

Mutual Solubility of Water and Pyridine Derivatives

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Mutual binary solubilities have been measured for derivatives of pyridine and piperidine. Data are given for 36 water-organic pairs at temperatures of 0-90 °C. It was found that 9 binary systems were miscible in all proportions over the temperature range, 14 showed partial solubility over the entire temperature range, and 13 were partially soluble at higher temperatures, but had lower critical solution temperatures and were completely miscible with water at lower temperatures. The very large number of systems exhibiting a lower critical solution temperature indicates that this feature is characteristic for these compounds.

Introduction

The derivatives of pyridine, piperidine, and quinoline (benzopyridine) are important in medicine, agriculture, and industrial chemistry. The volume of commercial pyridine chemicals is quite large, but the economic aspects resemble more those of specialty chemicals than those of commodities. Commercial transactions occur with little publicity, trade secrets are carefully guarded, and patents proliferate.

Very little previous work on the solubility of the pyridines in water has been reported in the literature. The first 42 volumes of the *Solubility Data Series* of the International Union of Pure and Applied Chemistry (1) do not give solubility data for a single pyridine. Sorensen and Arlt (2) give data for four pyridines published between 1898 and 1921. The 2,4-dimethylpyridine gives data which are fairly consistent with Table III, but appears to have missed the lower critical solution temperature. The data for 2,6-dimethylpyridine show a lower critical solution temperature of about 44 °C in comparison to a temperature of 34 °C in Table V. The data for 3-methylpyridine indicate only partial miscibility at 60 °C whereas experiments by the author indicate clearly that 3-methylpyridine is consolute with water.

Sorensen and Arlt also give data for piperidine and seven derivatives. Very early data reported that piperidine and water are only partially miscible, but experiments by the author show that piperidine and water are consolute. Data for 1-ethylpiperidine, 1-methylpiperidine, and 4-methylpiperidine show close agreement with Tables XIX, XXII, and XXVI, but data for 2-methylpiperidine show a lower critical solution temperature of 80 °C in comparison to 70 °C in Table XX and data for 3-methylpiperidine show a lower critical solution temperature of 56 °C in comparison to 67 °C in Table XXI.

Experimental Section

As before, most samples were measured using the method of standard additions. Water and organic were brought into equilibrium at a given temperature in a thermostat, and samples of each layer were removed with a syringe for analysis. To determine the amount of water in the organic layer sample, a weighed quantity of a solvent such as pyridine was added and the ratio of the water to pyridine peak measured with a Gow-Mac Series 550 thermal conductivity gas chromatograph (GC), a 1.9-m by 2.2-mm-internal-diameter column packed with Chromosorb 103 packing, and a Hewlett-Packard 3390A recorder-integrator. The percentage of water in the sample

Table I. Pyridines Miscible with Water in All Proportions

compound	consolute range/°C
pyridine [110-86-1]	0-95
2-methylpyridine [109-06-8]	0-95
3-methylpyridine [108-99-6]	0-95
4-methylpyridine [108-89-4]	0-95
4-acetylpyridine [1122-54-9]	0-95
3-picolylamine [3731-52-0]	0-95
piperidine [110-89-4]	0-95
2-piperidineethanol [1484-84-0]	45 (mp)-95
1-acetylpyridine [618-42-8]	0-95

Table II. Mutual Solubility *S* of Water (B) and 2,3-Dimethylpyridine^a (A) [583-61-9]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
16.0	17.15	67.6	50.0	4.82	36.4
18.0	12.15	65.6	60.0	4.37	33.3
20.0	10.40	58.5	70.0	4.30	29.8
25.0	8.60	52.9	80.0	4.33	29.0
30.0	6.91	47.0	90.0	4.35	27.2
35.0	5.99	43.4	std dev	0.20	1.0
40.0	5.37	40.5			

^a Purity: 99 mass %. The lower critical solution temperature for this system is 16 °C. Below this temperature, A and B are miscible in all proportions.

