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Physicochemical Characterization of Aqueous Two-Phase Systems Containing Tween20 and Sodium Salts from T = (288.15 to 318.15) K

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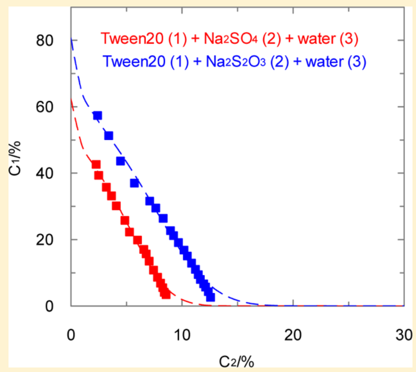
ABSTRACT: The present work studies the characterization of binary and ternary mixtures based on the use of surfactant and different salts in aqueous solutions that can form two different liquid phases. This characterization study was centered in the determination of several physical properties such as density, speed of sound, and refractive index. Also different derivative properties were calculated such as excess molar volume and isentropic compressibility. The present study analyzes aqueous binary mixtures in the homogeneous zone and also ternary mixtures (Tween20 + salt + water). This last kind of mixtures was studied in the homogeneous zone, analyzing the influence of surfactant and salt concentration and also phases in equilibrium. The influence of temperature upon the physical properties for homogeneous mixtures was also analyzed in the present work.



1. INTRODUCTION

This paper reports on aqueous two-phase systems (ATPS) that are based mainly in the use of two polymers or a polymer and a salt in aqueous solution. Several studies have concluded that this kind of separation media can have an important amount of uses mainly in the separation by liquid−liquid extraction of certain substances that can be influenced by the presence of an organic medium.[1] Substances such as enzymes or other with biological origin can be the aim of these extraction systems. ATPS have been used in extraction strategies for antioxidants purification.[2]

An important increase in the development of ATPS for different extraction processes has been observed, bringing about an enhancement in the studies of thermodynamics and equilibrium in these systems.[3,4] But in relation to studies based on separation processes of the solutes of interest, the development was lower.[5−7] The majority of the studies existing in the literature are centered on the use of a specific polymer (polyethylene glycol, PEG) using different average molecular weights; thus, an important amount of work must be performed in this research field to analyze the mass transfer processes between the two aqueous phases using different contact devices. There is a lack of information for this type of processes, and only in very specific studies have these aqueous two-phase systems been used to carry out liquid−liquid extraction processes at lab-scale.[8,9] When mass transfer studies are performed at lab or pilot plant scale or to perform scale-up work, several aspects such as the hydrodynamic into the contactor or the interfacial area between both phases are important parameters that must be taken into account.[10] With respect to mass transfer processes the liquid phases physical properties are important variables that can affect the global mass transfer rate because the diffusivity is highly influenced by different properties, mainly by the viscosity.[11,12] In this kind of systems (ATPS) the polymer or polymers used in their formulation must be taken into account because these solutes can produce important changes in different properties. The present work characterizes ternary systems in equilibrium and also homogeneous mixtures in relation to several physical properties that can contribute interesting information about the interactions between solutes and the influence upon mass transfer processes.

2. EXPERIMENTAL SECTION

2.1. Materials. Reagents employed in present work were polyoxyethylenesorbitan monolaurate (Tween20) (Sigma-Aldrich, purity > 0.998), sodium sulfate (Panreac, purity ≥ 0.990) and sodium thiosulfate (Panreac, purity ≥ 0.990). Bidistilled water was used to prepare aqueous binary and tertiary mixtures. All solutions were prepared by mass using an analytical balance (Kern 770) with a precision of 10^{-4} g. The uncertainty in the mole fraction for the prepared sample solutions was found to be ± 0.0007.

2.2. Methods. The solubility curves corresponding to the aqueous two-phase systems used in the present work were obtained using the cloud point titration method at T = 298.15 K. A known amount of salts was added to Tween20 aqueous solutions under stirring, until turbidity is observed. A dropwise addition of water was performed until a monophasic region was reached. All the samples were weighed with an analytical balance (Kern 770). The ternary system compositions were determined by the weight quantification of all components.

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The tie-lines determination consisted on the mixture of different amounts of compounds within the immiscibility region of known mass fraction to the ampules. The temperature was kept constant, and the mixture was stirred vigorously and then allowed to settle for 24 h to ensure that equilibrium and a complete separation of the layers was reached. The uncertainty in the composition determination is ± 2 %. The experimental results have been confirmed with a previous study.[13]

The density and speed of sound data corresponding to pure components (water and Tween20) and binary and ternary mixtures of different compounds were measured with an Anton Paar DSA 5000 vibrating tube densimeter and sound analyzer. The uncertainty in the density and speed of sound measurements were $\pm\ 2\cdot10^{-4}$ g·cm^{-3} and $\pm$ 0.7 m·s^{-1}, respectively.

Refractive index data were measured using an Atago RX-5000 refractometer. Before measurements, the refractometer was calibrated using distilled−deionized water taking into account the instrument instructions. Pure compounds and binary and ternary mixtures were directly injected from the solution stored at working temperature to avoid evaporation processes. The measurements were done after the liquid mixtures reached a constant temperature. This procedure was repeated at least three times and the average of these readings was taken for the refractive index values. The uncertainty corresponding to refractive index measures is $\pm\ 5\cdot10^{-4}$.

3. RESULTS AND DISCUSSION

3.1. Binary Systems: Tween20 (or Salts) + Water. The first part of the characterization studies of this kind of systems was centered on the analysis of binary mixtures: aqueous solutions of Tween20, sodium sulfate, and sodium thiosulfate. The concentration ranges used for each solute were chosen on the basis of their solubility data. The experimental values corresponding to density, speed of sound, and refractive index of these systems are included in Tables 1-3 at different temperatures. In relation with the system Tween20 + water the experimental values of density and refractive index show an increase when surfactant presence increases in the mixture. An increase in temperature causes a decrease in the value of these physical properties. On the other hand the influences of surfactant concentration and temperature upon the speed of sound show a very different behavior in comparison with the previously commented properties. The influence of surfactant concentration shows a complex behavior: the speed of sound increases until it reaches a maximum value. After this first increase, the opposite effect was observed. The behavior is more complex if the influence of temperature is analyzed because at low surfactant concentration an increase in the speed of sound with temperature is observed. But this influence is inverted at high surfactant concentration. This behavior is confirmed when isentropic compressibility is calculated. The influence of surfactant concentration and temperature is shown in Figure 1. The influence of temperature is opposite than that previously mentioned for speed of sound, but a change in the influence of temperature is also observed for this property. A Tween20 aqueous solution with a concentration near to 25 % in weight shows an isentropic compressibility value independent of temperature, and it indicates that a temperature-resistant structure is produced due to aggregation processes. Several studies[14,15] observed similar behaviors for other aqueous solutions due to the formation of clathrates or other structures in aqueous solution.

