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QUARTERLY TECHNICAL REPORT

The goal of this project is to develop a catalyst and a process for the conversion of syngas to isobutylene. However, due to the low conversion and selectivity generally experienced in the industry in direct syngas conversion to isobutylene, indirect conversion via branched C₄ alcohol intermediates is being explored. The objectives of the current program are to develop a catalyst and process for the conversion of syngas to isobutanol and to evaluate the commercial potential of the new process. The research program underway at UOP will identify and optimize key catalyst and process characteristics.

This report covers the testing of a Cu/Zn/Al methanol synthesis catalyst in combination with basic co-catalysts and Pd/K on Zr/Zn/Mn oxide catalysts for the conversion of syngas to higher alcohols. Two types of basic metal oxide co-catalysts have been evaluated for the production of isoalcohols, KOH on Al₂O₃ or SiO₂ and alkali metal impregnated Mg/Al MOSSs. Catalytic performance of Cu/Zn/Al oxide mixed with K/Al₂O₃ is virtually identical to that of the methanol synthesis catalyst with SiO₂, indicating that this material is inert. In contrast, the K/SiO₂ co-catalyst reduces the activity and selectivity of the Cu/Zn/Al catalyst. Therefore, this approach has been abandoned. Previous testing of Mg/Al MOSS co-catalysts with Cu/Zn/Al oxide has shown promotion of DME formation, rather than isoalcohols, presumably by methanol dehydration on residual acid sites. Addition of 0.2-0.3 wt. % alkali (Na, K, and Cs) to the Mg/Al MOSS is not effective for reducing the formation of DME.

Keim and co-workers have reported that a catalyst consisting of Pd and an alkali metal impregnated onto a Zr/Zn/Mn mixed metal oxide support is active for syngas conversion to higher alcohols with up to 75% selectivity to isobutanol¹. The best results were obtained at high pressures (> 3600 psig)^{1a}. We have attempted to reproduce these results with testing at more desirable conditions (1100 psig). Pd has been impregnated on a pre-formed Zr/Zn/Mn oxide from either PdCl₂ or Pd(NO₃)₂ and two levels of alkali (K) have been tested. All of the Pd/K on Zr/Zn/Mn oxide catalysts

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tested have shown low activity for syngas to alcohols, with methanol as the only alcohol product. The primary products in these tests were C₁₋₄ hydrocarbons. Blank reactor testing has demonstrated that a substantial portion of the light hydrocarbons produced in these 450 °C tests are due to reactions on the stainless steel reactor walls and quartz reactor packing material. Attempts to reduce the extent of these side reactions by the use of a porcelain-lined reactor have been unsuccessful.

EXPERIMENTAL

Catalysts

Cu/Zn/Al oxide catalysts were prepared by co-precipitating an aqueous solution of nitrate salts with sodium carbonate at 50 °C and pH 7. After extensive water washing, the precipitate was dried at 110 °C for 12 hours, sized to 20-40 mesh and calcined at 400 °C in air for 2 hours.

A commercial Mg/Al MOSS (Metal Oxide Solid Solution) sample was obtained from Alcoa (Sorbplus) and used as received after sizing to 20-40 mesh. Separate portions of this material were impregnated with aqueous solutions of NaOH, KOH and CsOH to afford catalysts samples containing 0.2 wt.% Na, 0.2 wt.% K and 0.3 wt.% Cs, respectively.

SiO₂, as 20-40 mesh granules, was prepared by crushing and sizing Davison Grade 05 silica gel. A portion of this material, as well as a sample of 20-40 mesh gamma alumina, were impregnated with an aqueous solution of KOH to give 5.3 wt.% K on SiO₂ and 5.0 wt.% K on Al₂O₃.

