

Figure 3. Comparison of correlated and experimental solubilities.

such compounds one procedure is to calculate γ for the PNA of equal carbon number, then multiply this value by about 2.0, effectively halving the solubility. An alternative procedure is to follow the approach of Pierotti et al. (5) and calculate the activity coefficient of the parent (unsubstituted) hydrocarbon for alkylbenzenes, then increase log γ by 0.622, i.e., a factor of 4.2 on γ , for each alkyl carbon present. The correlation obtained is shown in Figure 2 and has the form

 $\log \gamma_{\rm w}^{\infty} = 3.5055 + 0.3417(N-6) - 0.002640(N-6)^2 \quad (4)$

where N is carbon number. Correlated and experimental values of solubility excluding the alkyl subsituted naphthalenes and anthracenes are compared in Figure 3. The average deviation in log solubility is about 0.26 which corresponds to a factor of 1.8 but in some cases the deviation may be as high as a factor of 3. Although these deviations are large, the calculated solubilities are sufficiently accurate for many environmental calculation purposes. Since the correlation extends over 5 orders of magnitude and uses only carbon number and melting point, the accuracy is regarded as satisfactory. More accurate correlations will probably be developed when more thermal, solubility, and volumetric data are available for these compounds.

In conclusion, aqueous solubility data have been obtained for 32 PNA and indan. For approximate solubility estimation, the best procedure presently available for liquid hydrocarbons is to calculate γ_w^{∞} from eq 4. The mole fraction solubility is then the reciprocal of γ_w^{∞} . For solid hydrocarbons (i.e., melting point above 25 °C) γ^{∞} can be calculated from eq 4, ($f_{\rm s}/f_{\rm r}$) from eq 3, and the solubility then calculated from eq 2. For alkyl-substituted naphthalenes or anthracenes the correlated solubilities are about double the experimental values and a correction of this magnitude is needed for such compounds.

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Vapor-Liquid Equilibrium of the Methane-n-Hexane System at Low Temperature

Yueh-Neu Lin, Roger J. J. Chen, Patsy S. Chappelear, and Riki Kobayashi*

Department of Chemical Engineering, William Marsh Rice University, Houston, Texas 77001

Measurements of the bubble-point compositions are reported and combined with earlier dew-point data from this laboratory to give K values for the methane-n-hexane system at seven temperatures, 0, -25, -50, -63, -75, -80, and -82.65 °C, from 20 up to 2675 psia. The data may also be evaluated isobarically without interpolation. Two liquid phases were observed in the temperature region between -77.24 (UCST) and -90.69 °C (LCST); detailed composition measurements were made over this entire three-phase region and associated two-phase regions at a total of five temperatures. Equilibrium constants are reported for all three binaries encountered: G-L1, G-L2, and L₁-L₂.

A number of studies of the vapor-liquid equilibrium of the methane-n-hexane binary system have been reported in the literature. Both liquid and gas phases were studied by Boomer and Johnson (1) at 25, 55, and 85 °C and by Poston and McKetta (9) over the range 100-340 °F. The lowest temperatures were

studied by Shim and Kohn (11) in the range -110 to 150 °C, but they did not measure dew points below 0 °C or any bubble points near the critical pressure. Shim and Kohn did not report the two liquid phases existing at temperatures between -77.24 and -90.69 °C. Davenport and Rowlinson (7) reported, in a study of hydrocarbon solubilities in methane, that the methane-nhexane system exhibited limited immiscibility, with an LCST of -90.6 °C. Earlier dew point studies in this laboratory (5) defined the three-phase region.

Experimental K values, obtained by combining the vaporphase measurements of the elution method (5) with those obtained for the liquid phases by use of gas chromatography measurements, are presented here for the CH₄-*n*-C₆H₁₄ binary system. Equilibrium constants k between the liquids for each component in this system are also evaluated.

Experimental Method and Procedure

The recycle equilibrium apparatus is the same as used by Elliot et al. (8) in the methane-n-butane investigation with some modifications. The boiling point of *n*-hexane is 68.95 °C.

Table I. Comparison of Dew Points Measured by the Elution and Chromatographic Methods

T . 00	_	-	Methane m	ole fraction
(°F)	Pressure, psia	Pressure, Pressure, psiakPa ^b		ya
0.01				
(32.02)	20.1	138.58	0.9550	0.9558
	25.1	173.06	0.9623	0.9643
	50.1	345.43	0.9804	0.9815
	100.1	690.16	0.9872	0.9898
	150.1	1034.90	0.9916	0.9927
-50.00	1600	11032	0.9890	0.9841
(-58.00)				

^a Experimental "elution" dew-point data from Chen et al. (5). ^b Pa: Pascal = kg/m s² = N/m²; 1 psia = 6.8947 kPa.

Therefore the problem of nonhomogeneous evaporation of the liquid phase in the sample line was more pronounced in this work than those encountered in the methane–*n*-butane (β) and methane–*n*-pentane systems (β). The temperature of the sampling lines was kept at more than 100 °C to transform and keep the sample in the vapor phase at essentially atmospheric conditions. A stirred pot with a volume of approximately 150 mL was used to homogenize the sample of the liquid phase (as a vapor) by mixing.

The experimental equipment and technique for the dew-point concentration data have been reported in detail in earlier publications (3-5) which should be consulted for itemized information.

In this bubble-point concentration investigation, a Barber-Coleman Gas Chromatograph Series 5000 Selecta System with flame ionization detection was used for analysis. The chromatographic column was a 4-ft length of $\frac{1}{8}$ in. o.d. stainless steel tubing packed with 80–100 mesh Duropak (OPN/PORASIL C). Helium was used as a carrier gas. The flow rates of air and hydrogen were determined to give maximum response. Sample was introduced into the sample loop and then bubbled through a water column to indicate the flow rate of the sample. The signal from the detector was integrated by an Autolab Model 6300 digital integrator and recorded on a Leeds and Northrup strip chart recorder. Peak areas were calibrated by preparing gravimetric samples in sample bombs. The calibration was continually checked during the course of the entire study.

The pressure in the system was indicated by three (0-300, 0-1000, 0-4000 psia) Heise gages with accuracy 0.1% of the full scale reading.

Temperature was measured by a Leeds and Northrup certified platinum resistance thermometer and reported on the IPTS (1968) scale.

The experimental procedure was the same as used by Elliot. The isotherms were investigated in order of decreasing temperature and increasing pressure. In addition, after an isotherm was completed, additional points were sometimes verified on later dates to verify the consistency of the measurements and to fill the regions of uncertainty.

The bubble-point data were taken after completion of the dew-point investigation. Several experimental dew points were also measured here chromatographically to check the consistency of both experimental procedures. These points, which agreed within the combined accuracy of both experimental procedures, are tabulated in Table I.

An average of 3 h was required to attain steady state, after which at least six analyses were made.

Materials Used

Ultrahigh purity methane with a purity of 99.97 mol % minimum, manufactured by Union Carbide Chemicals Corp., was purchased from IWECO. Research grade *n*-hexane (99.99%) was provided by Phillips Petroleum Co. and was used without further purification. A Model 451 A high-pressure purifier cartridge manufactured by Matheson Gas Products was used in the methane line to remove traces of oil, water, and particles down to approximately 12 μ .

Error Analysis

The error analysis is the same as Elliot's work because the same equipment and experimental procedure technique were used.

The contributing factors are temperature, controlled to 0.02 °C; pressure, measured by Heise gauges calibrated to 0.1% of full scale and controlled within 1 psi; and concentration, determined by chromatography from peak area ratios calibrated to a maximum error of 2% or 0.005 in mole fraction. The vast majority of the data are valid to four significant figures.

The overall error in the dew-point data is either less than 2% or 0.000 01 in mole fraction of *n*-hexane, depending on which is larger.

The maximum error in the resulting K values is 2%.

Results

Experimental results are shown in three tables.

Table I gives the dew points measured by both elution and chromatography methods for comparison purposes. The agreement is satisfactory.

Table II presents all experimental data except in the temperature-pressure region in which only two liquids exist without presence of vapor. The dew points and bubble points are shown along with limiting conditions. Equilibrium constants *K* are calculated for each component where data are available. Note that this table includes vapor-liquid equilibrium constants at the three-phase conditions. We define these by subscripts on the *K* to indicate the phases for which the *K* is calculated, with the third phase indicated outside parentheses. Thus, $(K_{GL_2})_{L_1}$ indicates the vapor-liquid equilibrium constant between the gas G and liquid phase L₂ rich in heavy component (*n*-hexane) with light liquid L₁ rich in light component (methane) present.

The compositions of the two liquids in equilibrium with each other with no vapor present are shown in Table III. Equilibrium constants, κ , defined as the ratio of concentrations of each component in the two liquids, are also reported in this table. Note that the first value at the lowest pressure in each isotherm is at the three-phase condition; hence these values are $(\kappa_{L_1L_2})_{G}$.