Table 1. Densities (ρ), Excess Molar Volumes (V^E), Speed of Sounds (c), Isentropic Compressibilities (κ_s), and Refractive Indices (n_D), of Tween20 (1) + Water (2) from T = (288.15 to 318.15) K[a]

C_1	ρ	V^E	c	κ_s	
%	g·cm^{-3}	cm^3·mol^{-1}	m·s^{-1}	TPa^{-1}	n_D
		T/K = 318.15			
0.0	0.9902	0.0000	1536.6	427.7	1.3298
4.0	0.9963	0.0056	1543.1	421.5	1.3348
17.7	1.0125	0.0199	1562.9	404.4	1.3405
8.7	1.0016	0.0103	1549.6	415.8	1.3527
30.2	1.0270	0.0321	1582.6	388.8	1.3701
40.4	1.0387	0.0414	1595.2	378.3	1.3878
49.9	1.0508	0.0505	1603.6	370.1	1.3977
67.2	1.0692	0.0603	1598.3	366.1	1.4330
78.5	1.0781	0.0591	1572.3	375.2	1.4378
89.5	1.0829	0.0449	1534.6	392.1	1.4521
100.0	1.0837	0.0000	1487.8	416.9	1.4618
		T/K = 308.15			
0.0	0.9940	0.0000	1520.3	435.3	1.3313
4.0	0.9989	0.0044	1528.5	428.5	1.3362
17.7	1.0157	0.0192	1558.5	405.3	1.3422
8.7	1.0045	0.0094	1538.5	420.6	1.3549
30.2	1.0316	0.0327	1588.1	384.3	1.3738
40.4	1.0449	0.0434	1608.5	369.9	1.3860
49.9	1.0574	0.0527	1624.4	358.4	1.4029
67.2	1.0755	0.0619	1624.9	352.1	1.4360
78.5	1.0867	0.0626	1605.3	357.1	1.4411
89.5	1.0912	0.0474	1567.6	372.9	1.4555
100.0	1.0916	0.0000	1520.4	396.3	1.4654
		T/K = 298.15			
0.0	0.9970	0.0000	1496.9	447.6	1.3326
4.0	0.9998	0.0046	1508.3	438.6	1.3375
17.7	1.0157	0.0202	1548.6	408.8	1.3437
8.7	1.0045	0.0099	1521.2	428.7	1.3568
30.2	1.0316	0.0345	1586.6	383.2	1.3760
40.4	1.0449	0.0458	1619.4	362.9	1.3884
49.9	1.0574	0.0558	1643.9	347.8	1.4060
67.2	1.0755	0.0661	1659.2	335.2	1.4400
78.5	1.0867	0.0663	1637.9	340.5	1.4444
89.5	1.0912	0.0500	1600.7	355.0	1.4590
100.0	1.0916	0.0000	1553.9	376.6	1.4690
		T/K = 288.15			
0.0	0.9991	0.0000	1466.4	465.5	1.3335
4.0	1.0045	0.0049	1480.5	454.2	1.3386
17.7	1.0233	0.0214	1532.7	416.0	1.3449
8.7	1.0108	0.0105	1497.3	441.3	1.3583
30.2	1.0412	0.0366	1584.9	382.3	1.3779
40.4	1.0561	0.0487	1627.4	357.5	1.3905
49.9	1.0704	0.0595	1661.6	338.4	1.4086
67.2	1.0914	0.0706	1685.3	322.6	1.4441
78.5	1.1031	0.0705	1670.9	324.7	1.4474
89.5	1.1077	0.0531	1635.1	337.7	1.4627
100.0	1.1078	0.0000	1588.5	357.7	1.4725

[a]Standard uncertainties u are $u(T)$ = 0.01 K, $u(p)$ = 20 Pa, $u(x)$ = 0.0007, and the combined expanded uncertainties U_c (level of confidence = 0.95, k = 2) are $U_c(\rho) = 2\cdot10^{-4}$ g·cm^{-3}, $U_c(c)$ = 1.2 m·s^{-1} and $U_c(n_D) = 5\cdot10^{-4}$.

The experimental data of the characterization studies using sulfate and thiosulfate aqueous solutions are included in Tables 2 and 3. These results have been compared with the literature[16]

Table 2. Densities (ρ), Speed of Sounds (c), Isentropic Compressibilities (κ_s), and Refractive Indices (n_D), of Na_2SO_4 (1) + Water (2) from T = (288.15 to 318.15) K[a]

C_1 %	ρ g·cm^{-3}	c m·s^{-1}	κ_s TPa^{-1}	n_D
		T/K = 318.15		
0.0	0.9902	1536.6	427.7	1.3298
1.9	1.0072	1556.0	410.1	1.3332
4.9	1.0336	1586.2	384.5	1.3377
5.4	1.0377	1589.5	381.4	1.3377
10.9	1.0887	1647.0	338.6	1.3457
13.9	1.1168	1678.1	318.0	1.3332
17.4	1.1514	1718.5	294.1	1.3497
22.6	1.1512	1718.7	294.1	1.3727
		T/K = 308.15		
0.0	0.9940	1520.3	435.3	1.3313
1.9	1.0112	1541.1	416.4	1.3346
4.9	1.0379	1572.5	389.7	1.3386
5.4	1.0420	1576.4	386.2	1.3392
10.9	1.0935	1637.5	341.1	1.3473
13.9	1.1218	1670.4	319.5	1.3392
17.4	1.1566	1713.7	294.4	1.3511
22.6	1.1567	1713.8	294.3	1.3749
		T/K = 298.15		
0.0	0.9970	1496.9	447.6	1.3326
1.9	1.0145	1519.1	427.2	1.3359
4.9	1.0416	1552.8	398.2	1.3399
5.4	1.0458	1557.2	394.4	1.3406
10.9	1.0978	1622.2	346.2	1.3469
13.9	1.1264	1657.9	323.0	1.3406
17.4	1.1615	1704.4	296.4	1.3528
22.6	1.1616	1704.6	296.3	1.3399
		T/K = 288.15		
0.0	0.9991	1466.4	465.5	1.3335
1.9	1.0169	1489.5	443.2	1.3370
4.9	1.0445	1526.1	411.1	1.3411
5.4	1.0488	1531.0	406.8	1.3418
10.9	1.1016	1600.6	354.3	1.3487
13.9	1.1305	1639.2	329.2	1.3418
17.4	1.1660	1689.8	300.4	1.3543
22.6	1.1661	1689.8	300.3	1.3411

[a]Standard uncertainties u are $u(T)$ = 0.01 K, $u(p)$ = 20 Pa, $u(x)$ = 0.0007, and the combined expanded uncertainties U_c (level of confidence = 0.95, k = 2) are $U_c(\rho) = 2{\cdot}10^{-4}$ g·cm^{-3}, $U_c(c)$ = 1.2 m·s^{-1} and $U_c(n_D) = 5{\cdot}10^{-4}$.

Table 3. Densities (ρ), Speed of Sounds (c), Isentropic Compressibilities (κ_s), and Refractive Indices (n_D), of $Na_2S_2O_3$ (1) + Water (2) from T = (288.15 to 318.15) K[a]