Table III. Mutual Solubility *S* of Water (B) and 2,4-Dimethylpyridine^a (A) [108-47-4]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
24.0	15.43	61.0	50.0	4.83	40.0
26.0	11.78	55.5	60.0	4.28	36.2
28.0	10.20	53.1	70.0	4.14	33.1
30.0	8.76	51.1	80.0	4.11	31.1
35.0	6.89	46.3	90.0	4.15	30.0
40.0	5.84	45.6	std dev	0.20	1.3
45.0	5.16	41.2			

^a Purity: 99 mass %. The lower critical solution temperature for this system is 24 °C. Below this temperature, A and B are miscible in all proportions.

could then be immediately calculated from the mass of pyridine added and the GC scale factors for water and pyridine, as determined from GC analyses of known water and pyridine solutions. This calibration was done for each system using at least three standard solutions covering the composition range of the unknown solutions.

Table IV. Mutual Solubility *S* of Water (B) and 2,5-Dimethylpyridine^a (A) [589-93-5]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
13.0	19.05	62.9	40.0	4.85	27.2
14.0	15.26	57.5	50.0	3.71	23.2
16.0	11.21	52.8	60.0	3.53	22.1
18.0	9.68	51.4	70.0	3.67	21.8
20.0	8.22	47.4	80.0	3.47	21.6
25.0	6.57	34.6	90.0	3.55	20.9
30.0	5.79	31.2	std dev	0.12	0.8

^a Purity: 96 mass %. The lower critical solution temperature for this system is 13 °C. Below this temperature, A and B are miscible in all proportions.

Table V. Mutual Solubility *S* of Water (B) and 2,6-Dimethylpyridine^a (A) [108-48-5]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
34.0	22.9	62.3	43.0	7.5	40.7
35.0	13.9	53.9	45.0	7.1	41.1
36.0	12.8	53.4	50.0	5.5	35.6
37.0	11.5	51.3	60.0	4.4	29.8
38.0	9.9	52.4	70.0	3.9	26.8
39.0	9.3	45.5	80.0	3.7	23.4
40.0	9.1	47.3	90.0	3.6	21.5
41.0	8.2	43.8	std dev	0.2	0.9

^a Purity: 99+ mass %. The lower critical solution temperature for this system is 34 °C. Below this temperature, A and B are miscible in all proportions.

Table VI. Mutual Solubility *S* of Water (B) and 3,4-Dimethylpyridine^a (A) [583-58-4]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	8.36	61.8	60.0	3.91	33.8
10.0	6.18	50.0	70.0	3.94	32.9
20.0	5.04	43.8	80.0	4.11	31.0
30.0	4.25	40.7	90.0	4.38	30.0
40.0	4.02	37.8	std dev	0.03	0.1
50.0	3.84	35.2			

^a Purity: 99.3 mass %.

Table VII. Mutual Solubility *S* of Water (B) and 3,5-Dimethylpyridine^a (A) [591-22-0]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	4.2	56.8	60.0	2.3	27.3
10.0	3.5	43.5	70.0	2.4	25.5
20.0	2.9	39.3	80.0	2.3	25.9
30.0	2.5	32.7	90.0	2.4	24.9
40.0	2.4	30.6	std dev	0.03	0.1
50.0	2.3	28.3			

^a Purity: 99+ mass %. A mixture of A and B freezes at -8 °C.

The amount of organic in the water layer was determined in a similar way by using a standard which did not interfere with the other components present. For example, 2-chloropyridine was determined using 2-methylpyridine as standard. As in the case of the organic layer, the calibration was done for each system using at least three standard solutions.

In some cases samples phase separated on cooling and had to be brought into solution by heating or by the addition of a solvent such as acetonitrile, lower alcohols, pyridine, or lower glycol ethers such as 2-methoxyethanol. For each system studied, three to five measurements of standard solutions were made to determine GC scale factors. From these, standard deviations were calculated on the basis of an

Table VIII. Mutual Solubility *S* of Water (B) and 2-Ethylpyridine^a (A) [100-71-0]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	9.80	42.8	60.0	2.56	15.8
10.0	5.72	30.7	70.0	2.48	15.3
20.0	4.35	25.9	80.0	2.51	14.2
30.0	3.60	21.7	90.0	2.58	13.5
40.0	3.17	18.2	std dev	0.04	0.3
50.0	2.66	15.6			

^a Purity: 99.9 mass %.

Table IX. Mutual Solubility *S* of Water (B) and 3-Ethylpyridine^a (A) [536-78-7]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	4.07	29.0	60.0	2.28	18.0
10.0	3.17	25.3	70.0	2.34	17.1
20.0	2.74	23.2	80.0	2.31	17.0
30.0	2.48	21.7	90.0	2.46	16.9
40.0	2.45	19.8	std dev	0.06	0.2
50.0	2.44	19.0			

^a Purity: 97 mass %.

