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Studies on Acoustic and Aggregation Properties of Sodium Dodecyl Sulfate in Amino Acid Solutions through Ultrasonic Velocity Technique

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Acoustic and aggregation properties of sodium dodecyl sulfate in aqueous amino acid systems have been studied through ultrasonic velocity techniques at different temperature as a function of concentration and at different temperature (288.15, 293.15, 298.15, 303.15, 308.15, 313.15, 318.15 and 323.15 K) and atmospheric pressure using density and sound velocity analyzer (DSA 5000, Anton paar, Austria). Densities and ultrasonic velocity of sodium dodecyl sulfate in aqueous amino acid have been measured and from the experimental data, adiabatic compressibility (β_S), apparent molar adiabatic compressibility (ϕ_k), critical micelle concentration (CMC), acoustic impedance (Z), relative association (R_A) and molar sound velocity (R_m) have been calculated. The results show significant information about acoustic properties of sodium dodecyl sulfate (solute-solute interactions, aggregation behaviour, relative association and structure formation) in aqueous and aqueous amino acid solution.

Keywords: Sodium dodecyl sulfate, Glycine, DL-alanine, Apparent molar volume, Critical micelle concentration, Hydration number.

INTRODUCTION

Surfactant, also called surface-active agent, that when added to a liquid, reduces its surface tension, thereby increasing its spreading and wetting properties. Surfactants have vast application in pharmaceuticals, biotechnology, agriculture, food industry and cosmetics industry [1-3]. But their interaction with various types of co-solutes, biological macromolecules is not clearly understood. So, it is important to investigate the interaction of sodium dodecyl sulfate (SDS) with various types of molecules in applied medium. Surfactants interact with working medium molecules through their head group and hydrophobic tail. Micellar properties of surfactant make more complexities in working medium but very operative toward many applications [4-8].

The studies of surfactant with amino acids have important fundamental and useful research interest [9-11]. The interaction of surfactant with protein has been investigated using various methods [12-14]. Surfactant interacts with protein and bind them leading to substantial changes in protein conformation. Surfactant modifies the protein structure and changes the function or character of surfactant-protein interaction. Several phenomena on the interaction mode of surfactants with proteins until unanswered. So, it is definitely important to understand the nature of surfactant-protein interactions.

Sodium dodecyl sulfate has a special place in laboratory and industrial use. Surfactant has unique character because of their hydrophilic and hydrophobic groups in the same molecule. It can bring conformational changes and modify the activities of many proteins [15-20]. To the best of our knowledge, no report has been available previously on the acoustic properties of SDS in aqueous amino acid solutions. Surfactant has unique character because of their hydrophilic and hydrophobic groups in the same molecule. In this paper, we explain the acoustic and aggregation properties of SDS in the various concentrations of glycine and DL-alanine through ultrasonic technique [21-24]. Among the various properties of physical parameter, acoustic [25,26] and aggregation property can give us potential information about structural changes of SDS in amino acid solutions.

EXPERIMENTAL

Sodium dodecyl sulfate (purity, mass fraction > 0.99), glycine (purity, mass fraction > 0.99) and DL-alanine (purity, mass fraction > 0.99) obtained from Fluka Chemical Company, Switzerland were used in this study. The specifications of the chemicals used in this study are given in Table-1.

In the previous literature the CMC value of aqueous SDS was reported around 0.009 m at 25 °C and mean aggregation number vary from 58 to 64. Distilled water (supplied) was purified by redistilled and deionized process using two ion exchange columns. The deionized water was further distilled in alkaline $KMnO_4$ medium. Conductivity of this purified water was 5×10^{-6} S cm^{-1}. For weighing, electric balance with an accuracy of ± 0.0001 g was used. For measurement of density and ultrasonic velocity, a densitometer (DSA-5000, Anton Paar, Austria) was used. Each solution was prepared by weight immediately before the measurement.

RESULTS AND DISCUSSION

The densities (ρ) and ultrasonic velocity (u) of SDS in aqueous and aqueous amino acid solutions are measured at different concentration of solutes and temperature, also presented in Tables 2 and 3.

Adiabatic compressibility (β_S) and apparent molar adiabatic compressibility (ϕ_K): Adiabatic compressibility (β_S), was calculated by densities and ultrasonic velocity data using eqn. 1:

TABLE-1
SPECIFICATIONS OF THE CHEMICALS

Chemical name	Molar mass (kg mol^{-1})	Purity declared by manufacturer	Origin
Sodium dodecyl sulfate	0.28838	Mole fraction ≥ 0.99	Fluka Chemical Company, Switzerland
Glycine	0.07507	Mole fraction ≥ 0.99	Fluka Chemical Company, Switzerland
DL-alanine	0.14614	Mole fraction ≥ 0.99	Fluka Chemical Company, Switzerland

TABLE-2
DENSITIES (ρ, kg m^{-3}) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K, RESPECTIVELY

m (mol kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
Water + SDS						
0.00000	999.101	998.206	997.045	995.646	994.032	992.215
0.00034	999.138	998.239	997.080	995.679	994.063	992.246
0.00089	999.171	998.272	997.109	995.708	994.094	992.273
0.00136	999.189	998.289	997.124	995.724	994.108	992.288
0.01499	999.932	999.007	997.823	996.400	994.766	992.932
0.02999	1000.638	999.694	998.491	997.054	995.406	993.558
0.04398	1001.294	1000.330	999.111	997.660	995.999	994.138
0.05807	1001.942	1000.959	999.725	998.258	996.580	994.706
0.07199	1002.582	1001.580	1000.327	998.845	997.155	995.273
0.08594	1003.218	1002.201	1000.932	999.436	997.731	995.835
0.10085	1003.897	1002.860	1001.571	1000.062	998.345	996.433
0.11498	1004.497	1003.443	1002.140	1000.615	998.886	996.965
0.12860	1005.091	1004.022	1002.706	1001.166	999.424	997.491
0.14257	1005.672	1004.584	1003.252	1001.702	999.945	998.002
0.15700	1006.295	1005.189	1003.841	1002.276	1000.507	998.549
0.17194	1007.184	1005.953	1004.580	1002.988	1001.199	999.222
0.18610	1007.654	1006.463	1005.084	1003.485	1001.687	999.707
0.19845	1008.073	1006.918	1005.524	1003.916	1002.109	1000.121
Water + Glycine (0.049 m) + SDS						
0.00000	1000.719	999.801	998.623	997.209	995.582	993.754
0.00035	1000.760	999.842	998.662	997.247	995.619	993.793
0.00062	1000.780	999.861	998.679	997.266	995.635	993.806
0.01394	1001.528	1000.584	999.382	997.951	996.306	994.464
0.02828	1002.155	1001.194	999.980	998.531	996.874	995.020
0.04222	1002.838	1001.862	1000.630	999.165	997.496	995.630
0.05679	1003.466	1002.470	1001.222	999.748	998.063	996.186
0.07115	1004.166	1003.152	1001.887	1000.394	998.698	996.807
0.08490	1004.793	1003.766	1002.484	1000.977	999.266	997.365
0.09953	1005.425	1004.376	1003.078	1001.559	999.837	997.921
0.11068	1005.891	1004.826	1003.515	1001.982	1000.247	998.320
0.12577	1006.537	1005.453	1004.147	1002.578	1000.830	998.891
0.14084	1007.217	1006.117	1004.771	1003.210	1001.445	999.493
0.14951	1007.620	1006.509	1005.153	1003.586	1001.814	999.858
0.17089	1008.543	1007.407	1006.029	1004.436	1002.645	1000.673
0.18048	1008.964	1007.815	1006.428	1004.825	1003.026	1001.042
0.19721	1009.887	1008.720	1007.313	1005.695	1003.881	1001.884

