Density, Speed of Sound, Surface Tension, and Refractive Index of AOT + 2,2,4-Trimethylpentane + Water Mixtures from (5 to 60) °C

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Density, speed of sound, surface tension, refractive index, and isentropic compressibility of AOT (sodium bis-(2-ethylhexyl) sulfosuccinate) + 2,2,4-trimethylpentane + water mixtures have been measured at different temperatures in the range of (5 to 60) °C. Mixtures employed in the present paper have a common characteristic based on the value of the *W* parameter (*W* = [water]/[AOT]) that remained constant at a value of 22.2 since the system is employed in numerous different studies due its stability. The effect of mixture composition has also been studied on the basis of the AOT concentration that was varied from (0.1 to 0.7) mol·dm^{-3}.

Introduction

Suitable combinations of water, alkane, and surfatant and/or cosurfactant can form transparent and thermodynamically stable systems that have been labeled as microemulsions. These mixtures are highly dynamic structures whose components rearrange themselves over time and space through interactions or collisions, coalescing and redispersing. Microemulsions are chemical systems of great interest from the point of view of pure chemistry as well as from that of applied chemistry because they have a great potential as solubilizators[1] or as nanoreactors,[2,3] permitting an important number of industrial applications.[4]

Specifically, the possibility to carry out chemical reactions into water droplets to get specific characteristics is nowadays an important research field. One aim in micro- and nanoparticle synthesis is to use the water pools in microemulsions as a reactive medium to grow the particles in the droplets to get particles with a fixed specific size.

Previous studies of our research group have contributed information and trends related to the influence of temperature upon the electrical conductivity value in these systems[5] and about physical properties of AOT (sodium bis(2-ethylhexyl) sulfosuccinate) + 2,2,4-trimethylpentane (isooctane) mixtures.[6] A well-known phenomenon occurs when water is added to the system. This phenomenon is called percolation, and it is usually considered that during percolation the droplets come in contact and ions are transferred by some kind of "hopping" mechanism and/or channels are formed through which the contents of microdroplets can be exchanged.

This phenomenon has great importance to the study of the mass transfer between water droplets when these water pools are employed as micro- and nanoreactors with specifically chosen geometric characteristics. Physical properties must be taken into account to explain the mass transfer processes[7,8] between continuous and discrete media and between water droplets.

Experimental Section

Materials. The reagents employed in the experimental procedures analyzed in the present paper were supplied by Sigma and Fluka with the maximum purity available commercially (> 99 %). The AOT was supplied by Sigma (Sigma Ultra purity), and due to its hygroscopic nature, it was vacuum-dried and used without any further purification.

Microemulsion systems were prepared by direct mixing of AOT solution (1 M) in 2,2,4-trimethylpentane and water under vigorous stirring. The water used for the mixtures was distilled−deionized water (κ = 0.10 to 0.50 μS·cm^{-1}).

The composition of the microemulsions were varied at different values of AOT concentration but maintaining the value of the *W* parameter ($W = C_{water}/C_{AOT}$) constant at a value of 22.2. The *W* parameter is related to the water droplets diameter. This value is commonly used in different investigations using these kinds of microemulsions because it allows work in a high range of microemulsion composition and with a constant water pool diameter. All the mixtures were prepared by mass using an analytical balance (Kern 770) with a precision of ± 10^{-4} g. The uncertainty of the samples preparation was ± 0.001 mol·dm^{-3}.

Density and Speed of Sound Measurements. Density of the pure liquid (2,2,4-trimethylpentane) and mixtures were measured with an Anton Paar DSA 5000 vibrating-tube densimeter and sound analyzer, with an accuracy of ± 10^{-6} g·cm^{-3} in relation to the density and ± 0.01 m·s^{-1} for the speed of sound. This apparatus allows temperature variation from (5 to 60) °C. The uncertainty in the density and speed of sound measurements was ± 3·10^{-5} g·cm^{-3} and ± 0.07 m·s^{-1}, respectively.

Surface Tension Measurements. The surface tension of the mixtures was measured using a Kruss K-11 tensiometer (accuracy of ± 0.01 mN·m^{-1}), which employs the Wilhelmy plate principle. The uncertainty of the measurement was ± 0.07 mN·m^{-1}. In general, each surface tension value reported was an average of five measurements. The samples were thermostated in a closed vessel before surface tension measurements to prevent evaporation of 2,2,4-trimethylpentane that could modify the mixtures composition.

