

Mutual Solubilities: Water-Glycol Ethers and Water-Glycol Esters

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Mutual binary solubilities have been measured for the ethers and esters of ethylene glycol, diethylene glycol, triethylene glycol, and propylene glycol. Data are given for 45 water-organic pairs at temperatures of 0-90 °C. It was found that 20 binary systems were consolute, 18 showed partial solubility over the entire temperature range, and 7 were partially soluble at higher temperatures, but had lower critical solution temperatures and were consolute at low temperatures. Neither the water layer nor the organic layer showed any consistent behavior with temperature. In some cases the solubility in each layer increased with temperature, in others the solubility in each layer decreased with temperature, and in still others the solubility in one layer increased with temperature while the solubility in the other layer decreased with temperature.

Introduction

Liquid-liquid solubility data are needed to check theoretical solubility relationships and to determine solubility parameters for liquid-liquid systems. Also the chemical and petroleum industries have a very strong interest in liquid-liquid solubility, particularly the solubility of organics in water and water in organics. Such information is needed for the design of liquid-liquid extractors and the design of decanters in distillation systems. In addition, liquid-liquid solubility is usually the easiest way to determine activity coefficient equations and even equations of state that are used to model liquid-liquid equilibria. These equations are of particular interest today because of the need to clean up aqueous waste streams which at one time were often simply dumped to the sewer.

The early solubility literature is summarized in books by Sorensen and Arlt (1) and the Solubility Data Series of the International Union of Pure and Applied Chemistry (2). Three previous papers (3-5) describe our research on the mutual solubility of organics and water, and give data for 220 binary and ternary systems. The present paper gives experimental data for an additional 45 water-organic pairs including 20 which are miscible in all proportions from 0 to 95 °C.

Experimental Section

As before, most samples were analyzed using the method of standard additions. Water and an 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 acetonitrile was added and the ratio of the water to acetonitrile peak measured with a Gow-Mac Series 550 thermal conductivity GC, a 6-ft by 2.2-mm internal diameter column, Chromosorb 101 packing, and a Hewlett-Packard 3390A recorder-integrator. The percentage of water in the sample could then be immediately calculated from the mass of acetonitrile added and the gas chromatograph (GC) scale factors for water and acetonitrile, as determined from GC analyses of known water and acetonitrile solutions. This calibration was done for each system using at least three standards covering the composition range of the unknown solutions.

The amount of the organic in the water layer was determined in a similar way by using a higher boiling material as standard. For example, 1-*tert*-butoxy-2-ethoxyethane was determined using 2-methoxyethyl ether as standard. As in the case of the organic layer, the calibration was done for each system using at least three standard solutions.

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 organic chemicals were supplied by commercial producers of the compounds.

In some instances, samples phase separated on cooling and had to be brought into solution by heating or by the addition of a solvent such as methanol. 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 average composition, and are listed in Tables II-XXVI. 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.

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

Summary of Data

It is often very hard to determine whether a given material is completely or only partially soluble in water. Handbooks and literature references only too often state that a material is "soluble" in water, or sometimes it is "very soluble" or even "freely soluble." But what exactly does this mean? Does it mean the material is quite soluble in water, does it mean the material is miscible with water in all proportions at room temperature, or does it mean the material is miscible with water in all proportions at all temperatures from zero to its boiling point? Because of these ambiguities, Table I lists those compounds which were found experimentally to be consolute with water, or miscible in all proportions between 0 and 95 °C.