The pressure-composition behavior is given in Figure 1. Note that at -77.24 °C, which is the upper critical solution temperature (UCST), light liquid (L₁) is equal to vapor (G) at p = 755 psia. For p > 755 psia, light liquid (L₁') is in equilibrium with heavy liquid (L₂). At -90.69 °C, which is the lower critical solution temperature (LCST), light liquid (L₁') is equal to heavy liquid (L₂) at 495.3 psia. For p > 495.3 psia, light liquid (L₁) is in equilibrium with gas (G).

At any given temperature τ between the UCST and LCST, there exists a single fixed pressure Π at which all three phases are present at the same time. At τ for pressures greater than Π up to the respective criticals, only two phases are allowed: L₁-G or L₁'-L₂ depending on the total composition in the equilibrium cell.

In Figure 1, the dashed isobaric lines connect the three phase concentrations, which are equilibrium tie lines for that particular three-phase equilibrium. The dot-dash lines are the loci for L_2 and L_1 with vapor G present. This is a quantitative determination of the schematic Figure 1 lines L_1 and L_2 of ref 7. We must note, however, that we do not agree with the statement in the legend of Figure 1 (7) that "Seven of the curves shown in Fig. 3 are the projections of the liquid-phase boundary curves L_1PL_2 ." These values in Figure 3 of ref 7 must rather be $G-L_2$ equilibria at concentrations of methane less than the concentration of the LCST and be $G-L_1$ equilibria at concentrations of methane

Table II.	Experimental Data of	the Vapor-Li	quid Equilibrium	of the Methane-	n-Hexane System

x methane [#]	y methane ^b	psia	kPa ^{.c}	K methane	K n-hexane
	$T = 0.01 ^{\circ}\text{C} = 3$	2.02 °F = 273.16 K	= 427.65 °R		
0.0000	0.0000	0.83 ^d	5.72	1120 °	1.000
0.0097	0.9643	25.1	173.1	99.41	0.03605
0.0196	0.9815	50.1	345.4	50.08	0.1887
0.0387	0.9898	100 1	690.2	25 58	0.01061
0.0507	0.00066	100.1	1094.0	20.00	0.01001
0.0507	0.99266	150.1	1034.9	17.51	0.007781
0.0744	0.99396	200.1	1379.6	13.36	0.006525
0.1116	0.99528	300.1	2069.1	8.918	0.005313
0.1469	0.99566	400.1	2758.6	6.778	0.005087
0.2127	0.99578	600	4136.8	4.682	0.005360
0.2742	0.99549	800	5515.8	3 63 1	0.006214
0 3328	0.99465	1000	6894 7	2 080	0.008019
0.0020	0.00040	1000	0034.7	2.505	0.000013
0.3880	0.99343	1200	82/3./	2.556	0.01075
0.4435	0.99166	1400	9652.6	2.236	0.01499
0.4924	0.9891	1600	11032	2.009	0.02147
0.5400	0.9849	1800	12410	1.824	0.03283
0.5933	0.9797	2000	13789	1.651	0.04991
0.6401	0.9692	2200	15169	1514	0.08558
0.0401	0.9092	2200	15100	1,514	0.06556
0.6564		2300	15857		
0.6949	0.9565	2400	16547	1.376	0.1426
0.7195		2500	17237		
0.7462	0.9400	2550	17582	1.260	0,2364
0.7758	0.0366	2800	17026	1 007	0.2004
0.7756	0.9300	2000	17920	1.207	0.2626
0.8025	0.93487	2650	18271	1.165	0.3301
0.9290	0.9290	2675 <i>h</i>	18443	1.000	1.000
	T - 05	01 °O - 10 00 °F	- 040 14 K - 440 05	°n	
0.000	7 = -25.	$01^{-0} = -13.02^{-1}$	= 248.14 K = 440.03	0 ° K	4 0000
0.000	0.0000	0.16	1.1032	8800 -	1.0000
0.009486	0.98990	20.1	138.58	104.4	0.01020
0.01152	0.99179	25.1	173.06	86.09	0.008306
0.02320	0 99557	50.1	345 43	42.91	0.004535
0.04630	0.00757	100.1	600.16	01 51	0.007000
0.04038	0.99757	100.1	690.16	21.51	0.002546
0.06884	0.99817	150.1	1034.9	14.50	0.001965
0.08998	0.99847	200.1	1379.6	11.10	0.001681
0.1340	0.99872	300.1	2069.1	7.453	0.001478
0 1819	0 99879	400 1	2758.6	5 491	0.001479
0.0505	0.00863	600.1	4126.0	2 040	0.001950
0.2595	0.99663	000.1	4130.8	3.646	0.001850
0.3347	0.99820	800	5515.8	2.982	0.002706
0.3998	0.99759	1000	6894.7	2.495	0.004015
0.4672	0.99632	1200	8273.7	2.133	0.006907
0.5252	0.99416	1400	9652.6	1.893	0.01230
0.5804	0 99052	1600	11032	1 707	0.02259
0.0004	0.03002	1700	11701	1.01	0.02200
0.0123	0.9869	1700	11/21	1.015	0.02003
0.6382	0.9844	1800	12410	1.542	0.04312
0.6937	0.9752	2000	13789	1.406	0.08097
0.7601	0.9644	2200	15168	1,269	0.1484
0.8191	0 9593	2300	15858	1 171	0 2250
0.0564	0.0564	0007	16119	1 000	1 000
0.3004	0.9304	2337	10113	1.000	1.000
	T=-50.	00 °C = −58.00 °F	= 223.15 K = 401.67	°R	
0.0000	0.0000	0.25 ^d	0.1724	32000 *	1.000
0.01415	0.99841	20.2	139.27	70.56	0.001613
0.01710	0 00972	25.2	179 75	58 A1	0.001202
0.01710	0.33012	20.2	110.10	00.41	0.001302
0.03370	0.999343	50.2	346.12	29.05	0.0006799
0.06372	0.999632	100.2	690.85	15.69	0.0003930
0.09213	0.999713	150.2	1035.6	10.85	0.0003161
0.1218	0.999757	200.2	1380.3	8.211	0.0002767
0 1771	0 999775	300.2	2069 8	5 645	0 0002734
0.0004	0.000765	400.2	0750.0	4 959	0.0002104
0.2294	0.444/22	400.2	2/59.3	4.338	0.0003179
0.3282	0.999594	600	4136.8	3.046	0.0006043
0.4207	0.999256	800	5515.8	2.375	0.001284
0.4952	0.99851	1000	6894.7	2.016	0.002952
0 5893	0 99613	1200	8273 7	1 690	0.009423
0.6510	0.00010	1200	00000	1.000	0.000420
0.0018	0.99013	1400	9052.0	1.519	0.02835
0.7011	0.9871	1500	10342	1.408	0.04316
0.7423	0.9841	1600	11032	1.326	0.06170
0.7774	0.9816	1700	11721	1.263	0.08266
0 8022	0.0010	1750	12066		
0.0022		1750	12000		
0.0189		1775	12238		
0.8444		1790	12342		
0.8522		1800	12410		
0.8922		1803	12431		

