

Turbidity of deuterated isobutyric acid and heavy water in the one-phase region near the critical solution point

Lori W. DaMore and D. T. Jacobs

Department of Physics, The College of Wooster, Wooster, Ohio 44691

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We have measured the total light scattered from a mixture of deuterated isobutyric acid and heavy water (deuterium oxide, D_2O) near its upper critical solution point. The resulting turbidity was measured in a reduced temperature region $10^{-6} < t < 10^{-2}$, where $t = (T - T_c)/T_c$ and T_c is the critical solution temperature, in a sample close to the critical composition. This completely deuterated mixture near its critical point exhibits similar properties to the undeuterated mixture and the turbidity can be explained using an Ising model. When the critical exponents ν and γ were fixed at the values predicted from renormalization-group theory, the amplitude ξ_0 of the correlation length was determined to be 0.343 ± 0.024 nm, while the amplitude of the turbidity τ_0 was $(3.51 \pm 0.03) \times 10^{-6} \text{ cm}^{-1}$, which seem consistent with two-scale-factor universality predictions.

INTRODUCTION

The effect of deuteration on the binary fluid mixture isobutyric acid and water has been investigated in the one- and two-phase regions by a number of people. The coexistence curve¹ and turbidity² for the undeuterated mixture found this system to obey the exponent and amplitude relations predicted by renormalization-group theory.³ The effect of isotope exchange has also been investigated by several authors⁴⁻¹⁰ who have looked at the coexistence curve in the two-phase region, and the correlation length in the one- and two-phase regions. They observe normal critical point behavior in the one-phase region but more complicated phenomena in the two-phase region where isotope effects provide a ternary system. Only one investigator¹¹ has measured the totally deuterated system, for which the coexistence curve was found to behave normally. The mixture of deuterated isobutyric acid in heavy water is particularly interesting because of the complementary information on the partially deuterated mixtures and the undeuterated system. This article presents the first measurement of light scattering in the totally deuterated mixture of isobutyric acid and water. The results will be compared to the undeuterated and partially deuterated isobutyric acid and water systems previously reported. Finally, the amplitude prediction from two-scale-factor universality will be discussed.

Modern theories of critical solution points have been very successful in explaining a wide variety of observed phenomena in low molecular weight fluid mixtures.³ In particular, the critical exponents experimentally measured in binary fluid mixtures are found to be universal and to agree with the renormalization-group predictions for the Ising model (space dimension $d = 3$ and order parameter dimension $n = 1$).³ Renormalization-group theory has also been used successfully to relate amplitudes that describe phenomena near a critical solution point. Two-scale-factor universality predicts a universal relationship among the amplitudes B of the coexistence curve, χ_0 of the osmotic compressibility, and

ξ_0 of the correlation length. These amplitudes are defined by³

$$\xi = \xi_0 t^{-\nu}, \quad T > T_c \quad (1)$$

$$\phi - \phi_c = B t^\beta, \quad T < T_c \quad (2)$$

and

$$\chi = \chi_0 t^{-\gamma}, \quad T > T_c \quad (3)$$

where ϕ is the volume fraction of one component in the upper or lower phase, ϕ_c is the critical composition, χ is the osmotic compressibility, t is the reduced temperature $t = |T - T_c|/T_c$, and β , ν , and γ are universal critical exponents predicted¹² from the $n = 1$ (Ising) model to be 0.325, 0.63, and 1.241, respectively. It has been shown¹³⁻¹⁴ that the amplitudes can be related by

$$R = \xi_0 \left(\frac{B^2}{k_B T_c \chi_0} \right)^{1/3} = 0.65-0.67 \quad (4)$$

with a predicted¹³⁻¹⁴ value of 0.65-0.67 for the three-dimensional Ising model. Experiments in liquid-gas systems¹⁵ and undeuterated liquid mixtures^{2,16} have confirmed this value within experimental error. The values of ξ_0 and χ_0 can both be determined, in principal, by turbidity measurements as described later.

