Viscosities of Binary Liquid Mixtures of *N,N*-Dimethylformamide with Substituted Benzenes at 303.15 and 313.15 K

Raghavan Srinivasa Ramadevi, Pannuru Venkatesu, and Murari Venkata Prabhakara Rao*
Department of Chemistry, Sri Venkateswara University, Tirupati 517 502, India

Viscosities of binary liquid mixtures of *N,N*-dimethylformamide with toluene, ethylbenzene, chlorobenzene, bromobenzene, nitrobenzene, and aniline at 303.15 and 313.15 K have been measured over the entire composition range.

Introduction

A knowledge of the viscosity of liquid mixtures is required in many chemical engineering designs. In the present work, viscosities of *N,N*-dimethylformamide with toluene, ethylbenzene, chlorobenzene, bromobenzene, nitrobenzene, and aniline have been measured at 303.15 and 313.15 K.

Experimental Section

Apparatus and Procedure. Viscosities of pure liquids and liquid mixtures were measured using an Ostwald viscometer. The viscometer was filled with 10.00 mL of a liquid or liquid mixture, its limbs were closed with Teflon caps, and the apparatus was placed in a thermostat maintained at 303.15 and 313.15 K. The time flow of each sample was measured at least six times. The caps of the limbs were removed during the measurement of flow time. The viscosities (η) of pure liquids and liquid mixtures were computed from the flow time and densities using the relation

$$\eta = k_v \rho t \qquad (1)$$

where K_v is the viscometer constant, ρ is the density, and t is the flow time for a given sample, respectively. Densities of liquid mixtures were computed from the experimental excess volumes which were determined dilatometrically (Ramadevi and Rao, 1995) using the relation

$$\rho = \frac{x_A M_A + x_A M_B}{V^o + V^E} \qquad (2)$$

where the subscripted x and M represent the mole fraction and molecular weight of the corresponding component. V^o stands for ideal molar volume, and V^E denotes excess molar volume. The viscometer was calibrated using triple-distilled water as the standard liquid. The uncertainty in the measured viscosity values is up to ±0.3%.

Materials. All the chemicals used in the present study are of analytical grade, and they are further purified by the methods described in our earlier papers (Ramadevi and Rao, 1995; Venkatesu and Rao, 1994). The purities of samples were checked by comparing the measured densities of the compounds with those reported in the literature (*TRC Thermodynamic Tables*, July 1995). Densities were determined with a bicapillary type pycnometer, with an uncertainity of 2 parts in 10^5. The purities of the samples were further confirmed by GLC single sharp peaks. The measured densities and those reported in the literature are listed in Table 1.

* To whom correspondence should be addressed.

Table 1. Densities at 303.15 K of Pure Compounds

compound	ρ/g·cm^{-3} exptl	ρ/g·cm^{-3} lit.
N,N-dimethylformamide	0.941 19	0.941 20
toluene	0.857 64	0.857 53
ethylbenzene	0.858 14	0.858 20
chlorobenzene	1.095 47	1.095 70
bromobenzene	1.481 47	1.481 50
nitrobenzene	1.193 37	1.193 46
aniline	1.013 14	1.013 30

Table 2. Mole Fraction (x_1) of *N,N*-Dimethylformamide, Density (ρ), and Viscosity of the Mixture (η) in the Mixtures of *N,N*-Dimethylformamide + Substituted Benzenes at 303.15 K

