COMPONENTS:	ORIGINAL MEASUREMENTS:
1. Methane; CH_4; [74-82-8] 2. Butane; C_4H_{10}; [106-97-8] 3. Water; H_2O; [7732-18-5]	McKetta, J. J.; Katz, D. L. *Ind. Eng. Chem.* <u>1948</u>, *40*, 853-862.

VARIABLES:	PREPARED BY:
	C. L. Young

EXPERIMENTAL VALUES: Experimental data in the three-phase region.

T/K (T/°F)	P/MPa (P/psi)	Phase[a]	x_{CH_4}	Mole fraction[b] $x_{C_4H_{10}}$	x_{H_2O}
310.9 (100)	4.35 (631)	V Lh Lw	0.8710 0.2076 0.000649	0.1290 0.7924 0.0000594	0.00184 0.000838 0.99929
	1.39 (202)	V Lh Lw	0.7850 0.0694 0.0002635	0.2150 0.9306 0.000087	0.00508 0.000654 0.9996495
	9.69 (1406)	V Lh Lw	0.8580 0.4505 0.001505	0.1420 0.5495 0.000045	0.001028 0.000864 0.99845
	6.75 (979)	V Lh Lw	0.8650 0.3070 0.001051	0.1350 0.6930 0.000065	0.001315 0.000871 0.998884
	3.27 (474)	V Lh Lw	0.8470 0.1479 0.00072	0.1530 0.8521 0.000080	0.002315 0.000809 0.9992
	1.46 (212)	V Lh Lw	0.7125 0.0480 0.000299	0.2875 0.9520 0.0000507	0.00485 0.000692 0.99965
	14.13 (1838)	V Lh Lw	0.8140 0.6240 0.001805	0.1860 0.3760 0.000033	0.000858 0.000824 0.998162
(cont.)	13.10 (1900)	V Lh Lw	0.7770 0.6690 0.001818	0.2230 0.3310 0.0000295	0.0008405 0.000831 0.99815

AUXILIARY INFORMATION

METHOD/APPARATUS/PROCEDURE:	SOURCE AND PURITY OF MATERIALS:
Equilibrium cell of approx. 1 dm^3 capacity fitted with glass window, 3 sampling ports, mercury injection port and stirring mechanism. Temperature measured with copper-constantan thermocouples. Pressure measured with Bourdon gauge. Methane then butane and water charged into cell. Samples taken after equilibrium established. Samples analysed by removing water and weighing the hydrocarbon and determining amounts from knowledge of mass, volume and pressure of gas. Details in source.	1. Phillips Petroleum Co. sample, purity 99.9 mole per cent, dried. 2. Phillips Petroleum Co. sample, purity 99.9 mole per cent, dried. 3. Redistilled in atmosphere of methane.
	ESTIMATED ERROR: $\delta T/K = \pm 0.12$; $\delta P/MPa = \pm 0.03$; δx_{CH_4}, $\delta x_{C_4H_{10}}$, δy_{CH_4}, $\delta y_{C_4H_{10}} = \pm 1\%$ (estimated by compiler).
	REFERENCES:

COMPONENTS:	ORIGINAL MEASUREMENTS:
1. Methane; CH_4; [74-82-8]	McKetta, J. J.; Katz, D. L.
2. Butane; C_4H_{10}; [106-97-8]	*Ind. Eng. Chem.*
3. Water; H_2O; [7732-18-5]	1948, *40*, 853-862.

EXPERIMENTAL VALUES:

Experimental data in the three-phase region.