The turbidity τ is the inverse of an effective extinction length and is defined by $\tau = (-1/L) \ln(I_t/I_0)$, where L is the length of the scattering medium, I_t is the transmitted light intensity, and I_0 the incident light intensity. The turbidity is caused by light scattering from concentration fluctuations in the fluid mixture near the critical point. By assuming Ornstein-Zernike scattering,¹⁷ which has accurately explained the angular distribution of scattered light near a critical point, an expression for the turbidity can be obtained. A small asymmetry in the forward direction caused Fisher¹⁸ to introduce a critical exponent η whose value is small ($\eta = 2 - \gamma/\nu \sim 0.030$), resulting in a negligible effect on the turbidity at the level of current experiments.^{16,19} The

turbidity can be developed by integrating the light scattered out of the incident beam to give¹⁷ (for $\eta = 0$)

$$\tau = \tau_0 (1 + t)t^{-\gamma} \left(\frac{2a^2 + 2a + 1}{a^3} \ln(1 + 2a) - \frac{2(1 + a)}{a^2} \right), \quad (5)$$

where

$$\tau_0 = \frac{\pi^3}{\lambda_0^4} \left(\frac{\partial n^2}{\partial \phi} \right)^2 k_B T_c \chi_0, \quad (6)$$

$a = 2k_0^2 \xi_0^2$, $k_0 = 2\pi n/\lambda_0$, n is the refractive index of the mixture, λ_0 is the vacuum wavelength of the light, and the turbidity amplitude τ_0 is a quantity dependent on the system. Good data close to T_c are crucial in determining ξ_0 which enters in a complicated fashion through a . The compressibility dominates far from T_c , so the turbidity has a simple power-law dependence $\tau = 8\tau_0 t^{-\gamma/3}$ for $T \gg T_c$. Close to T_c , the turbidity varies much more slowly and is a function of both τ_0 and ξ_0 : $\tau = [\tau_0 / (k_0^2 \xi_0^2)] \ln(2a)$ for $T > T_c$. If experiments very close to T_c become possible, then the nonzero value of η becomes important and such a logarithmic dependence is not expected but rather the turbidity goes to a large (but finite) constant, as recently discussed by Ferrell.²⁰ The compressibility amplitude χ_0 cannot be determined from τ_0 in this study since measurements of the composition dependence of the refractive index, $\partial n^2 / \partial \phi$, are not available.

The effects of deuteration on the critical point have been of interest for some time. Several measurements in the undeuterated isobutyric acid and water system have been carried out; two of particular importance to this experiment are the coexistence curve,¹ where the amplitude $B = 0.536$ when $\beta = 0.328$, and the turbidity,² where $\xi_0 = (0.3625 \pm 0.0065)$ nm and $\tau_0 = (1.08 \pm 0.02) \times 10^{-5} \text{ cm}^{-1}$. The system can then be partially deuterated in a number of ways in order to study isotope effects on the hydrogen bonding in this system. Heavy water (D_2O) can be mixed with isobutyric acid (COOH) and/or the hydroxyl ion in the acid can be deuterated (COOD). Such partially deuterated systems form a ternary system below the critical point and the coexistence curve must be appropriately interpreted.⁴ The dependence of critical temperature and composition on the amount of deuteration was investigated by Gansen and Woermann⁵ which has been generalized to other systems by Van Hook *et al.*⁶ and Schön *et al.*⁷ with a universal relationship proposed by Jacobs.²¹ The correlation length ξ_0 was also measured in the one-phase region of the partially deuterated system by Oswald *et al.*,⁸ who found $\xi_0 = (0.31 \pm 0.02)$ nm, and by Gulari *et al.*,⁹ who found $\xi_0 = (0.313 \pm 0.016)$ nm, with normal Ising exponents. The latter group also measured the correlation length in the two phase region and found⁹ renormalized exponents and a much smaller $\xi_0 \approx 0.06$ nm. For totally deuterated isobutyric acid (all eight hydrogens replaced by deuterium) and heavy-water system, only the coexistence curve has been measured: it was found¹⁰ that the system behaved as the undeuterated mixture (giving Ising-like exponents) but with an amplitude ($B = 0.61$) that was larger than the undeuterated system.

