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APPENDICES

APPENDIX A

A.1 STAINLESS STEEL TUBING

Annealed 304 or 316 stainless steel tubing ASTM A-296 or equivalent. Minimum ultimate tensile stength 75,000 psi. For metal temperatures not to exceed -20° to 100°F. Allowable working pressure loads calculated from S value as specified by Table 302.3.1A and Paragraph 304.1.2 of Code for Pressure piping ANSI B31.3.

Table A.1 Stainless Steel Tubing

Tube O.D. (In.)	Tube Wall Thickness (Inches)				
	.028	.035	.049	.065	.083
			---- Working Pressure (Psig)--		
1/8	9,993	12,675			
3/16	6,359	8,175	11,775		
1/4	4,575	5,906	8,700	11,718	
5/16		4,593	6,712	9,225	
3/8		3,768	5,456	7,537	
1/2		2,775	3,975	5,437	7,162

A.2 Minimum Radius of Bending

Radius of Bend is defined to be the radius to the center of the tube. (see Fig. A.1)

The table below gives a radius that can be obtained if proper tubing and equipment are used. Column "A" gives the smallest bend that can be obtained utilizing the greatest care and best equipment on copper tubing. Column "B" gives annealed steel and stainless steel tubing in addition to copper tubing.

Tube O.D. Diameter (inches)	A Minimum Tube Bend Radius Optimun Condition (inches)	B Minimum Tube Bend Radius Optimun Condition (inches)
1/8 "	0.250 "	0.500 "
1/4 "	0.500 "	1.000 "
3/8 "	0.750 "	1.500 " to 2.000 "
1/2 "	1.000 "	1.500 " to 2.000 "
5/8 "	1.250 "	1.500 " to 2.000 "
3/4 "	1.500 "	3.000 "
7/8 "	1.750 "	3.500 "
1 "	2.000 "	4.000 "
1 1/4 "	2.500 "	2.500 "
1 1/2 "	3.000 "	3.000 "
2 "	4.000 "	4.000 "

Material, tube wall thickness and equipment used will influence the smallest bend possile. The above table is only an indication of bends that can be expected. Follow the recommendations of the manufacturers of the tube bender and tubing when attempting to obtain minimum radius bends.

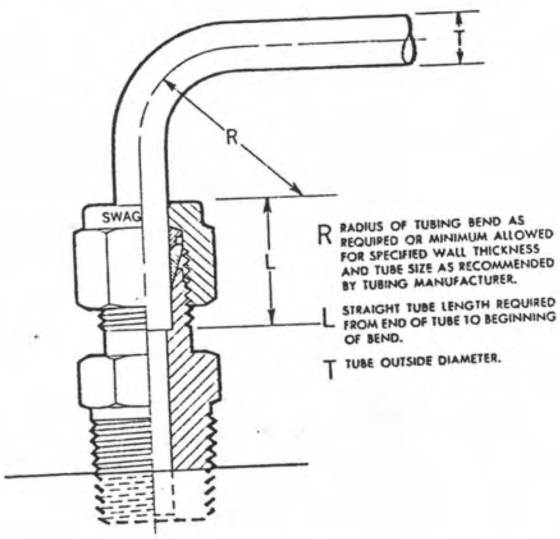

Fig. A.1 MINIMUM RADIUS OF BEND

APPENDIX B

EXAMPLE OF ANALYSIS OF EXPERIMENTAL DATA

The original data at 75 atg, 320°C and 2,000 hr^{-1} for catalyst No.3, the IFP-type catalyst, are shown in **Figs. B.1-B.3**. **Fig. B.1** shows the raw data obtained from a dry gas sample with the GC-8AIT, a Thermal Conductivity Detector type, using a MS-5A column; the sample is taken at SP-2. **Figs. B.2-B.3** show the raw data obtained from two wet gas samples with the GC-8AIF, a Flame Ionization Dectector type, using a Porapak-T column and a Porapak-Q column, respectively. The samples are taken at SP-1. Using the above data, the calculation procedure is as follows:

Let m = moles of CO and H_2 dry gas contained in the 0.5-ml dry gas sample taken at SP-2 at 32°C and detected by MS-5A.

n = moles of CO_2 and H_2O in the 1-ml wet gas sample analyzed with GC-8AIT using column Porapak Q.

o = moles of hydrocarbons and alcohols in the 1-ml wet gas sample analyzed with GC-8AIF using column Porapak T (that is, the sum of CH_4, C_2H_6, C_3H_6, C_3H_8, i-C_4H_{10}, n-C_4H_{10}, i-C_5H_{12}, n-C_5H_{12}, C_6H_{14}, CH_3OH, C_2H_5OH, i-C_3H_7OH, n-C_3H_7OH).

c = moles of condensible components at 32°C in the 0.5-ml wet gas sample (such as, alcohols, water, and n-hexane)

d = compensation factor for the effect of temperature on gasous volume (T = 32°C to T=T)

$$d = (273 + T) / (273 + 32) \quad \text{.... 5.1}$$

F = total moles contained in 0.5-ml of wet gas sample

X = ratio of condensible portion to uncondensible portion

$$X = \frac{c}{(F-c)} \quad \text{....5.2}$$

Rearrange eq. 5.2 to obtain

$$\frac{1}{(1+X)} = \frac{(F-c)}{F} \quad \text{.... 5.3}$$

Material Balance (basis:0.5ml of wet gas sample)

$$F = \frac{m}{(d)(1+X)} + n + o \quad \text{.... 5.4}$$

From eq. 5.2

$$F = \frac{c(1+X)}{X} \quad \text{.... 5.5}$$

Since eq. 5.4 = eq. 5.5, then

$$\frac{c(1+X)}{X} = \frac{m}{(d)(1+X)} + n + o \quad \text{.... 5.6}$$

Rearrange eq. 5.6 to obtain

$$(n+o-c)X^2 + (m/ +n+o-2c)(X+c) = 0 \quad \text{....5.7}$$

equation 5.7 is quadratic equation. The variable X can be solved as follow

let $\alpha = (n+o-c)$

$\beta = m/d + n + o - 2c$

$\gamma = (\beta^2 + 2\alpha c)^{0.5}$

then $X = \frac{-\beta+\gamma}{2\alpha}$, $\frac{-\beta-\gamma}{2\alpha}$

since X must greater than zero

then $$X = \frac{-\beta+\gamma}{2} \quad \text{.... 5.8}$$

The moles of CO and H_2 in the dry gas sample at SP-2 can be converted to those of the wet gas sample at SP-1 by multiplying with 1/(d(1+X)).

Since the feed gas (synthesis gas) contains H_2 and CO at a ratio of 1 to 1.25, the atomic ratios of H:C, C:O, and H:O in the feed are 2:1.25, 1:1, and 2:1.25, respectively. This fact is used in carrying out the overall elemental C, H and O balances to account for those hydrocarbons (C_7H_{16}, etc.) that might ecape detection.

The Total CO conversion (%) and product selectivity (%) are defined as follows.

$$\text{Total CO conversion (\%)} = \frac{\text{(total g-atom of C that is converted)}}{\text{sum of g-atom of C in the feed}} \cdot 100$$

$$\text{Product Selectivity (\%)} = \frac{\text{(g-atom of C that is converted to the product)}}{\text{total g-atom of C that is converted}} \cdot 100$$

$$\text{Space Time Yield of a Product} = \frac{\text{(\% total CO conversion)(\% Selectivity)GHSV(1.25)}}{\text{(22.4)(2.25)(10000)(No.of Carbon Atom in Product)}}$$

(mol/lit.cat./hr)

Specifically, from Table B.1 we have

m = 1.9342 E-05

n = 2.1958 E-06

o = 1.9891 E-06

c = 1.3058 E-06

d = 1.2852

Therefore, X = 7.76933 E-02

and $\frac{1}{d(1+X)}$ = 0.72013

Thus:

mole of CO in the 0.5-ml wet gas sample=(1.4461738E-05)(0.72013)=1.041436E-05

mole of H_2 in the 0.5-ml wet gas sample=(4.8802661E-06)(0.72013=3.5144356E-06

Therefore the products contained in the 0.5-ml wet gas sample are:

CO	=	1.0414360 E-05
H_2	=	3.5144356 E-06
CO_2	=	1.6692231 E-06
H_2O	=	5.2664352 E-07
CH_4	=	1.0539832 E-06
C_2H_6	=	8.0750425 E-08
C_3H_6	=	1.6094098 E-08
C_3H_8	=	3.0016769 E-08
i-C_4H_{10}	=	4.3774627 E-10
n-C_4H_{10}	=	1.5414540 E-09
i-C_5H_{12}	=	0
n-C_5H_{12}	=	8.2772839 E-09
C_6H_{14}	=	4.7631956 E-09
CH_3OH	=	3.0918572 E-07
C_2H_5OH	=	2.4275351 E-07
i-C_3H_7OH	=	1.0880064 E-08
n-C_3H_7OH	=	2.1497775 E-07

Then the g-atoms of C, H, and O are found to be 1.5049846E-05, 1.797919E-05, and 1.5058667E-05, respectively. Therefore, ratios of C:O, H:O, and H:C are 9.99414, 1.19394 and 1.19464, respectively. After adjusting the three ratios to the correct values by taking into account the undetected compounds, the correct total g-atoms of C, H, and O become 1.5058667E-05, 2.40938672E-05, and 1.5058667E-05, respectively.