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$\begin{split} r = -83.00 \ ^{\circ}\text{C} = -81.40 \ ^{\circ}\text{F} = 210.15 \ \times 378.27 \ ^{\circ}\text{R} \\ 0.0005 1 0.0552 \ 7600^{\circ}\text{ r} \\ 10.0553 \ 0.099485 \ 20.2 \ 139.27 \ 763.95 \ 0.00051 \\ 0.00052 \ 0.099781 \ 50.2 \ 346.12 \ 26.44 \ 0.00022 \\ 0.007307 \ 0.999868 \ 150.2 \ 1005.6 \ 9.284 \ 0.00014 \\ 0.0070 \ 0.999868 \ 150.2 \ 1005.6 \ 9.284 \ 0.00014 \\ 0.0070 \ 0.999868 \ 150.2 \ 1005.6 \ 9.284 \ 0.00013 \\ 0.0070 \ 0.999868 \ 150.2 \ 1005.6 \ 9.284 \ 0.00013 \\ 0.0070 \ 0.999868 \ 100.2 \ 1005.6 \ 9.284 \ 0.00013 \\ 0.0070 \ 0.999868 \ 100.2 \ 1005.6 \ 9.284 \ 0.00013 \\ 0.0070 \ 0.999868 \ 100.2 \ 1005.6 \ 9.284 \ 0.00013 \\ 0.00984 \ 0.000 \ 515.8 \ 1.946 \ 0.00013 \\ 0.00984 \ 0.000 \ 5515.8 \ 1.946 \ 0.00013 \\ 0.00984 \ 0.000 \ 65515.8 \ 1.946 \ 0.00073 \\ 0.0284 \ 1.000 \ 6552.6 \ 1.221 \ 0.0518 \ 1.221 \ 0.0518 \ 1.221 \ 0.0518 \ 1.220 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.0000 \ 1.000 \ 1.000 \ 1.0$	x methane*	y methane ^b	psia	kPac	K methane	K n-hexan
0.000 0.000 0.000* 0.000* 0.000* 0.000* 0.000* 0.000* 0.01867 0.998589 25.2 173.75 55.54 0.000416 0.01867 0.998586 150.2 180.35 13.68 0.00014 0.0737 0.998686 150.2 180.3 7.067 0.00014 0.0179 0.998680 200.2 1380.3 7.067 0.00014 0.0170 0.998680 200.2 1380.3 7.067 0.00014 0.0170 0.999780 400.2 206.8 3.703 0.00014 0.1811 0.999780 400.2 206.8 1.704 0.00014 0.181 1400 9652.4 1.221 0.06181 1.001 1.813 0.99730 1000 6694.7 1.616 0.01732 1.827 0.9872 1420 9760.5 1.221 0.06181 1.827 0.9872 1440 9924.1 1.000 1.000 1.827 0.989		$\tau = -63.0$	00 °C = -81.40 °F	= 210.15 K = 378.27	°R	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.0000	0.0000	0.008 <i>ª</i>	0.0552	76000 <i>°</i>	1.000
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.01563	0.999495	20.2	139.27	63.95	0.0005130
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.01867	0 999589	25.2	179 75	53 5A	0.0004100
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.01007	0.999369	20.2	173.75	55.54	0.0004180
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.03782	0.999781	50.2	346.12	26.44	0.0002276
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.07307	0.999868	100.2	690.85	13.68	0.0001424
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.1079	0.999888	150.2	1035.6	9.264	0.0001256
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0 1411	0 999903	200.2	1380.3	7 097	0.0001120
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.1411	0.333300	200.2	1380.3	1.001	0.0001128
12700 0.999978 400.2 2769.3 3.703 0.000167 1381 0.999786 600 4136.8 2.776 0.000367 15139 0.99970 1000 6894.7 1.818 0.00736 15162 0.99730 1000 6894.7 1.868 0.00736 17156 0.99177 1200 2737.7 1.386 0.02894 18091 0.9882 1400 9652.6 1.221 0.06181 18279 1420 9780.5 1.221 0.06181 1.000 1.000 18273 0.9872 14420 9780.5 1.000	0.2071	0.999894	300.2	2069.8	4.828	0.0001337
3381 0.999768 600 4136.8 2.576 0.00033 5139 0.999402 600 5515.8 1.451 0.00708 7.156 0.99730 1000 6694.7 1.518 0.00234 7.1576 0.99177 1200 8273.7 1.386 0.2824 7.757 1.390 9652.6 1.221 0.05181 3.873 1440 9952.4 0.000 1.000 3.871 1443 9949.1 1.000 1.000 0.9872 1443* 9949.1 1.000 1.000 0.0000 0.0000 0.0002* 0.0158 200000* 1.000 0.01860 0.99948 100.0 684.7 1.041 0.00005 0.01860 0.999895 250.0 137.8 5.515 0.00015 0.0242 0.999895 0.00.0 247.7 0.414 0.00026 0.0442 7.194 0.00026 1.0141 0.00005 0.04422 7.194	0.2700	0.999878	400.2	2759.3	3.703	0.000167
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.3881	0.999798	600	4136.8	2.576	0.000330
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.5139	0 999402	800	5515.8	1 945	0.001230
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.0100	0.003402	1000	0010.0	1.040	0.001200
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.0102	0.99730	1000	6894.7	1.618	0.007036
1776 1300 6863.1 0.06181 18279 1420 9790.5 1.221 0.06181 18279 1420 9790.5 1.221 0.06181 18713 1440 9924.4 1.000 1.000 19872 0.872 1433 9940.5 1.000 1.000 0.0000 0.0002" 0.0138 20000" 1.000 0.0150 0.999843 19.9 172.1 51.28 0.00010 0.04742 0.999955 150.0 1034.2 7.14 0.00000 0.04742 0.999955 150.0 1034.2 7.14 0.00002 13410 0.999955 150.0 1034.2 7.14 0.00016 13412 0.999939 300.0 266.4 3.760 0.00016 15366 0.999832 600.0 4136.8 1.970 0.00016 15376 0.999849 100.0 6243.3 1.644 0.00016 15375 0.99964 700 <td< td=""><td>0.7156</td><td>0.99177</td><td>1200</td><td>8273.7</td><td>1.386</td><td>0.02894</td></td<>	0.7156	0.99177	1200	8273.7	1.386	0.02894
38091 0.9882 1400 9652.6 1.21 0.06181 1420 970.5 1435 9893.9 1435 9893.9 13713 1440 9924.4 1.000 1.000 0.9872 0.9872 1443 ° 9949.1 1.000 1.000 0.0000 0.002" 0.0138 20000° 1.000 0.01850 0.999848 19.9 137.21 51.28 0.000151 0.02438 0.999865 25.0 172.37 41.02 0.000051 0.03600 0.999819 100.0 268.4 3.760 0.000051 0.03600 0.999819 300.0 2068.4 3.760 0.000163 0.3412 0.999819 300.0 2068.4 3.760 0.000163 1.3412 0.999819 300.0 2468.4 3.760 0.000163 1.3412 0.999819 300.0 2468.4 3.760 0.000163 1.5676 0.99572 900 6205.3 1.311 0	0.7576		1300	8963.1		1. Sec. 1. Sec
jazza isola jazza jazza <t< td=""><td>0.8091</td><td>0.9882</td><td>1400</td><td>9652.6</td><td>1 2 2 1</td><td>0.06181</td></t<>	0.8091	0.9882	1400	9652.6	1 2 2 1	0.06181
$\begin{array}{ccccc} 1.225 & 1.225 & 1.225 & 1.205 & 1.2$	0.0001	0.0002	1400	0700 5	1.221	0.00101
18568 1435 9983.9 13713 1440 9928.4 9.872 0.8872 1443 ⁿ 9949.1 1.000 1.000 $T = -75.10$ °C = -103.18 °F = 198.05 K = 356.49 °R 0.0001 0.0002 ^s 0.0138 20000* 1.000 0.0908 0.999846 19.9 137.21 51.28 0.00015 0.04742 0.999927 50.0 344.74 21.09 0.00007 0.09090 0.999949 100.0 668.47 10.41 0.00007 0.0909052 200.0 137.69 5.515 0.00005 0.1813 0.999953 300.0 2066.4 3.760 0.00002 0.2255 0.999849 500.0 3447.4 2.387 0.00123 0.2425 0.999849 500.0 3447.4 2.381 0.00014 0.5156 1.452 0.00015 1.515 1.452 0.00015 0.5476 0.999789 800 5515 0.311 0.0178 0.5165 0.997	0.8279		1420	9790.5		
18713 1440 9926.4 1.000 1.000 $r = -75.10$ °C = -103.18 °F = 198.05 K = 356.49 °R 0.0000 0.0000 0.002° 0.0138 200000° 1.000 0.01950 0.999846 19.9 137.21 51.28 0.00155 0.0243 0.999845 25.0 172.37 41.02 0.00007 0.04742 0.999845 150.0 134.47 1.04 0.00008 0.04603 0.999945 150.0 134.42 7.194 0.00008 0.1340 0.999952 200.0 1376.8 5.51 0.000182 0.1340 0.999913 300.0 2066.4 3.760 0.000182 0.2660 0.999933 500.0 3447.4 2.367 0.000182 0.3412 0.999843 500.0 3447.4 2.367 0.000182 0.3612 0.999843 500.0 3447.4 2.367 0.000182 0.3642 0.99972 900 6205.3 1.311 0.0172 1.5756 0.999640 700 4828.3 1.452 0.00007 0.	0.8568		1435	9893.9		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.8713		1440	9928.4		
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	0.9872	0.9872	1443 ^h	9949.1	1 000	1 000
$T = -75.10 \ {}^{\circ}\text{C} = -103.18 \ {}^{\circ}\text{F} = 198.05 \ {}^{\circ}\text{K} = 358.49 \ {}^{\circ}\text{R}$ $1.000 0.0000 0.0000 0.999848 19.9 37.21 0.0132 0.0999848 0.999848 19.9 37.21 0.132 0.00001 0.999984 0.9999827 50.0 34.47 2.09 0.00007 0.000 0.999985 150.0 1034.2 7.194 0.00005 0.999985 2.200.0 137.8 5.515 0.000012 0.999983 0.00 2.068.4 3.760 0.00002 0.009999 3.00.0 2.068.4 3.760 0.0000 0.0001 2.265 0.999983 0.00 2.068.4 3.760 0.00012 0.0001 2.255 0.99983 0.00 2.068.4 3.760 0.00012 0.0001 2.255 0.99983 0.00 2.068.4 3.760 0.00012 0.0001 2.255 0.99983 0.00 2.068.4 3.760 0.0003 2.10 2.25 0.99983 0.00 2.068.4 3.760 0.0003 2.000 2.000 0.000 $		0.0012		001011	1.000	1.000
Autum U.0000 0.002^{-2} 0.0138 20000^{-9} 1.000 0.01350 0.999848 19.9 137.21 51.28 0.00115 0.02438 0.999849 100.0 689.47 10.41 0.000056 0.04742 0.999955 150.0 1034.2 7.194 0.000056 0.1380 0.999952 200.0 1376.9 5.515 0.000056 0.1313 0.999952 200.0 2068.4 3.760 0.000026 0.3412 0.999919 400.0 2757.9 2.931 0.000126 0.5076 0.9999832 600.0 4136.8 1.970 0.00034 0.5372 0.900 5515.8 1.452 0.00076 0.5676 0.999543 1000 688.47 1.225 0.0300 1.5336 0.99572 900 6205.3 1.311 0.0178 1.5676 0.999544 1050 7239.5 1.000 1.000 1.8468 10557 723.7	0.0000	T = -75.1	$10 ^{\circ}\text{C} = -103.18 ^{\circ}\text{F}$	= 198.05 K = 356.49	"R	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.0000	0.0000	0.002	0.0138	200000	1.000
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.01950	0.999848	19.9	137.21	51.28	0.000155
0.04742 0.999927 50.0 344.74 21.06 0.00007 0.06603 0.999955 150.0 1034.2 7.194 0.00005 0.1813 0.999955 150.0 1034.2 7.194 0.00005 0.1813 0.999952 200.0 1378.9 5.515 0.00005 0.2660 0.9999833 500.0 2447.4 2.387 0.00018 0.2425 0.999883 500.0 3447.4 2.387 0.00018 0.5076 0.999843 500.0 447.4 2.387 0.00018 0.5076 0.999843 1000 6205.3 1.311 0.00184 0.567 0.99979 800 5615.8 1.452 0.0067 0.515 1000 6294.7 1.225 0.3300 1.5832 1000 6294.7 1.225 0.3300 1.5934 0.9945 1000 6394.7 1.200 1.000 1.502 0.39964 1057 723.5 1.000 1.000 <td< td=""><td>0.02438</td><td>0.999885</td><td>25.0</td><td>172.37</td><td>41.02</td><td>0.000118</td></td<>	0.02438	0.999885	25.0	172.37	41.02	0.000118
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0 04742	0 000027	50.0	244 74	21.00	0.0000764
0.00003 0.099955 100.0 699.7 10.11 0.00005 0.1390 0.999955 150.0 1034.2 7.194 0.00005 0.1613 0.999952 200.0 1378.9 5.515 0.00005 0.2660 0.999919 400.0 2757.9 2.931 0.000122 0.4225 0.999832 600.0 4136.8 1.970 0.000341 0.5076 0.999832 600.0 4136.8 1.970 0.000341 0.5672 0.99759 800 5615.8 1.452 0.000675 0.8117 0.999435 1000 6894.7 1.225 0.0300 0.8468 1050 7239.5 1.311 0.178 0.8392 10057 h 7287.7 1.000 1.000 0.20082 20.0 137.89 1.25 0.0304 0.4431 50.0 344.74 1.25 0.0004 1.447 1.50 1034.2 1.447 1.25 0.2008 200.0	0.0000	0.000010	100.0	044.74	21.00	0.0000760
1.1380 0.999955 150.0 1034.2 7.194 0.000055 0.2660 0.999939 300.0 2068.4 3.760 0.000062 0.3412 0.999919 400.0 2757.9 2.931 0.000182 0.4225 0.999832 600.0 4136.8 1.970 0.00038 0.5376 0.999832 600.0 4136.8 1.970 0.00038 0.5376 0.999832 600.0 515.8 1.452 0.00078 0.5372 0.99759 800 5515.8 1.452 0.00078 0.5462 1055 7273.9 1.000 1.000 1.8466 1055 7273.9 1.000 1.000 0.04831 55.0 3.44.74 .0004 .0034.2 0.04831 550.0 3.44.74 .000 .0048 0.02082 20.0 1378.9 .000 .0004 0.0484 50.0 3.44.74 .000 .0004 0.02082 200 1378.9	0.09003	0.999949	100.0	689.47	10.41	0.0000564
)1613 0.999952 200.0 1376.9 5.515 0.000082 0.699939 300.0 2068.4 3.760 0.000082 0.3412 0.999919 400.0 2757.9 2.931 0.000122 0.999832 600.0 4136.8 1.970 0.000341 1.5236 0.999640 700 4226.3 1.684 0.000845 0.6872 0.99759 800 5615.8 1.452 0.00675 0.7596 0.999752 900 6205.3 1.311 0.0178 0.8468 1050 7.239,5 1.8468 1055 7.273.9 1.8468 1055 7.273.9 1.99364 0.99364 1057 h 7.277.7 1.000 1.000 7 = -77.24 $^{\circ}$ C = -107.03 $^{\circ}$ F = 195.91 K = 352.64 $^{\circ}$ R 0.0000 $T = -77.24 {}^{\circ}$ C = -107.03 $^{\circ}$ F = 195.91 K = 352.64 $^{\circ}$ R 0.0000 $T = -77.24 {}^{\circ}$ C = -107.03 $^{\circ}$ F = 195.91 K = 352.64 $^{\circ}$ R 1.000 1.000 689.47 1.000 1.000 689.47 1.000 1.000 1.000 1.000 1.000 1.000 7 = -77.24 $^{\circ}$ C = -107.03 $^{\circ}$ F = 195.91 K = 352.64 $^{\circ}$ R 1.0000 0.007° 0.048 1.04831 50.0 344.74 1.05528 100 689.47 1.447 150 1034.2 1.1449 200 1378.9 1.2688 300 2068.4 1.3555 400 2757.9 1.4429 500 344.74 1.5323 600 4136.8 1.4429 500 344.74 1.5323 600 4136.8 1.6422 700 426.3 1.7177 0.99763 7.55 525.5 1.390 0.00840 $T = -80.00 {}^{\circ}$ C = -112.00 ${}^{\circ}$ F = 193.15 K = 347.60 ${}^{\circ}$ R 0.0000 0.00096 20.1 138.58 45.25 0.000097 1.000 0.0012 0.099964 100.1 690.16 10.04 0.000040 0.00240 0.999952 25.1 173.06 36.65 0.000096 1.000 0.0012 0.099964 100.1 690.16 10.04 0.000040 0.2851 0.999950 20.1 344.74 2.129 0.000124 1.6897 0.999932 55.1 1.390 0.00840 1.5802 0.999843 692' 4.771.2 1.381 0.00240 1.5802 0.999843 692' 4.771.2 1.381 0.00240 1.99944 0.999933 692' 4.771.2 1.381 0.00240 1.999841(L_1) 0.999833 692' 4.771.2 1.381 0.00240 1.9998(2) 0.999567 675 4653.9 1.1448 0.00140 1.9914(L_1) 0.998933 692' 4.771.2 1.381 0.00240 1.9998(2) 0.999567 675 4653.9 1.1448 0.00140 1.9914(L_1) 0.998933 692' 4.771.2 1.31 0.0446 1.9914(L_1) 0.998933 692' 4.771.2 1.381 0.00240 1.9998(2) 0.999567 0.78' 4881.5 1.000 1.1000 1.000 1.0000 0.0003^{\circ} 0.00641 35000 $^{\circ}$ 1.000 1.000 1.0000 0.0003^{\circ} 0.00641 35000 $^{\circ}$ 1.000 1.000 1.0000 0.0003^{\circ} 0.00641 35000 $^{\circ}$ 1.000 1.000 1.00000 0.0003^{\circ}	0.1390	0.999955	150.0	1034.2	7.194	0.0000523
1.2660 0.999393 300.0 2086.4 3.760 0.000023 0.3412 0.99919 400.0 2757.9 2.931 0.000123 0.4225 0.999833 500.0 3447.4 2.367 0.000185 0.5076 0.999832 600.0 4136.8 1.970 0.00035 0.5836 0.999540 700 4826.3 1.684 0.000865 0.5676 0.99572 900 6205.3 1.311 0.0175 0.5176 0.995435 1000 6894.7 1.225 0.0300 0.8468 1050 7233.5 0.0300 1.000 1.000 0.8932 1005 723.9 0.0481 0.0481 0.0481 0.0481 0.0481 0.0481 0.0481 0.0481 0.00147 0.048 0.0086 9.0000* 0.00840 1.000 1.000 0.00840 1.000 0.00840 1.000 0.00840 1.000 0.00840 1.000 0.00840 1.000 0.00840 1.000 0.0	0.1813	0.999952	200.0	1378.9	5.515	0.0000586
Actor Cost of the second	0 2660	0 999939	300.0	2068.4	3 760	0.000083
1.3412 0.999819 40.0 2/2/19 2.931 0.00012 1.4225 0.999833 500.0 3447.4 2.367 0.000186 1.5076 0.999832 600.0 4136.8 1.970 0.000386 1.5076 0.999840 700 4826.3 1.684 0.000866 1.6872 0.99789 800 5515.8 1.452 0.00077 1.5117 0.99435 1000 6894.7 1.225 0.0300 1.848 1055 7273.9	0.2000	0.3333333	400.0	2000.4	3.700	0.000000
1.4225 0.999833 500.0 3447.4 2.367 0.00018 1.5576 0.999832 600.0 4136.8 1.970 0.000341 1.5836 0.999640 700 4826.3 1.684 0.000845 0.6872 0.99769 800 5515.8 1.452 0.00675 7.556 0.99572 900 6205.3 1.311 0.0178 1.8117 0.99435 1000 6894.7 1.225 0.0300 1.8466 1050 7239.5 1.000 1.000 1.000 1.99364 0.99364 1057 h 7287.7 1.000 1.000 1.0000 0.0070' 0.048 0.02082 20.0 137.89 1.0000 0.0072' 0.044 0.034.2 1.1407 150 1034.2 1.1407 150 1034.2 1.1407 150 1.034.8 1.523 1.2698 300 2065.5 1.390 0.00840 7 1.2429 500 3.447.4 2.129 0.0000* 1.000 1.02210 0.999632	0.3412	0.999919	400.0	2757.9	2.931	0.000123
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.4225	0.999893	500.0	3447.4	2.367	0.000185
0.5936 0.999640 700 4826.3 1.664 0.000866 0.6972 0.99779 600 5515.8 1.452 0.00075 0.59172 900 6205.3 1.311 0.0175 0.8468 1050 7239.5 0.000 0.0000 0.8932 1055 7273.9 0.000^{-7} 0.048 0.99364 0.99364 1057^{h} 7287.7 1.000 1.000 0.0000 0.007^{-7} 0.048 0.000^{-7} 0.048 0.000^{-7} 0.048 0.0000 0.007^{-7} 0.048 0.007^{-7} 0.048 0.0552 0.000^{-7} 0.048 0.0052 20.0 137.89 0.0484 $0.068.4$ 0.0552 0.00840 0.1849 200 1376.9 0.00840 0.00840 0.00840 0.4822 700 4826.3 1.900 0.00040^{-7} 0.00890^{-7} 0.0000^{-7} 0.0000^{-7} 0.0000^{-7} 0.0000^{-7} 0.0000^{-7} 0.00000^{-7} 0.00000^{-7}	0.5076	0.999832	600.0	4136.8	1.970	0.000341
0.8672 0.99789 800 5515.8 1.452 0.0000 0.99789 800 5515.8 1.452 0.0007 0.99364 0.99572 900 6205.3 1.311 0.0178 0.8468 1050 7239.5 0.0300 1.000 1.000 0.8468 1057 723.9 0.0007 0.048 0.99364 0.977 723.7 1.000 1.000 0.0000 0.007 0.048 0.008 1.000 0.0202 20.0 137.89 0.0481 1.000 0.0431 50.0 344.74 0.0086.4 1.3555 1.0407 150 1034.2 1.1407 1.4429 500 3447.4 1.555 400 2757.9 1.4429 500 3447.4 1.000 1.6422 700 4826.3 1.000 1.000 1.000 0.2210 0.999905 20.1 138.58 45.25 0.000097 0.02210 0.999905	0.5936	0 999640	700	4826 3	1 684	0.000886
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.6070	0.00780		-020.0	1.004	0.000000
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.0872	0.99789	800	5515.8	1.452	0.00675
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.7596	0.99572	900	6205.3	1.311	0.0178
0.8468 1050 7239,5 0.8932 1055 7273.9 0.99364 0.99364 1057 ^h 7287.7 1,000 1.000 $T = -77.24^{\circ} C = -107.03^{\circ} F = 195.91 K = 352.64^{\circ} R$ 0.000 0.007 ^d 0.048 0.0000 0.007 ^d 0.048 0.048 0.09528 0.04831 0.00528 100 689.47 1.1407 150 1034.2 0.1449 200 1378.9 2.2688 300 2.068.4 0.2688 300 2.068.4	0.8117	0.99435	1000	6894.7	1.225	0.0300
