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INVESTIGATION ON TEMPERATURE-DEPENDENT VOLUMETRIC AND ACOUSTICAL PROPERTIES OF HOMOLOGOUS SERIES OF GLYCOLS CONTAINING D-PANTHENOL

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Abstract

Density and velocity measurement of aqueous D-Panthenol and glycols i.e Ethylene glycol (EG), Diethylene glycol (DEG) and Triethylene glycol (TEG), at the temperature variation of (293.15 K, 298.15 K, 303.15 K and 308.15 K) over entire range of concentration was measured using Anton- Paar DSA 5000 M. These experimental data were used to calculate various acoustic and thermodynamic properties such as intermolecular free length, acoustic impedance, adiabatic compressibility, Wada's constant, Rao's Constant and Vander Waal's constant which gave the insight of the intermolecular reactions inside the mixture of vitamin B5 D-Panthenol and glycols.

Introduction

The use of chemicals in the medical field requires attention of the public in every areas including ultrasonic behaviour. Usually, ultrasonic research can be widely used to learn molecular interactions when combined with other water resources. Much of the study has been done in molecular interactions on products and mixtures in various forms of the body. It plays an important role in developing molecular science (Kaur *et al.,* 2016) (Kaur *et al.,* 2018) (Hammes *et al.,* 1966). In recent years, ultrasonic technology has been an effective way to find out about more efficient method for gaining information about behavior of liquids and solids having its ability of featuring the physiochemical behavior of the medium (Aminabhavi *et al.,* 1995) (Schmelzer *et al.,* 2004). Concern over a period of 20,000Hz (20 kHz). It is usually used for non-destructive techniques (NDT). The NDT is used to test as it cannot cause disorder to the structure. This approach has a wide range of scientific and business analyses to investigate properties without causing any damage. The NDT has a number of non-destructive tests such ultrasonic, magnetic particle, radiography and eddy current testing and low coherence of interferometry (Wananje *et al., 2015*) (Kaur *et al.,* 2018) (Thakur *et al.,* 2019).

Ultrasound techniques can be a huge source of information about the structural and molecular changes that take place in liquid mixtures. Within the framework of the theory of physical acoustics, these kind of techniques could also provide useful information about the mixing solution and its temperature dependence (Parveen *et al., 2012*) (Ali *et al., 1999*). The ultrasonic speed technique is an interesting and effective technique to study the physicochemical properties of liquid - liquid mixtures, electrolytic solutions and polymeric solutions. These solutions find wide applications in the medical, pharmaceutical, leather, textile, chemical and solvent solutions industries (Kaur *et al., 2018*) (Rajulu *et al., 1995*). The study, understanding and analyzation of the thermodynamic properties of mixtures and liquid solutions were most significant for their applications in these industries (Zhang *et al., 2008*) .

The spread of ultrasound waves into a substance has become a major test to study its properties. Such studies, such as changes in temperature and concentration, are useful to obtain the insight into the structure and the various linkages of the bound molecular complexes and other related molecular processes. The velocity and the associated acoustic parameters help us to characterize the thermodynamic and physical and chemical aspects of liquid mixtures like molecular association and dissociation (Morenas *et al., 1978*) (Chakraborty *et al., 2018*) (Ku *et al., 2000*) (Rao *et al., 1990*).

Ultrasonic velocity measurement allows us to accurately measure some important and applicable thermodynamic and acoustic parameters and their excessive values. These excessive ultrasound, intrinsically molecular free length, adiabatic compressibility and acoustic impedance in liquid mixtures plays an important role to understand the interactions between the solute and the solvent (Chakraborty *et al., 2020*) (Thakur *et al., 2019*) (Thakur *et al., 2019*).

There may be existence of different types of interaction on the mixing of solvent. The magnitude of forces depends upon the type of solvent used and it decreases or increases accordingly. In the mixing components it is found that bond breaking or breaking of liquid order predominates over other types of molecular interactions. The ultrasonic velocity (c) and density (ρ) were used to calculate the parameters such as free adiabatic compressibility, acoustic impedance, intermolecular free length, Wada's constant, Rao's constant and Vander Waal's constant. The trends of these acoustical parameters have the ability to reveal the nature and behavior of a system more precisely (Thakur *et al., 2020*) (Manon *et al., 2017*) (Thakur *et al., 2014*) (Pathania *et al., 2015*) (Mehrotra *et al., 1989*).

Materials and Methods

The ternary liquid mixture of an aqueous solution of D-panthenol and glycols of varying concentrations in the range of molar fractions was investigated by ultrasonic velocity and density measurement by ultrasound technique using Anton-Paar DSA 5000 M.

Chemicals

In the present investigation chemical used are ethylene glycol, diethylene glycol, triethylene glycol and D-Panthenol, having molecular weight of 62.07 g/mol, 106.12 g/mol, 150.18 g/mol and 205.251 g/mol respectively. The biologically active compound D-Panthenol was used to prepare the solvent mixtures with degassed and triple distilled water and the mass fraction purities of EG, DEG, TEG and D-Panthenol are more than 0.99. The specifications of the chemicals are given in Table 1, which have been used in the study. Without further purifications the chemicals are used, although, for two days before their use, the chemicals were kept in desiccators over P_2O_5 after vacuum dried.

Measurements

The ternary liquid mixture of an aqueous solution of D-panthenol and glycols of varying concentrations in the range of molar fractions was investigated by ultrasonic velocity and density measurement by ultrasound technique using Anton-Paar DSA 5000 M. The temperature varies from (293.15, 298.15 , 303.15 and 308.15) K. The sample is manually inserted in the equipment by the means of a syringe in the equipment. The two physically independent properties of a single specimen is being defined, as the multipurpose tool is equipped with a density cell and a cell where the speed of sound is determined separately. In both the cells the temperature is controlled by built in Peltier-thermostat. The density and velocity of the sound and the values obtained are used as inputs for various concentration computation models that are integrated into the DSA. The data obtained is used for calculating different acoustic and thermodynamic parameters such as adiabatic compression, free intermolecular length, acoustic impedance, the constant of Rao, constant of Wada, and Vander Wall constant.