In other words, the g-atoms of C and H in those compounds that have escaped detection are (1.5058667E-05 - 1.5049846 E-05) = 8.821 E-09 mole and (2.40938672 E-05 - 1.797919 E-05) = 6.1146772 E-06 mole, respectively. It is assumed that no oxygen containing compounds escape detection.

Next we proceed the calculations as follows:

The g-atoms of carbon that has been converted

$= (1.5058667\text{E-}05 - 1.041436\text{E-}05)$ g-atom

$= 4.6443077\text{E-}06$

Then The Total CO conversion $= \frac{(4.6443077\text{E-}06)(100)}{1.5058667\text{E-}05}$ %

$= 30.84$ %

Similarly,

CH_4 selectivity $= \frac{(1.053983\text{E-}06)(100)}{4.6443077\text{E-}06}$ %

$= 22.694$ %

C_2H_6 selectivity $= \frac{(1.615008\text{E-}07)(100)}{4.6443077\text{E-}06}$ %

$= 3.48$ %

C_3H_6 selectivity $= \frac{(4.828229\text{E-}08)(100)}{4.6443077\text{E-}06}$ %

$= 1.04$ %

C_3H_8 selectivity $= \frac{(9.005030\text{E-}08)(100)}{4.6443077\text{E-}06}$ %

$= 1.94$ %

i-C_4H_{10} selectivity $= \frac{(1.750985\text{E-}09)(100)}{4.6443077\text{E-}06}$ %

$= 0.04$ %

n-C_4H_{10} selectivity $= \frac{(6.165816\text{E-}08)(100)}{4.6443077\text{E-}06}$ %

$= 1.33$ %

i-C_5H_{12} selectivity $= 0$ %

$= 0$ %

n-C_5H_{12} selectivity $= \frac{(4.138642\text{E-}08)(100)}{4.6443077\text{E-}06}$ %

$= 0.89$ %

$$C_6H_{14} \text{ selectivity} = \frac{(2.857917E-08)(100)}{4.6443077E-06} \%$$
$$= 0.62 \%$$

$$CH_3OH \text{ selectivity} = \frac{(3.091857E-07)(100)}{4.6443077E-06} \%$$
$$= 6.66 \%$$

$$C_2H_5OH \text{ selectivity} = \frac{(4.855070E-07)(100)}{4.6443077E-06} \%$$
$$= 10.45 \%$$

$$i\text{-}C_3H_7OH \text{ selectivity} = \frac{(3.264019E-08)(100)}{4.6443077E-06} \%$$
$$= 0.70 \%$$

$$n\text{-}C_3H_7OH \text{ selectivity} = \frac{(6.449332E-07)(100)}{4.6443077E-06} \%$$
$$= 13.88 \%$$

and

$$\text{Space Time Yield of Ethanol} = \frac{(30.84)(10.45)(2000)(1.25)}{(22.4)(2.25)(10000)(2)}$$
$$= 0.7996 \quad \text{(mol/lit.cat/hr)}$$

OPERATING CONDITION : PRESSURE 75 atg SPACE VELOCITY 2000 hr^{-1} TEMP 310 °C DATE 09/4/30' IFP-23

PRODUCT	AREA	MOLE / CC.	Mole /0.5 CC.	Adj. Mole/ 0.5 CC.	C-g.atom	H-g.atom	O-g.atom	% Selectivity
H_2	27.6400		4.8002661E-06	3.5147266E-06		7.0208712E-06		
CO	4.0550		1.4461738E-05	1.0415222E-05	1.0415222E-05		1.0415222E-05	
CO_2	1.2400	3.3384461E-06	1.6692231E-06	1.6692231E-06	1.6692231E-06		3.3384461E-06	35.9522
H_2O	0.5075	1.0532870E-06	5.2664352E-06	5.2664352E-06		1.0532870E-06	5.2664352E-07	
CH_4	75.0307	2.1079665E-06	1.0539832E-06	1.0539832E-06	1.0539832E-06	4.2159330E-06		22.7010
C_2H_6	14.4179	1.6150085E-07	8.0750425E-08	8.0750425E-08	1.6150085E-07	4.8450255E-07		3.4704
C_3H_6	4.4646	3.2188196E-08	1.6094098E-08	1.6094098E-08	4.8282294E-08	9.6564544E-08		1.0399
C_3H_8	0.6016	6.0033537E-08	3.0016769E-08	3.0016769E-08	9.0050306E-08	2.4013415E-07		1.9395
$i-C_4H_{10}$	0.1433	8.7549254E-10	4.3774627E-10	4.3774627E-10	1.7509851E-09	4.3774627E-09		0.0378
$n-C_4H_{10}$	5.2992	3.0829081E-08	1.5414540E-08	1.5414540E-08	6.1658161E-08	1.5414540E-07		1.3280
$i-C_5H_{12}$	0.0000	0	0	0	0	0		0
$n-C_5H_{12}$	3.6352	1.6554568E-08	8.2772839E-09	8.2772839E-09	4.1386419E-08	9.9327406E-08		0.0914
C_6H_{14}	2.6470	9.5263911E-09	4.7631956E-09	4.7631956E-09	2.0579173E-08	6.6884738E-08		0.6155
MeOH	13.0867	6.1837144E-07	3.0918572E-07	3.0918572E-07	3.0918572E-07	1.2367429E-06	3.0918572E-07	6.6593
EtOH	16.3788	4.8550702E-07	2.4275351E-07	2.4275351E-07	4.8550702E-07	1.4565211E-06	2.4275351E-07	10.4570
i-PrOH	0.3097	2.1760129E-08	1.0880064E-08	1.0880064E-08	3.2640193E-08	8.7040515E-08	1.0880064E-08	0.7030
n-PrOH	7.6105	4.2995551E-07	2.1497775E-07	2.1497775E-07	6.4493326E-07	1.7198220E-06	2.1497775E-07	13.8907

m = 1.9342004E-05	n = 2.1958666E-06	α = 1.90909530E-06	1.5043903E-05	1.7944536E-05	1.5058109E-05	99.6633 %
c = 1.3044406E-06	d = 1.2885246	A = 2.879604E-06	C:O = 0.99905	H:O = 1.19160	H:C = 1.19281	
B = 1.6585490E-05	G = 1.7032320E-05	X = 7.7604119E-02	Adj. Mole C	Adj. Mole H	Adj. Mole O	
1+X = 1.0776	C conver = 4.6428867E-06	% CO conver = 30.8331	1.5058109E-05	2.4092974E-05	1.5058109E-05	

TABLE B.1 Calculation of Experimental Data

Appendix C

C.1 Summary of Experimental Results for Catalyst No.1

Experiment No.1-1 $Rh_1Mn_1Fe_{0.1}/SiO_2$ Catalyst

Feed CO : H_2 = 1 : 2

Reaction Pressure = 40 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	3.54	56.39	4.25	15.58	0.203	0.022	0.075
280	11.25	43.46	3.16	10.26	0.971	0.077	0.289
310	52.70	51.00	2.20	20.94	2.564	0.179	1.730
340	89.40	31.36	0.93	43.92	2.543	0.124	11.26

Experiment No.1-2 $Rh_1Mn_1Fe_{0.1}/SiO_2$ Catalyst

Feed CO : H_2 = 1 : 2

Reaction Pressure = 60 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	2.54	46.54	6.99	16.10	0.206	0.041	0.092
280	13.32	44.86	3.75	14.99	0.791	0.092	0.387
310	76.83	21.03	1.26	8.43	1.917	0.168	1.359
340	98.64	15.64	0.60	19.80	1.479	0.089	4.325

Experiment No.1-3 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1 : 2

Reaction Pressure = 80 atg

GHSV = 1,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity			STY (mol/lit.cat.-hr)		
		Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	3.22	65.34	9.56	15.27	0.172	0.028	0.049
280	30.80	16.76	6.29	14.18	0.484	0.144	0.312
310	58.25	25.66	4.04	30.14	0.993	0.175	1.585
340	95.12	14.65	1.05	45.57	0.788	0.074	4.903

