00	0.00
Butylene	0.10	0.50	0.80	0.70
Butane	0.00	0.00	0.00	0.00
Oil composition (wt%)				
Oxygenates	89.0	92.1	88.4	95.5
Non-aromatics	1.44	0.60	0.00	0.00
Benzene	4.28	5.20	8.47	2.08
Toluene	0.31	0.60	0.94	0.40
o-Xylene	0.02	0.20	0.23	0.10
m-Xylene	0.03	0.20	0.03	0.10
p-Xylene	0.20	0.20	0.50	0.10
Ethylbenzene	0.12	0.40	0.29	0.30
C9-Aromatics	0.10	0.10	0.65	0.40
C10+-Aromatics	4.53	0.40	0.48	1.00
Petroleum fraction (wt%)				
Gasoline	90.3	82.9	76.1	90.7
Kerosene	1.06	4.80	8.42	1.36
Gas oil	1.30	3.98	6.89	1.69
LVGO	0.30	0.54	0.55	0.43
HVGO	0.00	0.00	0.00	0.00

Data were taken at the eighth hour of time-on-stream

Table A2 Product distribution over metallic Fe and Fe_3O_3-modified Al_2O_3

Catalyst	Non-catalysts	Al_2O_3	Fe	Fe_2O_3
Ethanol conversion (%)				
	99.2	98.7	97.4	98.3
Product yield (wt%)				
Gas yield	82.6	76.3	88.9	89.0
liquid yield	6.20	3.10	2.70	3.40
water	11.2	20.6	8.4	17.6
Gas composition (wt%)				
Methane	0.00	0.00	3.10	2.30
Ethylene	99.1	96.0	78.6	82.7
Ethane	0.60	0.50	2.40	1.90
Propylene	0.20	1.00	2.40	1.70
propane	0.00	0.00	0.00	0.00
Butylene	0.10	0.50	0.80	0.60
Butane	0.00	0.00	0.00	0.00
	0.00	0.00	12.10	10.80
Oil composition (wt%)				
Oxygenates	89.0	92.1	77.7	95.5
Non-aromatics	1.44	0.60	0.00	0.00
Benzene	4.28	5.20	17.30	2.60
Toluene	0.31	0.60	1.10	0.10
o-Xylene	0.02	0.20	0.20	0.10
m-Xylene	0.03	0.20	0.30	0.10
p-Xylene	0.20	0.20	0.30	0.10
Ethylbenzene	0.12	0.40	0.50	0.40
C9-Aromatics	0.10	0.10	1.40	0.70.
C10+-Aromatics	4.53	0.40	1.10	0.60
Petroleum fraction (wt%)				
Gasoline	90.3	82.9	75.6	90.7
Kerosene	1.06	4.80	12.3	1.36
Gas oil	1.30	3.98	7.70	1.69
LVGO	0.30	0.54	0.57	0.43
HVGO	0.00	0.00	0.00	0.00

Data were taken at the eighth hour of time-on-stream

Table A3 Product distribution over metallic Ni and NiO-modified Al_2O_3

Catalyst	Non-catalysts	Al_2O_3	Ni	NiO
Ethanol conversion (%)				
	99.2	98.7	99.3	98.9
Product yield (wt%)				
Gas yield	82.6	76.3	87.8	83.5
liquid yield	6.20	3.10	3.90	3.20
water	11.2	20.6	8.4	13.4
Gas composition (wt%)				
Methane	0.00	0.00	24.90	3.10
Ethylene	99.1	96.0	43.8	80.6
Ethane	0.60	0.50	2.20	2.60
Propylene	0.20	1.00	0.70	2.30
propane	0.00	0.00	0.00	0.00
Butylene	0.10	0.50	0.30	0.70
Butane	0.00	0.00	0.00	0.00
Oil composition (wt%)				
Oxygenates	89.0	92.1	84.9	89.8
Non-aromatics	1.44	0.60	0.20	0.30
Benzene	4.28	5.20	10.20	5.70
Toluene	0.31	0.60	0.80	1.20
o-Xylene	0.02	0.20	0.10	0.30
m-Xylene	0.03	0.20	0.20	0.30
p-Xylene	0.20	0.20	0.50	0.30
Ethylbenzene	0.12	0.40	0.40	0.30
C9-Aromatics	0.10	0.10	1.10	0.90
C10+-Aromatics	4.53	0.40	1.60	0.86
Petroleum fraction (wt%)				
Gasoline	90.3	82.9	86.2	92.0
Kerosene	1.06	4.80	2.84	2.84
Gas oil	1.30	3.98	2.07	2.07
LVGO	0.30	0.54	0.50	0.50
HVGO	0.00	0.00	0.00	0.00