Ethylene Glycol Monoethers. The methyl, ethyl, isopropyl, propyl, *tert*-butyl, and 2-chloroethyl monoethers (Table I) were all found to be consolute with water from 0 to 95 °C. It is interesting to note that the 2-chloroethyl monoether is consolute with water. The solubility is greatly decreased by the substitution of hydrogen by chlorine, but this is not enough to render this material insoluble in water. 2-Butoxyethanol and 2-isobutoxyethanol (Tables II and III) both show partial solubility in water at higher temperatures, but have lower critical solution temperatures and are consolute with water at room temperature. 2-(Hexyloxy)ethanol and

Table I. Compounds Consolute with Water from 0 to 95 °C

ethylene glycol monomethyl ether (109-86-4)
 ethylene glycol monoethyl ether (110-80-5)
 ethylene glycol monopropyl ether (2807-30-9)
 ethylene glycol monoisopropyl ether (109-59-1)
 ethylene glycol mono-*tert*-butyl ether (7580-85-0)
 ethylene glycol mono(2-chloroethyl) ether (628-89-7)
 ethylene glycol monomethyl ether acetate (110-49-6)
 ethylene glycol dimethyl ether (110-71-4)
 diethylene glycol monomethyl ether (111-77-3)
 diethylene glycol monoethyl ether (111-90-0)
 diethylene glycol monobutyl ether (112-34-5)
 diethylene glycol dimethyl ether (111-96-6)
 triethylene glycol monomethyl ether (112-35-6)
 triethylene glycol monoethyl ether (112-50-5)
 triethylene glycol monobutyl ether (143-22-6)
 triethylene glycol dimethyl ether (112-49-2)
 tetraethylene glycol monomethyl ether (23783-42-8)
 propylene glycol monomethyl ether (107-98-2)
 propylene glycol monoethyl ether (1569-02-4)
 propylene glycol dimethyl ether (7778-85-0)

Table II. Mutual Solubility *S* of Water (B) and 2-Butoxyethanol^a (A) (111-76-2)

<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
49.0	21.3	57.7	60.0	11.3	48.2
50.0	18.9	54.5	70.0	10.1	42.7
51.0	17.5	53.4	80.0	9.46	40.5
53.0	14.8	53.7	90.0	9.70	40.3
55.0	13.5	52.1	std dev	0.15	0.6

^a Purity: 99 mass %. The lower critical solution temperature for this system is 49 °C. Below this temperature, A and B are miscible in all proportions.

Table III. Mutual Solubility *S* of Water (B) and 2-Isobutoxyethanol^a (A) (4439-24-1)

<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
25.0	16.1	55.4	40.0	7.4	38.1
25.0	17.6	58.7	50.0	6.0	34.1
26.0	16.0	57.2	60.0	6.0	31.7
26.0	16.5	53.8	70.0	5.7	31.1
27.0	14.1	48.3	80.0	4.9	29.8
28.0	12.9	48.8	90.0	5.3	29.5
30.0	10.5	41.8	std dev	0.7	2.9
35.0	7.7	38.8			

^a Purity: 99 mass %. The lower critical solution temperature for this system is 25 °C. Below this temperature, A and B are miscible in all proportions.

Table IV. Mutual Solubility *S* of Water (B) and 2-(Hexyloxy)ethanol^a (A) (112-25-4)

<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	3.24	25.9	60.0	0.68	13.1
10.0	2.53	21.4	70.0	0.71	13.1
20.0	1.87	18.0	80.0	0.68	12.9
30.0	1.92	15.9	90.0	0.65	12.1
40.0	0.88	14.7	std dev	0.05	1.0
50.0	0.73	13.8			

^a Purity: 99+ mass %.

2-phenoxyethanol (Tables IV and V) both show low solubility, which is to be expected from the higher molecular weight of the ether group.

Ethylene Glycol Monoether Acetates. Ethylene glycol monomethyl ether acetate (Table I) is consolute with water from 0 to 95 °C. 2-Ethoxyethyl acetate, 2-butoxyethyl acetate, and 2-phenoxyethyl acetate (Tables VI–VIII) all show partial

Table V. Mutual Solubility *S* of Water (B) and 2-Phenoxyethanol^a (A) (122-99-6)

<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
10.0	2.56	9.35	60.0	3.57	13.34
20.0	2.89	10.18	70.0	3.37	14.09
30.0	2.54	10.82	80.0	4.54	15.23
40.0	2.97	11.32	90.0	5.58	16.08
50.0	3.19	12.40	std dev	0.16	0.18

^a Purity: 98 mass %. The solution froze slightly below 10 °C.