Water + Glycine (0.466 m) + SDS						
0.00000	1014.209	1013.124	1011.805	1010.278	1008.557	1006.654
0.00034	1014.250	1013.165	1011.846	1010.316	1008.596	1006.693
0.00064	1014.257	1013.172	1011.851	1010.323	1008.601	1006.701
0.01455	1014.949	1013.840	1012.501	1010.957	1009.220	1007.302
0.02873	1015.490	1014.366	1013.014	1011.453	1009.700	1007.770
0.04149	1015.973	1014.833	1013.469	1011.898	1010.136	1008.199
0.05671	1016.607	1015.449	1014.066	1012.477	1010.704	1008.753
0.07014	1017.317	1016.141	1014.742	1013.140	1011.330	1009.387
0.08458	1017.871	1016.678	1015.263	1013.649	1011.848	1009.874
0.09834	1018.414	1017.210	1015.776	1014.151	1012.337	1010.349
0.11258	1019.000	1017.775	1016.332	1014.689	1012.863	1010.865
0.12687	1019.540	1018.298	1016.837	1015.181	1013.344	1011.332
0.14028	1020.096	1018.840	1017.367	1015.696	1013.847	1011.827
0.15060	1020.458	1019.193	1017.708	1016.031	1014.171	1012.143
0.16942	1021.156	1019.869	1018.366	1016.671	1014.797	1012.756
0.18166	1021.545	1020.245	1018.732	1017.028	1015.143	1013.091
0.19292	1021.958	1020.649	1019.122	1017.406	1015.551	1013.455
Water + DL-alanine (0.049 m) + SDS						
0.00000	1000.564	999.650	998.477	997.068	995.444	993.618
0.00150	1000.723	999.807	998.627	997.212	995.583	993.757
0.01442	1001.330	1000.393	999.196	997.766	996.124	994.283
0.02820	1001.977	1001.025	999.794	998.366	996.709	994.860
0.04313	1002.647	1001.674	1000.442	998.980	997.319	995.456
0.05686	1003.314	1002.326	1001.079	999.607	997.925	996.051
0.06819	1003.740	1002.735	1001.474	999.996	998.305	996.422
0.08441	1004.468	1003.441	1002.161	1000.658	998.947	997.049
0.09751	1005.058	1004.015	1002.720	1001.204	999.481	997.571
0.11443	1005.717	1004.658	1003.348	1001.817	1000.082	998.158
0.12739	1006.005	1004.909	1003.591	1002.048	1000.301	998.368
0.13981	1006.551	1005.463	1004.127	1002.573	1000.814	998.870
0.15325	1007.432	1006.323	1004.968	1003.399	1001.627	999.671
0.16465	1007.977	1006.854	1005.485	1003.904	1002.121	1000.153
0.17467	1008.264	1007.130	1005.756	1004.165	1002.376	1000.403
0.19849	1009.288	1008.128	1006.731	1005.114	1003.302	1001.311
Water + DL-alanine (0.438 m) + SDS						
0.00000	1011.856	1010.828	1009.555	1008.064	1006.374	1004.498
0.00082	1011.931	1010.902	1009.627	1008.135	1006.443	1004.566
0.00156	1011.944	1010.914	1009.639	1008.146	1006.454	1004.576
0.01554	1012.640	1011.589	1010.294	1008.789	1007.080	1005.185
0.03025	1013.304	1012.229	1010.918	1009.379	1007.670	1005.770
0.05630	1014.393	1013.290	1011.946	1010.399	1008.652	1006.726
0.06954	1014.967	1013.844	1012.487	1010.923	1009.164	1007.226
0.07950	1015.390	1014.253	1012.883	1011.302	1009.529	1007.593
0.09943	1016.231	1015.060	1013.670	1012.050	1010.264	1008.318
0.11285	1016.769	1015.580	1014.174	1012.541	1010.737	1008.780
0.12791	1017.372	1016.161	1014.740	1013.080	1011.266	1009.297
0.14159	1017.890	1016.659	1015.230	1013.550	1011.733	1009.754
0.15603	1018.432	1017.208	1015.750	1014.080	1012.250	1010.243
0.16924	1018.924	1017.683	1016.218	1014.560	1012.711	1010.693
0.18305	1019.438	1018.179	1016.700	1015.020	1013.160	1011.140
0.19867	1020.018	1018.745	1017.250	1015.558	1013.687	1011.645

TABLE-3
ULTRASONIC VELOCITY (u, m s^{-1}) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K, RESPECTIVELY

m (mol kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
Water + SDS						
0.00000	1466.28	1482.58	1496.78	1509.18	1519.76	1528.78
0.00034	1466.62	1482.86	1496.90	1509.40	1519.93	1528.99
0.00089	1466.82	1482.86	1497.10	1509.49	1520.17	1529.22
0.00136	1466.84	1482.93	1497.12	1509.52	1520.29	1529.28
0.01499	1468.00	1483.60	1498.30	1510.70	1520.99	1529.90
0.02999	1468.35	1484.70	1498.50	1510.52	1520.94	1529.66
0.04398	1468.99	1484.82	1498.62	1510.49	1520.67	1529.29
0.05807	1469.31	1484.97	1498.68	1510.34	1520.43	1528.92

0.07199	1469.60	1485.08	1498.74	1510.23	1520.17	1528.53
0.08594	1469.89	1485.24	1498.78	1510.14	1519.95	1528.19
0.10085	1470.21	1485.43	1498.81	1510.04	1519.73	1527.83
0.11498	1470.47	1485.58	1498.84	1509.97	1519.54	1527.52
0.12860	1470.77	1485.73	1498.90	1509.89	1519.32	1527.19
0.14257	1470.94	1485.89	1498.92	1509.83	1519.18	1526.96
0.15700	1471.00	1486.03	1499.04	1509.78	1519.03	1526.72
0.17194	1471.12	1486.27	1499.07	1509.62	1518.66	1526.14
0.18610	1471.22	1486.34	1499.10	1509.44	1518.37	1525.73
0.19845	1471.27	1486.53	1499.30	1509.37	1518.14	1525.39
Water + Glycine (0.049 m) + SDS						
0.00000	1469.23	1485.31	1499.43	1511.74	1522.32	1531.27
0.00035	1469.40	1485.40	1499.49	1511.79	1522.44	1531.39
0.00062	1469.43	1485.55	1499.54	1511.86	1522.49	1531.44
0.01394	1471.59	1487.80	1501.10	1513.29	1523.70	1532.61
0.02828	1471.80	1487.30	1501.14	1513.07	1523.36	1532.17
0.04222	1471.86	1487.40	1501.11	1512.97	1523.18	1531.74
0.05679	1472.10	1487.58	1501.13	1512.89	1522.96	1531.40
0.07115	1472.40	1487.74	1501.15	1512.85	1522.73	1531.06
0.08490	1472.70	1487.92	1501.21	1512.73	1522.55	1530.74
0.09953	1473.00	1488.10	1501.26	1512.58	1522.31	1530.38
0.11068	1473.16	1488.14	1501.19	1512.45	1522.06	1530.00
0.12577	1473.47	1488.31	1501.22	1512.34	1521.77	1529.62
0.14084	1473.82	1488.54	1501.30	1512.25	1521.57	1529.26
0.14951	1474.03	1488.65	1501.35	1512.17	1521.47	1529.09
0.17089	1474.50	1488.93	1501.41	1512.12	1521.15	1528.59
0.18048	1474.71	1489.04	1501.45	1512.05	1520.98	1528.33
0.19721	1475.00	1489.54	1501.79	1512.26	1521.06	1528.28
Water + Glycine (0.466 m) + SDS						
0.00000	1492.57	1507.85	1521.31	1532.99	1543.02	1551.50
0.00034	1492.70	1508.00	1521.46	1533.14	1543.04	1551.53
0.00064	1492.78	1508.05	1521.49	1533.16	1543.12	1551.62
0.01455	1494.41	1509.46	1522.70	1534.20	1544.04	1552.87
0.02873	1494.41	1509.36	1522.47	1533.86	1543.30	1552.10
0.04149	1494.46	1509.30	1522.30	1533.56	1543.19	1551.87
0.05671	1494.66	1509.35	1522.22	1533.35	1542.82	1551.29
0.07014	1495.03	1509.59	1522.31	1533.28	1542.62	1550.72
0.08458	1495.18	1509.62	1522.22	1533.07	1542.29	1550.50
0.09834	1495.37	1509.67	1522.13	1532.84	1541.91	1549.90
0.11258	1495.55	1509.72	1522.03	1532.61	1541.56	1549.71
0.12687	1495.72	1509.74	1521.92	1532.35	1541.17	1548.88
0.14028	1495.90	1509.81	1521.86	1532.18	1540.88	1548.37
0.15060	1495.98	1509.80	1521.76	1531.98	1540.57	1547.70
0.16942	1496.18	1509.81	1521.59	1531.64	1540.07	1547.00
0.18166	1496.18	1509.71	1521.38	1531.33	1539.65	1546.49
0.19292	1496.27	1509.67	1521.25	1531.10	1539.30	1546.02
Water + DL-alanine (0.049 m) + SDS						
0.00000	1469.87	1485.97	1499.99	1512.19	1522.74	1531.68
0.00150	1470.50	1486.53	1500.58	1512.78	1523.37	1532.10
0.01442	1472.73	1487.88	1501.76	1513.81	1524.77	1533.30
0.02820	1472.93	1487.96	1501.74	1513.68	1524.10	1532.99
0.04313	1472.51	1488.03	1501.64	1513.71	1523.74	1532.20
0.05686	1473.02	1488.44	1501.98	1513.64	1523.66	1532.08
0.06819	1472.70	1488.10	1502.03	1513.56	1523.48	1531.81
0.08441	1472.98	1488.15	1501.39	1512.83	1522.57	1530.71
0.09751	1473.26	1488.31	1501.43	1512.75	1522.35	1530.40
0.11443	1473.82	1488.72	1501.74	1512.90	1522.40	1530.33
0.12739	1473.40	1488.20	1501.05	1512.11	1521.52	1529.35
0.13981	1473.55	1488.26	1501.07	1512.02	1521.32	1529.03
0.15325	1474.60	1489.15	1501.78	1512.59	1521.74	1529.30
0.16465	1474.82	1489.26	1501.80	1512.47	1521.50	1528.97
0.17467	1474.95	1489.31	1501.74	1512.39	1521.35	1528.75
0.19849	1474.99	1489.58	1501.76	1512.15	1520.91	1528.10