A Zr/Zn/Mn oxide (1/1/1 molar) support was prepared by co-precipitating an aqueous solution of nitrate salts with potassium hydroxide at 50 °C and pH 11. The solid was washed with H₂O, dried at 127 °C for 15 hours, sized to 20-40 mesh and calcined at 327 °C in air for 3 hours. Analysis of this material showed that it contained 6.3 wt.% K. This material was impregnated with an aqueous Pd(NO₃)₂ solution and re-calcined at 327 °C to afford a final catalyst with 0.14% Pd and 4.6% K. Another portion of the calcined Zr/Zn/Mn oxide was washed with additional H₂O to a K content of 1.42 wt.%. A samples of this material was impregnated with an aqueous solution of Pd(NO₃)₂ and re-calcined at 327 °C. The Pd and K contents of this catalyst were 0.15% and 0.8%, respectively. Another portion of the low K support was impregnated with an aqueous solution of PdCl₂ and re-calcined at 300 °C and 400 °C following the procedure of Poutsma, etal.². This material contained 0.18% Pd and 1.6% K. A sample of SiO₂ was also impregnated with PdCl₂, using the same

procedure, to afford a material with 0.15% Pd.

Catalytic Testing Procedure

The catalytic testing of catalyst mixtures containing Cu/Zn/Al oxide was accomplished as follows. The Cu/Zn/Al oxide component and either the basic co-catalyst or silica, as an inert, were mixed in a 1:1 weight ratio as 20-40 mesh granules. This catalyst mixture (6g total) was loaded into a 3/8" I.D. stainless steel reactor. After pressure testing at 1500 psig with N₂, the catalyst was reduced with 2% H₂/N₂ at 250 °C, 0 psig, 0.20 scf/hr for 6 hours. After purging with N₂, plant pressure was raised to 1100 psig and temperature to 310 °C (or 230 °C for Run 127). Synthesis gas (47/47/6 mole% CO/H₂/Ar) was cut-in at 2250 hr⁻¹ CO GHSV and continued for 16 hours. The testing of Pd/K/Zr/Zn/Mn oxide catalysts was identical, except for elimination of silica/co-catalyst component and the use of 350 °C or 450 °C process temperatures.

A listing of the pilot plant runs described in this report is given in Table 1.

Data Analysis

CO and H₂ conversions were determined by analysis of the product gas after the condensation of any liquid products at 0 °C. An argon internal standard (6% of feed) was employed. Selectivities are based on moles of carbon from CO converted to each product, including CO₂. For catalyst screening tests, the averages of results obtained between 8 and 16 hours on stream are reported.

RESULTS AND DISCUSSION

Testing of Cu/Zn/Al Catalyst with Basic Metal Oxide Co-Catalysts

Two preparations of co-precipitated Cu/Zn/Al oxide catalyst have been employed in the work described in this report. The results of reference runs of these two materials and a commercial low temperature methanol synthesis catalyst, ICI 51-3, are given in Table 2. These materials show comparable performances for methanol synthesis at 310 °C. The lab prepared catalysts give slightly higher CO conversions, but also more DME and CO₂, than the commercial sample. The presence of some residual

acidity in the laboratory prepared materials may be the explanation of the slightly lower selectivity. These results were deemed similar enough for catalyst screening purposes.

One of the approaches that has been investigated to increase the production of higher, branched alcohols from syngas has been the combination of conventional methanol synthesis catalysts, such as Cu/Zn/Al oxide, with a basic co-catalyst. There is strong evidence in the literature that a base-catalyzed aldol condensation type mechanism leads to the selective formation of isobutanol in these systems. While the metal oxide support of the methanol synthesis catalyst can provide the basic functionality, particularly when impregnated with alkali, it is of interest to determine whether the addition of a stronger base component to the catalyst formulation as a physical mixture can lead to improved performance. Pilot plant evaluations of 5 wt. % K (as KOH) on Al_2O_3 and SiO_2 as basic co-catalysts for the promotion of isoalcohol formation in combination with a Cu/Zn/Al oxide catalyst are summarized in Table 3. Conversions and selectivities with the K/ Al_2O_3 co-catalyst is nearly identical to that of the SiO_2 reference. Therefore, this material appears to be inert. Addition of K/ SiO_2 to the Cu/Zn/Al oxide resulted in a significant decrease in conversion and increase in DME selectivity. Potassium migration could be a possible explanation for this observation, but further investigation has not been pursued.