The speed of sound and density obtained are used as inputs for different concentration computation models that are integrated into the DSA. For the preparation of the solutions, the degassed and triple distilled water of specific conductance less than 10^{-6} S·cm^{-1}, have been used and the weighing of solutions were done on the balance having precision of $\pm$ 0.00001g. The solutions were having uncertainties in the molalities within $\pm$ 2×10^{-5} mol·kg^{-1}. The precision in the sound speed and the density measurements were $\pm$ 1×10^{-2} ms^{-1} and $\pm$ 1×10^{-3} mol·kg^{-1} respectively and the corresponding standard uncertainty in them approximately was found to be within $\pm$ 5×10^{-2} mS^{-1} and $\pm$ 5×10^{-3} mol·kg^{-1} respectively.

Theory of evaluated parameters

The following equations are used to find the Acoustic impedance (1), adiabatic compressibility (2), intermolecular free length (3), Wada's constant (4), Rao's constant (5) and Vander Waal's constant (6) in the liquid mixture

$$Z = \rho \times c \quad (1)$$

$$\beta = {}^{1}/_{[\rho(c^2)]} \quad (2)$$

$$L_F = K_T (\beta)^{1/2} \quad (3)$$

$$W = (\beta)^{-\frac{1}{7}}\left(\frac{M}{\rho}\right) \quad (4)$$

$$R = {}^{[(c^{\frac{1}{3}})M]}/_{\rho} \quad (5)$$

$$b = \left(\frac{M}{\rho}\right)[1 - (RT/Mc^2)\sqrt{1 + (Mc^2/3RT)} - 1] \quad (6)$$

Where,

Z= Acoustic impedance, β=Adiabatc compressibility, L_F= Intermolecular free length, W= Wada's constant (independent of temperature), R=Rao's constant, b= Vander Waal constant,

M=Effective molecular weight, K_T= Temperature of dependent Jacobson's constant, ρ=Density of mixture and c = Ultrasonic velocity in the medium.

Result and Discussion

Table 1 Values of Acoustic Impedence, of glycols in aqueous solution of D-Panthenol at different temperature and at experimental temperature =0.1MPa

$^a m_A/\ (\mathrm{mol \cdot kg^{-1}})$	Z/ (kg m^{-2}S^{-1})			
	T= 293.15 K	**T=298.15 K**	**T= 303.15 K**	**T= 308.15 K**
EG + 0.05 m D-Panthenol				
0.0000	1488.67	1500.30	1511.31	1518.01
0.0992	1492.93	1504.18	1514.68	1521.21
0.2000	1497.53	1507.90	1518.19	1524.68
0.2945	1501.52	1511.62	1521.59	1527.91
0.3997	1506.17	1516.21	1525.72	1531.53
0.4998	1510.57	1520.12	1529.42	1534.97
EG + 0.10 m D-Panthenol				
0.0000	1496.55	1507.90	1516.39	1525.00
0.0999	1500.57	1511.52	1519.53	1528.30
0.1988	1504.50	1515.28	1522.74	1531.63
0.3027	1508.67	1519.04	1526.41	1534.96
0.3854	1512.21	1522.50	1529.83	1538.10
0.5123	1517.10	1527.58	1534.79	1542.55
EG + 0.15 m D-Panthenol				
0.0000	1503.55	1514.79	1523.82	1530.89
0.0994	1507.52	1518.66	1527.23	1534.41
0.1993	1511.35	1522.06	1530.52	1537.79
0.3044	1515.40	1525.90	1534.31	1540.98
0.3960	1518.94	1529.46	1537.90	1544.21
0.5015	1522.77	1533.23	1541.82	1547.51
DEG + 0.05 m D-Panthenol				
0.0000	1488.67	1500.30	1510.81	1518.01
0.0979	1496.03	1507.72	1516.92	1524.20
0.1987	1503.59	1514.91	1523.70	1530.71
0.2991	1511.34	1522.24	1530.24	1536.98
0.4009	1518.70	1529.45	1537.15	1543.67
0.4969	1525.57	1536.16	1543.37	1549.45
DEG + 0.10 m D-Panthenol				
0.0000	1496.55	1507.90	1517.99	1525.00
0.0994	1504.10	1515.15	1524.53	1531.44
0.2020	1511.85	1522.38	1531.32	1537.93
0.3062	1519.62	1529.82	1538.36	1544.71
0.3978	1526.34	1536.68	1544.52	1550.88
0.5004	1533.87	1543.89	1551.60	1557.40
DEG + 0.15 m D-Panthenol				
0.0000	1503.55	1514.84	1523.82	1530.89
0.1047	1511.27	1521.96	1530.35	1537.28
0.1978	1518.88	1528.80	1536.89	1543.68
0.2993	1526.64	1536.41	1543.64	1550.33
0.3962	1533.85	1543.44	1550.13	1556.69
0.4990	1541.19	1550.77	1557.63	1563.40
TEG + 0.05 m D-Panthenol				
0.0000	1488.67	1500.30	1510.81	1518.01
0.1010	1500.22	1511.55	1520.66	1527.57
0.1988	1511.33	1522.19	1530.79	1536.71
0.3009	1522.12	1532.77	1541.13	1545.93
0.4125	1534.18	1544.75	1551.96	1556.45
0.4963	1543.57	1553.10	1560.57	1564.24
TEG + 0.10 m D-Panthenol				