Data were taken at the eighth hour of time-on-stream

Table A4 Product distribution over metallic Cu and Cu_2O-modified Al_2O_3

Catalyst	Non-catalysts	Al_2O_3	Cu	Cu_2O
Ethanol conversion (%)				
	99.2	98.7	97.7	98.4
Product yield (wt%)				
Gas yield	82.6	76.3	69.4	79.7
liquid yield	6.20	3.10	5.30	4.70
water	11.2	20.6	25.3	15.7
Gas composition (wt%)				
Methane	0.00	0.00	0.60	0.00
Ethylene	99.1	96.0	93.5	95.1
Ethane	0.60	0.50	0.90	1.00
Propylene	0.20	1.00	1.10	0.90
propane	0.00	0.00	0.00	0.00
Butylene	0.10	0.50	0.40	0.30
Butane	0.00	0.00	0.00	0.00
Oil composition (wt%)				
Oxygenates	89.0	92.1	87.2	88.9
Non-aromatics	1.44	0.60	0.40	0.20
Benzene	4.28	5.20	3.40	7.40
Toluene	0.31	0.60	1.10	0.90
o-Xylene	0.02	0.20	0.40	0.20
m-Xylene	0.03	0.20	0.40	0.30
p-Xylene	0.20	0.20	0.50	0.30
Ethylbenzene	0.12	0.40	0.30	0.20
C9-Aromatics	0.10	0.10	2.10	0.86
C10+-Aromatics	4.53	0.40	4.30	0.70
Petroleum fraction (wt%)				
Gasoline	90.3	82.9	91.7	95.8
Kerosene	1.06	4.80	2.13	0.97
Gas oil	1.30	3.98	2.28	1.29
LVGO	0.30	0.54	0.46	0.33
HVGO	0.00	0.00	0.00	0.00

Data were taken at the eighth hour of time-on-stream

Table A5 Product distribution over metallic Pd and PdO-modified Al_2O_3

Catalyst	Non-catalysts	Al_2O_3	Pd	PdO
Ethanol conversion (%)				
	99.2	98.7	99.3	97.6
Product yield (wt%)				
Gas yield	82.6	76.3	93.6	94.4
liquid yield	6.20	3.10	1.90	2.80
water	11.2	20.6	4.5	2.8
Gas composition (wt%)				
Methane	0.00	0.00	1.90	2.10
Ethylene	99.1	96.0	86.7	84.2
Ethane	0.60	0.50	2.50	2.70
Propylene	0.20	1.00	1.50	1.60
propane	0.00	0.00	0.00	0.00
Butylene	0.10	0.50	0.40	0.60
Butane	0.00	0.00	0.00	0.00
Oil composition (wt%)				
Oxygenates	89.0	92.1	39.4	75.5
Non-aromatics	1.44	0.60	0.40	0.10
Benzene	4.28	5.20	42.40	16.40
Toluene	0.31	0.60	1.30	1.00
o-Xylene	0.02	0.20	1.30	0.30
m-Xylene	0.03	0.20	0.90	0.60
p-Xylene	0.20	0.20	0.90	0.30
Ethylbenzene	0.12	0.40	0.50	0.40
C9-Aromatics	0.10	0.10	0.50	1.10
C10+-Aromatics	4.53	0.40	12.40	4.30
Petroleum fraction (wt%)				
Gasoline	90.3	82.9	52.2	56.4
Kerosene	1.06	4.80	22.4	11.6
Gas oil	1.30	3.98	21.4	27.7
LVGO	0.30	0.54	0.53	0.82
HVGO	0.00	0.00	0.00	0.00