Experiment No.1-4 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1 : 2

Reaction Pressure = 80 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity			STY (mol/lit.cat.-hr)		
		Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	3.22	33.69	8.84	17.86	0.154	0.042	0.082
280	13.50	29.94	5.52	28.42	0.381	0.071	0.369
310	52.43	26.49	3.39	30.52	1.734	0.265	2.847
340	94.48	17.78	1.45	61.01	1.908	0.204	12.709

Experiment No.1-5 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1 : 2

Reaction Pressure = 80 atg

GHSV = 4,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity			STY (mol/lit.cat.-hr)		
		Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	3.06	22.50	4.66	14.90	0.202	0.042	0.136
280	8.56	9.03	2.32	6.56	0.189	0.059	0.154
310	39.76	16.84	2.51	20.79	1.742	0.298	3.040
340	88.43	18.48	1.61	51.45	3.677	0.849	18.714

Experiment No.1-6 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1 : 2

Reaction Pressure = 80 atg

GHSV = 8,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity			STY (mol/lit.cat.-hr)		
		Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	3.04	30.10	6.22	7.29	0.514	0.112	0.084
280	2.00	35.82	11.33	30.68	0.338	0.135	0.341
310	9.71	36.65	6.31	29.58	1.939	0.365	1.932
340	92.05	9.41	5.20	9.12	4.975	2.850	3.326

C.2 Summary of Experimental Results for Catalyst No.1

Experiment No.2-1 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 40 atg

GHSV = 2,000 hr^{-1}

Temp.	% CO	% Selectivity			STY (mol/lit.cat.-hr)		
(°C)	Conv.	Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	2.01	38.94	7.27	11.85	0.173	0.036	0.047
280	4.24	67.83	4.28	15.53	0.439	0.045	0.154
310	33.91	11.12	0.70	4.06	0.584	0.059	0.337
340	59.58	45.28	1.54	15.81	3.965	0.228	2.630

Experiment No.2-2 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 60 atg

GHSV = 2,000 hr^{-1}

Temp.	% CO	% Selectivity			STY (mol/lit.cat.-hr)		
(°C)	Conv.	Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	6.46	9.91	2.02	3.11	0.131	0.034	0.044
280	7.97	33.33	2.99	13.02	0.429	0.057	0.254
310	21.87	44.72	2.35	14.68	1.508	0.127	0.803
340	82.54	21.57	0.83	9.11	2.651	0.171	2.158

Experiment No.2-3 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 80 atg

GHSV = 1,200 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	1.80	28.71	7.33	14.29	0.077	0.019	0.053
280	3.30	45.42	10.16	34.82	0.209	0.049	0.195
310	12.76	17.48	2.95	19.35	0.271	0.056	0.391
340	50.28	23.69	3.18	43.47	1.244	0.219	4.039

Experiment No.2-4 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 80 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	2.47	50.65	12.19	48.27	0.293	0.075	0.307
280	70.55	20.61	1.17	55.06	2.826	0.234	12.670
310	85.88	15.22	0.23	43.89	2.113	0.048	12.508
340	94.76	13.36	0.01	50.50	2.097	0.002	16.717

Experiment No.2-5 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 80 atg

GHSV = 4,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	1.24	18.93	8.96	26.08	0.131	0.055	0.168
280	24.81	3.17	2.17	22.96	0.459	0.267	3.101
310	71.87	0.99	0.76	42.39	0.380	0.271	21.137
340	90.21	0.45	0.05	35.62	0.331	0.023	28.030

Experiment No.2-6 $Rh_1Mn_1Fe_{0.1}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 80 atg

GHSV = 8,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	2.35	12.98	7.38	78.54	0.433	0.172	2.089
280	90.83	0.73	0.64	20.07	0.746	0.574	25.591
310	83.35	0.24	0.07	54.63	0.209	0.059	69.746
340	77.78	0.29	0.03	6.37	0.156	0.022	7.349

C.3 Summary of Experimental Results for Catalyst No. 3

Experiment No.3-1 $Co_1Ba_{0.05}Ag_{0.01}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction pressure = 40 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	13.82	1.25	0.26	4.95	0.092	0.011	0.221
280	12.23	7.29	4.38	21.29	0.313	0.159	0.576
310	85.42	12.56	1.93	33.21	2.291	0.490	13.610
340	96.78	42.49	0.12	12.39	1.899	0.036	17.664

Experiment No.3-1 $Co_1Ba_{0.05}Ag_{0.01}SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction pressure = 60 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	82.16	47.15	15.37	37.96	12.363	3.132	8.066
280	33.63	4.76	2.55	14.96	0.464	0.212	1.547
310	83.76	1.83	0.34	60.42	0.311	0.071	21.617
340	96.31	1.07	0.25	18.88	0.302	0.061	6.856

Experiment No.3-3 $Co_1Ba_{0.05}Ag_{0.01}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction pressure = 80 atg

GHSV = 1,000 hr^{-1}

Temp.	% CO	% Selectivity			STY (mol/lit.cat.-hr)		
(°C)	Conv.	Alcs.	EtOH	HC	Alcs.	C_2OH	HC
250	8.26	5.26	0.60	9.61	0.051	0.006	0.112
280	15.65	12.81	5.78	42.99	0.306	0.112	1.054
310	89.93	1.80	0.28	57.29	0.162	0.031	10.217
340	96.57	3.15	1.43	51.08	0.327	0.168	8.802

Experiment No.3-4 $Co_1Ba_{0.05}Ag_{0.01}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction pressure = 80 atg

GHSV = 2,000 hr^{-1}

Temp.	% CO	% Selectivity			STY (mol/lit.cat.-hr)		
(°C)	Conv.	Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	2.52	6.71	1.03	9.90	0.067	0.012	0.168
280	14.49	7.56	1.53	22.93	0.345	0.055	1.071
310	27.43	12.75	6.50	42.57	1.119	0.461	4.604
340	89.13	2.19	0.50	74.30	0.369	0.111	25.561

Experiment No.3-5 $Co_1Ba_{0.05}Ag_{0.01}/SiO_2$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction pressure = 80 atg

GHSV = 4,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	0.68	12.84	3.36	10.33	0.149	0.043	0.154
280	5.27	8.83	3.52	26.28	0.283	0.092	0.884
310	85.74	2.15	0.93	40.87	0.831	0.401	29.017
340	96.20	2.39	0.44	45.70	0.867	0.106	16.741

C.4 Summary of Experimental Results for Catalyst No. 2

Experiment No.4-1 $Co_1Cu_1Cr_{0.8}K_{0.096}$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 40 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	1.58	37.19	10.15	9.79	0.130	0.039	0.055
280	1.95	26.27	8.80	14.12	0.122	0.042	0.101
310	7.80	29.04	9.26	25.20	0.551	0.180	0.754
340	48.18	9.45	3.34	28.73	1.075	0.399	6.045

Experiment No.4-2 $Co_1Cu_1Cr_{0.8}K_{0.096}$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 60 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	2.08	10.44	4.18	6.07	0.047	0.022	0.037
280	9.57	29.22	9.98	15.12	0.703	0.237	0.460
310	35.18	28.29	10.56	42.89	2.296	0.837	5.919
340	77.75	8.13	2.10	45.02	1.385	0.405	17.362

Experiment No.4-3 $Co_1Cu_1Cr_{0.8}K_{0.096}$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 75 atg

GHSV = 1,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity Alcs.	EtOH	HC	STY (mol/lit.cat.-hr) Alcs.	EtOH	HC
250	6.61	20.88	5.83	14.15	0.175	0.047	0.162
280	22.98	21.16	7.29	55.66	0.651	0.207	1.452
310	54.62	25.64	9.34	41.52	1.734	0.632	5.114
340	80.15	7.45	1.83	49.76	0.668	0.180	8.205

Experiment No.4-4 $Co_1Cu_1Cr_{0.8}K_{0.096}$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 75 atg

GHSV = 2,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity			STY (mol/lit.cat.-hr)		
		Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	6.15	28.30	5.56	17.68	0.542	0.085	0.280
280	16.28	25.87	6.93	15.98	1.139	0.280	0.903
310	30.84	31.83	10.45	32.04	2.562	0.799	3.985
340	87.87	1.28	0.22	40.32	0.210	0.048	14.705