C_1 %	ρ g·cm^{-3}	c m·s^{-1}	κ_s TPa^{-1}	n_D
		T/K = 318.15		
0.0	0.9902	1536.6	427.7	1.3298
4.6	1.0276	1577.2	391.2	1.3378
9.8	1.0698	1622.2	355.2	1.3501
15.3	1.1170	1675.2	319.0	1.3610
19.3	1.1561	1720.5	292.2	1.3720
25.3	1.2100	1785.7	259.2	1.3855
29.8	1.2531	1839.2	235.9	1.3949
31.7	1.2748	1865.9	225.3	1.3994
		T/K = 308.15		
0.0	0.9940	1520.3	435.3	1.3313
4.6	1.0319	1563.0	396.7	1.3393
9.8	1.0745	1611.0	358.6	1.3511
15.3	1.1222	1667.6	320.4	1.3621
19.3	1.1616	1715.9	292.4	1.3744
25.3	1.2158	1786.2	257.8	1.3880
29.8	1.2592	1843.4	233.7	1.3957
31.7	1.2810	1872.3	222.7	1.4004
		T/K = 298.15		
0.0	0.9970	1496.9	447.6	1.3326
4.6	1.0356	1542.6	405.8	1.3407
9.8	1.0788	1594.3	364.7	1.3526
15.3	1.1269	1655.0	324.0	1.3634
19.3	1.1668	1707.4	294.0	1.3762
25.3	1.2214	1783.4	257.4	1.3897
29.8	1.2650	1845.3	232.2	1.3972
31.7	1.2870	1876.5	220.7	1.4019
		T/K = 288.15		
0.0	0.9991	1466.4	465.5	1.3335
4.6	1.0385	1515.5	419.3	1.3419
9.8	1.0824	1571.7	374.0	1.3541
15.3	1.1313	1636.8	329.9	1.3650
19.3	1.1716	1694.4	297.3	1.3779
25.3	1.2268	1776.8	258.2	1.3917
29.8	1.2707	1844.6	231.3	1.3991
31.7	1.2928	1878.3	219.3	1.4038

[a]Standard uncertainties u are $u(T)$ = 0.01 K, $u(p)$ = 20 Pa, $u(x)$ = 0.0007, and the combined expanded uncertainties U_c (level of confidence = 0.95, k = 2) are $U_c(\rho) = 2\ {\cdot}10^{-4}$ g·cm^{-3}, $U_c(c)$ = 1.2 m·s^{-1} and $U_c(n_D) = 5{\cdot}10^{-4}$.

with good agreement. Figure 2 shows an example of the influence of liquid composition and temperature upon the experimental data corresponding to the refractive index of sodium thiosulfate aqueous solutions. An increase in salt concentration produces also an increase in this physical property. On the other hand a decrease in this property was observed when temperature increases. These behaviors are similar to those previous seen for density.

For speed of sound and isentropic compressibility data a decrease in these values was observed when salts concentration increased in the mixture. When sodium thiosulfate is used, the effect of temperature consists in a decrease in the value of these properties for all compositions. This behavior is different from the previous one analyzed for Tween20 aqueous solutions. The experimental data of density and refractive index corresponding to sodium sulfate aqueous solutions show similar trends than the data corresponding to sodium thiosulfate aqueous solutions. But the effect caused by composition upon the speed of sound is the opposite of the corresponding one for sodium thiosulfate aqueous solutions, because an increase in salt concentration causes also an increase in this property. Also systems with this salt show a certain type of interaction or aggregation, because the influence of temperature upon the speed of sound and isentropic compressibility data are different at low and high solute concentration solutions. The presence of temperature-resistant structures for this system is produced in a high salt concentration (about 27 %).

The experimental density data corresponding to the binary system Tween20 + water have been employed to calculate the excess molar volume (see Table 1). These data indicate that Tween20 + water mixtures have an expansive behavior due to the positive values for this property for all temperatures tested.

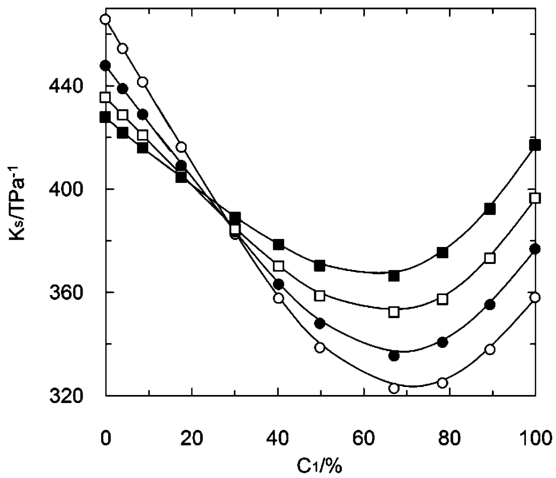

Figure 1. Influence of Tween20 concentration and temperature upon isentropic compressibility for the mixture Tween20 (1) + water (2). ○, T = 288.15 K; ●, T = 298.15 K; □, T = 308.15 K; ■, T = 318.15 K.

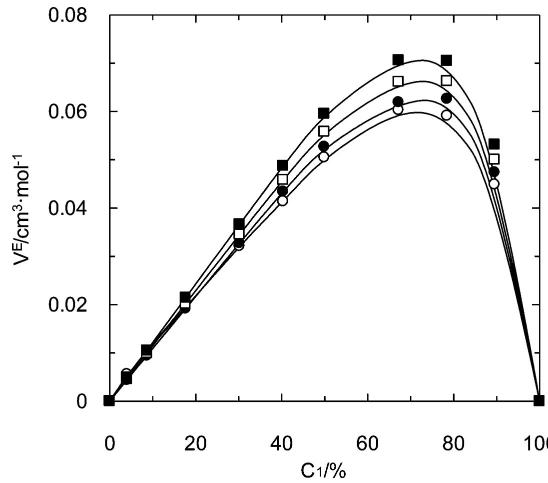

Figure 3. Influence of Tween20 concentration and temperature upon molar excess volume for the mixture Tween20 (1) + water (2): ○, T = 288.15 K; ●, T = 298.15 K; □, T = 308.15 K; ■, T = 318.15 K.

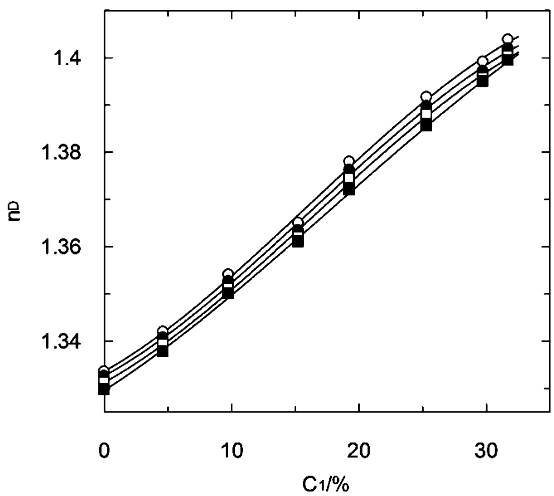

Figure 2. Influence of salt composition and temperature upon refractive index for $Na_2S_2O_3$ (1) + water (2) system: ○, T = 288.15 K; ●, T = 298.15 K; □, T = 308.15 K; ■, T = 318.15 K. Solid lines represent values from eq 1.

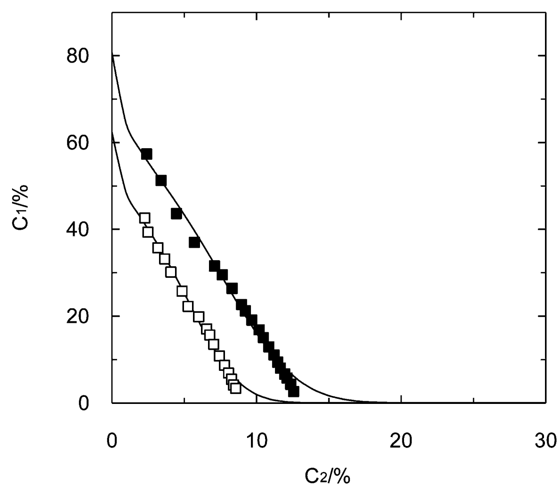

Figure 4. Liquid–liquid equilibrium corresponding to the ATPS used in present work. □, Tween20 (1) + Na_2SO_4 (2) + Water (3); ■, Tween20 (1) + $Na_2S_2O_3$ (2) + water (3).