This work describes precise measurements of the turbidity in the one-phase region close to the critical solution point of the totally deuterated mixture of isobutyric acid and water. The turbidity data are analyzed to determine consistency with Eq. (5), to determine the amplitudes ξ_0 and τ_0 , to test the two-scale-factor amplitude ratio R , and to compare our results with those in related systems.

EXPERIMENTAL METHODS

The deuterated isobutyric acid came from Merck, Sharpe, and Dohme in Canada and was at least 94 at. % deuterated by mass spectrometric analysis. Deuterium oxide came from the Aldrich Chemical Co. and was 99.96 at. % deuterated. The sample was prepared¹⁰ by S. Greer at the University of Maryland, sealed in a quartz ampoule, and loaned to our lab for the purpose of this study. Using a sample prepared at the same time as that used for the coexistence curve study¹⁰ helps allow the critical amplitudes obtained from this experiment to be meaningfully combined with those from the coexistence curve. This mixture is somewhat sensitive to contamination from water vapor in the air and precautions were taken when the fluids were transferred into the optical cell (described later) just before the start of our experiment. The effect of minute impurities on the critical point is principally seen as a shift in the critical temperature, with negligible effects on the critical composition, amplitude, or exponents.²²

Our light-scattering cell is a commercial (Spectrocell) optical glass cell with a cylindrical design 22 mm in diameter and a path length of 5.00 cm. It has a fill tube which was heated and drawn closed to seal the sample. The optical cell was filled with a 88.5 mole % D_2O sample transferred in air over a 2 min period from the sealed quartz ampule. The critical composition was determined by Greer¹⁰ to be 88.2 mole % of D_2O , which is very close to the composition used in this experiment.

The temperature of the cell was controlled by immersion in a well-stirred, filtered water bath, as described previously.^{16,23} A pair of optical glass windows was sealed to an insulated, cylindrical tank that housed the water, optical cell, stirrer, temperature control, and filtering attachments. The temperature was coarsely controlled by a separate circulating bath passing water through a sealed copper tube in the optical tank, and finely controlled with a Tronac PTC-41 to give ± 0.2 mK maximum excursions over an hour and a long term stability less than 1 mK. The temperature was monitored with a Thermometrics thermistor in a separate ac bridge to an accuracy of ± 10 mK and a precision of ± 0.2 mK.

The optical system was designed and refined to optimize the precision and accuracy of the light-intensity measurements which allowed the turbidity to be determined. The optics have been fully described^{16,23} and were modified by adding a laser power amplitude controller that provided an incident intensity that varied less than 0.1% long term and 0.02% short term.

The low-power laser beam ($\lambda_0 = 632.8$ nm) traveled through the water bath where the cell was oriented with the

laser beam along the cell's cylindrical axis. The cell could be moved out of the beam path to determine the absolute turbidity of the fluid sample. The detection, computer averaging and experimental procedure are the same as described previously.^{16,23}

EXPERIMENTAL RESULTS

The procedure of taking intensity measurements with the cell in and out of the beam path corrects for reflected and absorbed light from the bath, but not for reflected light from the cell windows. The turbidity due to reflections from the cell windows can be calculated from the refractive indices of the cell windows, water, and the fluid mixture. The refractive index of the deuterated isobutyric acid and water solution was measured by a beam-displacement technique and found to be 1.381 ± 0.007 . Water and the optical glass windows had refractive indices of 1.333 and 1.52, respectively. The contribution to the measured turbidity due to the reflectance at normal incidence is then $0.0026 \pm 0.0001 \text{ cm}^{-1}$ for the optical glass cell. The turbidity τ_r , due to reflectance from the cell windows is subtracted from the measured turbidity at each temperature to obtain the absolute turbidity τ of the deuterated isobutyric acid and heavy water mixture:

$$\tau = -\frac{1}{L} \ln(I_1/I_2) - \tau_r, \quad (7)$$

where I_1 and I_2 are the ratios of the transmitted to reference intensities with and without the cell in the beam, respectively. A rather long (5 cm) path length cell was used because of the small amount of light scattering which occurs in this system.