0.0000	1496.55	1507.90	1517.99	1525.00
0.1045	1508.07	1518.74	1527.62	1534.07
0.2013	1519.14	1529.55	1537.66	1543.10
0.3005	1529.70	1540.09	1547.72	1552.07
0.3998	1540.38	1550.88	1558.04	1561.51
0.5023	1551.76	1561.01	1568.65	1571.14
TEG + 0.15 m D-Panthenol				
0.0000	1503.55	1514.84	1523.82	1530.89
0.0997	1515.12	1526.33	1533.88	1540.32
0.1990	1526.44	1537.44	1544.24	1549.77
0.3043	1537.21	1547.97	1554.15	1559.25
0.4005	1547.85	1558.63	1564.80	1568.40
0.4937	1558.26	1567.91	1574.39	1577.29

[a] m_A is the molality of glycols in the aqueous solution D-Panthenol; standard uncertainties *u* are *u(m)* = 2×10^{-5} mol·kg^{-1}, *u(T)*=0.01K, *u(ρ)=0.05*(kg·m^{-3}),*u(p)*=0.01MPa, *u(c)*= 0.5 m·s^{-1} and at the experimental pressure=0.1 MPa,

Table 2 : Values of Adiabatic Compressibility, (*β*), of glycols in aqueous solution of D-Panthenol at different temperature and at experimental temperature =0.1MPa

$^a m_A$ / (mol · kg^{-1})	β× 10^{-10}/(N/m^2)			
	T= 293.15 K	**T=298.15 K**	**T= 303.15 K**	**T= 308.15 K**
EG + 0.05 m D-Panthenol				
0.0000	4.51008	4.43462	4.36471	4.31917
0.0992	4.48821	4.41568	4.34861	4.30439
0.2000	4.4644	4.39732	4.33208	4.28818
0.2945	4.44390	4.37905	4.31597	4.27321
0.3997	4.42004	4.35640	4.29606	4.25645
0.4998	4.39773	4.33705	4.27852	4.24084
EG + 0.10 m D-Panthenol				
0.0000	4.47218	4.39895	4.34446	4.28847
0.0999	4.45162	4.38155	4.32964	4.27293
0.1988	4.43148	4.36301	4.31436	4.25745
0.3027	4.41012	4.34458	4.29698	4.24224
0.3854	4.39225	4.32746	4.28058	4.22779
0.5123	4.36778	4.30284	4.25678	4.20755
EG + 0.15 m D-Panthenol				
0.0000	4.43822	4.36713	4.30906	4.26253
0.0994	4.41804	4.34813	4.29282	4.24626
0.1993	4.39908	4.33178	4.27754	4.23056
0.3044	4.37879	4.31318	4.25955	4.21605
0.3960	4.36121	4.29587	4.24248	4.20147
0.5015	4.34242	4.27774	4.22371	4.18663
DEG + 0.05 m D-Panthenol				
0.0000	4.51008	4.43462	4.36759	4.31917
0.0979	4.47201	4.39728	4.33825	4.28981
0.1987	4.43369	4.36170	4.30595	4.25935
0.2991	4.39419	4.32561	4.27472	4.23016
0.4009	4.35773	4.29074	4.24212	4.19912
0.4969	4.32377	4.25851	4.21287	4.17265
DEG + 0.10 m D-Panthenol				
0.0000	4.47218	4.39895	4.33532	4.28847
0.0994	4.43312	4.36313	4.30398	4.25818
0.2020	4.39373	4.32760	4.27150	4.22785
0.3062	4.35461	4.29139	4.23818	4.19630
0.3978	4.32168	4.25851	4.20946	4.16823
0.5004	4.28527	4.22411	4.17673	4.13873
DEG + 0.15 m D-Panthenol				
0.0000	4.43822	4.36700	4.30906	4.26253
0.1047	4.39883	4.33167	4.27746	4.23211
0.1978	4.36057	4.29844	4.24652	4.20255
0.2993	4.32230	4.26195	4.21519	4.17202
0.3962	4.28764	4.22905	4.18537	4.14330
0.4990	4.25225	4.19464	4.15106	4.11348
TEG + 0.05 m D-Panthenol				
0.0000	4.51008	4.43462	4.36759	4.31917
0.1010	4.45073	4.37849	4.32035	4.27422
0.1988	4.39453	4.32623	4.27185	4.23182
0.3009	4.34122	4.27565	4.22338	4.18956
0.4125	4.28283	4.21923	4.17358	4.14227
0.4963	4.23776	4.18064	4.13411	4.10702
TEG + 0.10 m D-Panthenol				
0.0000	4.47218	4.39895	4.33532	4.28847
0.1045	4.41367	4.34475	4.28864	4.24600
0.2013	4.35819	4.29212	4.24122	4.20404
0.3005	4.30704	4.24231	4.19484	4.16302
0.3998	4.25614	4.19184	4.14731	4.12083
0.5023	4.20290	4.14576	4.10006	4.07814
TEG + 0.15 m D-Panthenol				
0.0000	4.43822	4.36700	4.30906	4.26253
0.0997	4.37946	4.31003	4.26120	4.21916
0.1990	4.32377	4.25654	4.21259	4.17547
0.3043	4.27223	4.20719	4.16725	4.13285
0.4005	4.22208	4.15817	4.11893	4.09220
0.4937	4.17406	4.11580	4.07603	4.05363

Table 3 Values of Waada's constant, *W* of glycols in aqueous solution of D-Panthenol at different temperature and at experimental temperature =0.1MPa