x_1	ρ/g·cm^{-3}	η/mPa·s	x_1	ρ/g·cm^{-3}	η/mPa·s
N,N-Dimethylformamide (1) + Toluene (2)			*N,N*-Dimethylformamide (1) + Ethylbenzene (2)		
0.0000	0.857 64	0.521	0.0000	0.858 14	0.584
0.1037	0.865 55	0.542	0.0997	0.864 71	0.597
0.1731	0.871 00	0.556	0.1997	0.871 32	0.614
0.2947	0.880 34	0.581	0.2999	0.878 10	0.631
0.3985	0.888 40	0.602	0.4154	0.886 27	0.652
0.4729	0.894 25	0.618	0.5109	0.893 51	0.667
0.6004	0.904 56	0.645	0.5840	0.899 33	0.679
0.7147	0.914 22	0.670	0.6991	0.909 25	0.696
0.7974	0.921 55	0.688	0.8014	0.919 06	0.709
0.8981	0.930 97	0.712	0.8872	0.928 04	0.719
1.0000	0.941 19	0.737	1.0000	0.941 19	0.737
N,N-Dimethylformamide (1) + Chlorobenzene (2)			*N,N*-Dimethylformamide (1) + Bromobenzene (2)		
0.0000	1.085 47	0.714	0.0000	1.481 47	0.985
0.1076	1.083 36	0.731	0.0879	1.446 58	0.982
0.2019	1.072 11	0.745	0.2075	1.396 00	0.973
0.2986	1.059 84	0.760	0.3085	1.350 29	0.963
0.3970	1.046 50	0.767	0.4055	1.303 59	0.949
0.5024	1.031 13	0.769	0.5063	1.251 90	0.931
0.6054	1.014 95	0.773	0.6027	1.199 19	0.905
0.7013	0.998 78	0.774	0.6877	1.149 83	0.879
0.7925	0.982 38	0.771	0.8054	1.076 56	0.831
0.8973	0.962 26	0.754	0.9002	1.012 99	0.789
1.0000	0.941 19	0.737	1.0000	0.941 19	0.737
N,N-Dimethylformamide (1) + Nitrobenzene (2)			*N,N*-Dimethylformamide (1) + Aniline (2)		
0.0000	1.193 37	1.628	0.0000	1.013 14	3.078
0.1017	1.173 45	1.524	0.1013	1.009 61	2.783
0.2145	1.150 15	1.416	0.2030	1.005 33	2.508
0.3053	1.130 38	1.331	0.3061	1.000 17	2.273
0.4040	1.107 80	1.246	0.4006	0.994 66	2.048
0.5021	1.084 14	1.165	0.5013	0.987 93	1.812
0.6003	1.059 13	1.085	0.6024	0.980 26	1.571
0.6968	1.033 16	1.002	0.6967	0.972 26	1.341
0.7975	1.004 47	0.917	0.8002	0.962 56	1.115
0.8975	0.974 21	0.826	0.9059	0.951 67	0.908
1.0000	0.941 19	0.737	1.0000	0.941 19	0.737

Results

The experimental results of viscosities, densities, and deviation in logarithm of the viscosity of the binary

0021-9568/96/1741-0479$12.00/0

Table 3. Mole Fraction (x_1) of *N,N*-Dimethylformamide, Density (ρ), and Viscosity of the Mixture (η), in the Mixtures of *N,N*-Dimethylformamide + Substituted Benzenes at 313.15 K