Water + DL-alanine (0.438 m) + SDS						
0.00000	1497.33	1512.32	1525.46	1536.85	1546.59	1554.80
0.00082	1497.40	1512.38	1525.54	1536.94	1546.78	1554.88
0.00156	1497.54	1512.50	1525.68	1537.17	1546.90	1554.94
0.01554	1498.74	1513.42	1526.66	1537.97	1547.99	1555.14
0.03025	1498.84	1513.38	1526.68	1537.69	1547.77	1554.80
0.05630	1499.00	1513.36	1526.60	1537.27	1546.00	1554.20
0.06954	1499.10	1513.48	1526.44	1536.99	1545.70	1553.75
0.07950	1499.20	1513.53	1526.27	1536.80	1545.40	1553.35
0.09943	1499.32	1513.38	1525.74	1536.27	1544.90	1552.14
0.11285	1499.57	1513.48	1525.54	1535.87	1544.57	1551.77
0.12791	1499.90	1513.66	1525.61	1535.75	1544.30	1551.37
0.14159	1500.00	1513.64	1525.45	1535.47	1543.91	1550.84
0.15603	1500.18	1513.68	1525.30	1535.21	1543.52	1550.31
0.16924	1500.79	1514.15	1525.66	1535.40	1543.55	1550.22
0.18305	1500.76	1513.99	1525.40	1534.95	1543.40	1549.45
0.19867	1500.89	1513.96	1525.16	1534.70	1542.99	1548.95

$$\beta_S = \frac{1}{\rho u^2} \quad (1)$$

where ρ (kg m^{-3}) and β_S (Pa^{-1}) are the density and adiabatic compressibility, respectively, of glucose and fructose in water. The calculated values of are presented in Table-4. And apparent molar adiabatic compressibility (ϕ_K), was calculated from densities and data using eqn. 2:

$$\phi_K = \frac{\beta_S \rho_o - \rho \beta_S^o}{m\rho\rho_o} + \frac{\beta_S M_2}{\rho} \quad (2)$$

TABLE-4
ADIABATIC COMPRESSIBILITY (β_S, 10^{-10} Pa^{-1}) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K, RESPECTIVELY

m (mol kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
Water + SDS						
0.00000	4.655	4.558	4.477	4.410	4.356	4.312
0.00034	4.653	4.556	4.476	4.408	4.355	4.311
0.00089	4.652	4.556	4.475	4.408	4.353	4.310
0.00136	4.651	4.555	4.474	4.407	4.352	4.309
0.01499	4.641	4.548	4.464	4.398	4.345	4.303
0.02999	4.635	4.538	4.460	4.396	4.343	4.301
0.04398	4.628	4.534	4.457	4.393	4.342	4.301
0.05807	4.623	4.531	4.454	4.391	4.341	4.301
0.07199	4.618	4.527	4.450	4.390	4.340	4.300
0.08594	4.614	4.523	4.448	4.387	4.338	4.300
0.10085	4.608	4.519	4.445	4.385	4.337	4.299
0.11498	4.604	4.516	4.442	4.383	4.336	4.299
0.12860	4.599	4.512	4.439	4.381	4.335	4.298
0.14257	4.596	4.509	4.436	4.379	4.333	4.297
0.15700	4.593	4.505	4.433	4.377	4.332	4.296
0.17194	4.588	4.500	4.430	4.375	4.331	4.297
0.18610	4.585	4.497	4.427	4.374	4.330	4.297
0.19845	4.583	4.494	4.424	4.372	4.330	4.297
Water + Glycine (0.049 m) + SDS						
0.00000	4.629	4.534	4.454	4.388	4.334	4.292
0.00035	4.628	4.533	4.453	4.387	4.333	4.291
0.00062	4.628	4.532	4.453	4.387	4.333	4.290
0.01394	4.611	4.515	4.441	4.376	4.323	4.281
0.02828	4.606	4.515	4.438	4.374	4.323	4.281
0.04222	4.603	4.512	4.435	4.372	4.321	4.281
0.05679	4.599	4.508	4.432	4.370	4.320	4.280
0.07115	4.593	4.504	4.429	4.368	4.318	4.280
0.08490	4.589	4.500	4.426	4.366	4.317	4.279
0.09953	4.584	4.496	4.423	4.364	4.316	4.279
0.11068	4.581	4.494	4.422	4.363	4.315	4.279
0.12577	4.576	4.490	4.419	4.361	4.315	4.279
0.14084	4.571	4.486	4.416	4.359	4.313	4.278
0.14951	4.568	4.483	4.414	4.358	4.312	4.278
0.17089	4.561	4.478	4.410	4.354	4.310	4.277
0.18048	4.557	4.475	4.408	4.353	4.310	4.277
0.19721	4.551	4.468	4.402	4.348	4.306	4.273

Water + Glycine (0.466 m) + SDS						
0.00000	4.426	4.341	4.270	4.212	4.164	4.127
0.00034	4.425	4.340	4.269	4.211	4.164	4.127
0.00064	4.424	4.340	4.269	4.211	4.164	4.126
0.01455	4.412	4.329	4.260	4.202	4.156	4.117
0.02873	4.409	4.327	4.259	4.202	4.158	4.119
0.04149	4.407	4.326	4.258	4.202	4.157	4.119
0.05671	4.403	4.323	4.256	4.201	4.157	4.119
0.07014	4.398	4.318	4.252	4.198	4.155	4.120
0.08458	4.395	4.316	4.251	4.197	4.155	4.119
0.09834	4.391	4.313	4.249	4.197	4.155	4.120
0.11258	4.388	4.311	4.247	4.196	4.155	4.119
0.12687	4.384	4.308	4.246	4.195	4.155	4.122
0.14028	4.381	4.306	4.244	4.194	4.154	4.122
0.15060	4.379	4.304	4.243	4.194	4.155	4.125
0.16942	4.375	4.301	4.241	4.193	4.155	4.126
0.18166	4.373	4.300	4.241	4.193	4.156	4.127
0.19292	4.371	4.299	4.240	4.193	4.156	4.128
Water + DL-alanine (0.049 m) + SDS						
0.00000	4.626	4.530	4.451	4.386	4.332	4.290
0.00150	4.621	4.526	4.447	4.382	4.328	4.287
0.01442	4.604	4.515	4.438	4.373	4.318	4.278
0.02820	4.600	4.512	4.435	4.372	4.319	4.277
0.04313	4.600	4.509	4.433	4.369	4.319	4.279
0.05686	4.594	4.503	4.428	4.366	4.316	4.277
0.06819	4.594	4.503	4.426	4.365	4.316	4.277
0.08441	4.588	4.500	4.427	4.367	4.318	4.281
0.09751	4.584	4.496	4.424	4.365	4.317	4.280
0.11443	4.578	4.491	4.419	4.361	4.314	4.278
0.12739	4.579	4.493	4.422	4.365	4.318	4.282
0.13981	4.575	4.490	4.420	4.363	4.317	4.282
0.15325	4.565	4.481	4.412	4.356	4.311	4.277
0.16465	4.561	4.478	4.410	4.354	4.311	4.277
0.17467	4.559	4.477	4.409	4.354	4.310	4.277
0.19849	4.554	4.471	4.404	4.351	4.309	4.277
Water + DL-alanine (0.438 m) + SDS						
0.00000	4.408	4.325	4.257	4.200	4.154	4.118
0.00082	4.407	4.325	4.256	4.199	4.153	4.117
0.00156	4.406	4.324	4.255	4.198	4.152	4.117
0.01554	4.396	4.316	4.247	4.191	4.144	4.114
0.03025	4.393	4.313	4.244	4.190	4.143	4.113
0.05630	4.387	4.309	4.240	4.188	4.148	4.112
0.06954	4.384	4.306	4.239	4.187	4.148	4.113
0.07950	4.382	4.304	4.238	4.187	4.148	4.113
0.09943	4.377	4.301	4.238	4.187	4.147	4.117
0.11285	4.374	4.299	4.237	4.187	4.147	4.117
0.12791	4.369	4.295	4.234	4.185	4.146	4.117
0.14159	4.366	4.293	4.233	4.185	4.147	4.118
0.15603	4.363	4.291	4.232	4.184	4.147	4.118
0.16924	4.357	4.286	4.228	4.181	4.145	4.117
0.18305	4.355	4.285	4.227	4.182	4.143	4.119
0.19867	4.352	4.283	4.226	4.181	4.144	4.120

where, m (mol kg^{-1}) = molality of SDS in binary or ternary system, ρ (kg m^{-3}) = density of SDS in binary or ternary system, β_S (Pa^{-1}) = adiabatic compressibility of SDS in binary or ternary system, ρ_0 (kg m^{-3}) = density of SDS in water, β_S° (Pa^{-1}) = adiabatic compressibility of SDS in water and M_2 (kg mol^{-1}) = molar mass of SDS.