$^a m_A$ / (mol · kg^{-1})	W/(m^3/mol)(Pa)$^{1/7}$			
	T= 293.15 K	**T=298.15 K**	**T= 303.15 K**	**T= 308.15 K**
EG + 0.05 m D-Panthenol				
0.0000	50.0772	50.2643	50.4424	50.6009
0.0992	50.0693	50.2503	50.4303	50.5862
0.2000	50.0658	50.2415	50.4164	50.5736
0.2945	50.0628	50.2327	50.4058	50.5614
0.3997	50.0613	50.2260	50.3985	50.5494
0.4998	50.0586	50.2226	50.3902	50.5351
EG + 0.10 m D-Panthenol				
0.0000	50.0318	50.2202	50.3718	50.5487
0.0999	50.0269	50.2068	50.3602	50.5394
0.1988	50.0241	50.2003	50.3507	50.5293
0.3027	50.0235	50.1946	50.3411	50.5165
0.3854	50.0216	50.1929	50.3357	50.5068
0.5123	50.0177	50.1859	50.3302	50.4920
EG + 0.15 m D-Panthenol				
0.0000	50.0005	50.1785	50.3505	50.5091
0.0994	49.9972	50.1727	50.3422	50.4983
0.1993	49.9893	50.1644	50.3308	50.4892
0.3044	49.9858	50.1584	50.3241	50.4784
0.3960	49.9824	50.1551	50.3199	50.4667
0.5015	49.9774	50.1504	50.3188	50.4557
DEG + 0.05 m D-Panthenol				
0.0000	85.6161	85.9360	86.2325	86.5115
0.0979	85.6022	85.9183	86.2003	86.4816
0.1987	85.5802	85.8988	86.1680	86.4491
0.2991	85.5763	85.8843	86.1465	86.4214
0.4009	85.5597	85.8676	86.1245	86.3976
0.4969	85.5524	85.8551	86.1095	86.3768
DEG + 0.10 m D-Panthenol				
0.0000	85.5386	85.8606	86.1458	86.4223
0.0994	85.5355	85.8389	86.1195	86.3939
0.2020	85.5278	85.8242	86.0997	86.3686
0.3062	85.5254	85.8111	86.0796	86.3479
0.3978	85.5125	85.7978	86.0610	86.3217
0.5004	85.4983	85.7899	86.0416	86.2988
DEG + 0.15 m D-Panthenol				
0.0000	85.4850	85.7872	86.0833	86.3546
0.1047	85.4810	85.7790	86.0708	86.3420
0.1978	85.4751	85.7651	86.0517	86.3158
0.2993	85.4655	85.7493	86.0248	86.2940

0.3962	85.4466	85.7257	86.0010	86.2682
0.4990	85.4397	85.7132	85.9802	86.2384
TEG + 0.05 m D-Panthenol				
0.0000	121.163	121.615	122.035	122.430
0.1010	121.125	121.568	121.965	122.356
0.1988	121.097	121.531	121.920	122.291
0.3009	121.062	121.482	121.868	122.231
0.4125	121.026	121.434	121.812	122.159
0.4963	121.012	121.400	121.787	122.132
TEG + 0.10 m D-Panthenol				
0.0000	121.053	121.509	121.912	122.304
0.1045	121.018	121.489	121.878	122.244
0.2013	120.998	121.458	121.830	122.196
0.3005	120.954	121.411	121.773	122.149
0.3998	120.914	121.376	121.739	122.089
0.5023	120.873	121.328	121.682	122.042
TEG + 0.15 m D-Panthenol				
0.0000	120.977	121.405	121.824	122.208
0.0997	120.965	121.392	121.775	122.136
0.1990	120.934	121.364	121.7325	122.095
0.3043	120.891	121.325	121.6813	122.037
0.4005	120.854	121.284	121.641	121.987
0.4937	120.815	121.264	121.610	121.928

Table 4 Values of Rao's constant, *R*,, of glycols in aqueous solution of D-Panthenol at different temperature and at experimental temperature =0.1MPa

$^a m_A / (\mathrm{mol \cdot kg^{-1}})$	R/ (m^3/mol)(m/s)$^{1/3}$			
	T= 293.15 K	**T=298.15 K**	**T= 303.15 K**	**T= 308.15 K**
EG + 0.05 m D-Panthenol				
0.0000	709.196	712.289	715.235	717.856
0.0992	709.066	712.058	715.034	717.613
0.2000	709.008	711.913	714.804	717.405
0.2945	708.958	711.766	714.629	717.203
0.3997	708.934	711.656	714.508	717.004
0.4998	708.889	711.600	714.370	716.767
EG + 0.10 m D-Panthenol				
0.0000	708.447	711.560	714.067	716.993
0.0999	708.366	711.338	713.874	716.840
0.1988	708.320	711.231	713.717	716.671
0.3027	708.309	711.137	713.558	716.460
0.3854	708.279	711.108	713.470	716.300
0.5123	708.214	710.992	713.378	716.055
EG + 0.15 m D-Panthenol				
0.0000	707.929	710.871	713.714	716.338
0.0994	707.875	710.775	713.577	716.158
0.1993	707.744	710.637	713.388	716.009
0.3044	707.686	710.539	713.278	715.830
0.3960	707.630	710.484	713.207	715.637
0.5015	707.548	710.405	713.189	715.455
DEG + 0.05 m D-Panthenol				
0.0000	1212.50	1217.78	1222.69	1227.30
0.0979	1212.27	1217.49	1222.15	1226.81
0.1987	1211.90	1217.17	1221.62	1226.27
0.2991	1211.84	1216.93	1221.26	1225.81
0.4009	1211.56	1216.65	1220.90	1225.42
0.4969	1211.44	1216.45	1220.65	1225.07
DEG + 0.10 m D-Panthenol				
0.0000	1211.22	1216.54	1221.25	1225.83
0.0994	1211.16	1216.18	1220.82	1225.36
0.2020	1211.04	1215.94	1220.49	1224.94
0.3062	1211.00	1215.72	1220.16	1224.60
0.3978	1210.79	1215.50	1219.85	1224.16
0.5004	1210.55	1215.37	1219.53	1223.78
DEG + 0.15 m D-Panthenol				
0.0000	1210.33	1215.32	1220.22	1224.71
0.1047	1210.26	1215.19	1220.01	1224.50
0.1978	1210.17	1214.96	1219.70	1224.07
0.2993	1210.01	1214.70	1219.25	1223.71
0.3962	1209.70	1214.31	1218.86	1223.28
0.4990	1209.58	1214.10	1218.51	1222.79
TEG + 0.05 m D-Panthenol				
0.0000	1715.91	1723.40	1730.34	1736.87
0.1010	1715.30	1722.61	1729.17	1735.64
0.1988	1714.83	1722.01	1728.43	1734.57
0.3009	1714.25	1721.19	1727.57	1733.58
0.4125	1713.65	1720.40	1726.65	1732.38
0.4963	1713.43	1719.84	1726.24	1731.94
TEG + 0.10 m D-Panthenol				
0.0000	1714.10	1721.63	1728.31	1734.78
0.1045	1713.53	1721.31	1727.74	1733.79
0.2013	1713.19	1720.79	1726.95	1733.01
0.3005	1712.47	1720.01	1726.00	1732.22
0.3998	1711.81	1719.43	1725.45	1731.23
0.5023	1711.13	1718.65	1724.49	1730.45
TEG + 0.15 m D-Panthenol				
0.0000	1712.85	1719.92	1726.85	1733.20
0.0997	1712.66	1719.70	1726.04	1732.01
0.1990	1712.13	1719.24	1725.33	1731.33
0.3043	1711.43	1718.59	1724.48	1730.36
0.4005	1710.82	1717.92	1723.81	1729.54
0.4937	1710.17	1717.58	1723.30	1728.57