1050 1250,0 1055 7273,9 0.99364 1057 n 7287.7 1,000 1,000 T = -77.24 °C = -107.03 °F = 195.91 K = 352.64 °R 0,007 d 0.048 0.0000 0.007 d 0.048 0.048 0.02082 20.0 137.89 0.04831 0.09528 100 689.47 1.1407 150 1034.2 1.1407 150 1034.2 1.1407 150 1034.2 1.849 200 1378.9 1.2555 1.390 0.00840 5.323 600 4136.8 1.5422 700 4826.3 1.000 1.7177 0.99763 755' 5205.5 1.390 0.00840 T = -80.00 °C = -112.00 °F = 193.15 K = 347.60 °R 1.000 1.000 0.000840 1.000 0.02210 0.999905 20.1 138.58 45.25 0.000097 0.02228 0.999932 25.1 173.06 36.65 0.000042 0.02240 0.999932 500.1 3447.4 2.129 0.00140 0.2251 0.999933<	0 8468		1050	7239 5	•	
1093 1273.9 0.99364 0.99364 1057° 7287.7 1.000 1.000 $T = -77.24 ^{\circ}C = -107.03 ^{\circ}F = 195.91 K = 352.64 ^{\circ}R$ 0.0000 0.007° 0.048 0.0000 0.007° 0.048 0.00262 20.0 137.89 0.04831 50.0 344.74 0.09528 1000 689.47 0.1447 150 1034.2 $0.137.89$ 0.2698 300 2068.4 0.2698 300 2068.4 0.00840 0.00840 0.4422 500 3447.4 0.00840 0.5323 600 4136.8 0.00840 0.7177 0.99763 755° 5205.5 1.390 0.00840 0.0000 0.0000° 0.0013° 0.00286 280000° 1.000 0.02210 0.9999905 20.1 138.58 45.25 0.000042 0.2728 0.9999922 250.1 136.68 1.723 0.00042 0.89802 0.999833 692°	0.0000		1055	7203.0		
1,99364 0,99364 1057" 7287.7 1,000 1,000 $T = -77.24 °C = -107.03 °F = 195.91 K = 352.64 °R 0.048 0.007" 0.048 0.0000 0.007" 0.048 0.048 0.02082 20.0 137.89 0.048 0.09528 100 689.47 1.107 1.1407 150 1034.2 1.108 1.849 200 1378.9 .2688 3.00 2068.4 .300 2068.4 1.6422 700 4826.3 $	0.0932		1055	7273.9		
$T = -77.24 \ ^{\circ}\text{C} = -107.03 \ ^{\circ}\text{F} = 195.91 \ \text{K} = 352.64 \ ^{\circ}\text{R}$ $0.0000 \qquad 0.007^{d} \qquad 0.048$ $0.02082 \qquad 20.0 \qquad 137.89$ $0.04831 \qquad 50.0 \qquad 344.74$ $0.09528 \qquad 100 \qquad 689.47 \qquad$ $1.407 \qquad 150 \qquad 1034.2$ $0.1849 \qquad 200 \qquad 1378.9$ $0.2698 \qquad 300 \qquad 2068.4 \qquad$ $1.3555 \qquad 400 \qquad 2757.9 \qquad$ $1.4229 \qquad 500 \qquad 3447.4 \qquad$ $1.5323 \qquad 600 \qquad 4136.8 \qquad$ $1.6422 \qquad 700 \qquad 4826.3 \qquad$ $1.7177 \qquad 0.99763 \qquad 755' \qquad 5205.5 \qquad 1.390 \qquad 0.00840$ $T = -80.00 \ ^{\circ}\text{C} = -112.00 \ ^{\circ}\text{F} = 193.15 \ \text{K} = 347.60 \ ^{\circ}\text{R} \qquad$ $1.000 \qquad 0.0000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000^{\circ} \qquad 1.000 \qquad$ $1.000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000^{\circ} \qquad 1.000 \qquad$ $1.000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000^{\circ} \qquad 1.000 \qquad$ $1.000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000^{\circ} \qquad 1.000 \qquad$ $1.000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000^{\circ} \qquad 1.000 \qquad$ $1.000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000^{\circ} \qquad 1.000 \qquad$ $1.000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000^{\circ} \qquad 1.000 \qquad$ $1.02210 \qquad 0.999905 \qquad 20.1 \qquad 1.38.58 \qquad 45.25 \qquad 0.000096 \$ $0.09964 \qquad 0.999964 \qquad 100.1 \qquad 690.16 \qquad 10.04 \qquad 0.000044 \$ $2.851 \qquad 0.999932 \qquad 50.1 \qquad 3.447.4 \qquad 2.129 \qquad 0.000128 \$ $0.6697 \qquad 0.999932 \qquad 500.1 \qquad 3.447.4 \qquad 2.129 \qquad 0.000128 \$ $0.6992 \qquad 0.999630 \qquad 600 \qquad 4.136.8 \qquad 1.723 \qquad 0.000422 \$ $0.5802 \qquad 0.999930 \qquad 6902 \qquad 4.771.2 \qquad 1.381 \qquad 0.00220 \$ $1.6864 (L_1) \qquad 0.998933 \qquad 692' \qquad 4.771.2 \qquad 1.013 \qquad 0.0446 \$ $1.9914 (L_1) \qquad 0.98933 \qquad 692' \qquad 4.771.2 \qquad 1.013 \qquad 0.0446 \$ $1.9914 (L_1) \qquad 0.989933 \qquad 692' \qquad 4.771.2 \qquad 1.013 \qquad 0.0446 \$ $1.9914 (L_1) \qquad 0.989933 \qquad 692' \qquad 4.771.2 \qquad 1.013 \qquad 0.0041 \$ $1.9914 (L_1) \qquad 0.998933 \qquad 692' \qquad 4.771.2 \qquad 1.013 \qquad 0.0046 \$ $1.9914 (L_1) \qquad 0.998942 \qquad 708' \qquad 4881.5 \qquad 1.000 \qquad 1.000 \$ $1.99262 \qquad 708' \qquad 4881.5 \qquad 1.000 \qquad 1.000 \$ $1.99262 \qquad 708' \qquad 4881.5 \qquad 1.000 \qquad 1.000 \$ $1.99262 \qquad 708' \qquad 4881.5 \qquad 1.000 \qquad 1.000 \$ $1.99363 \qquad 0.999930 \qquad 0.00641 \qquad 35000^{\circ} \qquad 1.000 \$ $1.000 \qquad 0.00000 \qquad 0.00093^{\circ} \qquad 0.00641 \qquad 35000^{\circ} \qquad 1.000 \$ $1.0200 \qquad 0.00000 \qquad 0.00093^{\circ} \qquad 0.$	0.99364	0.99364	1057"	7287.7	1.000	1.000
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		T = -77.2	24 °C = -107.03 °F	= 195.91 K = 352.64	°R	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.0000		0.007 <i>ª</i>	0.048		
0.04831 50.0 344.74 0.09528 100 689.47 0.1407 150 1034.2 0.1849 200 1378.9 0.2698 300 2068.4 0.3555 400 277.9 0.4429 500 3447.4 0.5323 600 4136.8 0.6422 700 4826.3 0.7177 0.99763 755' 5205.5 1.390 0.00840 T=-80.00 °C = -112.00 °F = 193.15 K = 347.60 °R 0.0000 0.0000 0.0013 ^d 0.00896 280000 ^s 1.000 0.02210 0.999905 20.1 138.58 45.25 0.000097 0.02728 0.999932 25.1 173.06 36.65 0.000042 0.2851 0.999932 500.1 3447.4 2.129 0.000128 0.5802 0.999933 692' 4771.2 1.381 0.00220 0.89044 (L ₁) 0.99933 692' 4771.2 1.381 0.00220 0.99883 692' 4771.2 1.381 0.00220 </td <td>0.02082</td> <td></td> <td>20.0</td> <td>137.89</td> <td></td> <td></td>	0.02082		20.0	137.89		
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1.6422 700 4826.3 0.7177 0.99763 $755'$ 5205.5 1.390 0.00840 $T = -80.00$ $^{\circ}C = -112.00$ $^{\circ}F = 193.15$ $K = 347.60$ $^{\circ}R$ 0.0000 0.0013^d 0.00896 280000^a 1.000 0.02210 0.999905 20.1 138.58 45.25 0.000097 0.02728 0.999932 25.1 173.06 36.65 0.000042 0.09964 0.999964 100.1 690.16 10.04 0.00042 0.2851 0.999970 300.1 2069.1 3.508 0.00042 0.4697 0.999932 500.1 3447.4 2.129 0.000128 0.6902 0.999830 600 4136.8 1.723 0.000405 0.6902 0.999333 692^i 4771.2 1.381 0.00220 $0.8664 (L_1)$ 0.999393 692^i 4771.2 1.013 0.4446 $0.9914 (L_1)$ 0.99888 700 4826.3 1.000 1.000 $T = -82.65$ °C = -116.77 °F = 190.50 K = 342.90 °R 1.000 1.000 $T = -82.65$ °C = -116.77 °F = 190.50 K = 342.90 °R 1.000 1.000 $T = -82.65$ °C = -116.77 °F = 190.50 K = 342.90 °R 1.000 1.02256 0.999924 20.0 137.89 44.33 0.000077 1.02803 0.999960 25.0 172.37 35.68 0.000047 1.047 0.999970 100.0 689.47 9.548 0.000037 <td>0.5323</td> <td></td> <td>600</td> <td>4136.8</td> <td></td> <td></td>	0.5323		600	4136.8		
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$T = -80.00 \ ^{\circ}\text{C} = -112.00 \ ^{\circ}\text{F} = 193.15 \ \text{K} = 347.60 \ ^{\circ}\text{R}$ $0.0000 \qquad 0.0000 \qquad 0.0013 \ ^{\circ} \qquad 0.00896 \qquad 280000 \ ^{\circ} \qquad 1.000$ $0.02210 \qquad 0.999905 \qquad 20.1 \qquad 138.58 \qquad 45.25 \qquad 0.000097$ $0.02728 \qquad 0.999932 \qquad 25.1 \qquad 173.06 \qquad 36.65 \qquad 0.00069$ $0.09964 \qquad 0.999964 \qquad 100.1 \qquad 690.16 \qquad 10.04 \qquad 0.00040$ $0.2851 \qquad 0.999970 \qquad 300.1 \qquad 2069.1 \qquad 3.508 \qquad 0.00042$ $0.4697 \qquad 0.999932 \qquad 500.1 \qquad 3447.4 \qquad 2.129 \qquad 0.000128$ $0.5802 \qquad 0.999830 \qquad 600 \qquad 4136.8 \qquad 1.723 \qquad 0.000405$ $0.6902 \qquad 0.999567 \qquad 675 \qquad 4653.9 \qquad 1.448 \qquad 0.00140$ $0.7239 \qquad 0.999393 \qquad 692 \ ^{\circ} \qquad 4771.2 \qquad 1.381 \qquad 0.00220$ $0.999393 \qquad 692 \ ^{\circ} \qquad 4771.2 \qquad 1.013 \qquad 0.0446$ $0.99988 \qquad T00 \qquad 4826.3 \qquad 1.008 \qquad 0.119$ $0.9988 \ (L_1) \qquad 0.99888 \qquad T00 \qquad 4826.3 \qquad 1.008 \qquad 0.119$ $0.9988 \ (L_1) \qquad 0.99882 \qquad 708 \ ^{\circ} \qquad 4881.5 \qquad 1.000 \qquad 1.000$ $T = -82.65 \ ^{\circ}\text{C} = -116.77 \ ^{\circ}\text{F} = 190.50 \ \text{K} = 342.90 \ ^{\circ}\text{R}$ $1.000 \qquad 0.0000 \qquad 0.00003 \ 0.000641 350000^{\circ} \qquad 1.000$ $1.000 \qquad 1.000 \qquad 1.000 \qquad 1.000 $	Q.7177	0.99763	/55/	5205.5	1.390	0.00840
0.00000.00000.0013 d0.0089628000 e1.0000.022100.99990520.1138.5845.250.000970.027280.99993225.1173.0636.650.000690.099640.999964100.1690.1610.040.000400.28510.999970300.12069.13.5080.000420.46970.999932500.13447.42.1290.0001280.58020.9998306004136.81.7230.0004050.69020.9995676754653.91.4480.001400.72390.99933692 d4771.21.3810.002200.99933692 d4771.21.0130.04460.9914 (L ₁)0.998987004826.31.0000.0000.9988 (L ₁)0.99882708 d4881.51.0001.0001.0000.00000.0003 d0.00641350000 e1.0001.022560.9999420.0137.8944.330.0000711.028030.99990025.0172.3735.680.0000411.01470.999970100.0689.479.5480.000033		$\tau = -80.0$	00 °C = -112.00 °F	= 193.15 K = 347.60	°R	
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Act 120.00006225.1173.0636.650.0000620.099640.999964100.1690.1610.040.0000420.28510.999970300.12069.13.5080.000420.46970.999932500.13447.42.1290.0001280.58020.9998306004136.81.7230.0004050.69020.9995676754653.91.4480.001400.72390.999393692'4771.21.3810.002200.9864 (L_1)0.999393692'4771.21.0130.04460.9914 (L_1)0.998987004826.31.0080.1190.9988 (L_1)0.99882708'4881.51.0001.000T = -82.65 °C = -116.77 °F = 190.50 K = 342.90 °R1.00000.00000.00093'0.00641350000*1.0001.022560.99992420.0137.8944.330.0000771.028030.99996025.0172.3735.680.0000411.0470.999970100.0689.479.5480.000033	0.02728	0 000030	05 1	179 00	70.20 DE EF	0.0000377
0.099640.999964100.1690.1610.040.000400.28510.999970300.12069.13.5080.000420.46970.999932500.13447.42.1290.0001260.58020.9998306004136.81.7230.0004050.69020.9995676754653.91.4480.001400.72390.999393692'4771.21.3810.002200.999393692'4771.21.0130.04460.999441.09.99393692'4771.21.0130.04460.9914 (L_1)0.998987004826.31.0001.0001.9918 (L_1)0.99882708'4881.51.0001.000T = -82.65 °C = -116.77 °F = 190.50 K = 342.90 °R0.00000.00000.0003''0.00641350000''1.0001.022560.99992420.0137.8944.330.0000770.28030.99996025.0172.3735.680.0000410.10470.999970100.0689.479.5480.000033	0.02120	0.3333322	25.1	173.06	30.00	0.0000699
0.2851 0.999970 300.1 2069.1 3.508 0.00042 0.4697 0.999932 500.1 3447.4 2.129 0.000126 0.5802 0.999830 600 4136.8 1.723 0.000405 0.6902 0.999567 675 4653.9 1.448 0.00140 0.7239 0.999333 692^i 4771.2 1.381 0.00220 0.999393 692^i 4771.2 1.013 0.0446 0.999393 692^i 4771.2 1.013 0.0446 0.99948 700 4826.3 1.008 0.119 0.99882 708^i 4881.5 1.000 1.000 $T = -82.65$ °C = -116.77 °F = 190.50 K = 342.90 °R 1.000 1.000 0.0000 0.0003^d 0.00641 350000^e 1.000 1.02256 0.999924 20.0 137.89 44.33 0.000077 1.02803 0.999960 25.0 172.37 35.68 0.000041 1.047 0.999970 100.0 689.47 9.548 0.000033	0.09964	0.999964	100.1	690.16	10.04	0.0000400
0.46970.999932500.1 3447.4 2.1290.0001280.58020.9998306004136.81.7230.0004050.69020.9995676754653.91.4480.001400.72390.999393692'4771.21.3810.002200.9864 (L_1)0.999393692'4771.21.0130.04460.9914 (L_1)0.998987004826.31.0080.1190.9986 (L_1)0.99882708'4881.51.0001.000 $T = -82.65 \ ^{\circ}C = -116.77 \ ^{\circ}F = 190.50 \ K = 342.90 \ ^{\circ}R$ 1.0001.0000.00000.00003 \ ^{\circ}0.00641350000 \ ^{\circ}1.0001.022560.99992420.0137.8944.330.0000771.028030.99996025.0172.3735.680.0000410.10470.999970100.0689.479.5480.000033	0.2851	0.999970	300.1	2069.1	3.508	0.0000420
1.111.1250.000120.58020.9998306004136.81.7230.0004050.69020.9995676754653.91.4480.001400.72390.999393692'4771.21.3810.002200.9864 (L_1)0.999393692'4771.21.0130.04460.9914 (L_1)0.998987004826.31.0080.1190.9988 (L_1)0.99882708'4881.51.0001.000T = -82.65 °C = -116.77 °F = 190.50 K = 342.90 °R0.00000.00000.0003d'0.00641350000e'1.0001.022560.99992420.0137.8944.330.0000770.28030.99996025.0172.3735.680.0000410.10470.999970100.0689.479.5480.000033	0.4697	0.999932	500 1	3447 4	2 1 2 0	0.000109
0.00020.000300.0004060.69020.9995676754653.91.4480.001400.72390.999393692'4771.21.3810.002200.9864 (L1)0.999393692'4771.21.0130.04460.9914 (L1)0.998887004826.31.0080.1190.9988 (L1)0.99882708'4881.51.0001.000 $T = -82.65 °C = -116.77 °F = 190.50 K = 342.90 °R$ 0.00000.00000.0003d'0.00641350000*1.0001.022560.99992420.0137.8944.330.0000710.028030.99996025.0172.3735.680.0000411.00470.999970100.0689.479.5480.000033	0.5802	0.000002	600.1	4400 0	4 700	0.000120
0.6902 0.999567 675 4653.9 1.448 0.00140 0.7239 0.999393 692^i 4771.2 1.381 0.00220 $0.9864 (L_1)$ 0.999393 692^i 4771.2 1.013 0.0446 $0.9914 (L_1)$ 0.99898 700 4826.3 1.008 0.119 0.99882 708^i 4881.5 1.000 1.000 $T = -82.65 \ ^\circ C = -116.77 \ ^\circ F = 190.50 \ K = 342.90 \ ^\circ R$ 0.0000 $0.0003\ ^\circ$ 0.00641 $350000\ ^\circ$ 1.000 0.02256 0.999924 20.0 137.89 44.33 0.000077 0.02803 0.999960 25.0 172.37 35.68 0.00041 0.1047 0.999970 100.0 689.47 9.548 0.000033	0.0002	0.999830	000	4136.8	1.723	0.000405
0.7239 0.999393 692^{i} 4771.2 1.381 0.00220 $0.9864 (L_1)$ 0.999393 692^{i} 4771.2 1.013 0.0446 $0.9914 (L_1)$ 0.99898 700 4826.3 1.008 0.119 $0.9986 (L_1)$ 0.99882 708^{i} 4881.5 1.000 1.000 $T = -82.65 \ ^{\circ}C = -116.77 \ ^{\circ}F = 190.50 \ K = 342.90 \ ^{\circ}R$ 0.0000 0.0003^{d} 0.00641 350000^{e} 1.000 0.02256 0.999924 20.0 137.89 44.33 0.000077 0.02803 0.999960 25.0 172.37 35.68 0.000041 0.1047 0.999970 100.0 689.47 9.548 0.000033	0.6902	0.999567	675	4653.9	1.448	0.00140
0.9864 (L1)0.999393692'4771.21.0130.04460.9914 (L1)0.998987004826.31.0080.1190.9988 (L1)0.99882708'4881.51.0001.000 $T = -82.65 °C = -116.77 °F = 190.50 K = 342.90 °R$ 0.00000.0000 0.00093'0.00641350000 °1.0000.022560.99992420.0137.8944.330.0000770.028030.99996025.0172.3735.680.0000410.10470.999970100.0689.479.5480.000033	0.7239	0.999393	6921	4771.2	1.381	0.00220
$0.9934(L_1)$ 0.99898 700 4826.3 1.013 0.0446 $0.9914(L_1)$ 0.99898 700 4826.3 1.008 0.119 0.99882 708^{4} 4881.5 1.000 1.000 $T = -82.65 \ ^{\circ}C = -116.77 \ ^{\circ}F = 190.50 \ K = 342.90 \ ^{\circ}R$ 0.0000 0.00093^{d} 0.00641 350000° 1.000 0.02256 0.999924 20.0 137.89 44.33 0.000077 0.02803 0.999960 25.0 172.37 35.68 0.00041 0.1047 0.999970 100.0 689.47 9.548 0.000033	0 9864 (L.)	0 000303	600/	4771 0	1.001	0.00220
$1.5914 (L_1)$ 0.59598 700 4826.3 1.008 0.119 0.99882 708^{i} 4881.5 1.000 1.000 $T = -82.65 \ ^{\circ}C = -116.77 \ ^{\circ}F = 190.50 \ K = 342.90 \ ^{\circ}R$ 0.0000 0.00093^{d} 0.00641 350000° 1.000 0.02256 0.999924 20.0 137.89 44.33 0.000077 0.02803 0.999960 25.0 172.37 35.68 0.00041 0.119 0.0003^{d} 0.00041 0.000077 0.02803 0.999970 100.0 689.47 9.548 0.000033^{d}	0.0014 (L1)	0.555355	092.	4//1.2	1.013	0.0446
$0.9988 (L_1)$ 0.99882 708^{\prime} 4881.5 1.000 1.000 $T = -82.65 \ ^{\circ}C = -116.77 \ ^{\circ}F = 190.50 \ K = 342.90 \ ^{\circ}R$ 0.0000 0.0003^{\prime} 0.00641 350000° 1.000 0.02256 0.999924 20.0 137.89 44.33 0.000077 0.2803 0.999960 25.0 172.37 35.68 0.000041 0.1047 0.999970 100.0 689.47 9.548 0.000033	0.9914 (L ₁)	0.99898	700	4826.3	1.008	0.119
$T = -82.65 \ ^{\circ}C = -116.77 \ ^{\circ}F = 190.50 \ K = 342.90 \ ^{\circ}R$ 0.00000.00003 \ 0.00093 \ 0.00641 \ 350000^{\circ}1.0000.022560.999924 \ 20.0 \ 137.89 \ 44.33 \ 0.0000770.0000770.028030.999960 \ 25.0 \ 172.37 \ 35.68 \ 0.0000410.000033 \ 0.000077 \ 9.548 \ 0.000033	0.9988 (L ₁)	0.99882	708 <i>'</i>	4881.5	1.000	1.000
0.0000 0.0000 0.00093 ^d 0.00641 350000 ^e 1.000 0.02256 0.999924 20.0 137.89 44.33 0.000077 0.02803 0.999960 25.0 172.37 35.68 0.000041 0.1047 0.999970 100.0 689.47 9.548 0.000033		<i>T</i> = −82.6	65 °C = -116.77 °F	= 190.50 K = 342.90	°R	
0.02256 0.999924 20.0 137.89 44.33 0.00007 0.02803 0.999960 25.0 172.37 35.68 0.000041 0.1047 0.999970 100.0 689.47 9.548 0.000033	0.0000	0.0000	0 00000	0 00641	350000#	1 000
0.9999960 25.0 172.37 35.68 0.000071 0.1047 0.999970 100.0 689.47 9.548 0.000033	0.02258	0.00004	0.00033	107.00	330000-	1.000
0.02803 0.999960 25.0 172.37 35.68 0.000041 0.1047 0.999970 100.0 689.47 9.548 0.000033	0.02200	0.999924	20.0	137.89	44.33	0.0000778
0.1047 0.999970 100.0 689.47 9.548 0.000033	0.02803	0.999960	25.0	172.37	35.68	0.0000412
	0.1047	0.999970	100.0	689.47	9.548	0.0000335