Previous testing of physical mixtures of a Cu/Zn/Al methanol synthesis catalyst and Mg/Al MOSS and MgO co-catalysts has failed to demonstrate an increase in the production of higher branched alcohols³. Rather, addition of the basic metal oxide promotes DME formation, presumably by methanol dehydration on residual acid sites. In an attempt to eliminate these potential sites, an Al/Mg MOSS sample has been impregnated with 0.2-0.3 wt. % alkali (Na, K, and Cs) and evaluated for higher alcohols production in combination with a Cu/Zn/Al catalyst. Table 4 shows that the addition of this level of alkali to the Mg/Al MOSS is not effective for reducing the formation of DME.

Evaluation of Pd/K on Zr/Zn/Mn Oxide Catalysts

Five pilot plant tests have been conducted on Pd/K on Zr/Zn/Mn oxide catalysts prepared based on the reports of Keim, et al.¹ The results of these tests are summarized in Table 5. The temperature, feed rate and H_2/CO feed ratio used in these tests are comparable to those used by Keim, but the pressure (1100 psig) is substantially lower than that reported in the literature. All tests conducted at 450 °C gave primarily light hydrocarbons and CO_2 rather than alcohols. A single test at 350 °C showed higher selectivity to methanol, but at low conversion. In contrast to the literature report, only a trace of higher alcohol products were observed in any of these tests. It is suspected that the poor performance of these catalysts is due to the low pressure used. However, failure to precisely reproduce the Keim catalyst formulation

from the limited description available in the literature¹ cannot be ruled out. A Pd/SiO₂ catalyst was also evaluated at 450 °C and found to give only light hydrocarbons and CO₂ (Table 6). The temperature dependence of light hydrocarbon and CO₂ formation raised suspicions that these products might be forming on the stainless steel reactor walls and fillers bars. Therefore, blank reactor activity at 450 °C has been evaluated.

Blank Reactor Testing

Table 6 shows a comparison of four blank reactor runs with the Pd/SiO₂ and Pd/K on Zr/Zn/Mn oxide catalyst tests at 450 °C. The yields of hydrocarbons and CO₂ obtained with the blank stainless steel reactor (Run 133) are higher than that of the Pd/SiO₂ catalyst and only slightly lower than the Pd/K on Zr/Zn/Mn oxide catalyst. Therefore, it appears that the majority of these by-products are due to non-catalytic reactions occurring on the stainless steel walls of the reactor. In an attempt to minimize these reaction, a ceramic reactor was evaluated. When the reactor filled with either alpha Al₂O₃ or quartz chips, light hydrocarbons and CO₂ yields were still greater than 2%. An empty ceramic-lined reactor gave about a 50% reduction in the by-product yields, indicating that some of the by-products form on the packing material. Due to poor performance of the Pd based catalysts and other outside reports of difficulties in reproducing the literature results⁴, further testing of high temperature catalysts for this application has been suspended.

CONCLUSIONS

Two types of basic metal oxide co-catalysts have been evaluated in combination with Cu/Zn/Al oxide methanol synthesis catalyst for the production of isoalcohols, KOH on Al₂O₃ or SiO₂ and alkali metal impregnated Mg/Al MOSSs. Catalytic performance with the K/Al₂O₃ co-catalyst is virtually identical to that of the SiO₂ blank, indicating that this material is inert. In contrast, the K/SiO₂ co-catalyst actually reduces the activity and selectivity of the Cu/Zn/Al methanol synthesis catalyst. Therefore, this approach has been abandoned. Previous testing of Mg/Al MOSS co-catalysts has shown promotion of DME, rather than isoalcohols, presumably by methanol dehydration on residual acid sites. Addition of 0.2-0.3 wt.% alkali (Na, K, and Cs) to the Mg/Al MOSS is not effective for reducing the formation of DME.