T/K (T/°F)	P/MPa (P/psi)	Phase[a]	Mole fraction[b]		
			x_{CH_4}	$x_{C_4H_{10}}$	x_{H_2O}
310.9	13.17	V	0.7490	0.2510	0.000831
(100)	(1910)	Lh	0.6975	0.3025	0.000832
		Lw	0.01852	0.000028	0.99812
	13.18	V	0.7390	0.2610	0.000835
	(1912)	Lh	0.7130	0.2870	0.000835
		Lw	0.001852	0.000028	0.99812
	12.96	V	0.8040	0.1960	0.000841
	(1880)	Lh	0.6420	0.3580	0.000828
		Lw	0.001822	0.0000314	0.99815
	8.41	V	0.8790	0.1210	0.00106
	(1220)	Lh	0.3860	0.6140	0.00082
		Lw	0.00129	0.00006	0.99865
344.3	11.60	V	0.7425	0.2575	0.0038
(160)	(1683)	Lh	0.5105	0.4895	0.0035
		Lw	0.00149	0.00072	0.99844
	10.20	V	0.7810	0.2190	0.004295
	(1479)	Lh	0.4380	0.5620	0.0035
		Lw	0.00135	0.00001	0.99858
	7.05	V	0.7960	0.2040	0.00539
	(1022)	Lh	0.2938	0.7062	0.00309
		Lw	0.00099	0.000091	0.99892
	3.69	V			
	(535)	Lh	0.1348	0.8652	0.0030
		Lw	0.00052	0.000098	0.99938
	1.32	V	0.3360	0.6640	0.02210
	(192)	Lh	0.0266	0.9734	0.00242
		Lw	0.000015	0.00021	0.99977
	11.27	V	0.7695	0.2305	0.00398
	(1635)	Lh	0.4965	0.5035	0.00352
		Lw	0.001462	0.000064	0.99847
	11.92	V	0.7155	0.2845	0.00366
	(1729)	Lh	0.5330	0.4670	0.00355
		Lw	0.001535	0.000064	0.9984
	7.25	V	0.7990	0.2010	0.00538
	(1051)	Lh	0.2975	0.7025	0.00327
		Lw	0.000975	0.000133	0.99889
	12.38	V	0.6645	0.3355	0.00354
	(1796)	Lh	0.5895	0.4205	0.00370
		Lw	0.001585	0.000048	0.99863
	4.16	V	0.7445	0.2554	0.00782
	(604)	Lh	0.1568	0.8432	0.00280
		Lw	0.000555	0.000165	0.99928
	12.48	V	0.6475	0.3525	0.00359
	(1810)	Lh	0.60000	0.4000	0.00360
		Lw	0.001602	0.000046	0.99835
377.6	8.56	V	0.5790	0.4210	0.01535
(220)	(1241)	Lh	0.3202	0.6898	0.01238
		Lw	0.000998	0.000205	0.9988
	9.07	V	0.5770	0.4230	0.01485
	(1316)	Lh	0.3476	0.6524	0.01255
		Lw	0.001091	0.000156	0.99875
	7.35	V			
	(1066)	Lh	0.2620	0.7380	0.01148
		Lw	0.000929	0.000119	0.99895
	5.90	V	0.5875	0.4125	0.02145
	(855)	Lh	0.1918	0.8082	0.01108
		Lw	0.000626	0.000256	0.99912

(cont.)

COMPONENTS:	ORIGINAL MEASUREMENTS:
1. Methane; CH_4; [74-82-8]	McKetta, J. J.; Katz, D. L.
2. Butane; C_4H_{10}; [106-97-8]	*Ind. Eng. Chem.*
3. Water; H_2O; [7732-18-5]	<u>1948</u>, *40*, 853-862.

EXPERIMENTAL VALUES:

Experimental data in the three-phase region.