The ϕ_K values was listed in Table-5 and graphically represented in Fig. 1(a) for water and in Fig. 1(b) for each system (at temperature). For each system, the magnitude of ϕ_K increases with concentration of SDS. Due to the relaxation of water molecules (as monomeric form) from the hydration sphere of co-sphere of SDS and amino acids to bulk caused by the interactions between them, ϕ_K increases. The water molecules in the monomeric form are more compressible [27,28]. From figure, it is observed that at lower concentration zone ϕ_K increases rapidly after that ϕ_K shows very slow increasing trend with the increase in concentration of SDS. So, there appeared a definite break point called CMC. After CMC, slow increasing trend reveals that CMC formation render the relaxation of water molecules to bulk.

Critical micelle concentration (CMC): The CMC's of SDS in aqueous and aqueous amino acid solutions was deter-

TABLE-5
APPARENT MOLAR ADIABATIC COMPRESSIBILITY (ϕ_K, 10^{-14} m^3 mol^{-1} Pa^{-1}) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K, RESPECTIVELY

m (mol kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
Water + SDS						
0.00034	-60.2	-46.4	-17.5	-33.8	-24.2	-30.5
0.00089	-32.4	-13.0	-15.1	-13.8	-20.0	-21.3
0.00136	-18.7	-8.2	-7.3	-7.0	-14.7	-13.0
0.01499	1.0	4.1	2.2	2.3	3.6	4.1
0.02999	4.2	4.3	5.1	6.0	6.3	6.9
0.04398	4.8	5.6	6.2	6.9	7.5	8.0
0.05807	5.5	6.2	6.8	7.6	8.1	8.6
0.07199	5.9	6.7	7.1	7.9	8.4	9.0
0.08594	6.2	6.9	7.4	8.1	8.7	9.2
0.10085	6.4	7.1	7.6	8.3	8.8	9.4
0.11498	6.6	7.3	7.8	8.4	9.0	9.5
0.12860	6.7	7.4	7.9	8.5	9.1	9.6
0.14257	6.9	7.5	8.0	8.6	9.1	9.6
0.15700	7.1	7.6	8.0	8.7	9.2	9.7
0.17194	7.1	7.6	8.0	8.7	9.2	9.8
0.18610	7.3	7.7	8.1	8.8	9.3	9.9
0.19845	7.4	7.7	8.2	8.9	9.4	9.9
Water + Glycine (0.049 m) + SDS						
0.00035	-28.6	-13.6	-7.6	-5.4	-16.7	-17.0
0.00062	-16.0	-19.3	-5.7	-6.6	-10.6	-10.3
0.01394	-2.7	-2.9	0.9	1.5	2.4	2.6
0.02828	2.9	4.3	5.0	5.8	6.4	6.8
0.04222	4.7	5.6	6.2	6.9	7.4	7.9
0.05679	5.6	6.3	6.9	7.5	8.1	8.6
0.07115	6.0	6.7	7.3	7.8	8.4	8.9
0.08490	6.2	6.9	7.5	8.0	8.6	9.1
0.09953	6.5	7.1	7.7	8.3	8.8	9.3
0.11068	6.7	7.3	7.9	8.4	8.9	9.5
0.12577	6.8	7.4	8.0	8.6	9.1	9.6
0.14084	6.9	7.5	8.1	8.6	9.1	9.7
0.14951	6.9	7.5	8.1	8.6	9.1	9.7
0.17089	7.0	7.6	8.2	8.7	9.2	9.7
0.18048	7.0	7.6	8.2	8.7	9.3	9.8
0.19721	7.0	7.5	8.0	8.6	9.1	9.6
Water + Glycine (0.466 m) + SDS						
0.00034	-20.4	-23.2	-22.6	-21.4	-0.7	-2.3
0.00064	-12.9	-11.6	-9.3	-8.1	-2.0	-4.0
0.01455	0.8	1.9	2.9	3.6	4.4	3.2
0.02873	5.0	5.7	6.4	7.0	8.1	7.5
0.04149	6.2	6.9	7.5	8.0	8.6	8.3
0.05671	6.7	7.3	7.9	8.5	9.0	9.0
0.07014	6.7	7.3	7.8	8.4	8.9	9.2
0.08458	7.0	7.5	8.1	8.6	9.2	9.3
0.09834	7.2	7.7	8.3	8.8	9.3	9.6
0.11258	7.3	7.8	8.4	8.9	9.4	9.6
0.12687	7.4	8.0	8.5	9.0	9.6	9.9
0.14028	7.5	8.0	8.6	9.1	9.6	10.0
0.15060	7.6	8.1	8.6	9.2	9.7	10.2
0.16942	7.7	8.2	8.7	9.3	9.8	10.3
0.18166	7.8	8.3	8.9	9.4	9.9	10.4
0.19292	7.8	8.4	8.9	9.4	9.9	10.4
Water + DL-alanine (0.049 m) + SDS						
0.00150	-22.9	-19.2	-19.5	-18.7	-19.6	-11.4
0.01442	-4.0	0.3	1.1	1.9	0.4	2.1
0.02820	1.9	4.3	5.0	5.5	5.9	6.0
0.04313	5.0	5.9	6.5	6.7	7.4	8.0
0.05686	5.3	6.1	6.6	7.2	7.8	8.3
0.06819	6.3	7.0	7.1	7.7	8.2	8.7
0.08441	6.7	7.3	7.9	8.4	9.0	9.5
0.09751	6.8	7.5	8.0	8.5	9.1	9.6
0.11443	6.9	7.5	8.1	8.6	9.1	9.6

0.12739	7.5	8.1	8.7	9.2	9.7	10.2
0.13981	7.6	8.2	8.7	9.2	9.7	10.2
0.15325	7.1	7.7	8.3	8.8	9.3	9.8
0.16465	7.1	7.7	8.3	8.8	9.3	9.9
0.17467	7.2	7.9	8.4	8.9	9.4	9.9
0.19849	7.4	7.9	8.5	9.0	9.5	10.0
Water + DL-alanine (0.438 m) + SDS						
0.00082	-0.2	0.6	-0.5	-1.0	-7.3	0.0
0.00156	-0.1	1.1	-0.1	-3.5	-2.9	3.0
0.01554	2.9	4.2	3.9	4.3	3.4	7.1
0.03025	5.5	6.4	6.2	6.9	6.3	8.4
0.05630	6.9	7.6	7.5	8.2	9.1	9.1
0.06954	7.2	7.7	7.8	8.5	9.3	9.4
0.07950	7.3	7.8	8.0	8.6	9.4	9.6
0.09943	7.5	8.1	8.5	9.0	9.6	10.1
0.11285	7.6	8.1	8.6	9.2	9.7	10.1
0.12791	7.6	8.1	8.6	9.2	9.7	10.1
0.14159	7.7	8.2	8.7	9.3	9.8	10.2
0.15603	7.7	8.3	8.8	9.3	9.8	10.3
0.16924	7.6	8.2	8.7	9.2	9.7	10.2
0.18305	7.7	8.3	8.8	9.3	9.7	10.4
0.19867	7.8	8.4	8.9	9.4	9.8	10.4