Attempts to produce isobutanol with Pd/K on Zr/Zn/Mn oxide catalysts, similar to those described by Keim and co-workers, at low pressure conditions have been

unsuccessful. Catalysts were prepared by the impregnation of Pd (0.15 wt.%) from either PdCl₂ or Pd(NO₃)₂ pre-formed K/Zr/Zn/Mn oxide. Materials with two levels of K were also prepared. All of these catalyst show only low activity for syngas to alcohols, with methanol as the only alcohol product. The primary products in these tests are C₁₋₄ hydrocarbons. Blank reactor testing has demonstrated that a substantial portion of the light hydrocarbons produced in these 450 °C tests are due to reactions on the stainless steel reactor walls and quartz reactor packing material. Attempts to reduce the extent of these side reactions by the use of a porcelain-lined reactor have been unsuccessful.

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Table 1. Run List

RUN	CATALYST		CATALYST DESCRIPTION		SIZE	LOADING g/g	CONDITIONS				
	A Book #	B Book #	CATALYST A	CATALYST B			TEMP (C) INLET	MAX	TOTAL PSIG	CO GHSV	FEED RATIO CO/H ₂ /Ar
124	7923-38	7923-2	.14%Pd(NO ₃)/4.6%K/Zr/Zn/Mn Oxides	Silica Gel (Davison)	20-40M	3/3	450		1100	2250	47/47/6
125	7923-42A	7923-2	.15%Pd(NO ₃)/0.8%K/Zr/Zn/Mn Oxides	Silica Gel (Davison)	20-40M	3/3	450		1100	2250	47/47/6
126	7923-20	7923-22	Cu/Zn/Al (30/45/25) Oxides (Lab)	Mg/Al Clay (Alcoa)	20-40M	3/3	310		1100	2250	47/47/6
127	7923-20	7923-22	Cu/Zn/Al (30/45/25) Oxides (Lab)	Mg/Al Clay (Alcoa)	20-40M	3/3	230		1100	2250	47/47/6
128	7923-42A	7923-2	.15%Pd(NO ₃)/0.8%K/Zr/Zn/Mn Oxides	Silica Gel (Davison)	20-40M	3/3	350		1100	2250	47/47/6
129	7923-20	7923-22	Cu/Zn/Al (30/45/25) Oxides (Lab)	Mg/Al Clay (Alcoa)	20-40M	3/3	310		1100	2250	47/47/6
130	7923-44		.18%Pd(Cl)/1.6%K/Zr/Zn/Mn Oxides	None	20-40M	3/0	450		1100	2250	47/47/6
131	7923-46		.15%Pd(Cl)/SiO ₂	None	20-40M	3/0	450		1100	2250	47/47/6
132	7923-42A		.15%Pd(NO ₃)/0.8%K/Zr/Zn/Mn Oxides	None	20-40M	3/0	450		1100	2250	47/47/6
133		7923-2	None	Silica Gel (Davison)	20-40M	0/3	450		1100	2250	47/47/6
134			Ceramic-Lined Reactor	a-Alumina Filled			450		1100	2250	47/47/6
135			Ceramic-Lined Reactor	Empty			250-450		1100	2250	47/47/6
136			Ceramic-Lined Reactor	Quartz Chips Filled			250-450		1100	2250	47/47/6
137	7923-58A	7923-2	Cu/Zn/Al Oxide (ICI 51-3 catalyst)	Silica Gel (Davison)	20-40M	3/3	230-310		1100	2250	47/47/6
138	7923-20	7923-2	Cu/Zn/Al Oxide (Lab PPT)	Silica Gel (Davison)	20-40M	3/3	230-310		1100	2250	47/47/6
139	7923-20	7923-78	Cu/Zn/Al Oxide (Lab PPT)	5.0% K (KOH)/Al ₂ O ₃	20-40M	3/3	310		1100	2250	47/47/6
140	7923-20	7923-76	Cu/Zn/Al Oxide (Lab PPT)	5.3% K (KOH)/SiO ₂	20-40M	3/3	310		1100	2250	47/47/6
141	7923-20	7923-2	Cu/Zn/Al Oxide (Lab PPT)	Silica Gel (Davison)	20-40M	3/3	310		1100	2250	47/47/6
142	7923-85	7923-2	Cu/Zn/Al Oxide (Lab PPT)	Silica Gel (Davison)	20-40M	3/3	310		1100	2250	47/47/6
143	7923-85	8074-10	Cu/Zn/Al Oxide (Lab PPT)	0.3% Cs / Mg/Al MOSS (Alcoa)	20-40M	3/3	310		1100	2250	47/47/6
144	7923-85	8074-8	Cu/Zn/Al Oxide (Lab PPT)	0.2% Na / Mg/Al MOSS (Alcoa)	20-40M	3/3	310		1100	2250	47/47/6
145	7923-85	7923-2	Cu/Zn/Al Oxide (Lab PPT)	Silica Gel (Davison)	20-40M	3/3	310		1100	2250	47/47/6
146	7923-85	8074-9	Cu/Zn/Al Oxide (Lab PPT)	0.2% K / Mg/Al MOSS (Alcoa)	20-40M	3/3	310		1100	2250	47/47/6