Data were taken at the eighth hour of time-on-stream

Table A6 Product distribution over metallic Cr and CrO_3-modified Al_2O_3

Catalyst	Non-catalysts	Al_2O_3	Cr	CrO_3
Ethanol conversion (%)				
	99.2	98.7	98.1	99.4
Product yield (wt%)				
Gas yield	82.6	76.3	85.5	88.3
liquid yield	6.20	3.10	2.30	2.90
water	11.2	20.6	12.2	8.8
Gas composition (wt%)				
Methane	0.00	0.00	3.70	6.80
Ethylene	99.1	96.0	82.9	68.7
Ethane	0.60	0.50	1.50	2.20
Propylene	0.20	1.00	2.10	3.90
propane	0.00	0.00	0.00	0.00
Butylene	0.10	0.50	0.60	1.00
Butane	0.00	0.00	0.00	0.00
Oil composition (wt%)				
Oxygenates	89.0	92.1	80.6	73.6
Non-aromatics	1.44	0.60	0.20	3.00
Benzene	4.28	5.20	10.90	2.70
Toluene	0.31	0.60	1.80	2.40
o-Xylene	0.02	0.20	0.00	2.50
m-Xylene	0.03	0.20	0.70	0.10
p-Xylene	0.20	0.20	0.70	2.30
Ethylbenzene	0.12	0.40	1.10	2.00
C9-Aromatics	0.10	0.10	1.90	4.80
C10+-Aromatics	4.53	0.40	1.20	6.60
Petroleum fraction (wt%)				
Gasoline	90.3	82.9	77.6	82.4
Kerosene	1.06	4.80	6.73	8.29
Gas oil	1.30	3.98	7.51	5.87
LVGO	0.30	0.54	0.52	0.46
HVGO	0.00	0.00	0.00	0.00

Data were taken at the eighth hour of time-on-stream

Appendix B Amount of Element Loading (wt%)

Table B1 Amount of element loading (wt%)

Sample	Element Loading (wt%)
Cobalt	4.85
Iron	5.12
Nickel	5.01
Copper	4.96
Palladium	1.02
Chromium	5.15

Determined using XRF

Appendix C X-ray Diffraction Patterns

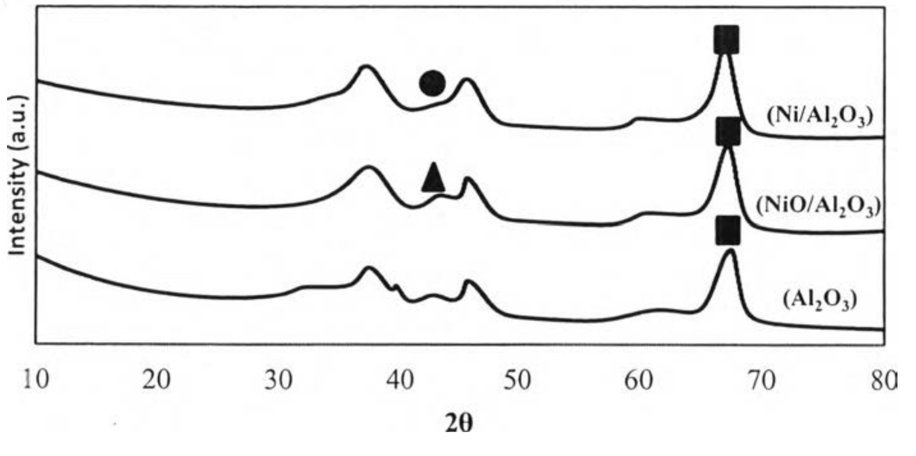

Figure C1 XRD pattern of Ni-modified catalysts.