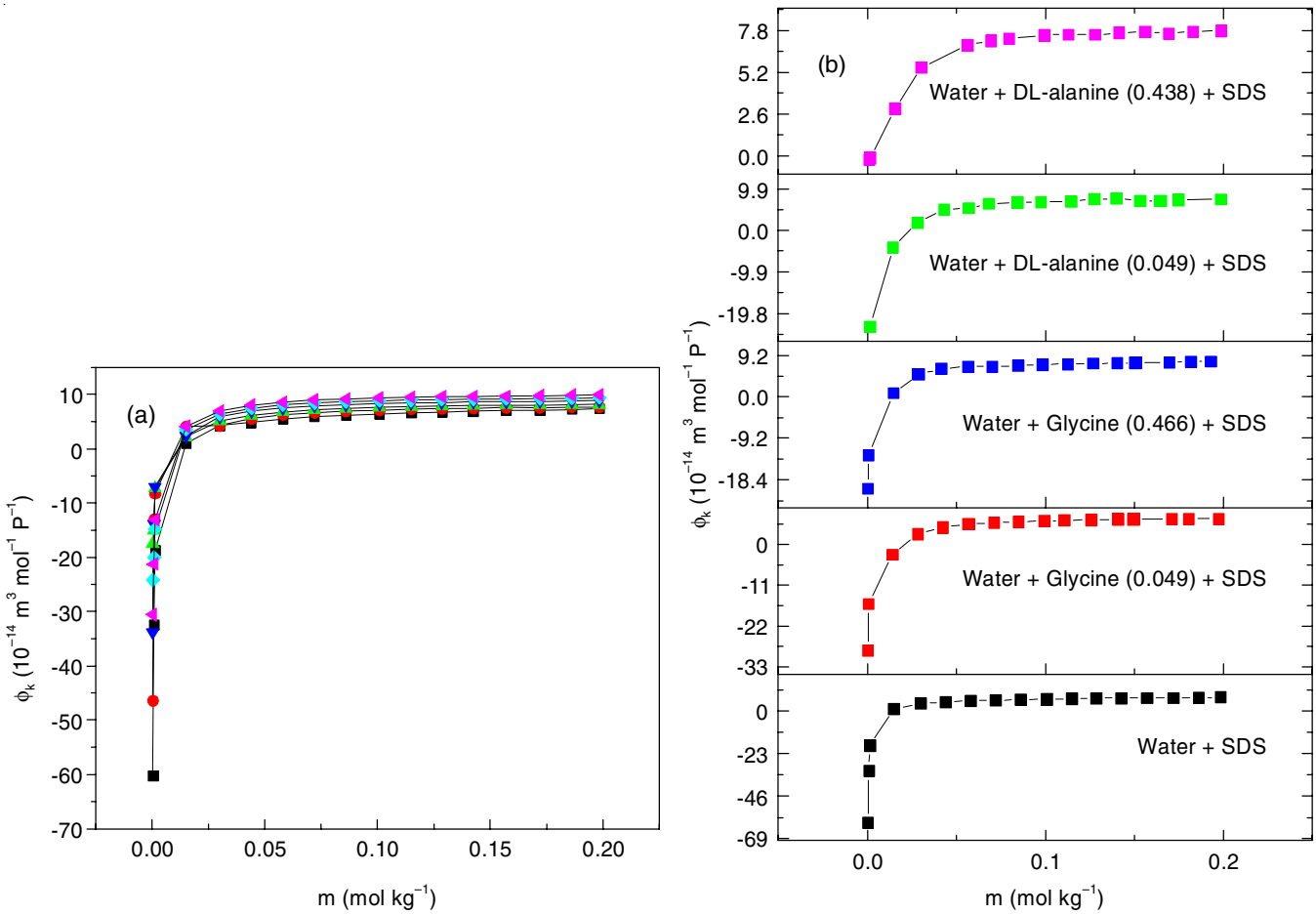

Fig. 1. Apparent molar adiabatic compressibility (ϕ_K) of SDS in (a) in water as a function of molality at different temperatures; ■ 288.15 K, ● 293.15 K, ▲ 298.15 K, ▼ 303.15 K, ◆ 308.15 K, ◀ 313.15 K. (b) in aqueous and aqueous amino acid solutions at 288.15 K

mined using ϕ_K data by extrapolation method (Table-6) shown in Fig. 2. It is observed that CMC values of SDS in aqueous solution are larger than the previous literature values (~ 0.009) [29]. And these values with the concentration of aqueous amino acid solution also larger than the aqueous solution indicate that glycine and alanine are water structure breakers. The addition of structure breakers causes the CMC increasing [30]. Critical micelle concentration values are not regular with temperature may be due to uncertainties association to low region concentration of SDS. SDS contains CH_3-$(CH_2)_{11}$-, SO_4^{2-} and amino acids have NH_3^+, COO^- and hydrophobic group. Micelle formation occurs due to the closeness of CH_3-(CH_2) - group of SDS.

TABLE-6
CMC (mol kg^{-1}) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K RESPECTIVELY

System	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
Water + SDS	0.01477	0.01457	0.01357	0.01357	0.01357	0.01407
Water + Glycine (0.049) + SDS	0.02449	0.02449	0.02203	0.02203	0.02278	0.02278
Water + Glycine (0.466) + SDS	0.02626	0.02626	0.02727	0.02727	0.02558	0.02821
Water + DL-alanine (0.049) + SDS	0.02449	0.02449	0.02203	0.02203	0.02278	0.02278
Water + DL-alanine (0.438) + SDS	0.03795	0.03626	0.03874	0.03425	0.03535	0.03767

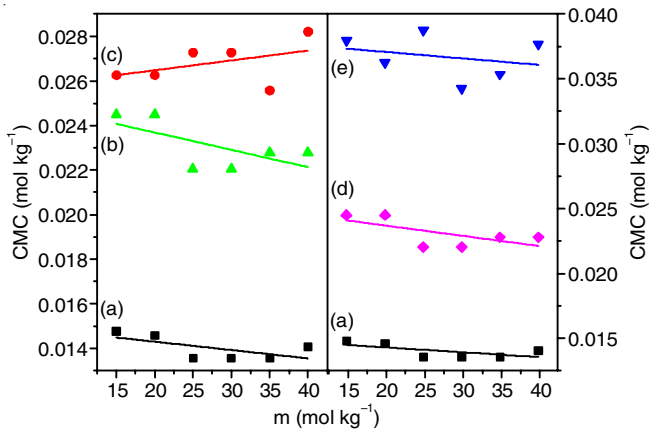

Fig. 2. Critical micelle concentration (CMC) of SDS in (a) ■ water (b) ▲ 0.049 m glycine (c) ● 0.466 m glycine (d) ◆ 0.049 m DL-alanine (e) ▼ 0.438 m DL-alanine as a function of molality at different temperatures

With the increasing concentration of amino acids in SDS solution, repulsion between COO^- (amino acid) and SO_4^{2-} (SDS) groups causes the increasing distance between SDS molecules. So, for this reason CMC also increases.

Acoustic impedance (Z): The acoustic impedance (Z) was calculated from the experimental density and ultrasonic velocity using eqn. 3:

$$Z = u\rho \quad (3)$$

Acoustic impedance of SDS in water and in aqueous amino acid solution is presented in Table-7 and shown in Figs. 3 and 4. Fig. 3 demonstrated that acoustic impedance increases with the increase molality of SDS. Acoustic impedance measure resistance to propagation of sound wave through any medium. The increase in Z with molality of SDS indicates that as concentration increases the sound wave as to face more resistance to flow. As the concentration increases solute-solute interaction increases. From Fig. 4, it is observed that acoustic impedances of SDS in DL-alanine are slightly greater from in glycine due to having an extra CH_3- group of DL-alanine. And

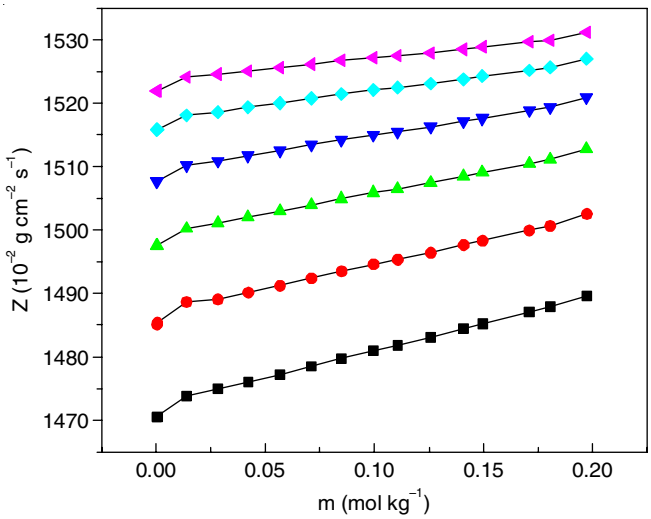

Fig. 3. Acoustic impedance (Z) of SDS in 0.049 m glycine as a function of molality at different temperatures; ■ 288.15 K, ● 293.15 K, ▲ 298.15 K, ▼ 303.15 K, ◆ 308.15 K, ◀ 313.15 K

TABLE-7
ACOUSTIC IMPEDANCE (Z, 10^{-2} g cm^{-2} s^{-1}) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K, RESPECTIVELY

m (mol kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
			Water + SDS			
0.00034	1465.36	1480.25	1492.53	1502.88	1510.91	1517.13
0.00089	1465.60	1480.30	1492.77	1503.01	1511.19	1517.40
0.00136	1465.65	1480.39	1492.81	1503.07	1511.33	1517.49
0.01499	1467.90	1482.13	1495.04	1505.26	1513.03	1519.09
0.02999	1469.29	1484.25	1496.24	1506.07	1513.95	1519.81
0.04398	1470.89	1485.31	1497.29	1506.96	1514.59	1520.33
0.05807	1472.16	1486.39	1498.27	1507.71	1515.23	1520.83
0.07199	1473.39	1487.43	1499.23	1508.49	1515.85	1521.30
0.08594	1474.62	1488.51	1500.18	1509.29	1516.50	1521.83
0.10085	1475.94	1489.68	1501.16	1510.13	1517.21	1522.38
0.11498	1477.08	1490.69	1502.05	1510.90	1517.85	1522.88
0.12860	1478.26	1491.71	1502.96	1511.65	1518.44	1523.36
0.14257	1479.28	1492.70	1503.79	1512.40	1519.10	1523.91
0.15700	1480.26	1493.74	1504.80	1513.22	1519.80	1524.50
0.17194	1481.69	1495.12	1505.94	1514.13	1520.48	1524.95
0.18610	1482.48	1495.95	1506.72	1514.70	1520.93	1525.28
0.19845	1483.15	1496.81	1507.58	1515.28	1521.34	1525.57