Table 2. Comparison of Lab Prepared and Commercial Cu/Zn/Al Methanol Synthesis Catalysts

Conditions: 310 °C, 1100 psig, 2250 hr⁻¹ CO GHSV,
1/1 H₂/CO (molar)

Run	137	138	141	145
Catalyst	Commercial	Lab Prepared		Lab Prepared
Mixed with	Cu/Zn/Al	Cu/Zn/Al		Cu/Zn/Al
SiO ₂ (1:1 wt.)	Oxide	Oxide		Oxide
	ICI 51-3	7923-20		7923-85
Conversions				
%				
CO	25.4	25.4	29.7	31.2
H ₂	34.4	39.1	40.2	40.6
Selectivities				
mole%				
C ₁ OH	54.3	57.1	54.3	46.0
C ₂ OH	3.2	2.2	2.4	2.5
C ₃ OHs	1.0	0.7	0.9	1.1
n-C ₄ OH	0.5	0.3	0.3	0.5
i-C ₄ OH	1.0	0.6	0.9	0.6
C ₅₊ OH	1.7	0.4	0.3	0.9
DME	3.8	6.6	6.5	7.5
C ₁ HCBN	1.6	1.2	1.3	1.1
C ₂₋₄ HCBNs	2.5	1.2	1.8	1.7
Others	15.4	3.6	3.4	7.7
CO ₂	15.0	26.1	27.9	30.4

**Table 3. Methanol Synthesis Catalysts with Basic Co-Catalyst -
Cu/Zn/Al Oxide with Supported Potassium Co-Catalysts**

Run Hours on Stream	141 8-16	139 8-16	140 8-16
Catalyst	Cu/Zn/Al Oxide + SiO ₂ 1:1 (wt.)	Cu/Zn/Al Oxide + K/Al ₂ O ₃ 1:1 (wt.)	Cu/Zn/Al Oxide + K/SiO ₂ 1:1 (wt.)
Conditions Temperature (C) Pressure (psig) CO GHSV (hr ⁻¹) H ₂ /CO (molar)	310 1100 2250 1/1		
Conversions (%) CO H ₂	29.7 40.2	27.5 39.5	13.5 15.4
Selectivities (%) C ₁ OH C ₂ OH C ₃ OHs n-C ₄ OH i-C ₄ OH C ₅₊ OH DME C ₁ HCBN C ₂₋₄ HCBNs Others CO ₂	54.3 2.4 0.9 0.3 0.9 0.3 6.5 1.3 1.4 3.4 27.9	61.9 1.4 0.6 0.2 0.7 0.6 7.2 1.5 1.3 2.5 22.1	44.9 0.6 0.3 0.1 0.2 1.1 19.1 2.9 2.8 2.9 25.1