Table X. Mutual Solubility *S* of Water (B) and 4-Ethylpyridine^a (A) [536-75-4]

<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A
0	4.95	37.2
10.0	4.02	32.8
20.0	3.34	29.6
30.0	3.22	28.8
40.0	2.89	26.2
50.0	2.83	24.4
60.0	2.74	22.6
70.0	2.89	21.8
80.0	2.82	21.0
90.0	2.88	20.8
std dev	0.06	1.2

^a Purity: 99+ mass %.

Table XI. Mutual Solubility *S* of Water (B) and 2,4,6-Trimethylpyridine^a (A) [108-75-8]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
6.5	13.05	77.2	50.0	1.85	25.5
7.5	9.73	65.4	60.0	1.71	21.6
8.2	6.10	58.0	70.0	1.66	18.1
20.0	3.57	45.3	80.0	1.54	17.1
30.0	2.61	36.2	90.0	1.63	15.3
40.0	2.10	30.3	std dev	0.01	1.4

^a Purity: 99 mass %. The lower critical solution temperature for this system is 6.5 °C. Below this temperature, A and B are miscible in all proportions.

average composition, and are given in Tables II-XXVIII. The temperature of the thermostat was controlled by a Braun Thermomix 1480 or a Lauda Brinkmann RM 20 water bath for the lower temperatures. The absolute temperature was measured by a calibrated thermometer accurate to 0.1 °C.

All experimental measurements were done at atmospheric pressure. Most organics came from laboratory supply houses such as Aldrich or TCI America in purities normally of 98% or better. A few of the organics were supplied by commercial producers of the compounds.

Several of the systems showed a high solubility which covered a large composition range, often including a lower critical solution temperature. These were simply analyzed

Table XII. Mutual Solubility *S* of Water (B) and 4-Isopropylpyridine^a (A) [696-30-0]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	1.55	17.2	60.0	0.92	12.0
10.0	1.38	15.7	70.0	0.97	11.7
20.0	1.22	15.5	80.0	1.09	11.5
30.0	1.09	13.1	90.0	1.08	12.0
40.0	1.02	13.4	std dev	0.05	0.4
50.0	0.97	12.7			

^a Purity: 95 mass %.**Table XIII. Mutual Solubility *S* of Water (B) and 5-Ethyl-2-methylpyridine^a (A) [104-90-5]**

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	2.09	27.0	60.0	0.92	14.0
10.0	1.54	24.9	70.0	0.92	13.0
20.0	1.20	19.7	80.0	0.88	12.1
30.0	1.05	15.6	90.0	0.89	12.3
40.0	0.88	15.2	std dev	0.04	0.3
50.0	0.85	14.0			

^a Purity: 98 mass %.**Table XIV. Mutual Solubility *S* of Water (B) and 4-*tert*-Butylpyridine^a (A) [3978-81-2]**

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	0.56	11.4	60.0	0.38	9.3
10.0	0.44	11.9	70.0	0.39	9.1
20.0	0.43	10.8	80.0	0.45	9.1
30.0	0.40	10.6	90.0	0.47	8.9
40.0	0.37	9.6	std dev	0.01	0.2
50.0	0.35	9.2			

^a Purity: 99 mass %.**Table XV. Mutual Solubility *S* of Water (B) and 5-Butyl-2-methylpyridine^a (A) [702-16-9]**

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	0.42	7.38	60.0	0.21	4.85
10.0	0.25	7.40	70.0	0.24	5.24
20.0	0.18	6.48	80.0	0.20	4.82
30.0	0.19	5.86	90.0	0.17	4.52
40.0	0.23	5.91	std dev	0.01	0.10
50.0	0.31	4.59			

^a Purity: 99 mass %.**Table XVI. Mutual Solubility *S* of Water (B) and 2-Chloropyridine^a (A) [109-09-1]**

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	3.61	1.90	60.0	2.47	2.49
10.0	3.07	1.99	70.0	2.56	2.98
20.0	2.77	2.05	80.0	2.63	3.13
30.0	2.53	2.18	90.0	2.83	2.95
40.0	2.48	2.19	std dev	0.02	0.15
50.0	2.45	2.48			

^a Purity: 99 mass %.

directly with the GC, using scale factors determined from an analysis of standard solutions.