Table 5 Values of Intermolecular free length, (L_f) of glycols in aqueous solution of D-Panthenol at different temperature and at experimental temperature =0.1MPa

$^a m_A / (\mathrm{mol \cdot kg^{-1}})$	L_f/(Å)			
	T= 293.15 K	**T=298.15 K**	**T= 303.15 K**	**T= 308.15 K**
EG + 0.05 m D-Panthenol				
0.0000	4.32703	4.33016	4.33506	4.35135
0.0992	4.31652	4.32090	4.32706	4.34390
0.2000	4.30507	4.31191	4.31883	4.33572
0.2945	4.29516	4.30294	4.31079	4.32815
0.3997	4.28362	4.29180	4.30084	4.31965
0.4998	4.27279	4.28226	4.29205	4.31172
EG + 0.10 m D-Panthenol				
0.0000	4.30881	4.31271	4.32500	4.33587
0.0999	4.29889	4.30417	4.31761	4.32800
0.1988	4.28916	4.29505	4.30999	4.32016
0.3027	4.27881	4.28597	4.30130	4.31243
0.3854	4.27013	4.27752	4.29308	4.30508
0.5123	4.25822	4.26533	4.28113	4.29476
EG + 0.15 m D-Panthenol				
0.0000	4.29241	4.29708	4.30734	4.32273
0.0994	4.28265	4.28772	4.29922	4.31447
0.1993	4.27345	4.27966	4.29153	4.30649
0.3044	4.26358	4.27046	4.28253	4.29910
0.3960	4.25501	4.26188	4.27394	4.29166
0.5015	4.24584	4.25287	4.26447	4.28407
DEG + 0.05 m D-Panthenol				
0.0000	4.32703	4.33016	4.33649	4.35135
0.0979	4.30872	4.31189	4.32191	4.33654
0.1987	4.29023	4.29441	4.30578	4.32112
0.2991	4.27107	4.27661	4.29015	4.30629
0.4009	4.25331	4.25933	4.27375	4.29046
0.4969	4.23671	4.24331	4.25899	4.27691
DEG + 0.10 m D-Panthenol				
0.0000	4.30881	4.31271	4.32044	4.33587
0.0994	4.28995	4.29511	4.30480	4.32053
0.2020	4.27085	4.27759	4.28852	4.30511
0.3062	4.25179	4.25966	4.27177	4.28902
0.3978	4.23569	4.24331	4.25727	4.27465
0.5004	4.21781	4.22614	4.24069	4.25949

DEG + 0.15 m D-Panthenol				
0.0000	4.29241	4.29702	4.30734	4.32273
0.1047	4.27333	4.27960	4.29152	4.30728
0.1978	4.25470	4.26315	4.27597	4.29221
0.2993	4.23599	4.24502	4.26017	4.27659
0.3962	4.21897	4.22860	4.24507	4.26185
0.4990	4.20152	4.21137	4.22764	4.24648
TEG + 0.05 m D-Panthenol				
0.0000	4.32703	4.33016	4.33649	4.35135
0.1010	4.29846	4.30267	4.31298	4.32868
0.1988	4.27124	4.27691	4.28870	4.30718
0.3009	4.24525	4.25184	4.26430	4.28557
0.4125	4.21660	4.22369	4.23909	4.26132
0.4963	4.19436	4.20433	4.21899	4.24315
TEG + 0.10 m D-Panthenol				
0.0000	4.30881	4.31271	4.32044	4.33587
0.1045	4.28053	4.28606	4.29712	4.31434
0.2013	4.25354	4.26002	4.27330	4.29297
0.3005	4.22850	4.23523	4.24987	4.27198
0.3998	4.20349	4.20996	4.22572	4.25027
0.5023	4.17707	4.18676	4.20158	4.22820
TEG + 0.15 m D-Panthenol				
0.0000	4.29241	4.29702	4.30734	4.32273
0.0997	4.26391	4.26890	4.28335	4.30068
0.1990	4.23671	4.24233	4.25885	4.27836
0.3043	4.21138	4.21766	4.23587	4.25647
0.4005	4.18659	4.19302	4.21124	4.23548
0.4937	4.16271	4.17160	4.18925	4.21547

Table 6 Values of Vander Waal constant, of glycols in aqueous solution of D-Panthenol at different temperature and at experimental temperature =0.1MPa

