

Supplementary

# Alumina Coated Silica Nanosprings (NS) Support Based Cobalt Catalysts for Liquid Hydrocarbon Fuel Production From Syngas

Abdulbaset Alayat, Elena Echeverria, Farid Sotoudehniakarani, David N. McIlroy and Armando G. McDonald \*

**Table S1.** The FT products identified by GC-MS for unmodified Co/NS catalyst reduced by H<sub>2</sub> at a temperature of 230 °C and H<sub>2</sub>/CO = 2.

Retention Time (min)	Identified Compounds	Mol(%)	M+ (m/z)
2.16	2-pentene 3-methyl	0.65	84
2.21	3-hexene-(z)	0.72	84
2.29	2-ethyl-1-pentanol	2.09	116
2.38	3-Methylhexane	0.45	100
2.56	cis-1,2 -dimethyl cyclopentane	7.4	98
2.65	Heptane	1.83	100
2.75	3-Heptene	1.21	98
2.77	Isopropylcyclobutane	1.0	98
2.88	Cycloheptane	0.68	98
3.35	Cyclopropane, (1,2-dimethylpropyl)	0.13	112
3.41	3-Methyl-1-heptene	0.78	112
3.54	5-Methyl-1-heptene	1.65	112
3.69	6-Methyl-1-heptene	1.38	130
3.71	1-octanol	1.24	130
3.84	3-Ethyl-4-methyl-1-pentanol	1.24	130
4.12	3,4-Dimethyl-1-hexene	0.38	112
4.20	Cyclopropane, pentyl	5.72	112
4.38	Octane	2.05	114
4.56	1,2-Diethylcyclobutane	0.76	112
4.75	2-Octene	0.48	112
5.54	Cis-3-Nonene	0.52	126
5.75	2,3-Diethyl-3-heptene	1.68	126
5.95	6-Methyl-1-octene	1.34	126
6.16	4-Ethylheptane	1.17	128
6.39	2-Nonene, (E)-	0.27	126
6.57	7-Methyl-1-octene	0.41	126
6.70	1-Nonene	3.37	126
6.93	Nonane	1.62	128
7.13	2-Nonene, (E)-	0.75	126
7.38	Cis-4-Nonene	0.68	126
7.90	2,3,5-Trimethylhexane	0.26	128
8.33	Cyclopropane, 1-methyl-2-pentyl-	0.49	140
8.48	1-Decene	1.09	140
8.74	3,7-Dimethyl-1-octanol	1.09	158
9.01	3-Methylnonane	0.48	142
9.21	cis-4-Decene	0.46	140
9.48	(Z)-2-Decene	0.25	140

9.63	4-Decene	2.62	140
9.73	Cyclopropane, 1-ethyl-2-pentyl-	0.26	140
9.88	Decane	1.63	142
10.09	trans-3-Decene	0.67	140
10.33	2-Methyl-4-nonene	0.66	140
10.37	3,7-Dimethyl-1-octene	0.31	140
11.32	2-Methyl-2-decene	0.17	154
11.45	4-Methyl-1-decene	0.48	154
11.59	2-Undecene, cis-	0.51	154
11.70	2,3,7-Trimethyloctane	0.35	156
11.81	2,5-Dimethylnonane	0.5	156
12.00	3-Methyldecane	0.47	156
12.64	1-Pentyl-2-propylcyclopropane	1.38	154
12.86	Dodecane	1.40	170
12.94	2,6-Dimethyldecane	0.07	168
13.33	cyclopentane, 1-butyl-2-propyl-	0.34	168
13.47	2-pentyl-1-heptene	0.15	168
14.27	4-Undecene, 5-methyl-, (E)-	0.65	168
14.39	4-Undecene, 7-methyl	0.34	168
14.50	4-Ethyldecane	0.47	170
14.74	2-Methyl-1-undecanol	0.49	186
14.80	2-Butyl-1-octanol	0.35	186
14.93	2,3-Dimethyldecane	0.35	170
14.99	5-Ethyl-2,2,3-trimethylheptane	0.20	170
15.55	Cyclopropane, 1-hexyl-2-propyl-	0.89	168
15.77	Tridecane	12.9	184
15.97	4-Dodecene, (E)-	0.48	168
16.20	2-Butyl-1-octanol	0.29	186
16.26	2-Dodecene, (E)-	0.03	168
17.23	1-Dodecanol, 2-methyl-	0.21	200
17.41	2,3-Dimethylundecane	0.25	184
17.72	2,5,9-Trimethyldecane	0.20	184
17.88	6-Tridecene	0.21	182
18.33	Cyclotridecane	0.38	182
18.52	Tridecane	0.73	184
18.61	2,6,8-Trimethyldecane	0.06	184
18.71	2-Methyldodecan-1-ol	0.27	200
18.86	2,5-Dimethyldodecane	0.03	198
19.95	2,6,7-Trimethyldecane	0.26	198
21.13	3-Methyltridecane	0.47	198

**Table S2.** The FT products identified by GC-MS for unmodified Co/Al<sub>2</sub>O<sub>3</sub> catalyst reduced by H<sub>2</sub> at a temperature of 230 °C and H<sub>2</sub>/CO = 2.