Table II (c	ontinued)
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x methane ^a	y methane ^b	psia	kPac	K methane	K n-hexane
0.3004	0.999988	300.0	2068.4	3.329	0.0000172
0.5041	0.999907	499.6	3444.6	1.984	0.000188
0.6487	0.999814	600	4136.8	1.541	0.000529
0.7438	0.999611	6387	4398.8	1.344	0.00152
0.9695 (L ₁)	0.999611	638/	4398.8	1.031	0.0128
0.9724 (L ₁)	0.999577	645/	4447.1	1.028	0.0153
0.9745 (L ₁)	0.999587	650	4481.6	1.026	0.0162
0.9897 (L ₁)	0.999609	655	4516.1	1.010	0.0380
0.9919 (L ₁)	0.999687	660	4550.5	1.008	0.0386
0.999847 (L ₁)	0.99847	665 <i>^h</i>	4565.0	1.000	1.000
	t = -86.9	2 °C = -124.46 °F	² = 186.23 K = 335.	21 °R	
0.0000		0.00054	d 0.00372		
0.06129		50.0	344.74		
0.1189		100	689.47		
0.1813		150	1034.2		
0.2357		200	1378.9		
0.3412		300	2068.4		
0.4593		400	2757.9		
0.6010		500	3447.4		
0.6826		540	3723.2		
0.8057	0.999837	559'	3854.1	1.241	0.000839
0.9505 (L1)	0.999837	559'	3854.1	1.052	0.00329
0.9776 (L ₁)		574	3957.6		
0.9871 (L ₁)		579	3992.0		
1.000 (L ₁)		582 <i>9</i>	4012.7		
	T = -90.6	9 °C = −131.24 °F	= 182.46 K = 328.4	43 °R	
		(LCS1	r)		
0.0000		0.00034	d 0.00234		
0.02766		20.0	137.89		
0.03463		25.0	172.37		
0.06623		50.0	344.74		
0.1308		100	689.47		
0.1907		150	1034.2		
0.2560		200	1378.9		
0.3822		300	2068.4		
0.5178		400	2757.9		
0.6100		450	3102.6		
0.7426		480	3309.5		
0.9286	0.999946	495.37	3414.9	1.077	0.000756
0.9640 (L ₁)		510	3516.3		
0.9876 (L ₁)		515	3550.8		
1.000 (L ₁)		516 <i>9</i>	3557.7		