T/K (T/°F)	P/MPa (P/psi)	Phase[a]	Mole fraction[b] x_{CH_4}	$x_{C_4H_{10}}$	x_{H_2O}
377.6 (220)	3.45 (500)	V	0.4268	0.5732	0.0324
		Lh	0.0775	0.9225	0.0098
		Lw	0.00027	0.000266	0.99946
	2.33 (338)	V	0.2380	0.7620	0.04365
		Lh	0.0267	0.9733	0.00882
		Lw	0.000185	0.000175	0.99964
	10.48 (1520)	V	0.5245	0.4755	0.01298
		Lh	0.4545	0.5455	0.01288
		Lw	0.001304	0.000098	0.9986
	10.07 (1460)	V	0.5550	0.4450	0.0136
		Lh	0.4105	0.5895	0.01172
		Lw	0.00117	0.000137	0.9987
	4.49 (651)	V	0.5335	0.4665	0.0287
		Lh	0.1264	0.8736	0.102
		Lw	0.00052	0.00019	0.99929
	2.08 (301)	V	0.1618	0.8382	0.0494
		Lh	0.01555	0.9845	0.0088
		Lw	0.00005	0.000286	0.99966
	10.34 (1499)	V	0.5350	0.4650	0.01348
		Lh	0.4360	0.5640	0.01276
		Lw	0.001258	0.0001305	0.99861
410.9 (280)	4.59 (665)	V	0.2220	0.7780	0.0606
		Lh	0.0906	0.9094	0.0341
		Lw	0.000286	0.00037	0.999344
	6.17 (895)	V	0.2406	0.7594	0.0485
		Lh	0.1680	0.8320	0.04285
		Lw	0.000455	0.000405	0.99914
	4.96 (720)	V	0.2358	0.7642	0.05725
		Lh	0.1067	0.8933	0.03705
		Lw	0.000375	0.000325	0.99930
	3.45 (500)	V	0.0836	0.9164	0.0718
		Lh	0.0053	0.9947	0.0274
		Lw	0.00006	0.00043	0.99951
	6.54 (948)	V	0.2348	0.7652	0.0439
		Lh	0.1880	0.8120	0.0456
		Lw	0.00055	0.00037	0.99908
	5.55 (805)	V	0.2428	0.7572	0.0536
		Lh	0.1378	0.8622	0.03815
		Lw	0.00046	0.00033	0.99921
	4.19 (608)	V	0.1977	0.8023	0.066
		Lh	0.0624	0.9376	0.0318
		Lw	0.00006	0.00052	0.99942

(cont.)

[a] *V* - vapor; *Lh* - liquid (hydrocarbon-rich); *Lw* - liquid (water-rich).

[b] In *V* and *Lh* phases the mole fraction of methane and butane are given on the dry basis.

COMPONENTS:	ORIGINAL MEASUREMENTS:
1. Methane; CH_4; [74-82-8]	McKetta, J. J.; Katz, D. L.
2. Butane; C_4H_{10}; [106-97-8]	*Ind. Eng. Chem.*
3. Water; H_2O; [7732-18-5]	<u>1948</u>, *40*, 853-862.

EXPERIMENTAL VALUES:

Experimental data in the two-phase region.

T/K (T/°F)	P/MPa (P/psi)	Phase[c]	x_{CH_4}	Mole fraction[d] $x_{C_4H_{10}}$	x_{H_2O}
310.9	24.27	Fh	0.7360	0.2640	0.000656
(100)	(3520)	Lw	0.00259	0.00011	0.9973
	20.66	Fh	0.7325	0.2675	0.00065
	(2996)	Lw	0.002414	0.000086	0.9975
	13.78	Fh	0.7310	0.2690	0.000804
	(1998)	Lw	0.01868	0.000032	0.9981
	20.66	Fh	0.0896	0.9104	0.000639
	(2996)	Lw	0.00081	0.00169	0.9975
344.3	20.81	Fh	0.6300	0.3700	0.00274
(160)	(3018)				
	14.12	Fh	0.6302	0.3698	0.00328
	(2048)	Lw	0.001682	0.000068	0.99825
	20.33	Fh	0.795	0.2005	0.00270
	(2948)	Lw	0.002158	0.000062	0.99778
	13.71	Fh	0.7996	0.2004	0.00339
	(1988)	Lw	0.001724	0.000026	0.99825
	20.67	Fh	0.1905	0.8095	0.00254
	(2998)	Lw	0.00132	0.0009	0.99778
	13.72	Fh	0.1874	0.8126	0.00316
	(1990)	Lw	0.00107	0.00068	0.99825
377.6	20.67	Fh	0.4915	0.5085	0.00795
(220)	(2998)	Lw	0.00208	0.00024	0.99768
	13.78	Fh	0.4945	0.5055	0.01056
	(1999)	Lw	0.00158	0.00158	0.99825
	20.66	Fh	0.0908	0.9092	0.00718
	(2996)	Lw	0.00073	0.00173	0.99754
410.9	20.67	Fh	0.2190	0.7810	0.0193
(280)	(2998)	Lw	0.00157	0.00083	0.9976
	13.78	Fh	0.2190	0.7810	0.0253
	(1999)	Lw	0.00113	0.00063	0.99824
	20.67	Fh	0.0765	0.9235	0.0177
	(2998)	Lw	0.00061	0.00184	0.99755

[c] *Fh* - fluid phase.