Retention Time (min)	Identified Compounds	Mol(%)	M+ (m/z)
2.15	3-Methyl-2-pentene	4.02	84
3.20	3-Methyl-3-hexene	2.32	98
3.35	Cyclohexane	0.52	84
4.12	1,8-Nonadien-3-ol	0.45	140
5.11	3-Methyl-1-heptanol	2.30	130
5.36	3-Methyl-4-methylenehexane	0.48	112
5.48	Cyclobutane, 1,2-diethyl-, trans	0.23	112
6.85	2,3,5-Trimethylhexane	0.45	128
6.94	2-methyl-3-methylene-heptane	0.24	128
7.53	4-Methyl-3-heptene	0.23	126
7.76	4-Nonene	0.56	126
7.87	2,4,6-Trimethylheptane	1.80	142
8.07	Cyclopropane, 1-methyl-2-pentyl	0.36	126
9.72	3-Ethyl-4-methylpentan-1-ol	0.36	130
10.04	4-Methyl-2-propyl-1-pentanol	0.23	144
11.11	3,7-dimethyl-1-octene	0.15	140
12.01	2,3,4-Trimethylhexane	0.16	128
12.50	(S)-3-Ethyl-4-methylpentanol	0.04	130
12.70	3,4-Dimethyl-1-octene	0.14	140
12.81	4-Methyldecane	0.19	156
13.12	3,4,5-Trimethylheptane	0.15	142
14.00	Undecane	0.43	156
14.51	5-Methyldecane	0.12	156
15.65	2,6-Dimethyldecane	0.02	170
15.74	4,5-Dimethylnonane	0.07	156
16.08	Octane, 3,4,5,6-tetramethyl	0.06	120
16.93	Tridecane	0.36	184
17.34	2,5,9-Trimethyldecane	0.04	184
18.58	4,7-dimethyl undecane	0.03	184
18.72	2-Methyl-6-ethyldecane	0.04	184
18.92	2,2,7-Trimethyldecane	0.05	184
19.20	2, 4-Dimethyl-1-(1-methylethyl)-benzene	0.02	148
19.72	Tetradecane	0.28	198
20.18	2,2,3-Trimethylhexane	0.01	128
21.06	3,5-Dimethylundecane	0.03	184
21.13	3-Methyl-3-ethyldecane	0.02	184
21.59	2,2-Dimethylundecane	0.62	184
24.83	Pentadecane	0.21	212
27.19	2,7,10-Trimethyldodecane	0.09	212
29.43	5,8-Diethyldodecane	0.05	226

**Table S3.** The FT products identified by GC-MS for unmodified Co/NS-Al-A catalyst reduced by H<sub>2</sub> at a temperature of 230 °C and H<sub>2</sub>/CO = 2.