Two effects were used to determine the onset of phase separation. The first was a large increase in the turbidity as the temperature was decreased in small (1–3 mK) steps toward T_c . Since the turbidity changes slowly with temperature close to, but above, T_c , a sudden turbidity increase signals the formation of large concentration fluctuations—the precursor of a second phase. When such an increase was observed, the system was held at the temperature for 1–2 d to look for the second indicator of phase separation: the appearance of two liquid phases separated by a distinct meniscus, which appeared to divide the phases equally in our cell. The phase-separation process takes several hours when very close to the critical temperature (< 1 mK) and can be easily missed if data are taken too quickly. The transition temperature in this cell was observed to be 42.193 ± 0.001 °C for runs 2 and 3 and 42.183 ± 0.001 °C for run 4 (run 1 did not get close enough to the critical point to observe the phase transition precisely). These values agree very well with Greer's value¹⁰ of $T_c = 42.193$. The shift in the phase-transition temperature from runs 2–3 and run 4 is not understood but could be the result of a shift in the critical temperature or a drift in our electronics during the month between those runs. Assuming a critical composition of 88.2 mole % D_2O ,¹⁰ our sample's composition would result in a negligible 30 μK difference between the phase-separation temperature and the critical temperature.

The turbidity data are presented in Table I in the order

they were taken over a ten week period. The background turbidity from the cell reflectivity (discussed earlier) has been subtracted from the experimentally determined turbidity to give the absolute turbidity in units of reciprocal centimeters. The reduced temperature t ranges from 10^{-6} to 10^{-2} and is determined from the experimentally measured phase-transition-temperature values for each sample which are taken as the critical temperature. The error in the turbidity $\delta\tau$ represents the experimental standard deviation propagated from the light-intensity measurements and includes the error in the path length determination. Light scattering in the forward direction is small²⁴ and our geometry and aperture sizes should give a negligible multiple scattering contribution to the measured turbidity. The data are plotted in Fig. 1. The almost linear dependence at large t in Fig. 1 has a slope of $-\gamma$ corresponding to the $t^{-\gamma}$ power-law dependence. At small t , the turbidity changes slowly in accordance with Eq. (5).

ANALYSIS AND DISCUSSION

The data shown in Table I can be analyzed using a properly weighted least-squares fit where the parameters ξ_0 , τ_0 , τ_b , ν , γ , and T_c can all be adjusted in Eq. (5). A properly weighted fit utilizes both the experimental uncertainty in the turbidity $\delta\tau$ given in Table I, and the propagated uncertainty in the reduced temperature. The error in the reduced temperature corresponds to the 1.0 mK uncertainty in the critical temperature. A nonlinear fit described in Bevington²⁵ was used to determine the parameter values. The errors in the parameters take into account the correlated errors²⁶ in the parameters, and are quoted in our results at the 99% confidence interval. Further details about this program will appear elsewhere.²⁷ In all of the fits reported here, one point at $t = 2.667 \times 10^{-3}$ was omitted from the fits as an outlier.

An additional parameter τ_b was added to the right-hand side of Eq. (5) as a constant, background turbidity that was necessary for this function to fit the data in Table I. This parameter accounted for scattering that was not due to the critical solution point and was presumably caused by a non-critical scattering in the sample.

The parameters ξ_0 , τ_0 , ν , γ , and τ_b were varied in the fits of Eq. (5) to the turbidity data reported in Table I. The critical temperature was allowed to vary within the range determined from observation; however, the other parameters did not change within experimental error, principally because the points close to T_c are not weighted strongly nor does the turbidity change rapidly in this region. The resulting values of the parameters are given in Table II, along with the uncertainties in the parameter values at the 99% confidence interval. The data reported in Table I were well explained by an $n = 1$ Ising model as shown by the three fits in Table II.