An increase in temperature produces an increase in excess molar volume. This behavior indicates that an increase in temperature increases the interactions between molecules. These behaviors are shown in Figure 3.

The experimental data corresponding to density and refractive index have been fitted using eq 1 previously recommended in the literature[17] for this kind of mixtures and systems.

$$n_D = A + Bx_1 + Cx_1^2 + Dx_1^3 \quad (1)$$

where A, B, and C are fitting parameters and x_1 is the polymer mass fraction. This kind of equation has been used also to fit the density neperian logarithm value.

3.2. Ternary Systems: Homogeneous Zone. This work includes also the characterization of ternary systems, analyzing the same properties as that for binary systems composed of solutes used in the ternary system (polymer+salt+water). In these mixtures the physical properties have been measured for homogeneous systems and also for equilibrium phases. The equilibrium diagram is shown in Figure 4 for both systems. The experimental values corresponding to the homogeneous zone of this kind of mixtures are included in Tables 4 and 5. Figure 5 shows an example of the influence of both solutes (polymer and salt) upon density. This figure indicates that both solutes cause a significant increase in this property.

With respect to the behavior corresponding to refractive index for ternary systems the experimental data show a similar behavior than the previous one shown for density, that is, an increase in this property when surfactant and/or salt concentration increases. An increase in temperature produces in all cases a decrease in density and refractive index. Then the influence of concentration and temperature for ternary systems is similar than the corresponding one for binary systems without an important influence caused by the presence of a third component.

As in binary systems (surfactant+water and salt+water), the most complex behavior was observed both for speed of sound and isentropic compressibility data. Figure 6 shows the behavior of different systems analyzing the influence of surfactant and salt concentration, and temperature used to determine density and speed of sound and to calculate isentropic compressibility. In relation to the influence of salt presence

Table 4. Densities (ρ), Speed of Sounds (c), Isentropic Compressibilities (κ_s), and Refractive Indices (n_D), of Tween20 (1) + Na_2SO_4 (2) + Water (3) from T = (288.15 to 318.15) K[a]

C_2	C_1	ρ	c	κ_s	
%	%	$g\cdot cm^{-3}$	$m\cdot s^{-1}$	TPa^{-1}	n_D
		T/K = 318.15			
0.0	0.0	0.9902	1536.6	427.7	1.3298
0.0	1.0	1.0837	1487.8	416.9	1.4618
1.6	0.0	1.0040	1553.3	412.8	1.3322
1.6	3.4	1.0074	1557.0	409.5	1.3372
1.6	8.4	1.0144	1565.1	402.5	1.3431
1.6	13.4	1.0204	1572.5	396.3	1.3501
1.6	23.4	1.0321	1586.6	384.9	1.3630
1.6	38.4	1.0489	1603.1	371.0	1.3836
1.6	83.4	1.0815	1555.5	382.1	1.4439
5.0	0.0	1.0348	1587.0	383.7	1.3370
5.0	0.0	1.0365	1588.2	382.5	1.3375
5.0	10.0	1.0450	1600.7	373.5	1.3521
5.0	20.0	1.0587	1610.3	364.3	1.3632
5.0	30.0	1.0626	1613.9	361.3	1.3710
6.5	0.0	1.0491	1602.4	371.2	1.3397
6.5	1.5	1.0515	1604.8	369.3	1.3430
6.5	5.5	1.0550	1608.6	366.3	1.3470
6.5	9.5	1.0592	1612.6	363.0	1.3509
8.6	0.0	1.0663	1623.1	356.0	1.3421
8.6	1.4	1.0692	1625.1	354.1	1.3433
8.6	3.4	1.0714	1626.9	352.6	1.3445
10.8	0.0	1.0875	1644.8	339.9	1.3451
		T/K = 308.15			
0.0	0.0	0.9940	1520.3	435.3	1.3313
0.0	1.0	1.0916	1520.4	396.3	1.4654
1.6	0.0	1.0079	1537.2	419.9	1.3337
1.6	3.4	1.0114	1544.0	414.7	1.3386
1.6	8.4	1.0188	1555.2	405.8	1.3450
1.6	13.4	1.0251	1566.6	397.5	1.3514
1.6	23.4	1.0374	1587.9	382.3	1.3656
1.6	38.4	1.0553	1615.8	362.9	1.3861
1.6	83.4	1.0897	1588.1	363.9	1.4471
5.0	0.0	1.0391	1573.3	388.8	1.3385
5.0	0.0	1.0397	1573.9	388.3	1.3391
5.0	10.0	1.0498	1598.3	372.9	1.3536
5.0	20.0	1.0633	1612.4	361.8	1.3647
5.0	30.0	1.0674	1620.0	357.0	1.3735
6.5	0.0	1.0536	1589.7	375.6	1.3411
6.5	1.5	1.0559	1593.2	373.1	1.3447
6.5	5.5	1.0597	1600.2	368.5	1.3484
6.5	9.5	1.0641	1607.5	363.7	1.3524
8.6	0.0	1.0714	1610.3	360.0	1.3436
8.6	1.4	1.0743	1615.1	356.9	1.3457
8.6	3.4	1.0761	1618.0	355.0	1.3462
10.8	0.0	1.0922	1634.9	342.5	1.3470
		T/K = 298.15			
0.0	0.0	0.9970	1496.9	447.6	1.3326
0.0	1.0	1.0997	1553.9	376.6	1.4690
1.6	0.0	1.0111	1515.3	424.0	1.3349
1.6	3.4	1.0148	1524.4	412.5	1.3400
1.6	8.4	1.0226	1539.8	401.8	1.3466
1.6	13.4	1.0293	1555.1	381.9	1.3531
1.6	23.4	1.0422	1585.0	356.3	1.3678
1.6	38.4	1.0612	1626.3	346.6	1.3885
1.6	83.4	1.0980	1621.1	397.3	1.4507
5.0	0.0	1.0428	1553.6	396.7	1.3399
5.0	0.0	1.0434	1554.3	375.0	1.3405
5.0	10.0	1.0544	1590.2	361.3	1.3541
5.0	20.0	1.0683	1609.6	353.7	1.3666
5.0	30.0	1.0728	1623.4	383.1	1.3756
6.5	0.0	1.0575	1571.2	379.8	1.3425
6.5	1.5	1.0599	1576.1	373.2	1.3462
6.5	5.5	1.0639	1586.9	366.9	1.3505
6.5	9.5	1.0686	1597.2	366.2	1.3540
8.6	0.0	1.0754	1593.5	362.3	1.3451
8.6	1.4	1.0785	1599.8	360.0	1.3473
8.6	3.4	1.0804	1603.6	347.7	1.3478
10.8	0.0	1.0965	1619.6	430.7	1.3485
		T/K = 288.15			
0.0	0.0	0.9991	1466.4	465.5	1.3335
0.0	1.0	1.1078	1588.5	357.7	1.4725
1.6	0.0	1.0135	1486.0	446.8	1.3359
1.6	3.4	1.0175	1497.9	438.1	1.3411
1.6	8.4	1.0256	1517.2	423.6	1.3478
1.6	13.4	1.0327	1537.1	409.9	1.3545
1.6	23.4	1.0464	1576.9	384.3	1.3697
1.6	38.4	1.0666	1633.5	351.4	1.3906
1.6	83.4	1.1062	1655.5	329.9	1.4543
5.0	0.0	1.0458	1527.0	410.1	1.3411
5.0	0.0	1.0464	1528.0	409.3	1.3418
5.0	10.0	1.0585	1576.6	380.1	1.3557
5.0	20.0	1.0725	1601.7	363.4	1.3683
5.0	30.0	1.0777	1622.2	352.6	1.3777
6.5	0.0	1.0607	1545.8	394.6	1.3437
6.5	1.5	1.0632	1552.3	390.3	1.3475
6.5	5.5	1.0675	1566.9	381.5	1.3519
6.5	9.5	1.0725	1581.3	372.9	1.3555
8.6	0.0	1.0789	1569.9	376.1	1.3465
8.6	1.4	1.0821	1577.9	371.2	1.3487
8.6	3.4	1.0841	1583.4	367.9	1.3492
10.8	0.0	1.1003	1597.9	356.0	1.3499