Refractive Index Measurements. Refractive index was determined to within ± 1·10^{-6} using an Atago RX-5000 refractometer. Before the measurements, the refractometer was calibrated using distilled−deionized water in accordance with the instrument instructions. Water was circulated into the

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Table 1. Density ρ for AOT + Isooctane + Water Microemulsions (W = 22.2) from (5 to 60) °C

t/°C	C_{AOT}/mol·dm^{-3} 0.1	0.2	0.3	0.4	0.5	0.6	0.7
	ρ/g·cm^{-3}						
5	0.7342	0.7632	0.7925	0.8214	0.8546	0.8876	0.9170
10	0.7323	0.7592	0.7886	0.8175	0.8508	0.8840	0.9135
15	0.7316	0.7552	0.7846	0.8136	0.8470	0.8803	0.9099
20	0.7289	0.7512	0.7806	0.8097	0.8432	0.8766	0.9062
25	0.7255	0.7488	0.7766	0.8057	0.8392	0.8728	0.9025
30	0.7220	0.7432	0.7725	0.8017	0.8353	0.8690	0.8988
35	0.7190	0.7400	0.7684	0.7976	0.8313	0.8652	0.8950
40	0.7159	0.7379	0.7642	0.7935	0.8273	0.8612	0.8911
45	0.7131	0.7360	0.7600	0.7894	0.8232	0.8572	0.8872
50	0.7102	0.7309	0.7558	0.7852	0.8191	0.8532	0.8833
55	0.7072	0.7290	0.7515	0.7809	0.8149	0.8491	0.8792
60	0.7041	0.7262	0.7472	0.7766	0.8103	0.8450	0.8752

Table 2. Speed of Sound u for AOT + Isooctane + Water Microemulsions (W = 22.2) from (5 to 60) °C

t/°C	C_{AOT}/mol·dm^{-3} 0.1	0.2	0.3	0.4	0.5	0.6	0.7
	u/m·s^{-1}						
5	1158.0	1154.2	1155.8	1162.2	1175.8	1194.9	1218.4
10	1137.7	1135.1	1137.6	1144.8	1159.3	1180.0	1204.3
15	1117.8	1115.7	1119.1	1127.1	1142.4	1164.4	1189.4
20	1097.2	1096.2	1100.4	1109.1	1125.2	1148.4	1174.0
25	1076.8	1076.7	1081.5	1090.9	1107.6	1131.9	1158.0
30	1056.7	1057.2	1062.6	1072.5	1089.8	1115.1	1141.7
35	1036.6	1037.7	1043.6	1054.1	1071.7	1098.0	1125.1
40	1016.5	1018.1	1024.6	1035.5	1053.8	1080.6	1108.3
45	996.6	998.73	1005.5	1016.9	1035.6	1063.1	1091.2
50	976.69	979.27	986.53	998.22	1017.3	1045.4	1073.9
55	956.77	959.76	967.35	979.43	998.91	1027.5	1056.5
60	937.01	940.37	948.25	960.55	980.88	1009.2	1038.9

Table 3. Surface Tension σ for AOT + Isooctane + Water Microemulsions (W = 22.2) from (5 to 60) °C

t/°C	[AOT]/mol·dm^{-3} 0.1	0.2	0.3	0.4	0.5	0.6	0.7
	σ/mN·m^{-1}						
5	20.0	20.1	20.2	20.3	20.4	20.5	20.8
10	19.6	19.7	19.8	19.9	20.0	20.1	20.4
15	19.2	19.3	19.4	19.5	19.6	19.9	20.2
20	18.8	18.9	19.0	19.1	19.3	19.5	19.8
25	18.4	18.4	18.5	18.7	19.0	19.1	19.4
30	18.1	18.1	18.2	18.3	18.6	18.7	19.0
35	17.7	17.7	17.9	18.0	18.2	18.5	18.7
40	17.3	17.4	17.5	17.7	17.9	18.1	18.3
45	16.9	17.0	17.1	17.3	17.5	17.7	18.0
50	16.5	16.6	16.7	16.9	17.1	17.3	17.6
55	16.1	16.2	16.4	16.7	16.8	17.1	17.3
60	15.8	15.9	16.0	16.3	16.5	16.8	17.0

instrument through a thermostatically controlled bath maintained constant to ± 0.1 °C. The mixtures were directly injected from the stock solution stored at the working temperature to avoid evaporation. The refractive index measurements were done after the liquid mixtures attained the constant temperature of the refractometer. This procedure was repeated at least three times. The average of these readings was taken for the refractive index values. The uncertainty of the measurement was ± $4{\cdot}10^{-5}$.