Table VI. Mutual Solubility *S* of Water (B) and 2-Ethoxyethyl Acetate^a (A) (111-15-9)

<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	31.3	4.76	60.5	14.6	7.77
9.6	28.7	5.06	70.6	13.4	8.09
19.7	25.2	5.52	80.6	12.6	8.53
30.0	21.7	6.32	90.0	12.1	9.13
40.0	18.6	6.80	std dev	0.9	0.08
49.8	16.4	7.22			

^a Purity: 99+ mass %.

Table VII. Mutual Solubility *S* of Water (B) and 2-Butoxyethyl Acetate^a (A) (112-07-2)

<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	3.01	1.34	60.0	0.92	2.82
9.9	2.14	1.50	70.0		2.65
20.4	2.11	1.70	80.0	1.05	2.76
30.0	1.50	1.93	90.2	1.28	2.81
40.0	1.33	2.16	std dev	0.15	0.07
50.0	1.03	2.27			

^a Purity: 99 mass %.

Table VIII. Mutual Solubility *S* of Water (B) and 2-Phenoxyethyl Acetate^a (A) (6192-44-5)

<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
20.0	0.44	0.80	70.0	0.28	1.72
30.0	0.49	1.18	80.0	0.37	1.93
40.0	0.29	1.14	90.0	0.45	1.92
50.0	0.28	1.26	std dev	0.03	0.03
60.0	0.24	1.45			

^a Purity: 99 mass %.

Table IX. Mutual Solubility *S* of Water (B) and 1,2-Diethoxyethane^a (A) (629-14-1)

<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	28.9	2.19	60.6	8.34	3.55
9.5	26.1	2.50	70.6	6.97	3.77
20.0	22.1	2.77	81.0	5.80	3.93
30.0	18.2	2.89	90.0	5.05	3.86
40.0	14.1	3.13	std dev	0.2	0.05
49.8	10.9	3.40			

^a Purity: 98 mass %.

solubility, with solubility decreasing with increasing molecular weight of the ether group.

Ethylene Glycol Diethers. Ethylene glycol dimethyl ether (Table I) is consolute with water from 0 to 95 °C. 1,2-Diethoxyethane, 1,2-dibutoxyethane, 1-*tert*-butoxy-2-methoxyethane, and 1-*tert*-butoxy-2-ethoxyethane (Tables IX–XII) all show partial solubility in water, with solubility decreasing with increasing molecular weight. The bis(2-chloroethoxy)ethane (Table XIII) shows very low solubility.

Table X. Mutual Solubility *S* of Water (B) and 1,2-Dibutoxyethane^a (A) (112-48-1)

<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	0.07	0.43	60.0	trace	0.59
10.0	0.10	0.52	70.0	trace	0.68
20.0	0.04	0.57	80.0	trace	0.76
30.0	0.06	0.56	90.0	trace	0.75
40.0	0.04	0.62	std dev	0.02	0.02
50.0	0.05	0.63			

^a Purity: 99+ mass %.**Table XI. Mutual Solubility *S* of Water (B) and 1-*tert*-Butoxy-2-methoxyethane^a (A) (66728-50-5)**

<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	21.91	2.53	60.0	4.49	3.54
10.0	18.11	2.62	70.0	3.48	3.58
20.0	14.28	2.77	80.0	3.07	3.84
30.0	11.68	2.94	90.0	2.86	3.84
40.0	7.63	3.14	std dev	0.06	0.05
50.0	5.40	3.24			

^a Purity: 99 mass %.**Table XII. Mutual Solubility *S* of Water (B) and 1-*tert*-Butoxy-2-ethoxyethane^a (A) (51422-54-9)**