The first fit allowed the five parameters τ_0 , ξ_0 , τ_b , ν , and γ to vary freely. When all 89 points were fit by Eq. (5), the values of the exponents were $\nu = 0.65 \pm 0.01$ and $\gamma = 1.2 \pm 0.2$ which are values close to the known Ising model values.¹² Because the turbidity has a complicated dependence on the critical exponents and because the background light-scattering introduces an additional parameter

TABLE I. Absolute turbidity τ in the one phase region of deuterated isobutyric acid in heavy water as a function of temperature T or reduced temperature $t = (T - T_c)/T_c$. T_c is the critical temperature taken as 315.343 K for runs 1–3 and 315.333 K for run 4. The absolute turbidity corrects the measured turbidity for the light reflected from the cell windows.

T, K	t	$\tau \text{ cm}^{-1}$	$\delta\tau \text{ cm}^{-1}$	T, K	t	$\tau \text{ cm}^{-1}$	$\delta\tau \text{ cm}^{-1}$
Run 1				315.3758	1.040E-04	0.2180	0.0011
315.8801	1.7032E-03	0.02430	0.000 08	315.3703	8.66E-05	0.2396	0.0012
315.8080	1.4746E-03	0.02798	0.000 12	317.1097	5.6312E-03	0.0077	0.0002
315.7802	1.3864E-03	0.02956	0.000 13	315.3635	6.50E-05	0.2704	0.0011
315.7543	1.3043E-03	0.03146	0.000 18	315.3581	4.79E-05	0.3058	0.0011
315.7117	1.1692E-03	0.03459	0.000 25	315.3567	4.34E-05	0.3162	0.0013
315.6852	1.0852E-03	0.03736	0.000 27	315.3548	3.74E-05	0.3316	0.0011
315.6568	9.951E-04	0.04089	0.000 25	315.3534	3.30E-05	0.3470	0.0012
315.5743	7.335E-04	0.05522	0.000 30	315.3520	2.85E-05	0.3610	0.0015
315.5324	6.006E-04	0.06638	0.000 06	315.3510	2.54E-05	0.3714	0.0014
315.4916	4.712E-04	0.08296	0.000 28	315.3502	2.28E-05	0.3870	0.0013
315.4650	3.869E-04	0.09793	0.000 14	315.3489	1.87E-05	0.4082	0.0010
Run 2				315.3481	1.62E-05	0.4389	0.0013
315.8773	1.6943E-03	0.02617	0.000 09	315.3460	9.5E-06	0.4812	0.0014
315.8049	1.4648E-03	0.02994	0.000 09	315.3440	3.2E-06	0.5139	0.0024
315.7226	1.2038E-03	0.03618	0.000 06	315.3437	2.2E-06	0.5320	0.0032
315.6407	9.441E-04	0.04579	0.000 05	Run 4			
315.5724	7.275E-04	0.05820	0.000 08	317.0404	5.4114E-03	0.0080	0.0002
315.5028	5.067E-04	0.07866	0.000 04	316.9717	5.1935E-03	0.0080	0.0002
315.4343	2.895E-04	0.12222	0.000 06	316.8757	4.8891E-03	0.0085	0.0002
315.3941	1.620E-04	0.17861	0.000 10	316.7653	4.5390E-03	0.0093	0.0002
315.3747	1.005E-04	0.22870	0.000 15	316.6693	4.2346E-03	0.0100	0.0002
315.3616	5.90E-05	0.28922	0.000 48	316.5874	3.9748E-03	0.0106	0.0002
315.3585	4.92E-05	0.31001	0.000 48	316.4919	3.6720E-03	0.0114	0.0002
315.3581	4.79E-05	0.31673	0.000 67	316.3970	3.3710E-03	0.0124	0.0002
315.3548	3.74E-05	0.33870	0.000 41	316.1751	2.6673E-03	0.0138	0.0002
315.3522	2.92E-05	0.36253	0.000 42	316.1989	2.7428E-03	0.0155	0.0002
315.3517	2.76E-05	0.37988	0.000 82	316.0981	2.4231E-03	0.0171	0.0002
315.3495	2.06E-05	0.39607	0.000 62	315.9760	2.0359E-03	0.0205	0.0002
315.3490	1.90E-05	0.41290	0.001 07	315.8649	1.6836E-03	0.0249	0.0003
315.3480	1.59E-05	0.42880	0.001 27	315.7853	1.4312E-03	0.0297	0.0002
315.3469	1.24E-05	0.45127	0.000 34	315.7051	1.1768E-03	0.0359	0.0002
315.3462	1.01E-05	0.47491	0.001 53	315.6361	9.580E-04	0.0440	0.0002
315.3454	7.6E-06	0.49477	0.001 11	315.5810	7.833E-04	0.0532	0.0002
Run 3				315.5139	5.705E-04	0.0710	0.0002
315.4622	3.780E-04	0.1003	0.0016	315.4737	4.430E-04	0.0886	0.0002
315.4230	2.537E-04	0.1307	0.0011	315.3914	1.820E-04	0.1651	0.0003
315.4096	2.112E-04	0.1460	0.0010	315.3592	7.99E-05	0.2374	0.0004
315.4028	1.896E-04	0.1575	0.0011	315.3580	7.61E-05	0.2576	0.0003
315.3958	1.674E-04	0.1693	0.0010	315.3498	5.01E-05	0.3031	0.0004
315.3914	1.535E-04	0.1814	0.0010	315.3414	2.35E-05	0.3706	0.0008
315.3837	1.291E-04	0.1986	0.0010	315.3396	1.78E-05	0.4157	0.0006
				315.3394	1.71E-05	0.4415	0.0014