Experiment No.4-5 $Co_1Cu_1Cr_{0.8}K_{0.096}$ catalyst

Feed CO : H_2 = 1.25 : 1

Reaction Pressure = 75 atg

GHSV = 4,000 hr^{-1}

Temp. (°C)	% CO Conv.	% Selectivity			STY (mol/lit.cat.-hr)		
		Alcs.	EtOH	HC	Alcs.	EtOH	HC
250	0.58	33.04	9.38	22.69	0.152	0.039	0.134
280	4.67	54.33	8.68	12.95	1.063	0.201	0.462
310	12.61	35.37	12.77	27.51	2.361	0.806	2.834
340	88.37	1.36	0.13	33.25	0.435	0.058	25.062

APPENDIX D

CALIBRATION CURVES

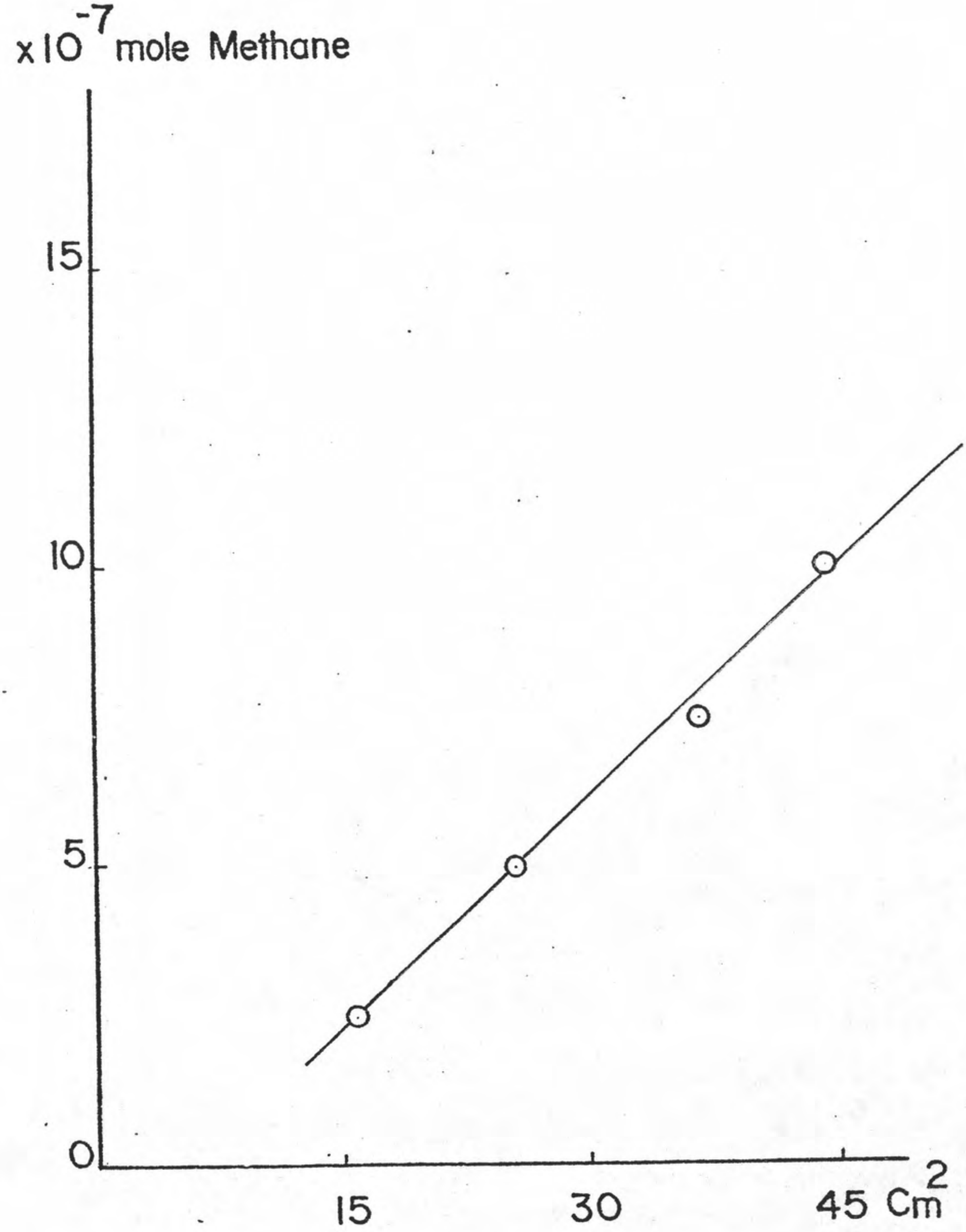

Fig. D.1 Calibration Curve for CH_4

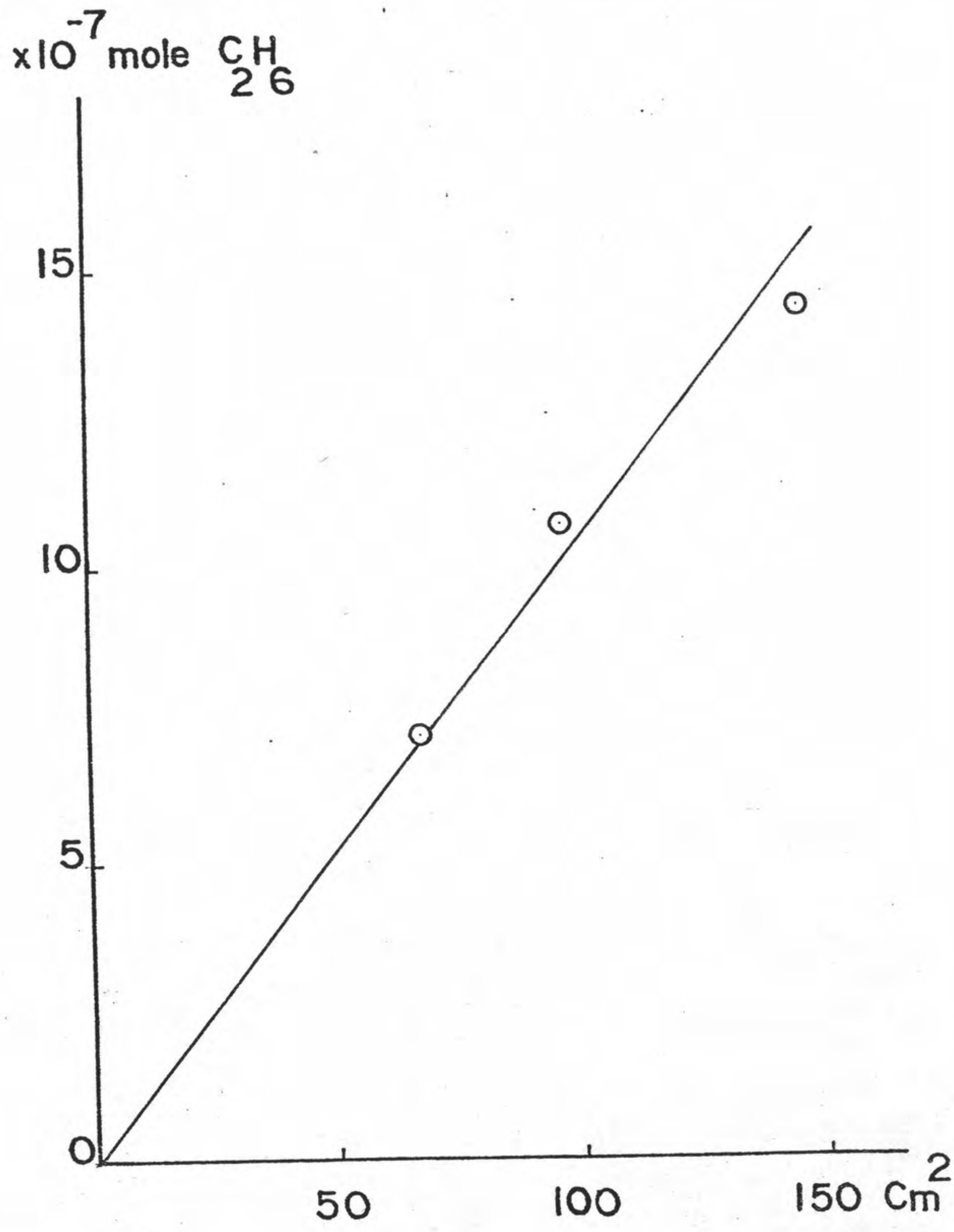

Fig. D.2 Calibration Curve for C_2H_6

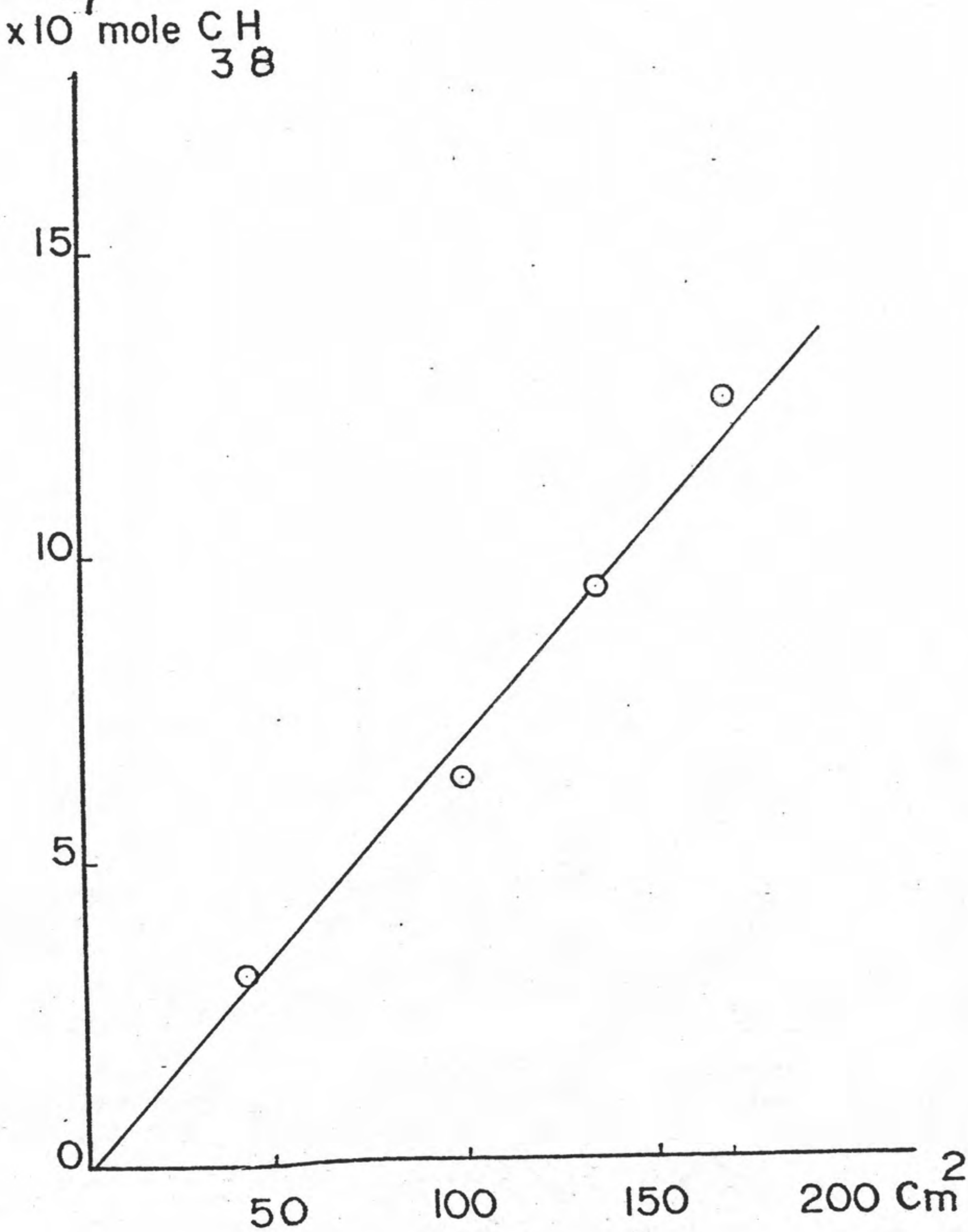

Fig. D.3 Calibration Curve for C_3H_8