$^{a}m_A$ / $(\mathrm{mol \cdot kg^{-1}})$	b/ (m^3/mol)			
	T= 293.15 K	**T=298.15 K**	**T= 303.15 K**	**T= 308.15 K**
EG + 0.05 m D-Panthenol				
0.0000	122.805	122.965	123.118	123.314
0.0992	122.703	122.858	123.026	123.220
0.2000	122.604	122.766	122.927	123.125
0.2945	122.519	122.674	122.838	123.036
0.3997	122.425	122.570	122.742	122.941
0.4998	122.332	122.486	122.653	122.849
EG + 0.10 m D-Panthenol				
0.0000	122.551	122.720	122.867	123.066
0.0999	122.461	122.620	122.781	122.982
0.1988	122.377	122.533	122.698	122.896
0.3027	122.294	122.447	122.606	122.804
0.3854	122.221	122.376	122.528	122.723
0.5123	122.118	122.263	122.421	122.606
EG + 0.15 m D-Panthenol				
0.0000	122.345	122.495	122.676	122.867
0.0994	122.260	122.408	122.592	122.776
0.1993	122.168	122.324	122.504	122.691
0.3044	122.082	122.237	122.417	122.607
0.3960	122.006	122.161	122.339	122.520
0.5015	121.921	122.078	122.261	122.433
DEG + 0.05 m D-Panthenol				
0.0000	209.957	210.231	210.492	210.828
0.0979	209.678	209.942	210.218	210.558
0.1987	209.375	209.659	209.923	210.272
0.2991	209.107	209.384	209.660	210.005
0.4009	208.826	209.109	209.385	209.734
0.4969	208.583	208.862	209.149	209.501
DEG + 0.10 m D-Panthenol				
0.0000	209.523	209.812	210.066	210.404
0.0994	209.262	209.523	209.792	210.130
0.2020	208.986	209.251	209.524	209.861
0.3062	208.722	208.976	209.249	209.594
0.3978	208.472	208.723	209.008	209.337
0.5004	208.194	208.470	208.736	209.076
DEG + 0.15 m D-Panthenol				
0.0000	209.172	209.422	209.738	210.064
0.1047	208.905	209.168	209.494	209.826
0.1978	208.639	208.912	209.238	209.559
0.2993	208.362	208.628	208.959	209.296
.3962	208.084	208.347	208.697	209.034
0.4990	207.829	208.082	208.410	208.754
TEG + 0.05 m D-Panthenol				
0.0000	297.130	297.517	297.887	298.363
0.1010	296.496	296.878	297.269	297.752
0.1988	295.906	296.298	296.697	297.186
0.3009	295.324	295.696	296.104	296.629
0.4125	294.684	295.039	295.486	295.989
0.4963	294.221	294.583	295.037	295.576
TEG + 0.10 m D-Panthenol				
0.0000	296.515	296.925	297.284	297.762
0.1045	295.892	296.370	296.756	297.208
0.2013	295.326	295.796	296.185	296.686
0.3005	294.739	295.204	295.596	296.170
0.3998	294.159	294.632	295.051	295.609
0.5023	293.548	294.068	294.445	295.070
TEG + 0.15 m D-Panthenol				
0.0000	296.018	296.373	296.819	297.280
0.0997	295.446	295.805	296.243	296.687
0.1990	294.847	295.227	295.670	296.162
0.3043	294.256	294.657	295.105	295.601
0.4005	293.686	294.082	294.533	295.078
0.4937	293.127	293.618	294.033	294.551