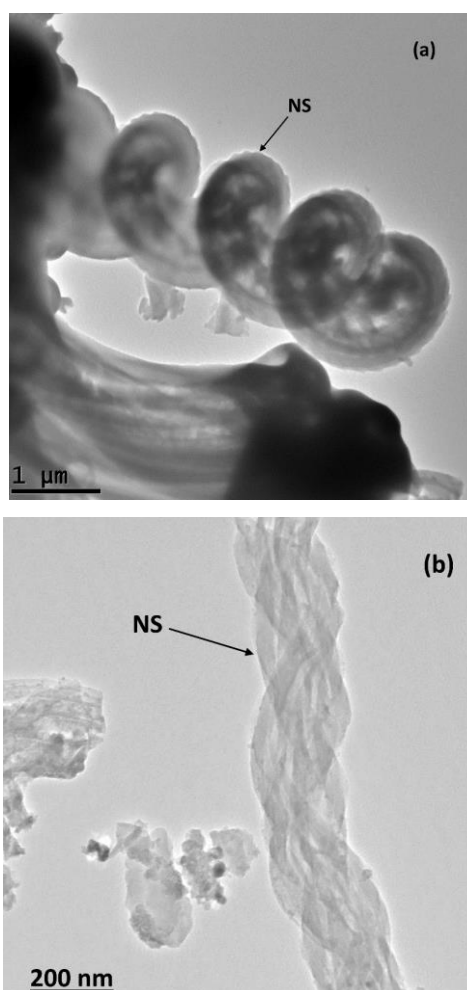
Retention Time (min)	Identified Compounds	Mol(%)	M+ (m/z)
2.52	Benzene	2.99	78
2.96	Cyclopropane, 1,2,3-trimethyl	0.76	84
3.01	3-Ethyl-2-pentene	9.62	98
3.07	Cyclopropane, 1,1-diethyl	0.78	98
3.12	4-Methyl-2-pentene	1.43	84
3.89	2-Methyl-3-ethyl-1-pentene	0.52	112
4.13	1,3,5-Cycloheptatriene	6.86	92
4.57	Heptane, 4-methylene	0.62	112
4.85	5-Methyl-1-heptene	4.03	112
5.08	1,2,4-Trimethylcyclopentane	0.68	112
6.01	3-Ethyl-2-methyl-1-heptene	0.21	140
6.41	Ethylbenzene	0.91	106
6.49	3-Ethylhexane	0.47	114
6.64	o-Xylene	2.51	106
6.97	2-Hexene, (E)-	0.54	84
7.27	1-Pentene, 2,3,3-trimethyl-5-phenyl	1.56	188
7.41	2,3-Dimethyl-1-hexene	0.59	112
7.53	2,3,4-Trimethylhexane	0.21	128
9.37	1-Ethyl-3-methylbenzene	1.73	120
9.66	3,6-Dimethyloctane	0.23	142
9.89	Benzene, (1-methylethyl)-	0.19	120
10.12	4-Nonene, 3-methyl-, (Z)-	0.28	140
10.32	1-Ethyl-2-methylbenzene	0.63	120
10.55	2,4,6-Trimethyloctane	0.74	156
11.59	Indane	0.35	118
11.86	Indene	0.15	116
12.30	Ethylcyclopropane	0.08	86
12.39	3-Ethyl-5-methylheptane	0.20	142
12.70	2,2-Dimethyloctane	0.15	142
12.99	Methyl-2,3-Dihydro-1H-indene	0.11	132
13.13	1-Ethenyl-4-ethylbenzene	0.27	132
13.59	2,5,9-Trimethyldecane	0.55	184
14.71	2,3-Dihydro-5-methyl-1H-indene	0.31	132
15.02	Indene, 1-methyl	0.32	130
15.22	2-Methyl indane	0.21	130
16.02	Naphthalene	0.51	128
16.52	2,5,9-Trimethyldecane	0.41	184
18.19	2,8-Dimethylundecane	0.09	184
18.46	1,2-dihydro-4-methylnaphthalene	0.19	144
18.75	Benzene, pentamethyl	0.11	184
19.13	2-Methylnaphthalene	1.07	142
19.30	2-Methyl-6-ethyldecane	0.58	184
19.61	3-Methylnaphthalene	0.17	142
21.95	2,3,5-Trimethylheptane	0.33	142

**Table S4.** The FT products identified by GC-MS for modified Co/NS-Al-B catalyst reduced by H<sub>2</sub> at a temperature of 230 °C and H<sub>2</sub>/CO = 2.

Retention Time (min)	Identified Compounds	Mol(%)	M+ (m/z)
2.60	2-Methyl-1-pentene	1.91	84
2.91	1-Heptene	1.90	98
3.13	3-Heptene	5.88	98
3.27	Cyclopropane,1,1 diethyl	1.03	98
3.87	Pentane, 2-cyclopropyl	0.39	112
4.01	Cyclopropane, (1,2-dimethylpropyl)	1.44	112
4.22	3-Methyl-1-heptanol	1.01	130
4.35	Heptane, 2-methyl	0.76	114
4.75	1-Octene	1.93	112
4.95	2-Octene	5.61	112
5.11	3-Octene, (3E)-	2.34	112
5.31	4-Octene, (4E)-	1.24	112
6.12	2,3-Dimethyl-2-heptene	0.23	126
6.37	Heptane, 2-methyl-3-methylene	0.98	126
6.61	2,3,4-Trimethylhexane	0.66	128
7.04	4-Nonene	0.88	126
7.31	4-Methyl-3-heptene	0.74	126
7.40	Cis-2-Nonene	1.58	126
7.54	3-Nonene	1.99	126
7.65	Methylpentyl cyclopropane	4.08	126
7.84	Cis-4-Nonene	2.09	126
8.06	2-Nonene	0.95	126
8.38	2,2,6-Trimethylheptane	0.15	156
9.12	4-Nonene, 5-methyl	0.34	140
9.20	Cyclopropane, 1,2-dimethyl-1-pentyl	0.42	140
9.34	2,6-Dimethyl-3-octene	0.42	140
9.52	1-Methyl-2-(3-methylpentyl)cyclopropane	1.40	140
9.72	2,6-Dimethyl-3-octene	0.40	140
9.80	2,5-Dimethyl-2-octene	0.49	140
9.92	4-Nonene, 2-methyl-, (Z)-	0.77	140
10.25	4-Nonene, 5-methyl-	1.07	140
10.51	Cis-4-Decene	2.16	140
10.63	Trans-3-Decene	1.44	140
10.69	Decane	1.28	142
10.86	3-Decene	1.41	140
11.12	2,4-Dimethyl-4-octene	0.55	140
11.79	Nonane, 2-methyl-3-methylene	0.18	154
12.11	4-Decene, 2-methyl-, (E)-	0.19	154
12.27	4-Decene, 7-methyl-, (E)-	0.26	154
12.44	2-Decene, 6-methyl-, (Z)-	0.37	154
12.67	4-Undecene, (E)-	0.71	154
12.85	Decane, 3-methyl-	0.42	154
13.09	Decane, 5-methyl	0.31	154
13.50	4-Undecene, (E)-	2.01	154
13.53	5-Undecene, (E)-	1.0	154
13.66	4-Decene, 2-methyl-, (E)-	0.94	154
13.73	Undecane	1.24	156
13.89	2-Undecene	0.89	154
14.15	4-Decene, 9-methyl-, (E)-	0.27	154