Summary of Data

Table I lists those compounds which were found experimentally to be miscible with water in all proportions (consolute). Note that both piperidine and 3-methylpyridine

Table XVII. Mutual Solubility *S* of Water (B) and 2-Bromopyridine^a (A) [109-04-6]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	2.75	1.18	60.0	2.28	1.81
10.0	2.48	1.15	70.0	2.44	2.01
20.0	2.30	1.28	80.0	2.50	2.35
30.0	2.29	1.39	90.0	2.86	2.38
40.0	2.13	1.45	std dev	0.05	0.04
50.0	2.20	1.64			

^a Purity: 99.8 mass %.**Table XVIII. Mutual Solubility *S* of Water (B) and 2-Acetylpyridine^a (A) [1122-62-9]**

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
9.0	35.18	18.52	50.0	9.66	8.73
12.0	28.81	14.93	60.0	9.83	9.27
20.0	21.76	11.65	70.0	8.94	9.34
25.0	15.68	10.62	80.0	8.89	9.18
30.0	13.17	9.39	90.0	9.08	9.90
40.0	10.85	9.26	std dev	0.2	0.2

^a Purity: 99 mass %. The lower critical solution temperature for this system is 9 °C. Below this temperature, A and B are miscible in all proportions.

Table XIX. Mutual Solubility *S* of Water (B) and 1-Methylpiperidine^a (A) [626-67-5]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
44.0	15.1	59.3	54.0	6.1	31.7
45.0	12.1	56.3	56.0	5.6	30.7
46.0	10.7	48.2	58.0		30.5
47.0	9.0	48.3	60.0		29.4
48.0	8.7	45.1	70.0	4.6	19.5
49.0	7.6	39.8	80.0	3.6	14.9
50.0	7.7	39.8	90.0	3.1	14.3
51.0	7.1	41.5	94.7		10.9
52.0	7.0	36.5	std dev	0.26	1.3

^a Purity: 99+ mass %. The lower critical solution temperature for this system is 44 °C. Below this temperature, A and B are miscible in all proportions.

Table XX. Mutual Solubility *S* of Water (B) and 2-Methylpiperidine^a (A) [109-05-7]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
70.0	17.9	64.6	80.0	8.2	45.1
71.0	14.6	60.3	81.0	8.1	43.6
72.0	13.1	54.8	82.0	8.0	43.6
73.0	11.6	55.4	84.0	7.8	41.5
74.0	11.2	53.6	86.0	7.6	39.8
75.0	10.5	52.0	88.0	7.2	38.8
76.0	9.7	50.3	90.0	7.2	38.2
77.0	9.8	50.1	92.5	6.8	35.9
78.0	8.8	48.0	std dev	0.3	1.0
79.0	8.6	46.8			

^a Purity: 99+ mass %. The lower critical solution temperature for this system is 70 °C. Below this temperature, A and B are miscible in all proportions.

are included, in spite of early literature references that these compounds phase separate.

The six dimethylpyridines (Tables II–VII) form an interesting series. The 3,4 and 3,5 isomers show only partial solubility between 0 and 90 °C, but the other four isomers all have lower critical solution temperatures between 13 and 34 °C. All three of the ethylpyridines (Tables VIII–X) are only partially soluble in water between 0 and 90 °C.

Table XXI. Mutual Solubility *S* of Water (B) and 3-Methylpiperidine^a (A) [626-56-2]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
67.0	13.7	69.8	80.0	6.9	54.9
68.0	13.7	67.3	90.0	6.4	49.7
70.0	10.2	65.5	std dev	0.2	1.0

^a Purity: 99 mass %. The lower critical solution temperature for this system is 67 °C. Below this temperature, A and B are miscible in all proportions.

Table XXII. Mutual Solubility *S* of Water (B) and 4-Methylpiperidine^a (A) [626-58-4]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
86.0	13.57	72.4	90.0	9.97	65.8
87.0	12.27	66.5	95.0	8.84	62.5
88.0	11.50	67.4	std dev	0.12	0.5

^a Purity: 99.9 mass %. The lower critical solution temperature for this system is 86 °C. Below this temperature, A and B are miscible in all proportions.