Scheme 1: EG/ DEG/ TEG and D-Panthenol interactions

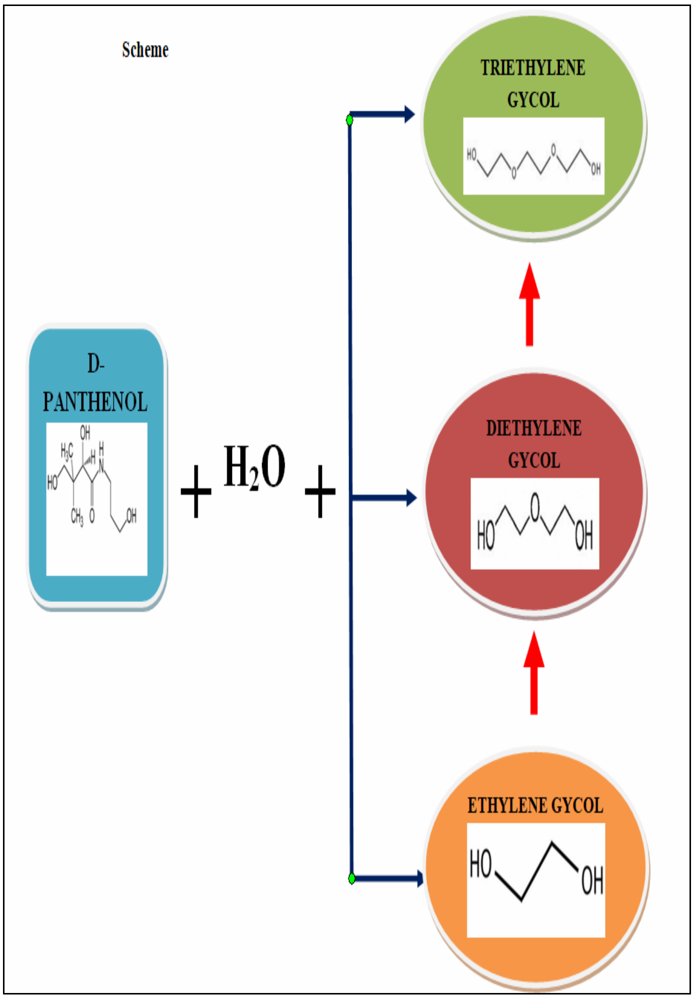
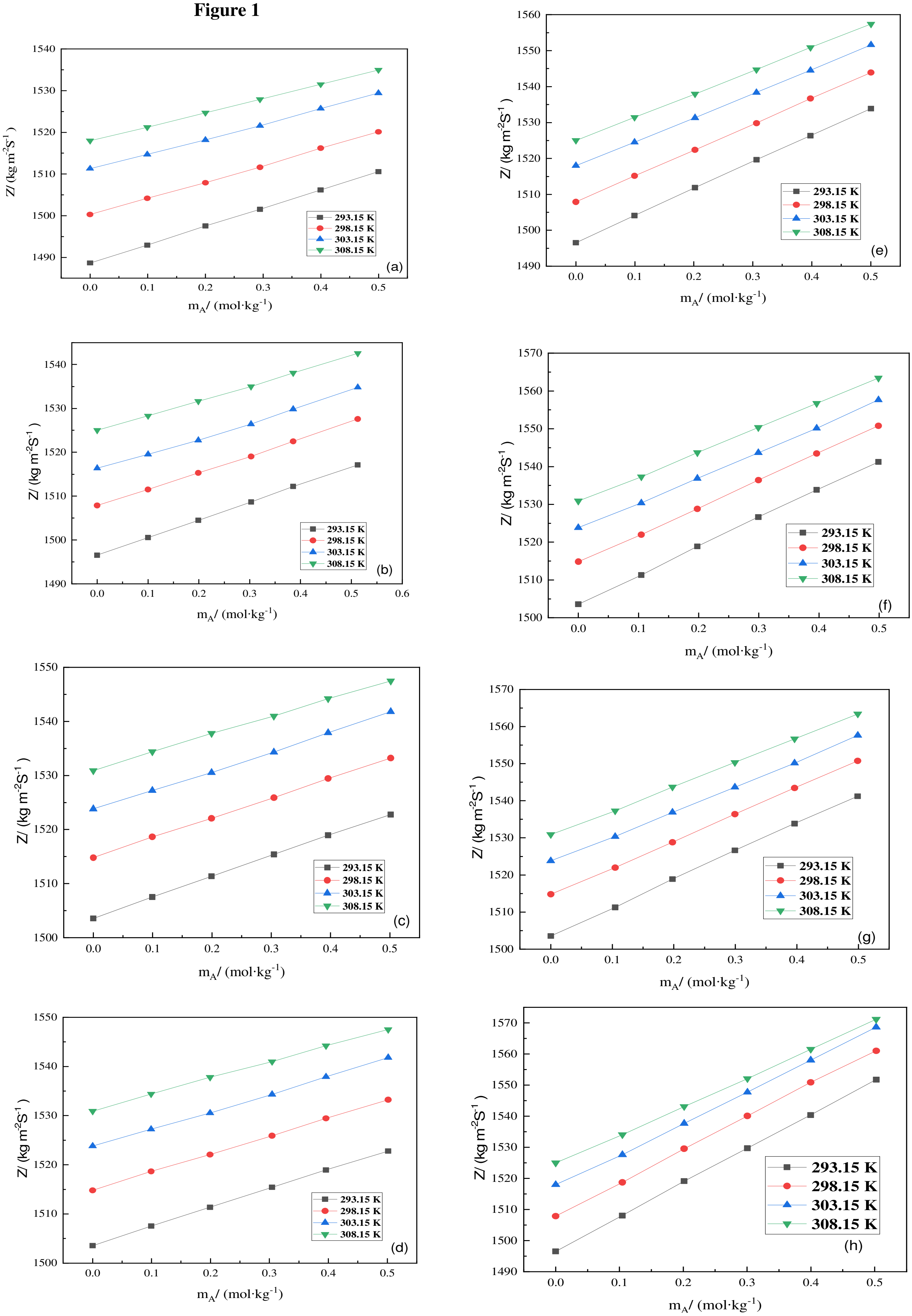