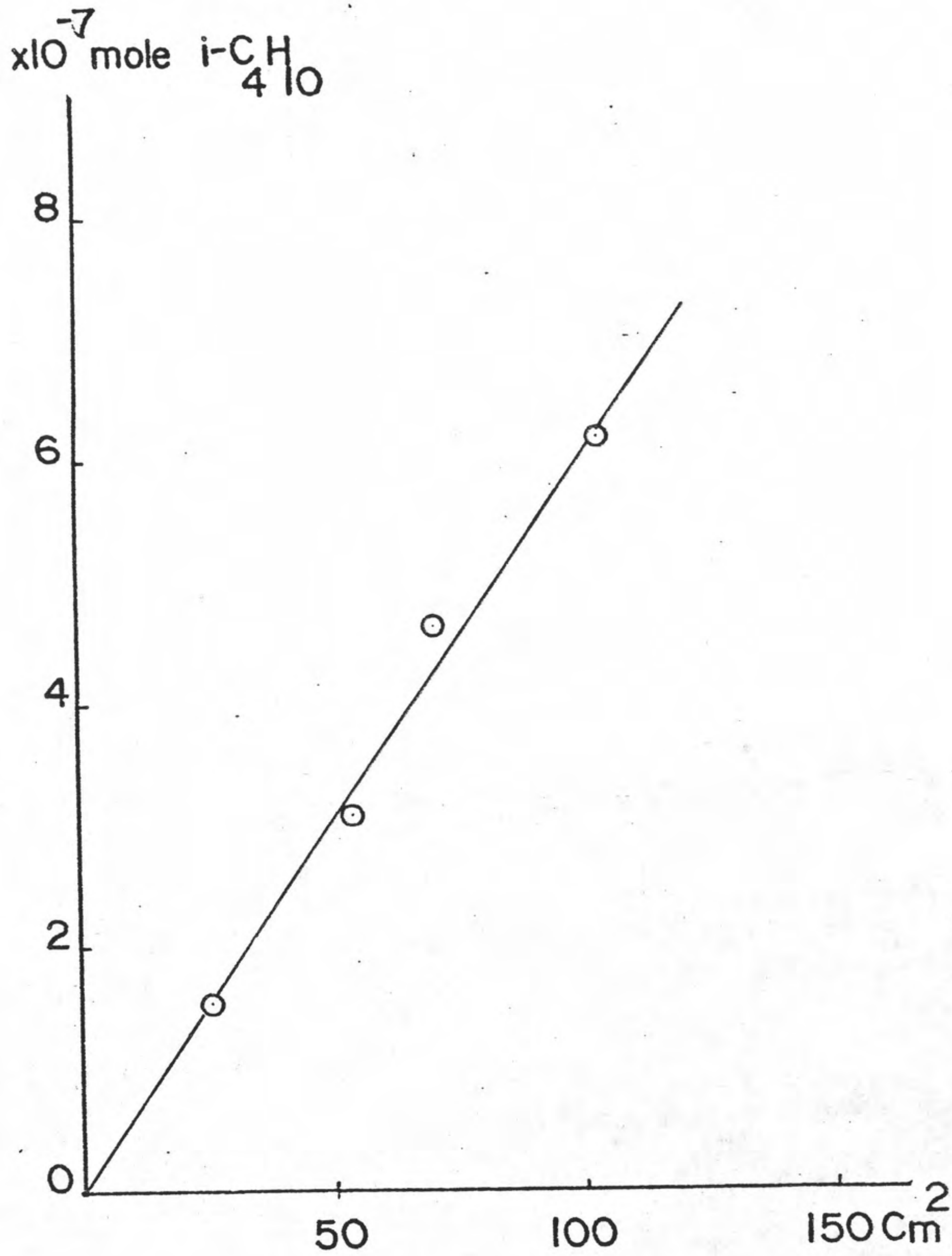

Fig. D.4 Calibration Curve for i-C_4H_{10}

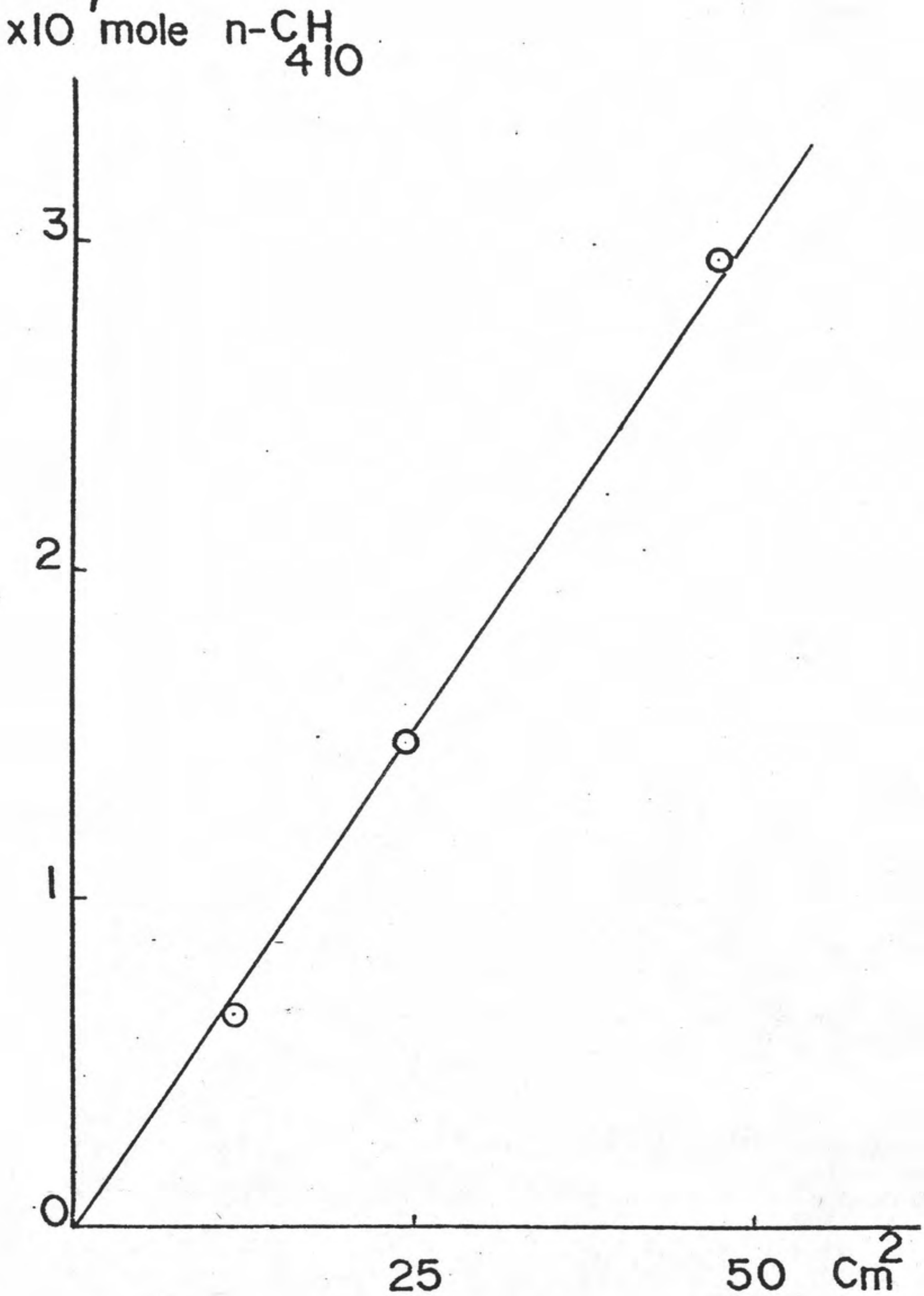

Fig. D.5 Calibration Curve for n-C_4H_{10}

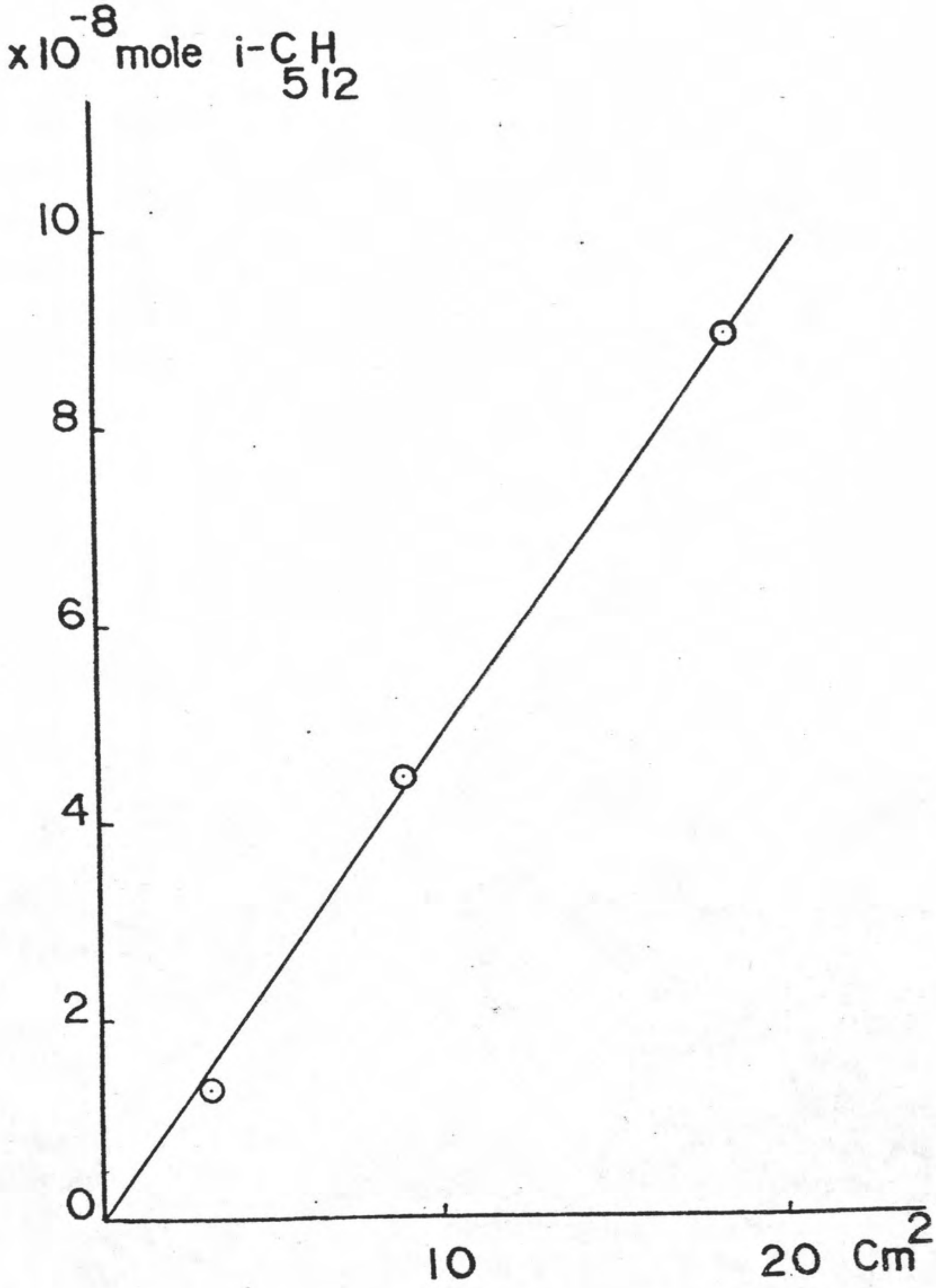

Fig. D.6 Calibration Curve for i-C_5H_{12}

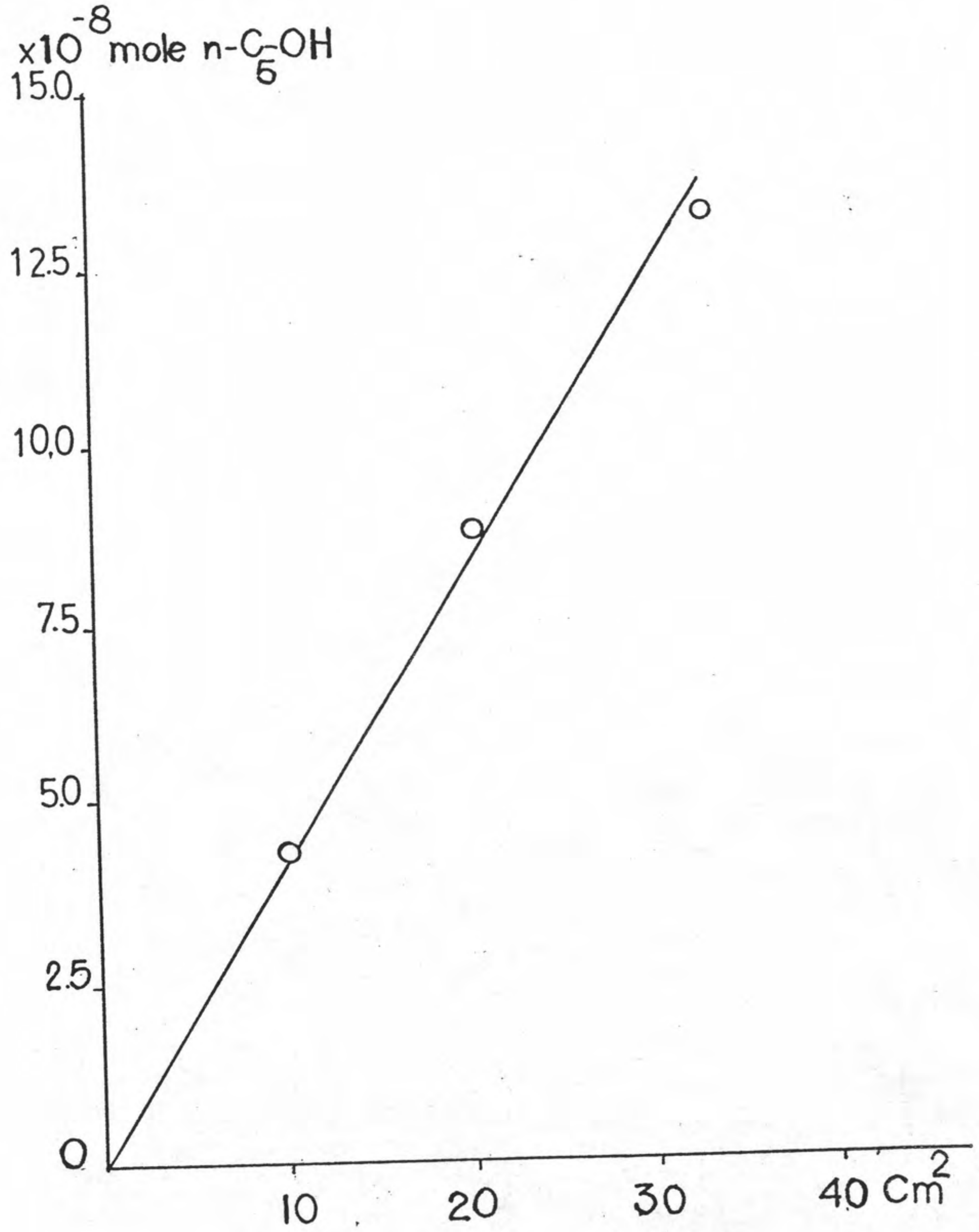

Fig. D.7 Calibration curve for n-C_5H_{12}

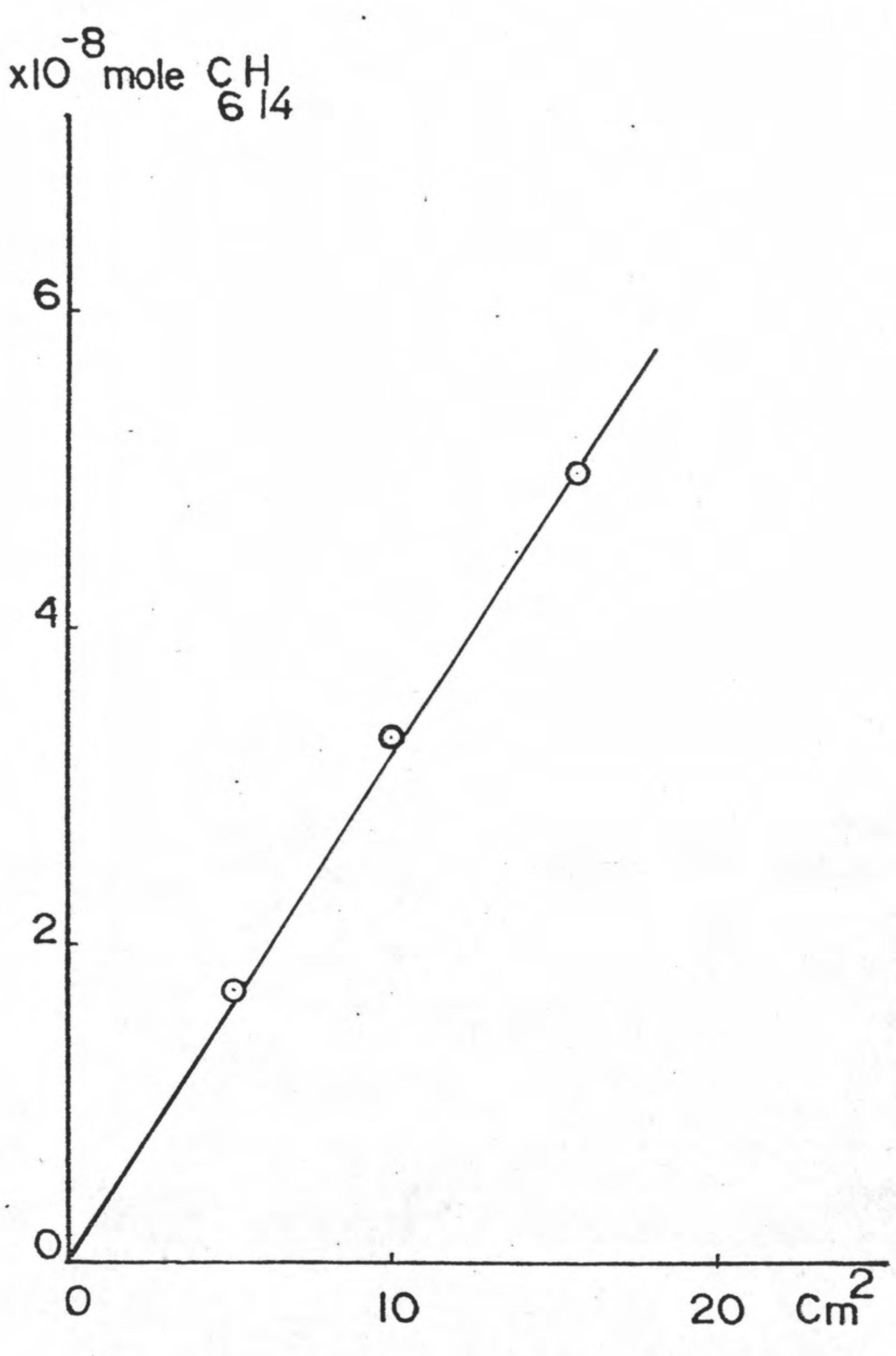