[a]Standard uncertainties u are $u(T)$ = 0.01 K, $u(p)$ = 20 Pa, $u(x)$ = 0.0007, and the combined expanded uncertainties U_c (level of confidence = 0.95, k = 2) are $U_c(\rho) = 2\cdot10^{-4}$ $g\cdot cm^{-3}$, $U_c(c)$ = 1.2 $m\cdot s^{-1}$ and $U_c(n_D) = 5\cdot10^{-4}$.

upon this property a clear decrease is observed in all the surfactant concentration and temperature ranges. The effect caused by the surfactant consists in a decrease in this property until a minimum is reached. On the other hand temperature produces a different influence depending on the surfactant concentration present in the mixture. As for the system Tween20 + water, at low surfactant concentration an increase in temperature produces a decrease in isentropic compressibility. This influence is the opposite when surfactant concentration increases. Then a temperature-resistant structure is observed also under the presence of different amounts of salt dye to an aggregation phenomenon produced in surfactant solution. The effect of salt concentration upon this aggregation process consists of a decrease in the value of surfactant concentration needed to achieve this structure when salt concentration increases in the mixture. This fact could be due to changes in the interactions between surfactant heads and water due to the presence of electrolytes. Table 6 and Figure 7 show

Table 5. Densities (ρ), Speed of Sounds (c), Isentropic Compressibilities (κ_s), and Refractive Indices (n_D), of Tween20 (1) + $Na_2S_2O_3$ (2) + Water (3) from T = (288.15 to 318.15) K[a]

C_2	C_1	ρ	c	κ_s		C_2	C_1	ρ	c	κ_s	
%	%	$g \cdot cm^{-3}$	$m \cdot s^{-1}$	TPa^{-1}	n_D	%	%	$g \cdot cm^{-3}$	$m \cdot s^{-1}$	TPa^{-1}	n_D
		T/K=318.15						T/K = 298.15			
0.0	0.0	0.9902	1536.6	427.7	1.3298	0.0	0.0	0.9970	1496.9	447.6	1.3326
0.0	1.0	1.0837	1487.8	416.9	1.4618	0.0	1.0	1.0997	1553.9	376.6	1.4690
1.9	0.0	1.0056	1553.8	411.9	1.3326	1.9	0.0	1.0129	1515.8	429.7	1.3352
1.9	23.1	1.0338	1587.8	383.7	1.3623	1.9	23.1	1.0440	1586.5	380.6	1.3673
1.9	38.1	1.0515	1605.3	369.0	1.3815	1.9	38.1	1.0643	1630.4	353.5	1.3867
1.9	49.0	1.0641	1611.8	361.7	1.3996	1.9	49.0	1.0787	1653.6	339.0	1.4072
1.9	10.1	1.0176	1568.9	399.3	1.3472	1.9	10.1	1.0261	1545.5	408.0	1.3499
1.9	13.1	1.0216	1573.1	395.6	1.3512	1.9	13.1	1.0306	1555.4	401.1	1.3562
4.9	0.0	1.0286	1577.8	390.5	1.3498	4.9	0.0	1.0365	1543.7	404.9	1.3427
4.9	0.1	1.0291	1578.7	389.9	1.3400	4.9	0.1	1.0370	1545.0	404.0	1.3427
4.9	5.1	1.0345	1585.9	384.4	1.3466	4.9	5.1	1.0433	1559.1	394.3	1.3499
4.9	10.1	1.0410	1592.7	378.7	1.3537	4.9	10.1	1.0501	1574.6	384.1	1.3575
4.9	20.1	1.0547	1606.8	367.2	1.3670	4.9	20.1	1.0622	1605.9	365.1	1.3719
4.9	30.1	1.0666	1617.1	358.5	1.3813	4.9	30.1	1.0784	1633.4	347.6	1.3851
7.0	0.0	1.0467	1597.6	374.3	1.3412	7.0	0.0	1.0551	1565.7	386.6	1.3436
7.0	3.0	1.0495	1601.3	371.6	1.3486	7.0	3.0	1.0582	1574.6	381.1	1.3511
7.0	13.0	1.0618	1614.0	361.5	1.3621	7.0	13.0	1.0718	1604.4	362.5	1.3657
7.0	23.0	1.0745	1624.3	352.7	1.3756	7.0	23.0	1.0858	1632.6	345.5	1.3792
7.0	28.0	1.0840	1634.5	345.3	1.3910	7.0	28.0	1.0955	1646.7	336.7	1.3954
9.9	0.0	1.0694	1622.6	355.2	1.3496	9.9	0.0	1.0784	1594.1	365.0	1.3529
9.9	0.1	1.0698	1623.0	354.9	1.3506	9.9	0.1	1.0788	1594.7	364.5	1.3527
9.9	5.1	1.0773	1630.3	349.3	1.3566	9.9	5.1	1.0869	1611.5	354.3	1.3605
9.9	10.1	1.0802	1633.3	347.0	1.3637	9.9	10.1	1.0904	1623.1	348.1	1.3666
12.0	0.0	1.0880	1642.7	340.6	1.3519	12.0	0.0	1.0973	1617.4	348.4	1.3555
12.0	1.0	1.0891	1644.0	339.7	1.3551	12.0	1.0	1.0986	1620.2	346.8	1.3588
12.0	3.0	1.0914	1646.8	337.9	1.3587	12.0	3.0	1.1011	1626.6	343.2	1.3619
		T/K = 308.15						T/K = 288.15			
0.0	0.0	0.9940	1520.3	435.3	1.3313	0.0	0.0	1466.4	465.5	1.3335	1466.4
0.0	1.0	1.0916	1520.4	396.3	1.4654	0.0	1.0	1588.5	357.7	1.4725	1588.5
1.9	0.0	1.0096	1537.8	418.8	1.3340	1.9	0.0	1486.7	445.6	1.3362	1486.7
1.9	23.1	1.0392	1589.1	381.1	1.3652	1.9	23.1	1578.7	382.8	1.3690	1578.7
1.9	38.1	1.0584	1619.1	360.5	1.3845	1.9	38.1	1638.4	348.2	1.3887	1638.4
1.9	49.0	1.0721	1633.4	349.6	1.4044	1.9	49.0	1671.7	329.7	1.4098	1671.7
1.9	10.1	1.0222	1559.9	402.1	1.3488	1.9	10.1	1524.6	418.0	1.3512	1524.6
1.9	13.1	1.0264	1566.9	396.8	1.3536	1.9	13.1	1537.2	409.3	1.3588	1537.2
4.9	0.0	1.0328	1563.8	395.9	1.3412	4.9	0.0	1516.6	418.3	1.3439	1516.6
4.9	0.1	1.0333	1564.6	395.3	1.3414	4.9	0.1	1518.0	417.3	1.3439	1518.0
4.9	5.1	1.0394	1575.1	387.8	1.3483	4.9	5.1	1536.9	404.5	1.3513	1536.9
4.9	10.1	1.0458	1586.1	380.1	1.3558	4.9	10.1	1556.6	391.7	1.3589	1556.6
4.9	20.1	1.0602	1608.4	364.6	1.3697	4.9	20.1	1598.1	366.1	1.3737	1598.1
4.9	30.1	1.0727	1627.2	352.1	1.3829	4.9	30.1	1636.4	344.7	1.3871	1636.4
7.0	0.0	1.0512	1584.5	378.9	1.3436	7.0	0.0	1540.4	398.2	1.3449	1540.4
7.0	3.0	1.0541	1590.7	374.9	1.3498	7.0	3.0	1552.0	391.1	1.3525	1552.0
7.0	13.0	1.0671	1611.9	360.7	1.3638	7.0	13.0	1591.6	366.9	1.3675	1591.6
7.0	23.0	1.0804	1630.4	348.2	1.3770	7.0	23.0	1630.3	344.9	1.3812	1630.3
7.0	28.0	1.0899	1642.8	340.0	1.3925	7.0	28.0	1646.4	335.2	1.3983	1646.4
9.9	0.0	1.0741	1610.9	358.8	1.3514	9.9	0.0	1571.1	374.4	1.3543	1571.1
9.9	0.1	1.0745	1611.7	358.3	1.3516	9.9	0.1	1571.5	374.1	1.3540	1571.5
9.9	5.1	1.0824	1623.4	350.6	1.3589	9.9	5.1	1593.8	360.8	1.3620	1593.8
9.9	10.1	1.0855	1630.2	346.7	1.3650	9.9	10.1	1610.3	352.3	1.3683	1610.3
12.0	0.0	1.0929	1632.6	343.3	1.3539	12.0	0.0	1596.0	356.5	1.3569	1596.0
12.0	1.0	1.0941	1634.6	342.1	1.3571	12.0	1.0	1599.9	354.3	1.3603	1599.9
12.0	3.0	1.0965	1639.1	339.5	1.3607	12.0	3.0	1608.3	349.8	1.3635	1608.3