Table XXIII. Mutual Solubility *S* of Water (B) and 2,6-Dimethylpiperidine^a (A) [504-03-0]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
27.0	11.96	54.88	45.0	3.98	24.18
28.0	9.29	51.64	50.0	3.52	20.81
29.0	8.79	52.79	55.0	3.05	18.34
30.0	8.20	47.06	60.0	2.97	15.41
31.0	7.21	42.04	65.0	2.66	13.57
32.0	6.89	41.37	70.0	2.43	12.45
33.0	6.46	39.40	75.0	2.18	11.22
34.0	6.18	38.30	80.0	2.11	9.51
35.0	5.86	35.79	85.0	1.98	9.08
36.0	5.35	35.41	92.0	1.94	8.43
38.0	5.60	32.96	std dev	0.15	0.75
40.0	5.09	31.22			

^a Purity: 99.9 mass %. The lower critical solution temperature for this system is 27 °C. Below this temperature, A and B are miscible in all proportions.

Table XXIV. Mutual Solubility *S* of Water (B) and 3,3-Dimethylpiperidine^a (A) [1193-12-0]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	7.00	57.1	60.0	2.38	22.7
10.0	4.81	52.8	70.0	2.07	21.5
20.0	3.97	44.7	80.0	1.92	16.2
30.0	3.65	34.5	90.0	2.01	13.9
40.0	2.97	30.5	std dev	0.02	0.1
50.0	2.74	27.5			

^a Purity: 97 mass %.

All four methylpiperidines (Tables XIX–XXII) have lower critical solution temperatures ranging from 44 to 86 °C. The two ethylpiperidines which are available (Tables XXVI and XXVII) also have lower critical solution temperatures of 8 and 9 °C.

Acknowledgment

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Registry numbers were supplied by the author.

Table XXV. Mutual Solubility *S* of Water (B) and 3,5-Dimethylpiperidine^a (A) [35794-11-7]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	3.86	52.3	60.0	1.50	29.8
10.0	3.21	49.6	70.0	1.42	27.0
20.0	2.45	43.2	80.0	1.43	24.7
30.0	2.08	38.3	90.0	1.43	22.7
40.0	1.73	34.8	std dev	0.05	0.7
50.0	1.59	31.3			

^a Purity: 99+ mass %.

Table XXVI. Mutual Solubility *S* of Water (B) and 1-Ethylpiperidine^a (A) [766-09-6]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
9.0	7.8	85.0	25.0	4.7	17.6
10.0	8.9	82.9	30.0	3.4	13.3
11.0	8.5		40.0	2.3	7.5
12.0	7.4	79.5	50.0	1.7	5.1
14.0	6.8		60.0	1.4	4.1
16.0	6.7	46.0	70.0	1.2	3.7
17.0	6.1	30.1	80.0	1.0	3.4
18.0	6.4	19.7	90.0	0.9	3.4
19.0	5.6	18.9	std dev	0.15	0.8
20.0	5.3	19.9			

^a Purity: 99 mass %. The lower critical solution temperature for this system is 9 °C. Below this temperature, A and B are miscible in all proportions.

Table XXVII. Mutual Solubility *S* of Water (B) and 2-Ethylpiperidine^a (A) [1484-80-6]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
8.0	14.83	71.2	50.0	3.13	23.7
10.0	9.94	60.6	60.0	2.58	20.5
15.0	7.27	52.2	70.0	2.37	16.7
20.0	6.04	46.3	80.0	2.13	14.5
30.0	4.84	33.9	90.0	1.94	11.9
40.0	3.72	29.6	std dev	0.05	0.5

^a Purity: 99+ mass %. The lower critical solution temperature for this system is 8 °C. Below this temperature, A and B are miscible in all proportions.

Table XXVIII. Mutual Solubility *S* of Water (B) and Quinoline^a (A) [91-22-5]

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in B	B in A		A in B	B in A
0	0.71	20.7	60.0	0.78	15.3
10.0	0.77	19.6	70.0	0.80	14.5
20.0	0.84		80.0	0.93	12.5
30.0	0.66	15.7	90.0	1.29	12.1
40.0	0.80	15.9	std dev	0.04	0.7
50.0	0.84	16.2			

^a Purity: 98 mass %.

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