Fig. D.8 Calibration Curve for C_6H_{14}

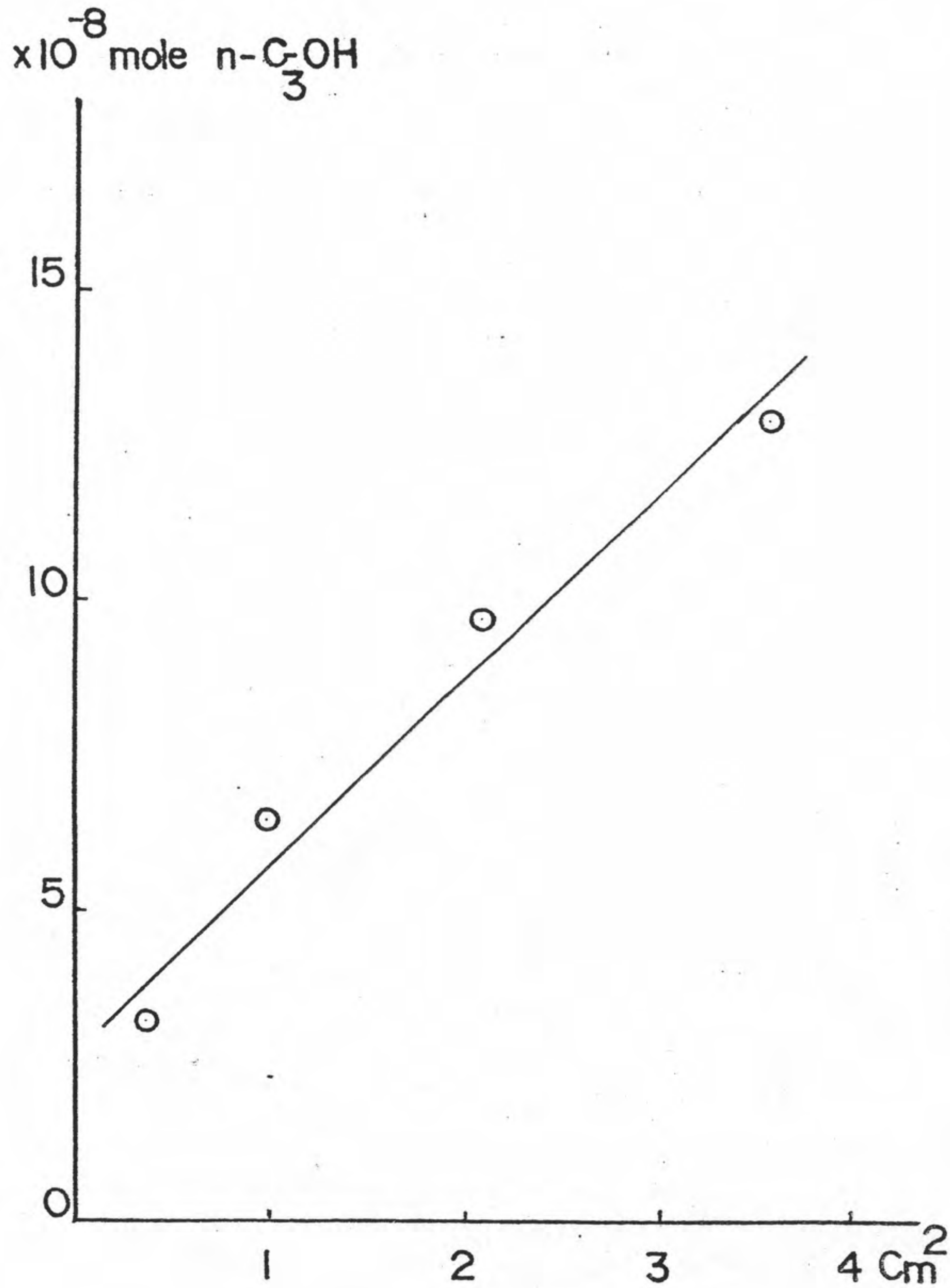

Fig. D.9 Calibration Curve for n-PrOH (n-C_3OH)

APPENDIX E

SUMMARY OF OVERALL SPACE TIME YIELDS OF THE THREE CATALYSTS

Table E.1 Summary of Overall Space Time Yield of $Rh_1Mn_1Fe_{0.1}/SiO_2$ Catalyst at the feed ratio of $CO:H_2$ = 1:2.