[a]Standard uncertainties u are $u(T)$ = 0.01 K, $u(p)$ = 20 Pa, $u(x)$ = 0.0007, and the combined expanded uncertainties U_c (level of confidence = 0.95, k = 2) are $U_c(\rho) = 2 \cdot 10^{-4}$ $g \cdot cm^{-3}$, $U_c(c)$ = 1.2 $m \cdot s^{-1}$ and $U_c(n_D) = 5 \cdot 10^{-4}$.

the critical aggregation concentration data corresponding to these systems and allow a confirmation of the influence of salt concentration upon this parameter. A similar behavior has been obtained for the other salt used in the present work

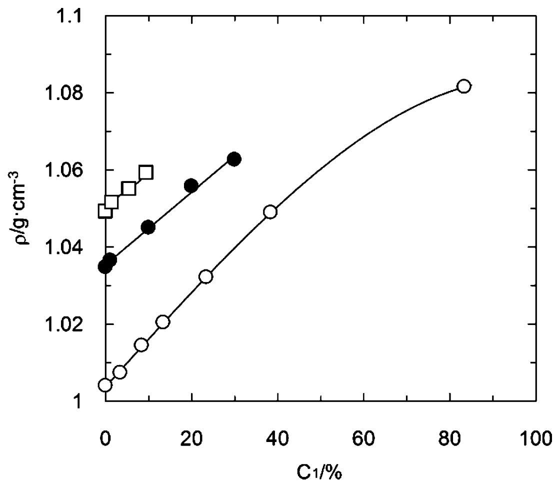

Figure 5. Influence of surfactant and salt concentration upon density values for Tween20 (1) + Na_2SO_4 (2) + Water (3) ternary system. T = 318.15 K: ○, C_2 = 1.565 %; ●, C_2 = 4.99 %; □, C_2 = 6.5 %. Solid lines correspond to eq 1.

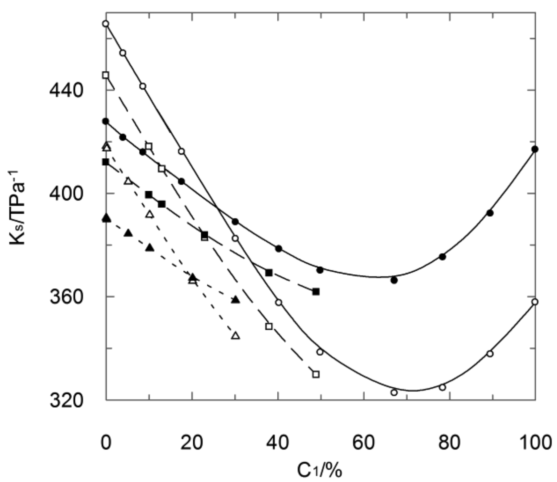

Figure 6. Influence of surfactant and salt concentration, and temperature upon the isentropic compressibility value for Tween20 (1) + $Na_2S_2O_3$ (2) + water (3). C_2 = 0 %: ○, T = 288.15 K; ●, T = 318.15 K. C_2 = 1.937 %: □, T = 288.15 K; ■, T = 318.15 K. C_2 = 4.865 %: △, T = 288.15 K; ▲, T = 318.15 K.

Table 6. Critical Aggregation Concentration (cac) for Tween (1) + Salt (2) Aqueous Solution

C_2/ %	cac/ %
Na_2SO_4	
0.00	25.6
1.56	23.5
4.98	17.1
6.50	
8.58	
$Na_2S_2O_3$	
0.00	25.6
1.93	23.2
4.86	20.3
7.00	16.9
9.88	
12.00	

(sodium sulfate) with the same effects caused by surfactant and salt concentration and temperature. High salts concentration

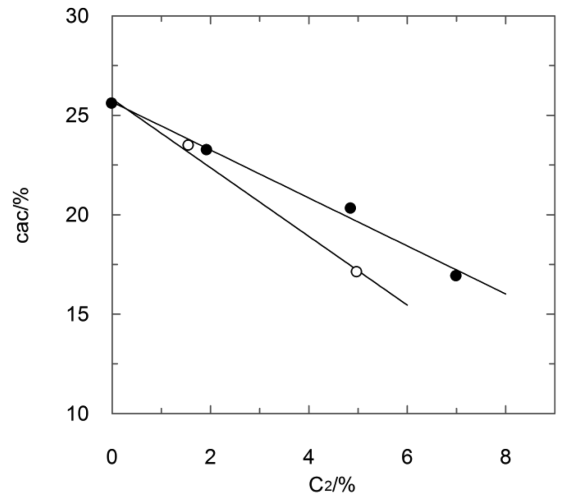

Figure 7. Influence of salt type and concentration upon critical aggregation concentration in Tween20 aqueous solutions. ○, Na_2SO_4; ●, $Na_2S_2O_3$.