Water + Glycine (0.049 m) + SDS						
0.00035	1470.52	1485.17	1497.48	1507.63	1515.77	1521.88
0.00062	1470.58	1485.34	1497.56	1507.73	1515.84	1521.95
0.01394	1473.84	1488.67	1500.17	1510.19	1518.07	1524.13
0.02828	1474.97	1489.08	1501.11	1510.85	1518.60	1524.54
0.04222	1476.04	1490.17	1502.06	1511.71	1519.37	1525.05
0.05679	1477.20	1491.25	1502.96	1512.51	1520.01	1525.56
0.07115	1478.53	1492.43	1503.98	1513.45	1520.75	1526.17
0.08490	1479.76	1493.52	1504.94	1514.21	1521.43	1526.71
0.09953	1480.99	1494.61	1505.88	1514.94	1522.06	1527.20
0.11068	1481.84	1495.32	1506.47	1515.45	1522.44	1527.43
0.12577	1483.10	1496.43	1507.45	1516.24	1523.03	1527.92
0.14084	1484.46	1497.65	1508.46	1517.10	1523.77	1528.48
0.14951	1485.26	1498.34	1509.09	1517.59	1524.23	1528.87
0.17089	1487.10	1499.96	1510.46	1518.83	1525.17	1529.62
0.18048	1487.93	1500.68	1511.10	1519.35	1525.58	1529.92
0.19721	1489.58	1502.53	1512.77	1520.87	1526.96	1531.16
Water + Glycine (0.466 m) + SDS						
0.00034	1513.97	1527.85	1539.48	1548.96	1556.30	1561.91
0.00064	1514.06	1527.91	1539.52	1548.99	1556.39	1562.02
0.01455	1516.75	1530.35	1541.74	1551.01	1558.28	1564.21
0.02873	1517.56	1531.04	1542.28	1551.43	1558.27	1564.16
0.04149	1518.33	1531.69	1542.80	1551.81	1558.83	1564.59
0.05671	1519.48	1532.67	1543.63	1552.48	1559.33	1564.87
0.07014	1520.92	1533.96	1544.75	1553.43	1560.10	1565.28
0.08458	1521.90	1534.80	1545.45	1553.99	1560.56	1565.81
0.09834	1522.91	1535.65	1546.14	1554.53	1560.93	1565.94
0.11258	1523.97	1536.56	1546.89	1555.12	1561.39	1566.55
0.12687	1524.95	1537.37	1547.54	1555.61	1561.74	1566.43
0.14028	1525.96	1538.25	1548.29	1556.23	1562.22	1566.68
0.15060	1526.58	1538.78	1548.71	1556.54	1562.40	1566.49
0.16942	1527.83	1539.81	1549.54	1557.17	1562.86	1566.73
0.18166	1528.42	1540.27	1549.88	1557.41	1562.96	1566.74
0.19292	1529.13	1540.84	1550.34	1557.75	1563.24	1566.82
Water + DL-alanine (0.049 m) + SDS						
0.00150	1471.56	1486.24	1498.52	1508.56	1516.64	1522.54
0.01442	1474.69	1488.46	1500.55	1510.43	1518.86	1524.53
0.02820	1475.84	1489.49	1501.43	1511.21	1519.08	1525.11
0.04313	1476.41	1490.52	1502.30	1512.17	1519.65	1525.24
0.05686	1477.90	1491.90	1503.60	1513.05	1520.50	1526.03
0.06819	1478.21	1492.17	1504.24	1513.55	1520.90	1526.33
0.08441	1479.56	1493.27	1504.63	1513.83	1520.97	1526.19
0.09751	1480.71	1494.29	1505.51	1514.57	1521.56	1526.68
0.11443	1482.25	1495.65	1506.77	1515.65	1522.52	1527.51
0.12739	1482.25	1495.51	1506.44	1515.21	1521.98	1526.85
0.13981	1483.20	1496.39	1507.26	1515.91	1522.56	1527.30
0.15325	1485.56	1498.57	1509.24	1517.73	1524.22	1528.80
0.16465	1486.58	1499.47	1510.04	1518.37	1524.73	1529.20
0.17467	1487.14	1499.93	1510.38	1518.69	1524.96	1529.37
0.19849	1488.69	1501.69	1511.87	1519.88	1525.93	1530.10
Water + DL-alanine (0.438 m) + SDS						
0.00082	1515.27	1528.87	1540.23	1549.44	1556.75	1561.98
0.00156	1515.43	1529.01	1540.39	1549.69	1556.88	1562.06
0.01554	1517.68	1530.96	1542.38	1551.49	1558.95	1563.20
0.03025	1518.78	1531.89	1543.35	1552.11	1559.64	1563.77
0.05630	1520.58	1533.47	1544.84	1553.26	1559.38	1564.65
0.06954	1521.54	1534.43	1545.50	1553.78	1559.86	1564.98
0.07950	1522.27	1535.10	1545.93	1554.17	1560.13	1565.14
0.09943	1523.66	1536.17	1546.60	1554.78	1560.76	1565.05
0.11285	1524.72	1537.06	1547.16	1555.13	1561.15	1565.39
0.12791	1525.96	1538.12	1548.10	1555.84	1561.70	1565.79
0.14159	1526.84	1538.86	1548.68	1556.28	1562.02	1565.97
0.15603	1527.83	1539.73	1549.32	1556.83	1562.43	1566.19
0.16924	1529.19	1540.92	1550.40	1557.76	1563.17	1566.80
0.18305	1529.93	1541.51	1550.87	1558.00	1563.71	1566.71
0.19867	1530.93	1542.34	1551.47	1558.58	1564.11	1566.99

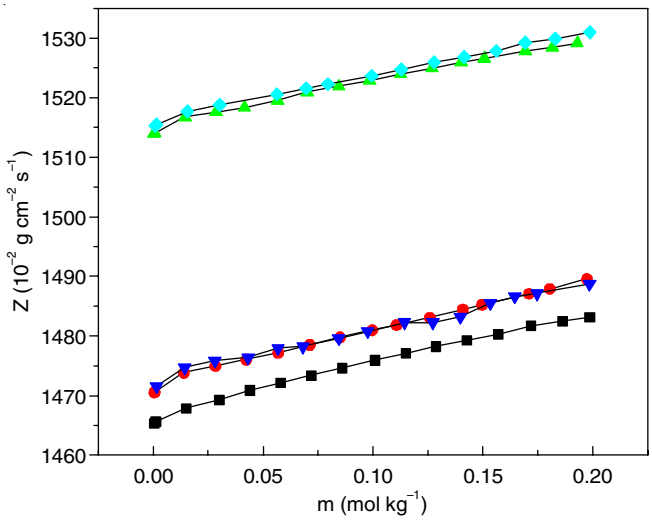

Fig. 4. Acoustic impedance (Z) of SDS in (a) ■ water (b) ● 0.049 m glycine (c) ▲ 0.466 m glycine (d) ▼ 0.049 m DL-alanine (e) ◆ 0.438 m DL-alanine solutions

solute-solute interaction increases for DL-alanine solvent system than glycine system. The positive acoustic impedance is an evidential parameter for solute-solvent and solute-solute interaction. The Z values indicate that there exists strong solute-solute along with solute-solvent interaction in aqueous and mixed aqueous solutions.

Relative association (R_A): The relative association (R_A) was calculated using eqn. 4:

$$R_A = \left(\frac{\rho}{\rho_o}\right)\left(\frac{u_o}{u}\right) \quad (4)$$

where, ρ, ρ_0 and u, u_0 are the density and ultrasonic sound velocity of solution and solvent respectively. The R_A, values of SDS in aqueous and aqueous amino acid solution at all studied temperatures are presented in Table-8 (Fig. 5). It is observed that R_A values show slow initial decrease and then linear increase with the increase in molality of SDS. It also increases with the increase in temperatures. The R_A, is defined as a measure of the extent of interaction between the component molecules (solute-solute) in a real mixture relative to that in an ideal one. The positive relative association, R_A demonstrates that solute-solute interactions causes association of SDS, which increases as SDS concentration.