		Rh..CATALYST		CO:H2=1:2			
P,GHSV	Temp	EtOH	Tot.Alc.	Tot.Alc2	Ratio1	Tot.HC	Tot.HC2
40,2000	250	0.022	0.203	0.578	2.842	0.075	0.164
	280	0.077	0.726	2.119	2.913	0.289	0.504
	310	0.179	2.563	8.276	3.229	1.729	3.404
	340	0.124	2.543	10.061	3.282	9.013	11.687
60,2000	250	0.041	0.206	0.871	4.219	0.092	0.188
	280	0.092	0.789	2.182	2.7633	0.387	0.734
	310	0.168	1.917	5.62	2.931	1.359	2.254
	340	0.089	1.479	4.626	3.128	4.325	5.859
80,1000	250	0.028	0.172	0.394	2.282	0.049	0.092
	280	0.144	0.484	0.768	1.587	0.312	0.65
	310	0.175	0.993	2.224	2.24	1.585	2.613
	340	0.074	0.788	2.074	2.63	4.903	6.451
80,2000	250	0.042	0.154	0.323	2.094	0.082	0.171
	280	0.1109	0.5937	1.203	2.026	0.575	1.142
	310	0.265	1.734	4.133	2.384	2.847	4.763
	340	0.204	1.988	5	2.62	12.709	17.158
80,4000	250	0.042	0.202	0.34	1.899	0.136	0.272
	280	0.059	0.189	0.39	2.35	0.154	0.334
	310	0.298	1.742	3.984	2.287	3.04	4.922
	340	0.849	3.677	9.729	2.646	18.714	27.084
80,8000	250	0.112	0.514	1.085	2.108	0.084	0.264
	280	0.135	0.338	0.854	2.525	0.341	0.731
	310	0.365	1.939	4.235	2.184	1.932	3.418
	340	2.85	4.975	10.309	2.072	3.326	7.885

Table E.2 Summary of Overall Space Time Yield of $Rh_1Mn_1Fe_{0.1}/SiO_2$ Catalyst at the feed ratio of $CO:H_2$ = 1.25:1.................................... 159

			Rh..CATALYST		CO:H2=1.25:1		
P,GHSV	Temp	CO-conver	EtOH	Tot.Alc.	Tot.Alc2	Ratio1	Tot.HC
40,2000	250	2.01	0.036	0.173	0.388	2.248	0.047
	280	4.24	0.045	0.439	1.427	3.243	0.154
	310	33.91	0.059	0.584	1.87	3.2	0.337
	340	59.58	0.228	3.965	13.384	3.375	2.63
60,2000	250	6.46	0.034	0.131	0.318	2.424	0.044
	280	7.97	0.057	0.429	1.318	3.074	0.254
	310	21.87	0.127	1.508	6.685	4.434	0.803
	340	82.54	0.171	2.651	8.933	3.332	2.158
80,1200	250	1.8	0.019	0.077	0.153	1.99	0.053
	280	3.3	0.049	0.209	0.445	2.127	0.195
	310	12.76	0.056	0.271	0.664	2.451	0.391
	340	58.28	0.219	1.244	3.258	2.62	4.039
80,2000	250	2.47	0.075	0.293	0.626	2.135	0.307
	280	70.55	0.205	2.484	7.213	2.903	11.136
	310	85.88	0.046	2.036	6.035	2.964	11.858
	340	94.76	0	2.095	6.278	2.996	16.717
80,4000	250	1.24	0.055	0.131	0.232	1.768	0.168
	280	24.81	0.267	0.459	0.779	1.697	3.101
	310	71.87	0.271	0.38	0.71	1.869	21.137
	340	98.21	0.023	0.331	0.406	1.226	28.03
80,8000	250	2.35	0.172	0.433	0.606	1.4	2.089
	280	90.83	0.574	0.746	1.324	1.773	25.591
	310	83.35	0.057	0.209	0.208	1.398	69.746
	340	77.75	0	0	0	0	7.538

Table E.3 Summary of Overall Space Time Yield of $Co_1Ba_{0.05}Ag_{0.1}/SiO_2$ Catalyst at the feed ratio of $CO:H_2$ = 1.25:1

CATALYST2 CO:H2=1.25:1

P,GHSV	Temp	EtOH	Tot.Alc.	Tot.HC	Tot.Alc2	Ratio1	Tot.HC2
40,2000	250	0.009	0.077	0.184	0.086	1.117	0.339
	280	0.133	0.261	0.48	0.442	1.695	1.292
	310	0.408	1.909	11.342	5.322	2.787	14.076
	340	0.0304	1.583	14.72	5.949	3.758	20.401
60,2000	250	0.169	0.6316	0.434	0.938	1.479	0.837
	280	0.212	0.448	1.547	0.709	1.576	2.496
	310	0.071	0.301	21.617	0.709	2.353	25.124
	340	0.061	0.299	6.948	0.506	1.687	9.224
80,1000	250	0.006	0.036	0.112	0.042	1.171	0.197
	280	0.112	0.306	1.054	0.465	1.517	1.668
	310	0.031	0.162	10.217	0.390	2.398	12.164
	340	0.168	0.327	8.802	0.734	2.242	12.058
80,2000	250	0.012	0.042	0.168	0.056	1.286	0.253
	280	0.055	0.326	1.071	0.441	1.347	1.649
	310	0.461	1.098	4.604	1.698	1.543	7.143
	340	0.111	0.358	25.59	0.912	2.537	32.768
80,4000	250	0.043	0.149	0.112	0.158	1.058	0.265
	280	0.092	0.283	0.884	0.350	1.357	1.374
	310	0.401	0.817	29.023	1.780	2.175	35.281
	340	0.106	0.854	16.745	2.216	2.591	43.714

Table E.4 Summary of Overall Space Time Yield of $Co_1Cu_1Cr_{0.8}K_{0.096}$ Catalyst at the feed ratio of $CO:H_2$ = 1.25:1

CATALYST3 CO:H2=1.25:1

P,GHSV	Temp	EtOH	Tot.Alc.	Tot.HC	Tot.Alc2	Ratio1	Tot.HC2
40,2000	250	0.039	0.222	0.055	0.258	2.105	0.092
	280	0.042	0.122	0.101	0.239	1.952	0.145
	310	0.18	0.551	0.754	1.115	2.026	1.528
	340	0.399	1.075	6.045	2.243	2.085	6.867
60,2000	250	0.022	0.036	0.037	0.058	1.596	0.063
	280	0.237	0.703	0.460	1.371	1.950	0.718
	310	0.837	2.22	5.921	4.464	2.011	6.796
	340	0.405	1.385	20.534	3.139	2.263	24.613
75,1000	250	0.047	0.175	0.162	0.331	1.890	0.232
	280	0.207	0.651	1.452	1.196	1.837	3.174
	310	0.632	1.734	5.114	3.466	1.997	5.720
	340	0.182	0.668	8.205	1.467	2.191	9.910
75,2000	250	0.085	0.542	0.280	0.839	1.548	0.540
	280	0.28	1.139	0.903	2.063	1.810	1.291
	310	0.799	2.562	3.985	4.850	1.893	4.901
	340	0.048	0.21	14.705	0.542	2.576	17.575
75,4000	250	0.039	0.127	0.134	0.167	1.308	0.358
	280	0.201	1.063	0.462	2.477	2.330	0.602
	310	0.806	2.361	2.834	4.425	1.874	3.470
	340	0.058	0.435	25.062	1.191	2.736	29.714

VITA

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