TABLE II. Parameter values resulting from fitting Eq. (5) to the absolute turbidity data in Table I. All fits were to the entire set of data which covered the reduced temperature region $10^{-6} < t < 10^{-2}$. A constant background turbidity τ_b was used to account for scattering far from the critical solution temperature T_c . Errors on the parameters are at the 99% confidence interval as described in the text. χ^2/N is the reduced chi squared as defined in Ref. 25. Fit 2 shows the parameter values giving the best fit to the data.

Fit	Points	ν	γ	τ_0 (10^{-6} cm^{-1})	ξ_0 (nm)	τ_b (10^{-3} cm^{-1})	χ^2/N
1	89	0.654 ± 0.009	1.19 ± 0.21	4.64 ± 0.05	0.24 ± 0.22	1.7 ± 0.3	0.364
2	89	0.63	1.241	3.51 ± 0.03	0.343 ± 0.024	2.0 ± 0.3	0.361
3	89	0.63	1.241	4.35 ± 0.10	0.47 ± 0.05	0	2.60

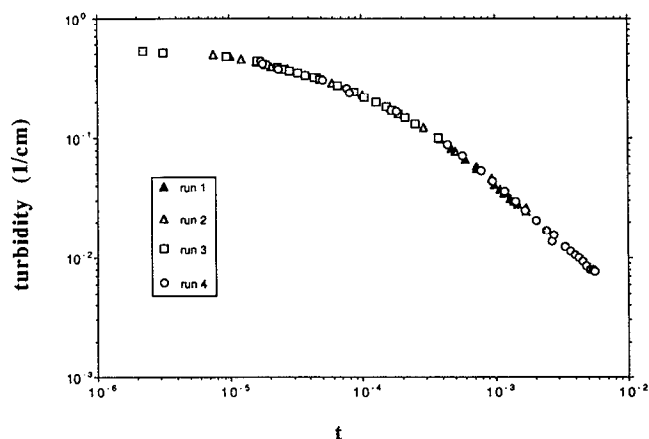


FIG. 1. Turbidity in deuterated isobutyric acid in heavy water (D_2O) as a function of reduced temperature $t = (T - T_c)/T_c$. All data were taken on the same sample. Runs 2 and 3 had an observed transition temperature of 42.193 °C while run 4 had a transition temperature of 42.183 °C. At small t , the turbidity increases slowly and appears flat in this plot. At larger temperatures, $3 \times 10^{-4} < t$, the turbidity has a power-law dependence on t and appears as a straight line with slope $-\gamma$. The errors in the data are too small to be visible except at very small t , where the error in t is 3×10^{-6} .

to the fits, it was not possible to accurately determine the critical exponents from this experiment.