<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	12.06	1.56	60.0	1.36	1.99
10.0	7.67	1.56	70.0	1.18	2.06
20.0	5.09	1.69	80.0	0.99	2.12
30.0	3.79	1.89	90.0	0.91	1.95
40.0	2.44	1.92	std dev	0.02	0.05
50.0	1.76	2.04			

^a Purity: 98 mass %.**Table XIII. Mutual Solubility *S* of Water (B) and Bis(2-chloroethoxy)ethane^a (A) (112-26-5)**

<i>t</i> /°C	<i>S</i> /(mass %)		<i>t</i> /°C	<i>S</i> /(mass %)	
	A in D	B in A		A in B	B in A
0	2.57	0.99	60.0	1.22	1.64
10.0	2.18	1.10	70.0	1.48	2.02
20.0	1.84	1.00	80.0	1.55	2.23
30.0	1.56	1.19	90.0	1.45	2.24
40.0	1.58	1.34	std dev	0.04	0.04
50.0	1.48	1.64			

^a Purity: 99.6 mass %.**Table XIV. Mutual Solubility *S* of Water (B) and Ethylene Glycol Diacetate^a (A) (111-55-7)**

<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	16.8	4.2	60.5	18.3	10.9
10.0	17.1	4.8	70.6	19.3	13.2
20.7	16.4	6.1	80.5	20.6	15.1
29.9	16.7	7.1	90.1	22.5	19.7
40.7	17.0	8.5	std dev	0.2	0.11
50.5	17.2	9.9			

^a Purity: 99 mass %.

Ethylene Glycol Diesters. Ethylene glycol diacetate (Table XIV) shows high solubility in water. Ethylene glycol dibutyrate (Table XV) shows quite low solubility because of the higher molecular weight.

Diethylene Glycol Monoethers. The methyl, ethyl, and butyl monoethers (Table I) are all consolute with water from 0 to 95 °C. Evidently the additional oxygen linkage in the

Table XV. Mutual Solubility *S* of Water (B) and Ethylene Glycol Dibutyrate^a (A) (105-72-6)

<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	0.32	0.99	60.0	0.18	1.69
10.0	0.33	0.93	70.0	0.23	1.72
30.0	0.20	0.98	80.0	0.22	2.06
40.0	0.22	1.20	90.0	0.20	2.32
50.0	0.19	1.46	std dev	0.01	0.03

^a Purity: 99.5 mass %.**Table XVI. Mutual Solubility *S* of Water (B) and Diethylene Glycol Monoethyl Ether^a (A) (112-59-4)**

<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
12.0	4.75	74.2	50.0	1.06	27.7
14.0	3.06	70.7	60.0	1.37	22.7
16.0	2.62	61.6	70.0	1.18	19.9
18.0	2.26	56.4	80.0	1.37	17.0
20.0	2.29	58.5	90.0	1.87	17.6
30.0	1.65	46.7	std dev	0.04	3.0
40.0	1.11	36.3			

^a Purity: 98 mass %. The lower critical solution temperature for this system is 12 °C. Below this temperature, A and B are miscible in all proportions.

Table XVII. Mutual Solubility *S* of Water (B) and Diethylene Glycol Monoethyl Ether Acetate^a (A) (112-15-2)

<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
44.0	48.0	32.3	60.0	28.4	18.9
45.0	46.6	25.3	70.0	20.9	18.3
46.0	44.3	24.7	80.0	17.4	17.2
47.0	43.0	22.2	90.0	15.6	17.9
48.0	41.2	24.0	std dev	0.4	0.12
50.0	39.6	21.7			

^a Purity: 99.9 mass %. The lower critical solution temperature for this system is 44 °C. Below this temperature, A and B are miscible in all proportions.

Table XVIII. Mutual Solubility *S* of Water (B) and Diethylene Glycol Monobutyl Ether Acetate^a (A) (124-17-4)

<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	9.09	2.88	60.0	1.19	4.03
10.0	5.12	3.05	70.0	1.04	4.49
20.0	2.86	3.09	80.0	1.43	4.83
30.0	2.91	3.44	90.0	1.14	4.84
40.0	1.96	3.55	std dev	0.07	0.03
50.0	1.48	4.06			

^a Purity: 99.9 mass %.

chain more than compensates for the higher molecular weight. As expected, diethylene glycol monoethyl ether (Table XVI) shows low solubility.