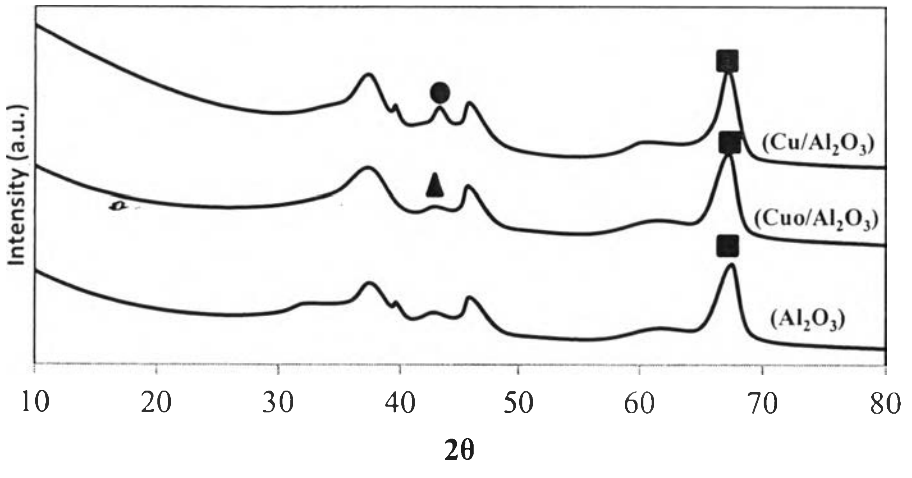

Figure C2 XRD pattern of Cu-modified catalysts.

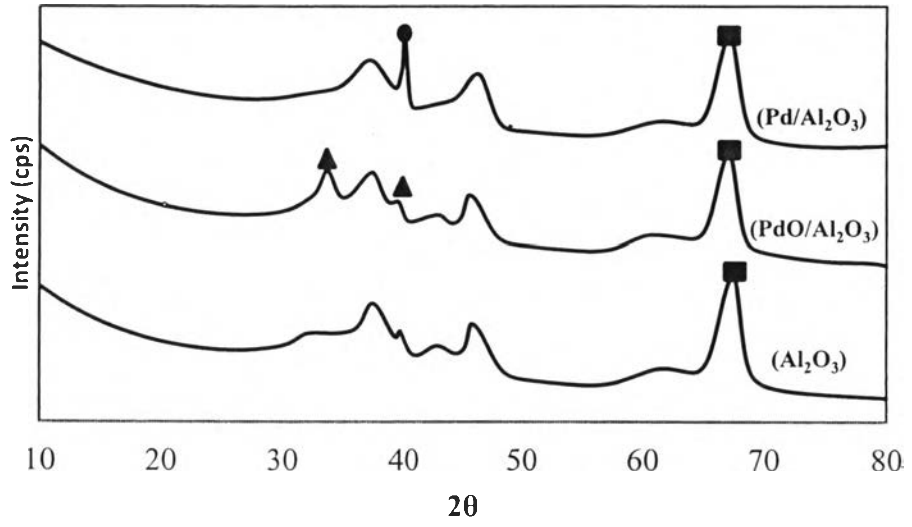

Figure C3 XRD pattern of Pd-modified catalysts.

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Proceedings:

1. Chokcharoenchai, B.; and Jitkarnka, S. (2015, April, 21). Environmental Friendly Route for Hydrocarbon and Oxygenate Production Using Fe-Promoted γ-alumina Catalyst. Proceedings of The 6th Research Symposium on Petrochemical and Materials Technology and The 21th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.
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1. Chokcharoenchai, B.; Jitkarnka, S. (2015, May, 20-22), Green Production of High Cost Solvents from Bio-Ethanol Using Alumina and Metallic Co-doped Al_2O_3 catalyst. Paper presented at The Energy, Science, Technology EST 2015 Conference & Exhibition, Karlsruhe, Germany.