Table 4. Methanol Synthesis Catalysts with Basic Co-Catalyst -
Cu/Zn/Al Oxide with Mg/Al MOSS Co-Catalysts

Run Hours on Stream	145 8-16	144 8-16	146 8-16	143 8-16	147 8-16
Catalyst	Cu/Zn/Al Oxide + SiO ₂ 1:1 (wt.)	Cu/Zn/Al Oxide + 0.2% Na Mg/Al MOSS 1:1 (wt.)	Cu/Zn/Al Oxide + 0.2% K/ Mg/Al MOSS 1:1 (wt.)	Cu/Zn/Al Oxide + 0.3% Cs/ Mg/Al MOSS 1:1 (wt.)	% Cs/ Cu/Zn/Al Oxide + SiO ₂ 1:1 (wt.)
Conditions Temperature (C) Pressure (psig) CO GHSV (hr ⁻¹) H ₂ /CO (molar)	310 1100 2250 1/1				
Conversions (%) CO H ₂	31.2 40.6	30.2 43.1	29.4 39.5	32.2 41.5	23.8 37.3
Selectivities (%) C ₁ OH C ₂ OH C ₃ OHs n-C ₄ OH i-C ₄ OH C ₅ + OH DME C ₁ HCBN C ₂₋₄ HCBNs Others CO ₂	46.0 2.5 1.1 0.5 0.6 0.9 7.5 1.1 1.7 7.7 30.4	41.8 0.4 0.2 0.0 0.1 0.5 23.3 0.6 0.5 2.1 30.5	40.5 0.5 0.2 0.1 0.3 0.6 23.9 0.7 0.4 2.4 30.4	41.1 0.5 0.2 0.1 0.4 0.8 21.5 0.8 0.9 3.1 30.6	63.2 2.1 0.8 0.3 0.6 0.4 6.7 1.0 1.3 3.7 20.2

Table 5. Evaluations of Pd/K on Zr/Zn/Mn Oxide Catalysts

Conditions: 1100 psig, 2250 hr⁻¹ CO GHSV,
1/1 H₂/CO (molar)

Run	124	125	128	132	130
Catalyst	0.14% Pd (Pd(NO ₃) ₂) on K/Zr/Zn/Mn (4.6%/1/1/1)	0.15% Pd (Pd(NO ₃) ₂) on K/Zr/Zn/Mn (0.8%/1/1/1)			0.18% Pd (PdCl ₂) on K/Zr/Zn/Mn (1.6%/1/1/1)
(Diluent)	SiO ₂	SiO ₂	SiO ₂	None	None
Temperature (°C)	450	450	350	450	450
Conversions (%)					
CO	14.3	8.5	6.2	17.9	8.5
H ₂	14.3	12.6	2.6	13.2	12.6
Selectivities (mole%)					
MeOH	1.5	7.7	39.4	10.9	7.7
C ₂₊ ALCs	2.0	0.2	0.8	1.6	0.2
DME	0.0	0.0	0.0	0.0	0.0
C ₁₋₄ HCBNs	33.2	43.1	4.3	34.8	43.1
CO ₂	40.9	45.4	20.1	44.9	45.4