Table 7. Fit Parameters and Standard Deviation Corresponding to eq 1 for Density ρ, for Tween20 (1) + Na_2SO_4 (2) + water (3) from T = (288.15 to 318.15) K

T/K	A	B	C	D	σ
			C_2 = 1.56 %		
288.15	6.921	0.1388	0.0180	−0.0697	$4 \cdot 10^{-7}$
298.15	6.918	0.1325	0.0140	−0.0645	$4 \cdot 10^{-7}$
308.15	6.915	0.1260	0.0134	−0.0622	$4 \cdot 10^{-7}$
318.15	6.911	0.1215	0.0070	−0.0544	$3 \cdot 10^{-7}$
			C_2 = 4.98 %		
288.15	6.953	0.0787	0.5513	−1.610	$7 \cdot 10^{-8}$
298.15	6.950	0.0586	0.6774	−1.869	$7 \cdot 10^{-8}$
308.15	6.946	0.0461	0.7291	−1.958	$7 \cdot 10^{-8}$
318.15	6.943	0.0250	0.8709	−2.229	$6 \cdot 10^{-7}$
			C_2 = 6.50 %		
288.15	6.967	0.1828	−1.916	12.82	$1 \cdot 10^{-8}$
298.15	6.964	0.1774	−1.946	13.01	$1 \cdot 10^{-8}$
308.15	6.960	0.1708	−1.882	12.45	$3 \cdot 10^{-8}$
318.15	6.956	0.1839	−2.337	15.39	$2 \cdot 10^{-8}$
			C_2 = 8.58 %		
288.15	6.984	−0.9051	113.0	−2414	$3 \cdot 10^{-8}$
298.15	6.980	−0.8523	107.1	−2290	$1 \cdot 10^{-8}$
308.15	6.977	−0.8497	105.5	−2252	$7 \cdot 10^{-8}$
318.15	6.972	−0.8537	105.8	−2247	$2 \cdot 10^{-8}$

avoids the formation of the temperature resistant structure. For this reason Figure 7 does not show critical aggregation concentration (cac) data for high salts concentrations.

Tables 7 to 10 show the values corresponding to fitting parameters of eq 1 used to fit experimental data of density and refractive index under the experimental conditions used in present work. Also the standard deviation corresponding to each system is included in these Tables. This kind of data allows a conclusion that this equation calculates the value of these properties with slight deviations in comparison with the experimental results.

3.3. Ternary Systems: Phases at Equilibrium. The present work also analyzes the physical properties corresponding to liquid ternary mixtures in equilibrium joined by tie lines. The experimental data for density, speed of sound, and

Table 8. Fit Parameters and Standard Deviation Corresponding to eq 1 for Refractive Index n_D, for Tween20 (1) + Na_2SO_4 (2) + Water (3) from T = (288.15 to 318.15) K

T/K	A	B	C	D	σ
			C_2 = 1.56 %		
288.15	1.336	0.1399	0.0103	$-9.7 \cdot 10^{-3}$	$2 \cdot 10^{-7}$
298.15	1.335	0.1355	0.0149	−0.0135	$1 \cdot 10^{-7}$
308.15	1.334	0.1308	0.0207	−0.0178	$7 \cdot 10^{-8}$
318.15	1.333	0.1270	0.0216	−0.0165	$1 \cdot 10^{-7}$
			C_2 = 4.98 %		
288.15	1.341	0.1450	$2.9 \cdot 10^{-3}$	−0.2762	$9 \cdot 10^{-8}$
298.15	1.340	0.1407	0.0159	−0.3045	$9 \cdot 10^{-8}$
308.15	1.339	0.1710	−0.2521	0.2260	$8 \cdot 10^{-8}$
318.15	1.337	0.1673	−0.1980	0.0509	$6 \cdot 10^{-8}$
			C_2 = 6.50 %		
288.15	1.344	0.3159	−4.416	25.26	$1 \cdot 10^{-8}$
298.15	1.343	0.3089	−4.342	24.94	$3 \cdot 10^{-8}$
308.15	1.341	0.2998	−4.642	28.88	$2 \cdot 10^{-8}$
318.15	1.340	0.2664	−3.643	21.87	$2 \cdot 10^{-8}$
			C_2 = 8.58 %		
288.15	1.347	0.2161	−3.972	0.0000	$2 \cdot 10^{-8}$
298.15	1.345	0.2075	−3.762	0.0000	$1 \cdot 10^{-8}$
308.15	1.344	0.1948	−3.469	0.0000	$4 \cdot 10^{-8}$
318.15	1.342	0.0961	−0.7903	0.0000	$2 \cdot 10^{-8}$

Table 9. Fit Parameters and Standard Deviation Corresponding to eq 1 for Density ρ, for Tween20 (1) + $Na_2S_2O_3$ (2) + Water (3) from T = (288.15 to 318.15) K

T/K	A	B	C	D	σ
			C_2 = 1.93 %		
288.15	6.923	0.1368	0.0127	−0.0296	$4 \cdot 10^{-8}$
298.15	6.921	0.1303	0.0111	−0.0300	$4 \cdot 10^{-8}$
308.15	6.917	0.1248	$8.0 \cdot 10^{-3}$	−0.0252	$2 \cdot 10^{-8}$
318.15	6.913	0.1206	$1.5 \cdot 10^{-3}$	−0.0244	$3 \cdot 10^{-8}$
			C_2 = 4.86 %		
288.15	6.947	0.1172	0.2281	−0.5371	$5 \cdot 10^{-8}$
298.15	6.944	0.1413	−0.2264	0.6394	$9 \cdot 10^{-8}$
308.15	6.940	0.1081	0.1956	−0.4609	$5 \cdot 10^{-8}$
318.15	6.936	0.0977	0.2400	−0.5533	$3 \cdot 10^{-8}$
			C_2 = 7.00 %		
288.15	6.964	0.1299	−0.0844	0.4367	$2 \cdot 10^{-7}$
298.15	6.961	0.1263	−0.1137	0.5141	$2 \cdot 10^{-7}$
308.15	6.957	0.1225	−0.1326	0.5654	$3 \cdot 10^{-7}$
318.15	6.953	0.1210	−0.1798	0.7006	$3 \cdot 10^{-7}$
			C_2 = 9.88 %		
288.15	6.987	0.3230	−4.280	22.11	$7 \cdot 10^{-8}$
298.15	6.983	0.3244	−4.587	24.33	$2 \cdot 10^{-8}$
308.15	6.979	0.3258	−4.696	24.78	$3 \cdot 10^{-8}$
318.15	6.975	0.3276	−4.956	26.70	$1 \cdot 10^{-8}$
			C_2 = 12.00 %		
288.15	7.004	0.1165	0.1439	0.0000	$3 \cdot 10^{-8}$
298.15	7.002	0.3607	−13.34	0.0000	$1 \cdot 10^{-8}$
308.15	6.997	0.1098	$-6 \cdot 10^{-3}$	0.0000	$5 \cdot 10^{-8}$
318.15	6.992	$9.9 \cdot 10^{-2}$	0.1476	0.0000	$1 \cdot 10^{-8}$

refractive index are included in Tables 11 and 12 for the ATPS employed in present work. These equilibrium phases are obtained by mixing certain amounts of each compound, stirring the mixture, and allowing them to settle for 24 h. Then the composition was determined, and the physical properties were measured.