^a All liquid-phase data are L₂ unless otherwise noted. ^b Vapor compositions from Chen et al. (5), except as noted by f. ^c Pa: Pascal = kg/m s² = N/m²; 1 psia = 6.8947 kPa. ^d Vapor pressure of *n*-hexane from Carruth (2). ^e $K_{CH_4}^{\infty}$. ^f Dew points measured by chromatography. ^g Vapor pressure of CH₄. ^h Critical pressure where liquid = gas. ^f Pressure at which L₁-L₂-G exists.

Table III. Liquid-Liquid E	quilibrium Data of the I	Methane- <i>n</i> -Hexane \$	System *
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x methane (L ₂)	x' methane (L1')	psia	kPa	ĸ methane	к n-hexane
	T = −77.24 °C = −107.03 °F = 1	195.91 K = 352.6	64 °R		
	(UCST L₁ ≡ G)			
0.7177	0.9976	755°	5205.5	1.3900	0.008502
0.7425	0.9851	800	5515.8	1.3267	0.05786
0.7701	0.9769	850	5860.5	1.2685	0.1005
0.7809	0.9674	880	6067.4	1.2388	0.1488
0.7950	0.9520	910	6274.2	1.1975	0.2342
0.8151	0.9390	950	6550.0	1.1520	0.3840
0.8416	0.9133	975	6722.4	1.0852	0.5474
0.8900 ^{<i>b</i>}	0.8900 <i>^b</i>	986 ^d	6798.2	1.000	1.000
	$T = -80.00 \ ^{\circ}C = -1$	12.00 °F = 193.	15 K = 347.67 °R		
0.7239	0.9864	692 <i>°</i>	4771.2	1.3626	0.04926
0.7415	0.9785	720	4964.2	1.3196	0.08317
0.7531	0.9716	740	5102.1	1.2901	0.1150
0.7649	0.9660	760	5240.0	1.2629	0.1446
0.7858	0.9522	800	5515.8	1.2118	0.2232
0.7949	0.9445	820	5635.7	1.1882	0.2706
0.8098	0.9377	840	5791.6	1.1579	0.3276

Table III. (C	continued)
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x methane (L ₂)	x' methane (L1')	psia	kPa	k methane	к n-hexane
0.8278	0.9238	860	5929.5	1.1160	0.4425
0.9004	0.9004	883 ^d	6088.1	1.000	1.000
	$T = -82.65 ^{\circ}\text{C} = -1000$	116.77 °F = 190.5	50 K = 342.90 °F	1	
0 7438	0.9695	638 <i>°</i>	4398.8	1.3034	0.1191
0 7756	0.9631	675	4653.9	1.2418	0.1644
0 7829	0.9486	700	4826.3	1.2117	0.2368
0.8042	0.9369	725	4998.7	1.1650	0.3223
0.8071	0.9484	730	5033.1	1,1751	0.2675
0.8297	0 9280	760	5240.0	1.1185	0.4228
0.8975	0.8975	770 <i>d</i>	5308.9	1.000	1.000
	$T = -86.92 \circ C = -$	124.46 °F = 186.3	23 K = 335.21 °F	3	
0 8057	0.9505	559°	3854.2	1.1797	0.2548
0.8199	0.9412	580	3998.9	1.1479	0.3265
0.8313	0.9335	600	4136.8	1,1229	0.3942
0.8515	0.9246	612	4219.6	1.0858	0.5077
0.9013	0.9013	624	4302.3	1.000	1.000
	T 00 00 00 -	101 01 95 - 100	40 K - 200 40 80	,	
	/ = −90.69 °C = −	131.24 = 1 = 182.4	40 N - 320.43 "	ו	
		$(\text{LCSTL}_1' \equiv \text{L}_2)$			1 000
0.9286	0.9286	495.3 <i>°</i>	3414.9	1.000	1.000

^a Except at pressure indicated with footnote c, no gas phase is present. ^b Estimated value. ^c L₁-L₂-G. ^d L₁ \equiv L₂.



Figure 1. Pressure-composition diagram for the methane-*n*-hexane system.

greater than the LCST. Nevertheless, the technique of Davenport and Rowlinson (7) does yield a value for the LCST quite close to our value: 182.6 K and 0.30 weight fraction *n*-hexane (0.926 mole fraction methane) as compared to our -90.69 °C (182.46 K) and 0.9286 mole fraction methane.

Note also that for the isotherm at -75 °C, which is slightly more than 2 °C above the UCST, the shape of the *p*-*x* plot is affected.

K values for each temperature as a function of pressure are



Figure 2. K value vs. pressure along isotherms for the methane-n-hexane system.

shown in Figure 2. Comparisons with BWRS equation predictions are good in general (*10*). Larger deviations occur at lower temperatures and pressures near critical.

Figure 3 reveals the details of the equilibrium constants between the UCST and LCST. K values and κ values are put together for each isotherm as a function of pressure in an expanded scale. The dot-dash lines are the respective loci for the



Figure 3. Equilibrium constants in the two liquid phase region.

equilibrium constants at the three phase conditions. These correspond to the dot-dash lines on Figure 1.

Cross plots of isobaric concentration vs. reciprocal absolute temperature are shown in Figure 4. Shim and Kohn's data (11) are also shown for comparison.

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Mr. Ray Martin provided invaluable assistance in the construction and maintenance of the equipment.

Glossary

- κ ratio of vapor concentration to liquid concentration
- ratio of light liquid concentration to heavy liquid concenк tration
- liquid concentration, mole fraction х
- vapor concentration, mole fraction у
- ω superscript denoting limiting value for the subscripted component at the limiting other pure component vapor pressure



Figure 4. Isobaric bubble point behavior for the methane-n-hexane system.

- L_1 light liquid in equilibrium with vapor
- L₁ light liquid in equilibrium with heavy liquid
- heavy liquid in equilibrium with vapor or L1' L_2
- G gas phase in equilibrium with liquid
- temperature in three-phase region τ
- Π pressure in L_1 - L_2 or L_1 -G regions

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