Diethylene Glycol Monoether Acetates. Diethylene glycol monoethyl ether acetate and diethylene glycol monobutyl ether acetate (Tables XVII and XVIII) show partial solubility at higher temperatures. However, the diethylene glycol monoethyl ether acetate has a lower critical solution temperature at 44 °C and is consolute with water below this temperature. Diethylene glycol monobutyl ether acetate shows moderate solubility at lower temperatures.

Diethylene Glycol Diethers. Diethylene glycol dimethyl ether (Table I) is consolute with water from 0 to 95 °C. 2-Ethoxyethyl ether and diethylene glycol *tert*-butyl methyl ether (Tables XIX-XXI) both show limited solubility at

Table XIX. Mutual Solubility *S* of Water (B) and 2-Ethoxyethyl Ether^a (A) (112-36-7)

<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
30.9	54.4	18.9	40.0	42.0	13.4
31.0	53.9	19.2	49.7	32.0	11.1
31.9	56.9	19.0	60.7	22.1	9.82
32.0	54.7	19.1	70.8	16.8	9.45
33.0	49.9	16.3	80.8	12.7	8.96
35.0	48.5		90.1	10.5	9.06
35.0	47.3	16.2	std dev	0.2	0.03

^a Purity: 99 mass %. The lower critical solution temperature for this system is 30 °C. Below this temperature, A and B are miscible in all proportions.

Table XX. Mutual Solubility *S* of Water (B) and 2-Butoxyethyl Ether^a (A) (112-73-2)

<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	0.89	1.05	60.0	0.081	1.41
10.0	0.50	1.09	70.0	0.069	
20.0	0.25	1.14	80.0	0.067	1.58
30.0	0.16	1.22	90.0	0.059	1.61
40.0	0.11	1.37	std dev	0.004	0.04
50.0	0.093	1.37			

^a Purity: 99 mass %.

Table XXI. Mutual Solubility *S* of Water (B) and Diethylene Glycol *tert*-Butyl Methyl Ether^a (A) (52788-79-1)

<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
20.0	60.6	18.56	40.0	23.7	8.66
21.0	61.4	15.64	50.0	16.3	7.88
22.0	57.2	11.68	60.0	9.74	7.06
23.0	55.4	10.49	70.0	7.46	6.78
24.0	46.3	10.56	80.0	5.97	6.94
26.0	46.2	10.97	90.0	5.07	7.08
28.0	39.0	9.90	std dev	0.80	0.40
30.0	36.7	9.86			

^a Purity: 97 mass %. The lower critical solution temperature for this system is 20.0 °C. Below this temperature, A and B are miscible in all proportions.

Table XXII. Mutual Solubility *S* of Water (B) and Propylene Glycol Monobutyl Ether^a (A) (5131-66-8)

<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
0	11.45	22.0	60.0	2.81	11.9
10.0	9.07	17.3	70.0	2.58	11.6
20.0	6.48	15.2	80.0	2.48	11.9
30.0	4.88	13.8	90.0	2.39	11.2
40.0	3.97	12.5	std dev	0.05	0.5
50.0	3.22	11.9			

^a Purity: 99 mass %.

higher temperatures, but have lower critical solution temperatures at 30 and 20 °C, respectively, and are consolute with water below these temperatures. The 2-butoxyethyl ether (Table XX) shows low solubility at all temperatures.

Triethylene Glycol Monoethers. The methyl, ethyl, and butyl monoethers of triethylene glycol (Table I) are all consolute with water from 0 to 95 °C. Evidently the two oxygen linkages in the chain more than compensate for the higher molecular weights.

Tetraethylene Glycol. Only the monomethyl ether (Table I) was available. It is consolute with water from 0 to 95 °C.