x_1	ρ/g·cm^{-3}	η/mPa·s	x_1	ρ/g·cm^{-3}	η/mPa·s
N,N-Dimethylformamide (1) + Toluene (2)			*N,N*-Dimethylformamide (1) + Ethylbenzene (2)		
0.0000	0.848 32	0.478	0.0000	0.849 43	0.531
0.1037	0.856 20	0.491	0.0997	0.855 59	0.542
0.1731	0.861 46	0.505	0.1996	0.862 15	0.556
0.2947	0.870 71	0.522	0.2997	0.869 06	0.568
0.3985	0.878 73	0.543	0.4154	0.877 38	0.584
0.4729	0.884 60	0.560	0.5109	0.884 60	0.597
0.6004	0.894 96	0.583	0.5840	0.890 33	0.608
0.7147	0.904 62	0.604	0.6991	0.899 89	0.625
0.7974	0.911 85	0.622	0.8014	0.909 14	0.641
0.8981	0.920 92	0.643	0.8872	0.917 71	0.652
1.0000	0.930 37	0.671	1.0000	0.930 37	0.671
N,N-Dimethylformamide (1) + Chlorobenzene (2)			*N,N*-Dimethylformamide (1) + Bromobenzene (2)		
0.0000	1.084 80	0.639	0.0000	1.468 17	0.895
0.1076	1.072 87	0.661	0.0879	1.433 20	0.889
0.2019	1.061 65	0.673	0.2075	1.382 78	0.879
0.2986	1.049 34	0.683	0.3085	1.337 31	0.870
0.3970	1.035 95	0.690	0.4055	1.290 85	0.854
0.5024	1.020 55	0.694	0.5063	1.239 40	0.838
0.6054	1.004 38	0.695	0.6027	1.186 88	0.816
0.7013	0.988 24	0.694	0.6877	1.137 69	0.792
0.7925	0.971 85	0.688	0.8054	1.064 72	0.749
0.8973	0.951 67	0.681	0.9001	1.001 60	0.711
1.0000	0.930 37	0.671	1.0000	0.930 37	0.671
N,N-Dimethylformamide (1) + Nitrobenzene (2)			*N,N*-Dimethylformamide (1) + Aniline (2)		
0.0000	1.183 67	1.389	0.0000	1.005 96	2.327
0.1017	1.163 71	1.307	0.1013	1.001 66	2.131
0.2145	1.140 35	1.220	0.2030	0.996 80	1.957
0.3083	1.120 54	1.157	0.3061	0.991 24	1.793
0.4040	1.097 89	1.091	0.4006	0.985 53	1.640
0.5021	1.074 15	1.023	0.5013	0.978 72	1.474
0.6003	1.049 04	0.952	0.6024	0.971 06	1.300
0.6968	1.022 95	0.884	0.6967	0.963 04	1.135
0.7975	0.994 09	0.809	0.8002	0.953 17	0.960
0.8975	0.963 64	0.738	0.9059	0.941 77	0.801
1.0000	0.930 37	0.671	1.0000	0.930 37	0.671

Table 4. Estimated Parameters of Eq 3 and Standard Deviation, $\sigma(\Delta\ ln\ \eta)$, for the Mixtures of *N,N*-Dimethylformamide with Substituted Benzenes at 303.15 K[a]

	mPa·s			
system	b_0	b_1	b_2	$\sigma(\Delta\ ln\ \eta)$
N,N-dimethylformamide + chlorobenzene	0.2550	0.0459	−0.0014	0.004
N,N-dimethylformamide + bromobenzene	0.3529	0.1009	0.0014	0.001
N,N-dimethylformamide + nitrobenzene	0.2528	0.1367	0.0070	0.002
N,N-dimethylformamide + aniline	0.7298	0.2332	−0.1070	0.004

[a] In the case of *N,N*-dimethylformamide with toluene and ethylbenzene systems the parameters b_0, b_1, b_2, and $\sigma(\Delta\ ln\ \eta)$ are not calculated because the experimental $\Delta\ ln\ \eta$ are very low, within the experimental error.

mixtures of *N,N*-dimethylformamide with toluene, ethylbenzene, chlorobenzene, bromobenzene, nitrobenzene, and aniline at 303.15 and 313.15 K are listed in Tables 2 and 3. The results of $\Delta\ ln\ \eta$ are fitted using the smoothing equation,

$$\Delta\ ln\ \eta = x_1x_2[b_0 + b_1(x_1 - x_2) + b_2(x_1 - x_2)^2] \quad (3)$$

The values of parameters b_0, b_1, and b_2 are obtained by the method of least squares and are reported in Tables 4 and 5, along with the standard deviation, $\sigma(\Delta\ ln\ \eta)$. The results for $\Delta\ ln\ \eta$ are graphically represented in Figures 1 and 2. These graphical representations show that the curves are symmetric for all the systems except for the systems of *N,N*-dimethylformamide with toluene and ethylbenzene. The algebraic values of $\Delta\ ln\ \eta$ at 303.15 and 313.15 K fall in the order aniline > bromobenzene > nitrobenzene > chlorobenzene > ethylbenzene > toluene.