The last two fits in Table II use the exponents fixed at their theoretical values of $\nu = 0.63$ and $\gamma = 1.241$.¹² The data were best fit by the parameters in Eq. (5) having the values $\tau_0 = (3.51 \pm 0.03) \times 10^{-6} \text{ cm}^{-1}$, $\xi_0 = (0.343 \pm 0.024) \text{ nm}$, and $\tau_b = (1.97 \pm 0.22) \times 10^{-3} \text{ cm}^{-1}$. It is necessary to include τ_b as a variable parameter, even though its value is small, as shown by the relatively large reduced chi square when $\tau_b = 0$ in the last fit.

Our determination for ξ_0 and τ_0 are compared to the values others have determined for the undeuterated or partially deuterated mixture isobutyric acid and water in Table III. In the one-phase region, the partially deuterated system has a value of ξ_0 which seems independent of the original deuteration of the hydroxyl ion in isobutyric acid. However, the partially deuterated system has a significantly lower value of ξ_0 than either the undeuterated mixture or the completely deuterated system reported here. While the values of ξ_0 for the undeuterated and completely deuterated system agree within experimental error, the value of τ_0 is much larger in the former system than in the latter. Since the amplitudes τ_0 , ξ_0 , and B are universally related through Eqs. (4) and (6), a larger τ_0 (with a similar ξ_0) should mean a larger value of B in the undeuterated than in the completely deuterated system. However, Greer¹⁰ found just the opposite—that B increases on deuteration. This can still be consistent with two-scale-factor universality if the refractive index dependence on composition appearing in Eq. (6) is much larger in the undeuterated than completely deuterated system. While data exist for isobutyric acid, water, and heavy water, only the density has been reported for completely deuterated isobutyric acid.¹¹ Even estimates for the refractive index variation on composition using, say, the Lorentz–Lorenz relation²⁸ require refractive index data which have not ap-

TABLE III. Values of the parameters τ_0 and ξ_0 are compared for the undeuterated system isobutyric acid (iba) and water, partially deuterated isobutyric acid with the hydroxyl ion deuterated (COOD) or not (COOH) with heavy water, and the completely deuterated isobutyric acid (*d*-iba) and heavy water.

System	τ_0 (10^{-6} cm^{-1})	ξ_0 (nm)
iba + H_2O	10.8 ± 0.2^a	0.3625 ± 0.0065^a
		0.315 ± 0.0015^b
		0.357 ± 0.007^c
iba(COOD) + D_2O	3.51 ± 0.03^f	0.31 ± 0.02^d
iba(COOH) + D_2O		0.313 ± 0.016^e
<i>d</i> -iba + D_2O		0.343 ± 0.024^f

^aReference 2.

^bReference 29.

^cReference 30.

^dReference 8.

^eReference 9.

^fThis work.

peared in the literature. Thus, it is not possible to verify two-scale-factor universality in this system at this time.

SUMMARY

From transmitted light-intensity data in the one-phase region of completely deuterated isobutyric acid and heavy water, the turbidity was well determined in the reduced temperature range $10^{-6} < t < 10^{-2}$. Although the data could not accurately determine the critical exponents, when the Ising model values of $\nu = 0.63$ and $\gamma = 1.241$ were used, the best fit to the data gave amplitudes $\xi_0 = 0.343 \pm 0.024 \text{ nm}$ and $\tau_0 = (3.51 \pm 0.03) \times 10^{-6} \text{ cm}^{-1}$. The amplitude ξ_0 of the correlation length is effectively the same as that found in the undeuterated isobutyric acid and water system but larger than in partially deuterated systems. Two-scale-factor universality could not be directly tested in this system.

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