14.43	2,4,6-Trimethyl-1-nonene	0.08	168
15.18	3-Undecene, 7-methyl-, (Z)-	0.42	168
15.30	2-Methyl-2-undecene	0.09	168
15.36	4-Methyl-1-undecene	0.49	168
15.38	1-Decene, 2,4-dimethyl	0.15	168
15.49	4-Methyl-1-undecene	0.51	168
15.61	2-Ethyl-1-decanol	0.52	186
15.69	5-Undecene, 3-methyl-, (Z)-	0.05	186
15.81	4-Methyl-1-undecene	0.29	168
15.92	5-Methyl-1-undecene	0.17	168
15.99	5-methyl-3-undecene	0.08	168
16.16	4-Methyl-5-undecene	0.14	168
16.25	4-Methyl-2-undecene	0.07	168
16.34	2-Methyl-2-undecene	0.05	168
16.41	5-Dodecene, (E)-	0.72	168
16.45	4-Dodecene	0.49	168
16.56	6-Dodecene, (E)-	0.54	168
16.66	Dodecane	1.15	170
16.81	9-Methyl-2-undecene	0.45	168
16.96	8-Methyl-1-undecene	0.05	168
17.06	9-Methyl-1-undecene	0.29	168
17.90	5-methyl-3-undecene	0.07	168
18.14	3,4-Dimethyl-1-decene	0.25	168
18.19	4-Methyl-1-undecene	0.23	168
18.31	2-Ethyl-1-decanol	0.43	186
18.45	3,8-dimethylundecane	0.13	186
18.62	6-Ethyl-2-methyldecane	0.35	184
18.95	4-Methyl-2-dodecen	0.08	182
19.14	6-Tridecene, (E)-	0.39	182
19.61	5-Tridecene, (E)-	1.03	182
19.23	3-Tridecene, (E)-	0.29	182
19.33	6-Tridecene, (Z)-	0.25	182
19.43	Tridecane	1.03	184
19.57	1-Tridecene	0.28	184
20.78	6-Methyltridecane	0.34	198
20.85	5-Methyltridecane	0.31	198
20.89	2,3,5,8-Tetramethyl-decane	0.28	198
21.12	2-methyltridecane	0.25	198
21.30	3-methyltridecane	0.40	198
21.59	6-Methyl Tridecane	0.05	196
21.73	7-Tetradecene	0.13	196
21.79	3-Tetradecene, (Z)-	0.11	196
21.97	7-Tetradecene (z)-	0.15	196
22.06	Tetradecane	1.45	196
22.19	7-Methyl-6-tridecene	0.19	196
22.31	2,3,5,8-Tetramethyl-decane	0.13	198
22.46	2-Hexyl-1-octanol	0.21	214
23.28	2,7,10-Trimethyldodecane	0.50	212
23.52	4-Methyltetradecane	0.31	212
23.65	2,6,11-Trimethyldodecane	0.25	212
23.82	3-Methyltetradecane	0.23	212
24.54	Pentadecane	1.28	212

26.22	2,7,10-Trimethyldodecane	0.17	212
26.90	Hexadecane	1.02	226
26.67	Pentadecane	0.04	226
29.14	3-Methylhexadecane	0.57	240



**Figure S1.** TEM micrographs (a and b) of prepared silica nanosprings (NS) as support (without catalyst).