[d] In the fluid phase the mole fraction of methane and butane are given on the dry basis.

COMPONENTS:	ORIGINAL MEASUREMENTS:
(1) Methane; CH_4; [74-82-8]	Froning, H. R.; Jacoby, R. H.; Richards, W. L.
(2) Carbon dioxide; CO_2; [124-38-9]	
(3) Hydrogen sulfide; H_2S; [7783-06-4]	*Proc., Ann. Conv., Nat. Gasoline Assn. Am., Tech. Papers* 1963, 42, 32-9.
(4) Water; H_2O; [7732-18-5]	*Chem. Abstr.* 1963, 59, 10812c.

EXPERIMENTAL VALUES:

Temperature		Total Pressure		Vapor Composition			Liquid Composition		
				CH_4	CO_2	H_2S	CH_4	CO_2	H_2S
$t/°F$	T/K	$p/psia$	p/MPa	y_1	y_2	y_3	$10^4 x_1$	$10^3 x_2$	$10^3 x_3$
85	302.6	60	0.41	0.6026	0.1928	0.1945	0.55	0.406	1.221
		252	1.74	0.0	0.5320	0.4656	0.0	4.690	11.54
		256	1.79	0.6145	0.1058	0.2774	2.41	0.960	7.448
		256	1.79	0.6340	0.1793	0.1844	2.48	1.570	4.878
		1002	6.91	0.9435	0.01498	0.04088	12.63	0.416	3.068
		1003	6.92	0.6324	0.08595	0.2810	9.43	2.275	19.99
		1006	6.94	0.9489	0.02538	0.02508	12.51	0.689	1.819
		1008	6.95	0.5985	0.1984	0.2025	8.36	5.035	13.77
100	310.9	15.2	0.105	0.6340	0.1926	0.1109	0.13	0.074	0.119
		17.3	0.119	0.0	0.4658	0.4794	0.0	0.252	0.635
		63	0.43	0.6183	0.2725	0.09406	0.58	0.553	0.555
		251	1.73	0.6158	0.1974	0.1831	2.15	1.473	4.138
		252	1.74	0.0	0.5331	0.4632	0.0	3.787	10.09
		256	1.77	0.0	0.2994	0.6969	0.0	2.215	15.48
		258	1.78	0.5979	0.05191	0.3465	2.13	0.408	7.727
		258	1.78	0.6130	0.09286	0.2904	2.25	0.732	7.265
		263	1.81	0.6392	0.04374	0.3135	2.40	0.393	8.276
		268	1.85	0.6171	0.08221	0.2971	2.20	0.732	7.662
		991	6.83	0.8421	0.08582	0.07113	9.90	1.935	4.852
		994	6.85	0.9381	0.01539	0.04546	12.83	0.395	3.140
		1002	6.91	0.9330	0.05185	0.01409	10.92	1.300	1.060
		1005	6.93	0.6093	0.04486	0.3449	8.04	1.048	21.181
		1006	6.94	0.5999	0.1894	0.2097	7.68	4.205	12.663
		1006	6.94	0.9482	0.02608	0.02478	11.74	0.615	1.696
		1011	6.97	0.5922	0.3075	0.09931	7.23	6.471	6.327
		1012	6.98	0.6103	0.08742	0.3013	7.91	1.947	18.475
		1014	6.99	0.9482	0.00879	0.04026	11.98	0.229	3.079
		1015	7.00	0.8284	0.05461	0.1161	10.22	1.274	7.506
115	319.3	64	0.44	0.6047	0.1939	0.1784	0.45	0.304	0.895
		254	1.75	0.0	0.5162	0.4780	0.0	3.119	9.037
		256	1.77	0.6384	0.09117	0.2647	2.09	0.589	5.340
		257	1.77	0.6820	0.1751	0.1372	2.20	1.103	2.719
		989	6.82	0.9477	0.01508	0.03575	10.34	0.294	2.209
		994	6.85	0.8605	0.06820	0.06980	9.42	1.544	4.057
		999	6.89	0.6152	0.08567	0.2977	7.22	1.638	16.68
		1012	6.98	0.6092	0.1895	0.1997	6.88	3.613	11.02
		1014	6.99	0.5987	0.04504	0.3548	7.06	0.861	18.74

The compositions are mole fraction. The water mole fraction in each phase can be obtained by difference.