Table 10. Fit Parameters and Standard Deviation Corresponding to eq 1 for Refractive Index n_D, for Tween20 (1) + $Na_2S_2O_3$ (2) + Water (3) from T = (288.15 to 318.15) K

T/K	A	B	C	D	σ
			C_2 = 1.93 %		
288.15	1.336	0.1999	−0.3700	−0.5492	$3 \cdot 10^{-6}$
298.15	1.335	0.1855	−0.3073	0.4671	$1 \cdot 10^{-6}$
308.15	1.334	0.1762	−0.2763	0.4290	$2 \cdot 10^{-7}$
318.15	1.333	0.1641	−0.2307	0.3573	$6 \cdot 10^{-8}$
			C_2 = 4.86 %		
288.15	1.344	0.1437	0.0764	−0.2536	$1 \cdot 10^{-8}$
298.15	1.343	0.1425	0.0620	−0.2215	$1 \cdot 10^{-8}$
308.15	1.341	0.1410	0.0295	−0.1285	$2 \cdot 10^{-8}$
318.15	1.345	0.0164	0.7308	−1.2756	$2 \cdot 10^{-5}$
			C_2 = 7.00 %		
288.15	1.345	0.3340	−1.871	4.864	$3 \cdot 10^{-7}$
298.15	1.343	0.3223	−1.769	4.571	$2 \cdot 10^{-7}$
308.15	1.343	0.2805	−1.478	3.937	$4 \cdot 10^{-7}$
318.15	1.341	0.3032	−1.665	4.348	$4 \cdot 10^{-8}$
			C_2 = 9.88 %		
288.15	1.354	−0.2459	11.78	−78.94	$5 \cdot 10^{-8}$
298.15	1.353	−0.2281	11.23	−75.44	$3 \cdot 10^{-8}$
308.15	1.351	0.1639	−0.7381	0.8348	$1 \cdot 10^{-8}$
318.15	1.350	0.8949	−22.34	147.0	$2 \cdot 10^{-8}$
			C_2 = 12.00 %		
288.15	1.357	0.4065	−6.150	0.0000	$1 \cdot 10^{-8}$
298.15	1.356	0.3843	−5.633	0.0000	$3 \cdot 10^{-8}$
308.15	1.354	0.3618	−4.483	0.0000	$4 \cdot 10^{-8}$
318.15	1.352	0.3642	−4.517	0.0000	$3 \cdot 10^{-8}$

Table 11. Densities (ρ), Speed of Sounds (c), Isentropic Compressibilities (κ_s), and Refractive Indices (n_D), of Tween20 (1) + Na_2SO_4 (2) + Water (3) Equilibrium Phases at T = 298.15 K[a]

tie line	C_1/%	C_2/%	ρ/g·cm^{-3}	c/m·s^{-1}	κ_s/TPa^{-1}	n_D
1	36.09	3.56	1.0724	1619.0	355.8	1.3723
2	48.80	0.20	1.0703	1634.5	349.7	1.3992
3	54.27	0.05	1.0722	1641.1	346.3	1.3599
1	3.23	9.20	1.0997	1637.6	339.1	1.3567
2	0.91	12.18	1.1055	1650.2	332.2	1.3578
3	0.30	13.13	1.1214	1670.3	319.6	1.4037

[a]Standard uncertainties u are $u(T)$ = 0.01 K, $u(p)$ = 20 Pa, $u(x)$ = 0.0007, and the combined expanded uncertainties U_c (level of confidence = 0.95, k = 2) are $U_c(\rho) = 2 \cdot 10^{-4}$ g·cm^{-3}, $U_c(c)$ = 1.2 m·s^{-1} and $U_c(n_D) = 5 \cdot 10^{-4}$.

Table 12. Densities (ρ), Speed of Sounds (c), Isentropic Compressibilities (κ_s), and Refractive Indices (n_D), of Tween20 (1) + $Na_2S_2O_3$ (2) + Water (3) Equilibrium Phases at T = 298.15 K[a]

tie line	C_1/%	C_2/%	ρ/g·cm^{-3}	c/m·s^{-1}	κ_s/TPa^{-1}	n_D
1	40.70	2.19	1.0914	1645.8	338.3	1.4004
2	53.58	0.07	1.0956	1659.0	331.6	1.3908
3	59.92	0.00	1.0924	1655.5	334.0	1.3835
1	5.50	14.53	1.1285	1678.5	314.5	1.3748
2	2.88	19.08	1.2348	1807.0	248.0	1.3930
3	1.65	20.96	1.1841	1748.1	276.4	1.3853

[a]Standard uncertainties u are $u(T)$ = 0.01 K, $u(p)$ = 20 Pa, $u(x)$ = 0.0007, and the combined expanded uncertainties U_c (level of confidence = 0.95, k = 2) are $U_c(\rho) = 2 \cdot 10^{-4}$ g·cm^{-3}, $U_c(c)$ = 1.2 m·s^{-1} and $U_c(n_D) = 5 \cdot 10^{-4}$.

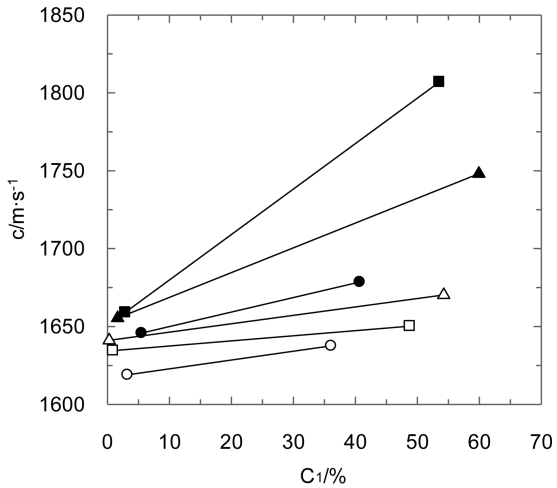

Figure 8. Influence of composition upon speed of sound in phases in equilibrium. (open symbols) Tween20 (1) + Na_2SO_4 (2) + water (3) system. (full symbols) Tween20 (1) + $Na_2S_2O_3$ (2) + water (3) system.

Figure 8 shows an example of the experimental data obtained for speed of sound corresponding to the Tween20 + sodium sulfate + water system at 298.15 K. In all cases the surfactant-rich phases show a higher value for speed of sound than the salt-rich phases. Different slopes in this plot are observed. When the other salt (sodium thiosulfate) is employed the values obtained for speed of sound are higher than the previously commented for sodium sulfate but the influence of surfactant and salt concentration is similar. Also a similar behavior is observed for density.

In relation to the value of refractive index corresponding to phases in equilibrium, the behavior is different than that previously commented for density and speed of sound. For these properties the slope of these plots (such as Figure 8) maintain the sign, but in relation to the influence of composition upon refractive index a change in slope sign is observed when surfactant concentration increases in the light phase (and decreases in the heavy phase) for both ATPS. This behavior indicates similar importance of both solutes upon the value of refractive index.

4. CONCLUSIONS

The present work characterizes liquid mixtures that involve the components of two aqueous two-phase systems based on surfactant + salt + water mixtures. The blends analyzed were binary aqueous solutions and ternary systems. The last type was divided into mixtures corresponding to the homogeneous zone and equilibrium phases. Salt aqueous solutions showed the same behavior as that in previous studies, but the influence of composition in surfactant solutions showed aggregation phenomena forming a temperature-resistant structure with the same value of speed of sound or isentropic compressibility for all temperatures.

For ternary homogeneous systems increases in density and refractive index are observed when salt and/or surfactant concentration increases in the mixture. Speed of sound and isentropic compressibility show a similar behavior as that of the Tween20 + water system. The presence of salt modifies slightly the critical aggregation concentration. Both salts show a similar influence upon the behavior of each property. This fact could be due to the same kosmotropic character of these solutes.

The analysis of equilibrium phases shows higher values for density and speed of sound for surfactant-rich phases for all systems. The behavior shown for refractive index is different than that of the other properties, and the composition of each phase can cause an important change in its value.

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Notes

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