Molar sound velocity (R_m): The molar sound velocity (R_m) was calculated using eqn. 5:

TABLE-8
RELATIVE ASSOCIATION (R_A) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K, RESPECTIVELY

m (mol kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
Water + SDS						
0.00034	0.99981	0.99984	0.99995	0.99989	0.99992	0.99989
0.00089	0.99970	0.99988	0.99985	0.99986	0.99979	0.99977
0.00136	0.99971	0.99985	0.99985	0.99985	0.99973	0.99975
0.01499	0.99966	1.00011	0.99977	0.99975	0.99993	0.99999
0.02999	1.00013	1.00006	1.00030	1.00053	1.00061	1.00078
0.04398	1.00035	1.00062	1.00084	1.00115	1.00138	1.00160
0.05807	1.00078	1.00114	1.00142	1.00185	1.00212	1.00242
0.07199	1.00122	1.00169	1.00198	1.00252	1.00287	1.00325
0.08594	1.00165	1.00220	1.00256	1.00317	1.00360	1.00404
0.10085	1.00211	1.00273	1.00318	1.00386	1.00436	1.00488
0.11498	1.00254	1.00322	1.00373	1.00446	1.00503	1.00562
0.12860	1.00292	1.00369	1.00426	1.00507	1.00572	1.00636
0.14257	1.00339	1.00415	1.00479	1.00565	1.00633	1.00703
0.15700	1.00397	1.00466	1.00530	1.00626	1.00700	1.00774
0.17194	1.00477	1.00526	1.00602	1.00708	1.00794	1.00880
0.18610	1.00517	1.00572	1.00650	1.00770	1.00862	1.00956
0.19845	1.00556	1.00605	1.00681	1.00818	1.00920	1.01021
Water + Glycine (0.049 m) + SDS						
0.00035	0.99993	0.99998	1.00000	1.00001	0.99996	0.99996
0.00062	0.99992	0.99990	0.99998	0.99998	0.99994	0.99994
0.01394	0.99920	0.99911	0.99965	0.99972	0.99982	0.99984
0.02828	0.99969	1.00005	1.00022	1.00045	1.00061	1.00069
0.04222	1.00033	1.00065	1.00089	1.00115	1.00136	1.00158
0.05679	1.00079	1.00114	1.00147	1.00178	1.00207	1.00236
0.07115	1.00128	1.00171	1.00212	1.00246	1.00286	1.00321
0.08490	1.00171	1.00220	1.00268	1.00312	1.00355	1.00398
0.09953	1.00213	1.00269	1.00324	1.00380	1.00428	1.00478
0.11068	1.00249	1.00311	1.00372	1.00431	1.00486	1.00543
0.12577	1.00292	1.00363	1.00433	1.00499	1.00563	1.00625
0.14084	1.00336	1.00413	1.00490	1.00568	1.00638	1.00710
0.14951	1.00362	1.00445	1.00525	1.00611	1.00682	1.00758
0.17089	1.00422	1.00516	1.00609	1.00699	1.00787	1.00873
0.18048	1.00449	1.00549	1.00646	1.00743	1.00836	1.00927
0.19721	1.00521	1.00606	1.00712	1.00816	1.00917	1.01015

Water + Glycine (0.466 m) + SDS						
0.00034	0.99995	0.99994	0.99994	0.99994	1.00003	1.00002
0.00064	0.99991	0.99991	0.99993	0.99993	0.99998	0.99997
0.01455	0.99950	0.99964	0.99977	0.99988	1.00000	0.99976
0.02873	1.00003	1.00022	1.00043	1.00060	1.00095	1.00072
0.04149	1.00047	1.00072	1.00099	1.00123	1.00146	1.00130
0.05671	1.00096	1.00130	1.00164	1.00194	1.00226	1.00222
0.07014	1.00141	1.00182	1.00224	1.00264	1.00301	1.00322
0.08458	1.00186	1.00233	1.00282	1.00328	1.00374	1.00385
0.09834	1.00227	1.00282	1.00338	1.00393	1.00447	1.00471
0.11258	1.00272	1.00335	1.00400	1.00462	1.00522	1.00534
0.12687	1.00314	1.00385	1.00457	1.00527	1.00595	1.00635
0.14028	1.00357	1.00434	1.00513	1.00589	1.00664	1.00717
0.15060	1.00387	1.00469	1.00554	1.00636	1.00717	1.00792
0.16942	1.00442	1.00535	1.00630	1.00721	1.00811	1.00899
0.18166	1.00480	1.00579	1.00680	1.00777	1.00873	1.00965
0.19292	1.00515	1.00621	1.00727	1.00830	1.00937	1.01032
Water + DL-alanine (0.049 m) + SDS						
0.00150	0.99973	0.99978	0.99976	0.99975	0.99973	0.99987
0.01442	0.99882	0.99946	0.99954	0.99963	0.99935	0.99961
0.02820	0.99933	1.00004	1.00015	1.00032	1.00038	1.00039
0.04313	1.00029	1.00064	1.00087	1.00091	1.00123	1.00151
0.05686	1.00060	1.00101	1.00128	1.00159	1.00189	1.00219
0.06819	1.00125	1.00165	1.00164	1.00203	1.00239	1.00274
0.08441	1.00178	1.00232	1.00275	1.00318	1.00363	1.00409
0.09751	1.00218	1.00279	1.00329	1.00378	1.00431	1.00482
0.11443	1.00246	1.00315	1.00371	1.00429	1.00488	1.00546
0.12739	1.00303	1.00375	1.00441	1.00505	1.00568	1.00631
0.13981	1.00347	1.00427	1.00494	1.00563	1.00633	1.00703
0.15325	1.00363	1.00453	1.00530	1.00608	1.00687	1.00766
0.16465	1.00403	1.00498	1.00581	1.00667	1.00753	1.00836
0.17467	1.00422	1.00522	1.00612	1.00698	1.00788	1.00876
0.19849	1.00522	1.00604	1.00708	1.00810	1.00911	1.01010
Water + DL-alanine (0.438 m) + SDS						
0.00082	1.00003	1.00003	1.00002	1.00001	0.99995	1.00002
0.00156	0.99995	0.99997	0.99994	0.99987	0.99988	0.99999
0.01554	0.99983	1.00003	0.99995	0.99999	0.99980	1.00047
0.03025	1.00042	1.00068	1.00055	1.00076	1.00052	1.00127
0.05630	1.00139	1.00175	1.00162	1.00204	1.00265	1.00260
0.06954	1.00189	1.00221	1.00226	1.00274	1.00335	1.00339
0.07950	1.00224	1.00259	1.00276	1.00324	1.00391	1.00402
0.09943	1.00299	1.00348	1.00389	1.00433	1.00496	1.00552
0.11285	1.00335	1.00393	1.00452	1.00508	1.00565	1.00622
0.12791	1.00373	1.00439	1.00504	1.00570	1.00635	1.00700
0.14159	1.00417	1.00489	1.00563	1.00635	1.00707	1.00780
0.15603	1.00459	1.00541	1.00624	1.00704	1.00784	1.00863
0.16924	1.00466	1.00556	1.00647	1.00739	1.00828	1.00914
0.18305	1.00519	1.00616	1.00712	1.00815	1.00882	1.01009
0.19867	1.00568	1.00674	1.00782	1.00885	1.00962	1.01092

$$R_m = Vu^{1/3} \quad (5)$$

where, V and u are the molar volume and ultrasonic sound velocity respectively. The R_m, values of SDS in aqueous and aqueous amino acid solution at all studied temperatures are presented in Table-9 and graphically represented in Fig. 6. The R_m values show an asymptotic increase with the increase in molality of SDS. The increase R_m values with the molality of SDS are an evidence of the structure of solution due to solute-solute, solute-cosolvent and solute-solvent interactions. The asymptotic nature reveals that the reinforcement of structure of solution approaches to attain a maximum value.

Conclusion

Adiabatic compressibility (β_S), apparent molar adiabatic compressibility (ϕ_K), critical micelle concentration (CMC), acoustic impedance (Z), relative association (R_A) and molar sound velocity (R_m) of SDS in aqueous and aqueous amino acid solutions are calculated by the measurement of density and ultrasonic velocity at six different temperatures and atmospheric pressure. The ϕ_K values increases due to the dehydration of hydration sphere of SDS by the interactions of amino acids. Critical micelle concentration values of SDS in aqueous amino acid solution are larger than aqueous solution indicate that

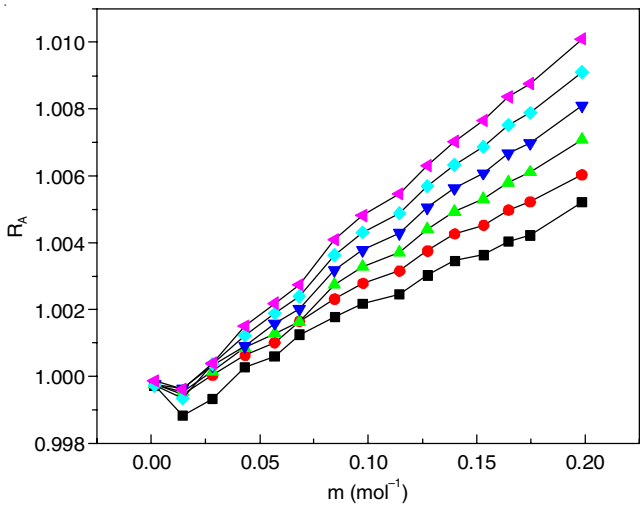

Fig. 5. Relative association (R_A) of SDS in 0.049 m DL-alanine as a function of molality at different temperatures; ■ 288.15 K, ● 293.15 K, ▲ 298.15 K, ▼ 303.15 K, ◆ 308.15 K, ◀ 313.15 K