Table XXIII. Mutual Solubility *S* of Water (B) and Propylene Glycol Mono-*tert*-butyl Ether^a (A) (57018-52-7)

<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
7.7	33.44	38.8	30.0	14.92	17.9
9.0	28.82	35.2	40.0	11.06	15.6
11.0	23.50	30.2	50.0	8.70	14.4
13.0	24.15	28.6	60.0	6.50	13.8
14.0	23.42	25.9	70.0	5.53	12.7
15.0	22.45	28.8	80.0	4.84	12.9
17.0	21.12		90.0		12.7
20.0	19.27		std dev	0.5	0.8
25.0	17.81	19.0			

^a Purity: 99+ mass %. The lower critical solution temperature for this system is 7.7 °C. Below this temperature, A and B are miscible in all proportions.

Table XXIV. Mutual Solubility *S* of Water (B) and Propylene Glycol Monophenyl Ether^a (A) (770-35-4)

<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	2.23	5.69	60.0	1.65	7.45
10.0	1.79	6.65	70.0	1.74	8.31
20.0	1.88	7.03	80.0	1.91	8.35
30.0	1.36	6.54	90.0	2.08	9.22
40.0	1.45	7.02	std dev	0.03	0.05
50.0	1.62	7.20			

^a Purity: 95 mass %.

Table XXV. Mutual Solubility *S* of Water (B) and Propylene Glycol Monomethyl Ether Acetate^a (A) (108-65-6)

<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	28.2	4.08	59.7	12.8	6.44
10.9	25.0	4.62	70.6	11.9	7.16
20.0	21.4	5.00	80.6	11.7	7.75
30.0	18.2	5.39	90.0	10.9	8.16
40.0	15.9	5.70	std dev	0.2	0.1
49.8	14.1	5.84			

^a Purity: 99 mass %.

Table XXVI. Mutual Solubility *S* of Water (B) and Propylene Glycol Diacetate^a (A) (623-84-7)

<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	6.80	3.22	60.0	7.49	6.95
10.0	7.13	3.58	70.0	7.56	7.64
20.0	7.60	4.04	80.0	7.94	8.95
30.0	7.00	4.68	90.0	7.96	9.82
40.0	7.31	4.86	std dev	0.06	0.15
50.0	7.54	6.03			

^a Purity: 97.6 mass %.

Propylene Glycol Monoethers. The methyl and ethyl monoethers (Table I) are consolute with water from 0 to 95 °C. The mono-*tert*-butyl ether (Table XXIII) shows partial solubility in water at higher temperatures, but has a lower critical solution temperature at 7.7 °C and is consolute with water below this temperature. The monobutyl and monophenyl ethers (Tables XXII–XXIV) both show limited solubility from 0 to 90 °C.

Propylene Glycol Monoether Acetates. Only the propylene glycol monomethyl ether acetate (Table XXV) was available. It shows fairly high solubility in water from 0 to 90 °C.

Propylene Glycol Diethers. Only the propylene glycol dimethyl ether (Table I) was available. It is consolute with water from 0 to 95 °C.

Propylene Glycol Diesters. Only propylene glycol diacetate was available (Table XXVI). It shows moderate solubility from 0 to 90 °C.

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Literature Cited

- (1) Sorensen, J. M.; Arlt, W. *Liquid-Liquid Equilibrium Data Collection*; DECHEMA: Frankfurt/Main, Germany, 1979; Vol. V, Part 1.
- (2) International Union of Pure and Applied Chemistry Solubility Data Series; Macmillan Publishing Co., Inc.: Riverside, NJ.
- (3) Stephenson, R.; Stuart, J.; Tabak, M. *J. Chem. Eng. Data* **1984**, *29*, 287-290.
- (4) Stephenson, R.; Stuart, J. *J. Chem. Eng. Data* **1986**, *31*, 56-70.
- (5) Stephenson, R. *J. Chem. Eng. Data* **1992**, *37*, 80-95.

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