Table 6. Blank Reactor Testing at 450 °C

	P700R131 13 HOS PVSQ2	P700R132 13 HOS P4/23/27m	18 HOS 20 HOS SIO2 / 316SS Filler Blank 316SS Reactor	P700R133 20 HOS SIO2 / 316SS Filler Blank 316SS Reactor	22 HOS	2 HOS 9 HOS None / a - Al2O3 Filler / Ceramic Reactor	P700R134 9 HOS	14 HOS	23 HOS 25 HOS Empty Ceramic - Unired Reactor	P700R135 25 HOS Empty Ceramic - Unired Reactor	27 HOS	23 HOS 25 HOS Quartz Chips Filled Ceramic - Unired Reactor	P700R136 25 HOS Quartz Chips Filled Ceramic - Unired Reactor	27 HOS
CO CONV (% w A)	6.74	18.23	9.41	9.70	6.37	6.51	6.52	6.88	2.45	2.79	3.38	7.29	8.28	4.47
H2 CONV (% w A)	8.26	12.84	6.22	8.03	8.50	4.86	8.02	4.01	4.37	3.88	3.84	11.87	15.88	17.76
CO + H2 CONV (% w A)	7.51	18.48	7.84	8.37	8.43	5.61	5.78	5.37	3.40	3.17	3.61	9.62	11.04	11.07
SELECTIVITY (%)														
C1OH	0.53	10.65	0.58	0.63	0.63	1.30	0.88	0.80	0.00	0.00	0.00	1.48	1.41	1.44
C2OH	0.35	0.28	0.40	0.39	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.33
HC3OH	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC3OH	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC3OH	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC3OH	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.10	0.06
HC3OH	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.10	0.00
HC3OH	0.00	0.04	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C8+OH	2.37	0.80	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1 Aldehyde	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2 Aldehyde	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3 Aldehyde	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C4 Aldehyde	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5 Aldehyde	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C6+ Aldehyde	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1	28.16	17.88	24.00	24.13	24.31	31.86	31.65	32.35	34.88	61.87	47.12	37.77	38.38	38.24
C2	14.56	6.14	13.21	13.18	13.21	5.62	7.79	8.97	0.00	0.00	0.00	18.48	15.56	18.40
C3	8.10	7.49	5.75	5.75	5.77	3.99	4.37	5.05	0.00	0.00	0.00	8.81	9.31	8.99
C4	1.40	1.78	0.10	0.11	0.11	0.17	0.18	0.20	0.00	0.00	0.00	0.20	0.28	0.21
C5	0.27	0.36	0.21	0.20	0.20	0.24	0.24	0.22	0.00	0.00	0.00	0.62	0.46	0.41
C6+ + UNKs	1.11	6.10	2.00	1.80	1.82	0.87	0.99	1.31	0.00	0.00	0.00	3.67	3.45	3.77
CO2	47.15	44.57	52.78	53.64	53.58	55.84	53.64	50.85	85.02	38.33	52.86	28.23	29.88	30.51
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
YIELD (%)														
C1OH	0.04	1.84	0.06	0.06	0.06	0.06	0.06	0.06	0.00	0.00	0.00	0.11	0.08	0.08
C2OH	0.02	0.05	0.04	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01
HC3OH	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC3OH	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC3OH	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HC3OH	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00
HC3OH	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
HC3OH	0.16	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C8+OH	0.00	0.11	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1 Aldehyde	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2 Aldehyde	0.00	0.18	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3 Aldehyde	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C4 Aldehyde	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5 Aldehyde	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C6+ Aldehyde	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1	1.78	3.22	2.28	2.10	2.03	2.06	1.75	0.43	0.88	1.68	1.88	2.75	2.40	1.71
C2	0.98	1.48	1.24	1.15	1.11	0.37	0.43	0.80	0.00	0.00	0.00	1.14	0.97	0.88
C3	0.41	1.38	0.54	0.50	0.48	0.26	0.25	0.34	0.00	0.00	0.00	0.72	0.58	0.40
C4	0.09	0.33	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.02	0.01
C5	0.02	0.06	0.02	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.04	0.02	0.02
C6+ + UNKs	0.07	1.11	0.19	0.14	0.14	0.06	0.06	0.09	0.00	0.00	0.00	0.22	0.22	0.15
CO2	3.18	8.12	4.86	4.67	4.49	3.64	2.88	3.40	1.88	1.03	1.78	2.13	1.86	1.38
TOTAL	6.74	18.23	9.41	8.70	8.37	6.51	5.52	5.88	2.45	2.70	3.38	7.29	8.28	4.47

DATE

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