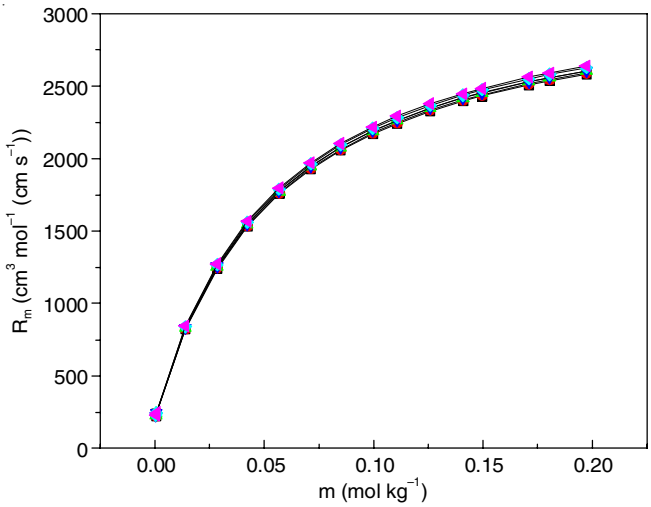

Fig. 6. Molar sound velocity (R_m) of SDS in 0.049 m glycine as a function of molality at different temperatures; ■ 288.15 K, ● 293.15 K, ▲ 298.15 K, ▼ 303.15 K, ◆ 308.15 K, ◀ 313.15 K

TABLE-9
MOLAR SOUND VELOCITY (R_m, cm^3 mol^{-1} (cm s^{-1})$^{1/3}$) OF SDS IN AQUEOUS AND AQUEOUS AMINO ACID SOLUTIONS AT 288.15, 293.15, 298.15, 303.15, 308.15 AND 313.15 K, RESPECTIVELY

m (mol kg^{-1})	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K	323.15 K
Water + SDS						
0.00034	223.78	224.81	226.25	226.71	228.77	230.06
0.00089	253.60	254.76	256.39	256.92	259.25	260.71
0.00136	278.63	279.90	281.69	282.27	284.82	286.42
0.01499	858.93	862.64	867.97	869.43	877.07	881.66
0.02999	1282.77	1288.12	1295.88	1297.73	1308.89	1315.38
0.04398	1562.27	1568.61	1577.91	1579.86	1593.25	1600.87
0.05807	1773.66	1780.72	1791.11	1793.05	1808.13	1816.52
0.07199	1936.26	1943.79	1955.07	1956.89	1973.23	1982.15
0.08594	2066.66	2074.55	2086.48	2088.18	2105.54	2114.86
0.10085	2179.97	2188.16	2200.67	2202.18	2220.43	2230.08
0.11498	2268.82	2277.23	2290.17	2291.53	2310.48	2320.35
0.12860	2341.29	2349.83	2363.12	2364.33	2383.83	2393.89
0.14257	2405.00	2413.73	2427.31	2428.37	2448.41	2458.62
0.15700	2461.79	2470.60	2484.47	2485.35	2505.88	2516.22
0.17194	2512.25	2521.05	2535.45	2535.77	2557.02	2567.42
0.18610	2554.82	2563.67	2578.10	2578.40	2599.83	2610.27
0.19845	2587.96	2596.87	2611.28	2611.56	2633.11	2643.59
Water + Glycine (0.049 m) + SDS						
0.00035	224.10	225.12	226.57	227.03	229.10	230.39
0.00062	239.12	240.21	241.75	242.24	244.46	245.83
0.01394	822.28	825.83	830.95	832.34	839.71	844.12
0.02828	1241.90	1247.06	1254.62	1256.38	1267.26	1273.58
0.04222	1531.04	1537.23	1546.36	1548.25	1561.48	1568.96
0.05679	1756.01	1762.95	1773.28	1775.16	1790.16	1798.47
0.07115	1926.59	1934.03	1945.24	1947.06	1963.37	1972.26
0.08490	2056.77	2064.58	2076.44	2078.12	2095.47	2104.74
0.09953	2169.73	2177.83	2190.27	2191.74	2209.99	2219.59
0.11068	2242.20	2250.47	2263.26	2264.61	2283.44	2293.22
0.12577	2325.82	2334.26	2347.41	2348.62	2368.09	2378.09
0.14084	2396.12	2404.69	2418.22	2419.16	2439.21	2449.35
0.14951	2431.76	2440.38	2454.09	2454.88	2475.25	2485.45
0.17089	2507.71	2516.43	2530.48	2531.03	2552.00	2562.34
0.18048	2537.15	2545.89	2560.08	2560.50	2581.70	2592.09
0.19721	2582.60	2591.37	2605.77	2605.96	2627.57	2638.02

Water + Glycine (0.466 m) + SDS						
0.00034	223.88	224.89	226.38	226.76	228.91	230.20
0.00064	240.57	241.65	243.25	243.66	245.97	247.34
0.01455	842.81	846.35	851.75	852.84	860.67	865.24
0.02873	1250.28	1255.32	1263.10	1264.40	1275.68	1282.13
0.04149	1513.88	1519.80	1529.05	1530.34	1543.90	1551.42
0.05671	1748.91	1755.54	1766.06	1767.24	1782.70	1791.07
0.07014	1908.22	1915.30	1926.64	1927.64	1944.43	1953.19
0.08458	2045.21	2052.64	2064.68	2065.50	2083.34	2092.66
0.09834	2151.43	2159.09	2171.65	2172.26	2190.94	2200.52
0.11258	2242.65	2250.50	2263.49	2263.90	2283.31	2293.26
0.12687	2319.64	2327.62	2340.99	2341.17	2361.20	2371.19
0.14028	2381.31	2389.39	2403.03	2403.03	2423.56	2433.62
0.15060	2423.28	2431.41	2445.25	2445.09	2465.96	2475.95
0.16942	2489.53	2497.73	2511.87	2511.43	2532.85	2542.92
0.18166	2526.88	2535.11	2549.41	2548.81	2570.53	2580.67
0.19292	2557.81	2566.03	2580.48	2579.72	2601.60	2611.86
Water + DL-alanine (0.049 m) + SDS						
0.00150	286.22	287.51	289.35	289.92	292.56	294.19
0.01442	839.89	843.48	848.69	850.09	857.59	862.07
0.02820	1241.01	1246.14	1253.68	1255.43	1266.26	1272.55
0.04313	1548.37	1554.58	1563.78	1565.75	1579.03	1586.54
0.05686	1758.29	1765.20	1775.51	1777.37	1792.34	1800.64
0.06819	1896.07	1903.44	1914.69	1916.45	1932.49	1941.26
0.08441	2054.08	2061.85	2073.67	2075.31	2092.60	2101.83
0.09751	2156.85	2164.88	2177.21	2178.71	2196.78	2206.32
0.11443	2266.08	2274.37	2287.24	2288.54	2307.47	2317.30
0.12739	2335.87	2344.31	2357.53	2358.64	2378.17	2388.18
0.13981	2393.58	2402.14	2415.63	2416.63	2436.58	2446.70
0.15325	2447.89	2456.51	2470.24	2471.02	2491.42	2501.64
0.16465	2488.64	2497.31	2511.25	2511.85	2532.58	2542.88
0.17467	2521.44	2530.15	2544.22	2544.74	2565.73	2576.09
0.19849	2587.76	2596.78	2611.12	2611.30	2632.88	2643.31
Water + DL-alanine (0.438 m) + SDS						
0.00082	253.23	254.33	255.96	256.39	258.75	260.17
0.00156	292.73	293.99	295.88	296.36	299.09	300.71
0.01554	885.58	889.24	894.84	895.96	903.94	908.33
0.03025	1297.41	1302.47	1310.28	1311.59	1323.05	1329.16
0.05630	1756.38	1762.96	1773.35	1774.49	1789.61	1797.64
0.06954	1915.48	1922.40	1933.45	1934.46	1950.83	1959.37
0.07950	2014.39	2021.56	2033.08	2033.99	2051.13	2059.94
0.09943	2173.05	2180.75	2193.08	2193.67	2212.09	2221.35
0.11285	2258.31	2266.02	2278.72	2279.17	2298.21	2307.67
0.12791	2338.60	2346.44	2359.54	2359.73	2379.40	2389.03
0.14159	2400.74	2408.68	2422.05	2422.04	2442.22	2451.96
0.15603	2457.25	2465.25	2478.84	2478.63	2499.27	2509.10
0.16924	2502.25	2510.27	2524.09	2523.64	2544.64	2554.54
0.18305	2543.86	2551.91	2565.93	2565.24	2586.63	2596.51
0.19867	2585.36	2593.41	2607.56	2606.70	2628.41	2638.41

glycine and alanine are water structure breakers. The Z values indicate strong solute-solute along with solute-solvent interaction in aqueous and aqueous amino acid solutions. The R_A values identify the interaction between the solute-solute molecules in a real mixture. The R_m values give an evidence for strengthening the structure of solution due to solute-cosolute-solvent interactions. So, aforesaid information's are valuable for understanding surfactant-protein interactions and for other application of surfactant in pharmaceuticals.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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