Table 5. Estimated Parameters of Eq 3 and Standard Deviation, $\sigma(\Delta\ ln\ \eta)$, for the Mixtures of *N,N*-Dimethylformamide with Substituted Benzenes at 313.15 K[a]

	mPa·s			
system	b_0	b_1	b_2	$\sigma(\Delta\ ln\ \eta)$
N,N-dimethylformamide + chlorobenzene	0.2319	−0.0428	0.0469	0.002
N,N-dimethylformamide + bromobenzene	0.3217	0.0714	−0.0490	0.002
N,N-dimethylformamide + nitrobenzene	0.2363	0.0653	−0.0815	0.002
N,N-dimethylformamide + aniline	0.6611	0.1799	−0.1597	0.002

[a] In the case of *N,N*-dimethylformamide with toluene and ethylbenzene the parameters b_0, b_1, b_2, and $\sigma(\Delta\ ln\ \eta)$ are not calculated because the experimental $\Delta\ ln\ \eta$ are very low, within the experimental error.

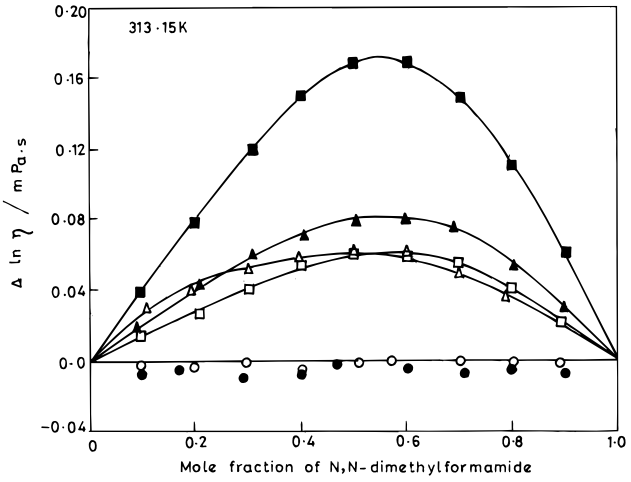

Figure 1.

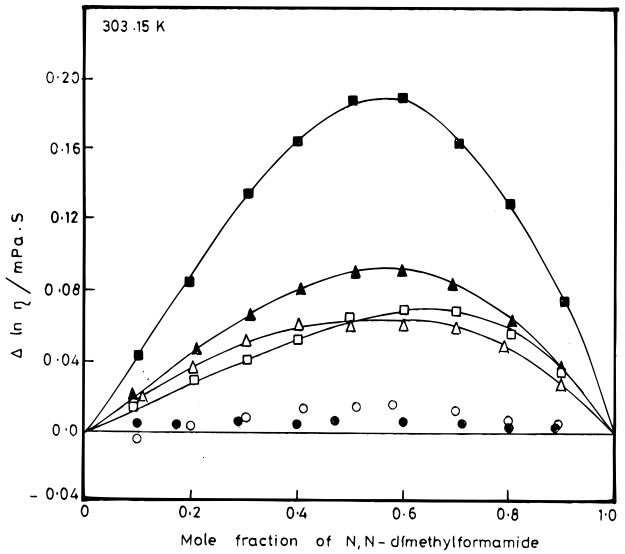

Figure 2.

Literature Cited

Ramadevi, R. S.; Rao, M. V. P. Excess Volumes of Substituted Benzenes with *N*,*N*-Dimethylformamide. *J. Chem. Eng. Data* **1995**, *40*, 65−67.

TRC Thermodynamic Tables, version 2.0; Texas A&M University: College Station, TX, July 1995.

Venkatesu, P.; Rao, M. V. P. Excess Volumes of Ternary Mixtures of *N*,*N*-Dimethylformamide + Methyl isobutyl ketone + 1-Alkanols at 303.15K. *Fluid Phase Equilibria* **1994**, *98*, 173−178.

Received for review July 28, 1995. Accepted January 21, 1996.[⊗] P.V. is very thankful to the Council of Scientific & Industrial Research (CSIR), New Delhi, for the award of a Research associateship.

JE950187N

[⊗] Abstract published in *Advance ACS Abstracts*, March 1, 1996.