Results

The experimental results obtained for the physical properties studied in the present paper are shown in Tables 1 to 4 at different temperatures between (5 and 60) °C and at different values of AOT concentration. The behaviors observed in the case of density (ρ) with respect to the AOT concentration and temperature (Figure 1) are similar to the trends obtained for the refractive index (n_D): a decrease in the value of these properties when temperature increases, and an increase in the refractive index and density when the AOT concentration increases in the mixture composition. In relation to the surface tension (σ) of the AOT + isooctane + water microemulsions, the experimental results obtained in the present work show an increase also when the AOT concentration increases in the mixture.

Table 4. Refractive Index n_D for AOT + Isooctane + Water Microemulsions (W = 22.2) from (5 to 60) °C

t/°C	C_{AOT}/mol·dm^{-3} 0.1	0.2	0.3	0.4	0.5	0.6	0.7
	n_D						
5	1.3991	1.3996	1.4001	1.4006	1.4012	1.4018	1.4024
10	1.3969	1.3976	1.3982	1.3986	1.3992	1.4003	1.4008
15	1.3946	1.3954	1.3960	1.3967	1.3973	1.3979	1.3989
20	1.3923	1.3931	1.3941	1.3949	1.3952	1.3961	1.3974
25	1.3901	1.3919	1.3924	1.3931	1.3935	1.3941	1.3961
30	1.3879	1.3894	1.3908	1.3915	1.3915	1.3921	1.3941
35	1.3859	1.3867	1.3881	1.3887	1.3899	1.3909	1.3927
40	1.3830	1.3848	1.3860	1.3867	1.3875	1.3885	1.3904
45	1.3810	1.3821	1.3840	1.3848	1.3855	1.3867	1.3893
50	1.3786	1.3798	1.3816	1.3825	1.3835	1.3847	1.3874
55	1.3766	1.3780	1.3795	1.3806	1.3816	1.3831	1.3859
60	1.3747	1.3762	1.3775	1.3786	1.3796	1.3816	1.3844

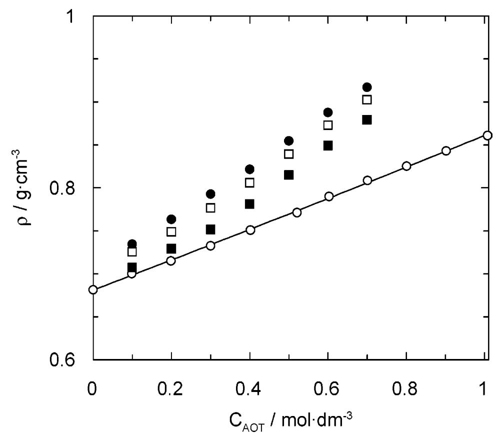

Figure 1. Effect of composition and temperature upon the density of AOT + 2,2,4-trimethylpentane + water systems: ○, AOT + 2,2,4-trimethylpentane mixture at t = 25 °C.[6] AOT + 2,2,4-trimethylpentane + water systems: ●, t = 5 °C; □, t = 25 °C; ■, t = 55 °C.

Other authors[9] have studied the effect of water composition on these kinds of systems (microemulsions) in relation to physical properties such as density and speed of sound. The results obtained by these researchers indicate an increase in these physical properties when the amount of water increases too. Mehta and Bala[9] observed trends for other microemulsions that are similar to those behaviors observed in the present paper, since when the AOT concentration increases, it is necessary that the water concentration increases too to maintain constant W. Experimental data presented in the present paper show an increase in all these physical properties when the surfactant concentration increases.

Conclusions

Experimental data of density, speed of sound, surface tension, and refractive index have been determined for ternary microemulsions formed by AOT + isooctane + water. The effect of temperature and AOT concentration has been studied, producing a decrease in these properties when temperature increases while the AOT concentration produces an increase.

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