The paper also gave values of the equilibrium ratio, $K = y_i/x_i$, for each gas at each temperature and pressure of measurment, and values of the total acid gas in the gas phase, $AG = y_2 + y_3$, and the gas phase ratio, $R = y_3/(y_2 + y_3)$.

The equilibrium ratios for each gas were correlated by equations which were a function of $t/°F, p/psia$, AG, and R. The equations are given on the following page.

COMPONENTS:	ORIGINAL MEASUREMENTS:
(1) Methane; CH_4; [74-82-8] (2) Carbon dioxide; CO_2; [124-38-9] (3) Hydrogen sulfide; H_2S; [7783-06-4] (4) Water; H_2O; [7732-18-5]	Froning, H. R.; Jacoby, R. H.; Richards, W. L. *Proc., Ann. Conv., Nat. Gasoline Assn. Am., Tech. Papers* <u>1963</u>, *42*, 32-9. *Chem. Abstr.* <u>1963</u>, *59*, 10812c.

VARIABLES: $T/K = 302.6 - 319.3$ $p_t/MPa = 0.105 - 7.00$	PREPARED BY: H. L. Clever

ADDITIONAL DATA AND COMMENTS:

The data were correlated to obtain the following equations for the equilibrium ratios as functions of $t/°F$, $p_t/psia$, AG, and R. AG and R were defined on the previous page.

$$K_{CH_4} = y_1/x_1 = 306{,}000/(p_t/psia) + 2.19(t/°F) + 3910(t/°F)/(p_t/psia)$$
$$-145.0\ AG - 121.6\ R$$

$$K_{CO_2} = y_2/x_2 = -3500/(p_t/psia) + 0.12(t/°F) + 360.0(t/°F)/(p_t/psia)$$
$$+ 8.30\ AG - 5825\ R/(p_t/psia)$$

$$K_{H_2S} = y_3/x_3 = 4.53 - 1087/(p_t/psia) + 110.4(t/°F)/(p_t/psia) + 4.65\ AG$$

The authors calculate equilibrium ratios, K, for the gas + water systems. To obtain the values the following AG and R values are used.

Methane + water   AG infinitesimal, R = 0.5

Carbon dioxide   AG = 1, R = 0
+ Water
Hydrogen sulfide AG = 1
+ Water

The objective of the study was to evaluate composition effects on K values. For methane the prescence of the acid gases increases the methane solubility in water. At 1000 psia K decreases 6 % as AG increases from 2.5 to 40 % and decreases 9 % as R changes from 0.2 to 0.8.

AUXILIARY INFORMATION

METHOD/APPARATUS/PROCEDURE:	SOURCE AND PURITY OF MATERIALS:
Equilibrium was attained in a 6.6 liter stainless steel bomb equiped with ports to sample both the gas and liquid phases. The systems was evacuated, 1.6 liters of distilled water was drawn in. The gases were added in the order hydrogen sulfide, carbon dioxide and methane. Each gas was added to a predetermined pressure to obatin the desired concentration. The bomb was gently rocked at 7 oscillations per minute in a thermostated bath. Equilibrium was attained in about 30 minutes, the usual mixing time was 60 minutes. Both vapor and liquid phases were sampled. The vapor phase was analyzed on a dry basis by mass spectrometry. The liquid phase was extracted and analyzed by mass spectrometry.	(1) Methane. Described as "pure grade". (2) Carbon dioxide. Described as "bone dry". (3) Hydrogen sulfide. Described as "purified'. (4) Water. Distilled.
	ESTIMATED ERROR: $\delta t/°F = \pm 0.1$ The correlating equations reproduce the data within ± 4 percent.
	REFERENCES: