

<p>COMPONENTS:</p> <p>(1) Butane; C<sub>4</sub>H<sub>10</sub>; [106-97-8]</p> <p>(2) Water; H<sub>2</sub>O; [7732-18-5], at high pressure</p>	<p>EVALUATOR:</p> <p>Colin L. Young, Department of Physical Chemistry, University of Melbourne, Parkville, Vic. 3052, Australia.</p> <p>December 1983</p>
<p>CRITICAL EVALUATION:</p> <p>There are four studies of this system at high temperatures and pressures. The data of Tsiklis and Maslennikova (1) are rejected since they are restricted to the critical region and are in serious disagreement with the data of Danniel <i>et al.</i> (2). Furthermore they appear to be anomalous when the data for alkane + water systems are considered. Therefore the data of Tsiklis and Maslennikova (1) are rejected. The limited data of Danniel <i>et al.</i> (2) are classified as tentative on the basis that they appear consistent with data in the critical region of other workers for alkane + water mixtures.</p> <p>There are significant discrepancies between the data of Reamer <i>et al.</i> (3) and Le Breton and McKetta (4). The latter data are probably the more reliable and are classified as tentative. The temperature range studied in references (1) and (2) does not overlap with the range studied in references (3) and (4).</p> <p><u>References</u></p> <ol style="list-style-type: none"><li>1. Tsiklis, D. S.; Maslennikova, V. Ya. <i>Dokl. Akad. Nauk. S.S.S.R.</i> <u>1964</u>, 157, 426.</li><li>2. Danniel, A.; Tödheide, K.; Franck, E. U. <i>Chem.-Ing.-Tech.</i> <u>1967</u>, 39, 816.</li><li>3. Reamer, H. H.; Sage, B. H.; Lacey, W. N. <i>Ind. Eng. Chem.</i> <u>1952</u>, 44, 609.</li><li>4. Le Breton, J. C.; McKetta, J. J. <i>Hydroc. Proc. Pet. Ref.</i> <u>1964</u>, 43 (6), 136.</li></ol>	

COMPONENTS:		ORIGINAL MEASUREMENTS:		
(1) Butane; C <sub>4</sub> H <sub>10</sub> ; [106-97-8] (2) Water; H <sub>2</sub> O; [7732-18-5]		Le Breton, J.G.; McKetta, J.J. <i>Hydroc. Proc. Pet. Ref.</i> <u>1964</u> , 43, 136-138.		
VARIABLES:		PREPARED BY:		
T/K: 310.9-410.9 P/kPa: 129.3-3044		W. Hayduk		
EXPERIMENTAL VALUES:				
t <sup>1</sup> /°F	T <sup>2</sup> /K	Total Pressure <sup>1</sup> /psia	Partial Pressure <sup>2</sup> P/kPa	Mol Fraction <sup>1</sup> /10 <sup>5</sup> x <sub>1</sub>
100	310.9	19.7	129.3	1.73
		23.7	156.9	1.92
		29.7	198.2	2.78
		34.7	232.7	2.92
		41.2	277.5	3.76
		52.2	353.4	(4.61) <sup>3</sup>
160	344.3	38.7	234.1	1.60
		44.7	275.5	1.89
		47.7	296.2	2.00
		58.7	372.0	2.58
		73.7	475.5	3.21
		85.7	558.2	3.86
		96.7	634.0	4.23
		108.7	716.8	4.93
125.2	830.5	(5.49) <sup>3</sup>		
continued...				
<sup>1</sup> Original data.				
<sup>2</sup> Calculated by compiler using vapor pressure data given by authors.				
<sup>3</sup> Average of several determinations made at pressure of appearance of second liquid phase.				
AUXILIARY INFORMATION				
METHOD/APPARATUS/PROCEDURE:		SOURCE AND PURITY OF MATERIALS:		
Water and butane were equilibrated in a cell at high pressure and constant temperature. A sample of the aqueous solution was passed into a low pressure Orsat gas buret for gas release under controlled conditions of temperature and pressure. At the pressure used (usually < 200 mm mercury) Henry's law, and the ideal gas law were assumed to describe the solubility, and gas volumetric properties, respectively. From a material balance as well as the vapor pressure and volume of water in the gas buret, the butane content of the original aqueous sample was calculated. Details in (1,2).  Data also reported for the three-phase system.		1. Phillips Petroleum Co. Certified purity of 99.9 mol per cent.		
		2. Distilled and deaerated.		
		ESTIMATED ERROR: δP/P = 0.01 (compiler) δx <sub>1</sub> /x <sub>1</sub> = 0.05 (authors)		
		REFERENCES:		
		1. Azarnoosh, A.; McKetta, J.J. <i>Pet. Ref.</i> <u>1958</u> , 37, 275.		
		2. Wehe, A.H.; McKetta, J.J. <i>Anal. Chem.</i> <u>1961</u> , 33, 291.		

## Butane in Water (High Pressure)

COMPONENTS:		ORIGINAL MEASUREMENTS:				
(1) Butane; C <sub>4</sub> H <sub>10</sub> ; [106-97-8]		Le Breton, J.G.; McKetta, J.J.				
(2) Water; H <sub>2</sub> O; [7732-18-5]		<i>Hydroc. Proc. Pet. Ref.</i> <u>1964</u> , 43, 136-138.				
VARIABLES:		PREPARED BY:				
T/K: 310.9-410.9		W. Hayduk				
P/kPa: 129.3-3044						
EXPERIMENTAL VALUES:						
t <sup>1</sup> /°F	T <sup>2</sup> /K	Total Pressure <sup>1</sup> /psia	Partial Pressure <sup>2</sup> P/kPa	Mol Fraction <sup>1</sup> /10 <sup>5</sup> x <sub>1</sub>		
220	377.6	68.7	355.1	2.24		
		82.7	451.7	2.81		
		102.7	589.6	3.84		
		119.7	706.8	4.49		
		126.7	755.0	4.84		
		140.7	851.6	5.39		
		147.7	899.8	6.32		
		180.7	1127	7.24		
		212.7	1348	8.02		
		227.7	1451	8.26		
		259.7	1672	(8.76) <sup>3</sup>		
		280	410.9	89.7	279.2	2.19
				129.7	550.0	4.23
				164.7	796.3	6.29
194.7	1003			7.64		
226.7	1224			9.17		
264.7	1486			11.01		
299.7	1727			12.26		
329.7	1934			13.31		
360.7	2148			14.40		
401.7	2430			15.70		
430.7	2630			16.415		
450.7	2768			16.86		
490.7	3044			(17.71) <sup>3</sup>		
				continued...		
<sup>1</sup> Original data.						
<sup>2</sup> Calculated by compiler using vapor pressures of water given by authors.						
<sup>3</sup> Average of two or more determinations made at the pressure of the appearance of the second liquid phase.						
Data were also reported for the system involving two liquid (butane-rich, water-rich) phases.						

COMPONENTS:	ORIGINAL MEASUREMENTS:
(1) Butane; C <sub>4</sub> H <sub>10</sub> ; [106-97-8]	Le Breton, J.G.; McKetta, J.J.
(2) Water; H <sub>2</sub> O; [7732-18-5]	<i>Hydroc. Proc. Pet. Ref.</i> <u>1964</u> , 43, 136-138.
VARIABLES:	PREPARED BY:
T/K: 310.9-410.9	W. Hayduk
P/kPa: 129.3-3044	

## EXPERIMENTAL VALUES: (concluded)

Smoothed values were presented by authors as follows:

Total Pressure <sup>1</sup> /psia	T/K	Partial Pressure <sup>2</sup> P <sub>1</sub> /kPa	Mol Fraction <sup>1</sup> /10 <sup>5</sup> x <sub>1</sub>
(0.9492) <sup>3</sup>	310.9		
20	(100°F)	131.3	1.75
40		269.2	3.45
52.2		353.4	(4.40) <sup>4</sup>
(4.741) <sup>3</sup>	344.3		
20	(160°F)	105.2	0.75
40		243.1	1.60
60		381.9	2.55
80		518.9	3.45
100		656.8	4.40
125.2		830.5	(5.50) <sup>4</sup>
(17.186) <sup>3</sup>	377.6		
20	(220°F)	19.4	0.15
40		157.3	1.00
60		295.2	1.85
80		433.1	2.75
100		571.0	3.60
200		1260	7.65
259		1672	(9.10) <sup>4</sup>
(49.203) <sup>3</sup>	410.9		
80	(280°F)	212.3	1.60
100		350.2	2.70
200		1040	9.70
300		1729	12.25
400		2419	15.65
490.7		3044	(17.80) <sup>4</sup>

<sup>1</sup>Original smoothed values.<sup>2</sup>Calculated by compiler using authors' vapor pressure for water.<sup>3</sup>Authors' vapor pressure for water.<sup>4</sup>Incidence of two liquid phases.

COMPONENTS:		ORIGINAL MEASUREMENTS:			
(1) Butane; C <sub>4</sub> H <sub>10</sub> ; [106-97-8] (2) Water; H <sub>2</sub> O; [7732-18-5]		Danneil, A.; Todheide, K., and Franck, E.U. <i>Chem. Ing-Tech.</i> <u>1967</u> , <i>13</i> , 816-821.			
VARIABLES:		PREPARED BY:			
T/K: 628.15, 637.15 P/MPa: 25.5-112.5		W. Hayduk			
EXPERIMENTAL VALUES:					
t <sup>1</sup> /°C	T/K	Pressure <sup>1</sup> P/bar	Pressure <sup>2</sup> P/MPa	Mol Fraction Butane: <sup>1</sup> in liquid/x <sub>1</sub>	in vapour/y <sub>1</sub>
355	628.15	255	25.5	0.025	0.124
		295	29.5	0.048	0.105
		510	51.0	0.055	-
		520	52.0	-	0.188
		590	59.0	0.043	0.287
		725	72.5	0.036	-
		735	73.5	-	0.356
364	637.15	690	69.0	0.077	0.256
		830	83.0	0.041	0.318
		1090	109.0	-	0.417
		1125	112.5	0.041	-
<sup>1</sup> Original data.					
<sup>2</sup> Total pressure calculated by compiler.					
AUXILIARY INFORMATION					
METHOD/APPARATUS/PROCEDURE:			SOURCE AND PURITY OF MATERIALS:		
Static bomb with magnetically operated stirrer. Pressure measured with Bourdon gauge. Temperature measured with NiCr-Ni thermocouple. Samples of vapour and liquid analysed by stripping out hydrocarbon with carbon dioxide and estimating volumetrically. Water estimated gravimetrically.			1. Purity specified as 95.5 mol per cent.		
			2. Triply distilled.		
			ESTIMATED ERROR:		
			δT/K = 0.7; δP/bar = ±1%		
			δx <sub>1</sub> = 0.005; δy <sub>1</sub> = 0.012 (authors)		
REFERENCES:					

COMPONENTS:				ORIGINAL MEASUREMENTS:		
(1) Butane; C <sub>4</sub> H <sub>10</sub> ; [106-97-8]				Reamer, H. H.; Sage, B. H.;		
(2) Water; H <sub>2</sub> O; [7732-18-5]				Lacey, W. N.		
				<i>Ind. Eng. Chem.</i>		
				<u>1952</u> , 44, 609-615.		
VARIABLES:				PREPARED BY:		
T/K: 310.9-410.9				W. Hayduk; C.L. Young		
P/MPa: 0.355-3.735						
EXPERIMENTAL VALUES:						
T/K	T/°F	Total Pressure p/psi	Gas Partial Pressure P/MPa	10 <sup>5</sup> x <sub>C<sub>4</sub>H<sub>10</sub></sub> <sup>a</sup>	x' <sub>C<sub>4</sub>H<sub>10</sub></sub> <sup>b</sup>	y <sub>C<sub>4</sub>H<sub>10</sub></sub>
310.9	100	52.45	0.355	6.2	0.9995	0.9833
344.3	160	125.4	0.832	8.7	0.9979	0.9662
377.6	220	259.3	1.669	14.0	0.9915	0.9459
410.9	280	590.9	3.735	22.0	0.9732	0.9292
<p><sup>a</sup> Mole fraction in water-rich liquid layer.</p> <p><sup>b</sup> Mole fraction in hydrocarbon-rich liquid layer.</p> <p>These data are at the limit of the three-phase region; at slightly lower pressures there are only two phases, gas and water.</p> <p>Mole fraction of water rather than those of butane were given in the original.</p> <p>Total pressure given in psia; gas partial pressure calculated in MPa by compilers.</p>						
AUXILIARY INFORMATION						
METHOD/APPARATUS/PROCEDURE:				SOURCE AND PURITY OF MATERIALS:		
<p>Static equilibrium cell. Pressure measured with pressure balance and temperature measured with platinum resistance thermometer. Mixture confined to cell, the volume of which could be varied by mercury injection or withdrawal. Equilibrium established and samples withdrawn at constant pressure. Water content of sample determined by absorption in calcium chloride. Butane estimated volumetrically. Additional three-phase data in source and ref. (1) but no additional gas solubility data.</p>				<p>No details given.</p>		
				ESTIMATED ERROR:		
				$\delta T/K = \pm 0.05$ ; $\delta P/MPa = \pm 0.007$ ; $\delta x_{C_4H_{10}} = \pm 5\%$ , $\delta x'_{C_4H_{10}}$ , $\delta y_{C_4H_{10}} = \pm 1\%$ (estimated by compilers).		
				REFERENCES:		
				<p>1. Reamer, H. H.; Olds, R. H.; Sage, B. H.; Lacey, W. N. <i>Ind. Eng. Chem.</i> <u>1944</u>, 36, 381.</p>		