Figure 1



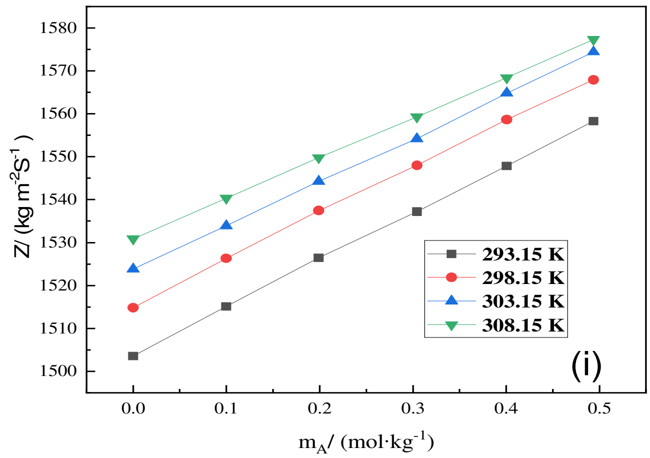
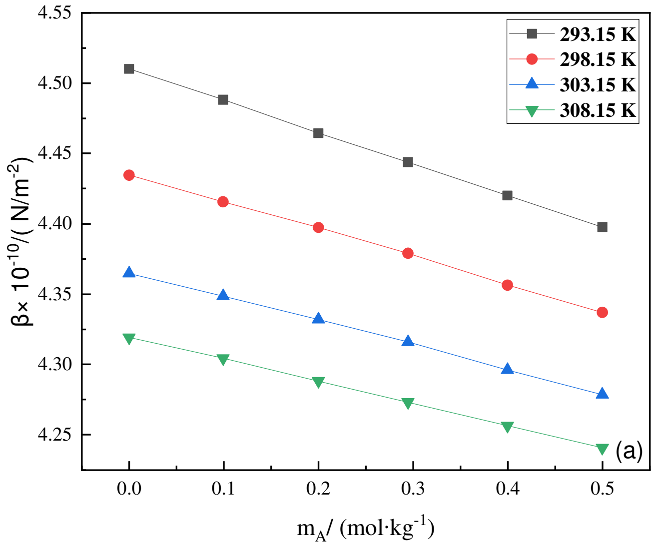
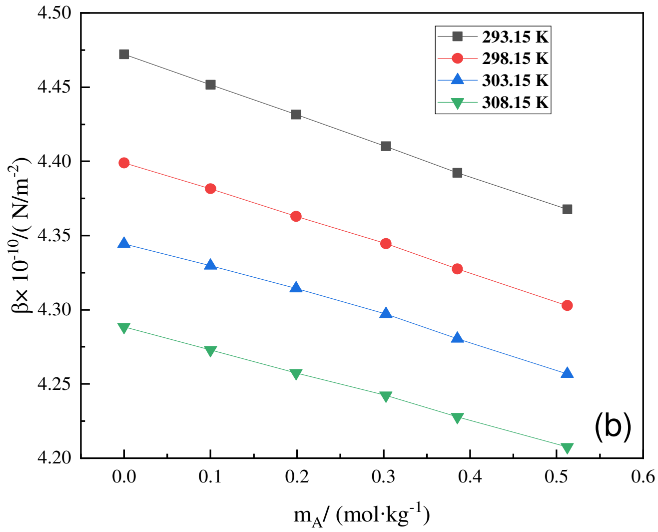
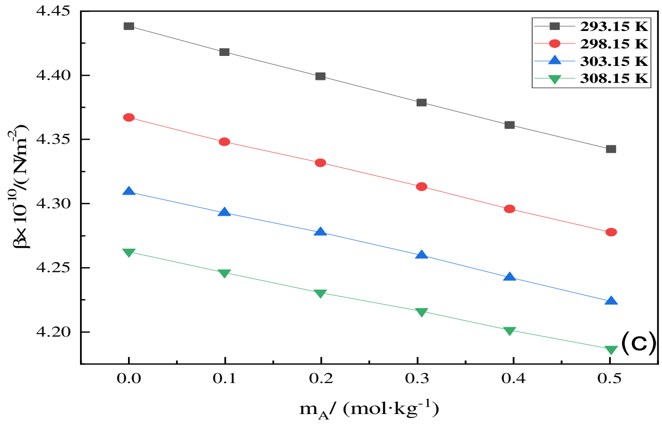


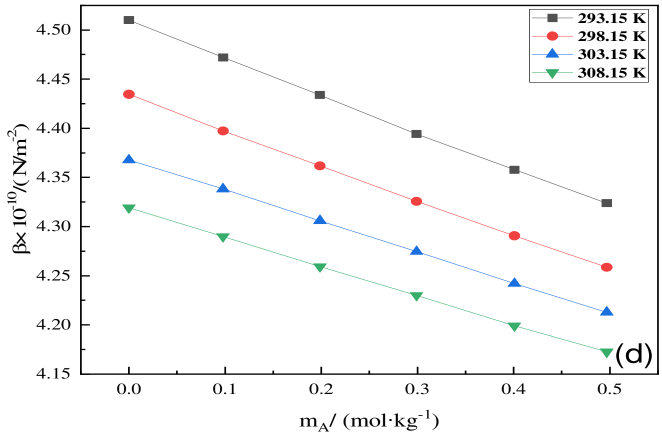
Figure 1: Variation of Acoustic Impedance, Z, of, ethylene glycol **(a)** 0.05 D-Panthenol, **(b)** 0.10 D-Panthenol and **(c)** 0.15 D-Panthenol, diethylene glycol **(d)** 0.05 D-Panthenol, **(e)** 0.10 D-Panthenol and **(f)** 0.15 D-Panthenol and triethylene glycol **(g)** 0.05 D-Panthenol, **(h)** 0.10 D-Panthenol and **(i)** 0.15 D-Panthenol in different concentration of aqueous D-Panthenol solutions at different temperature.

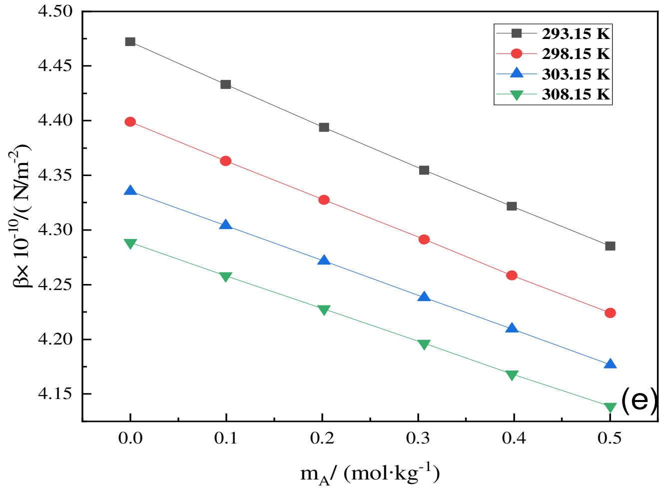
Figure 2

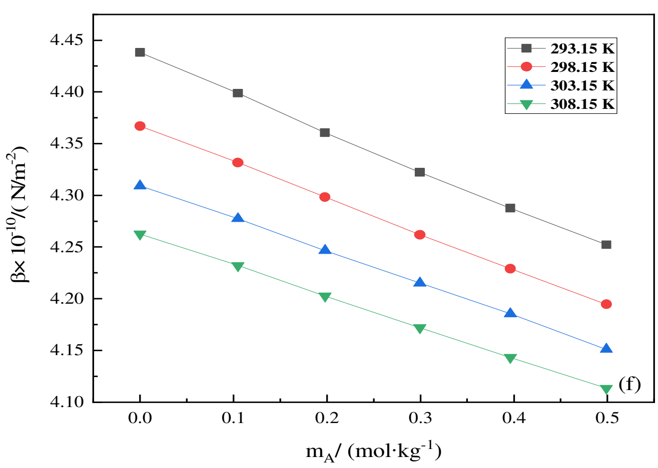












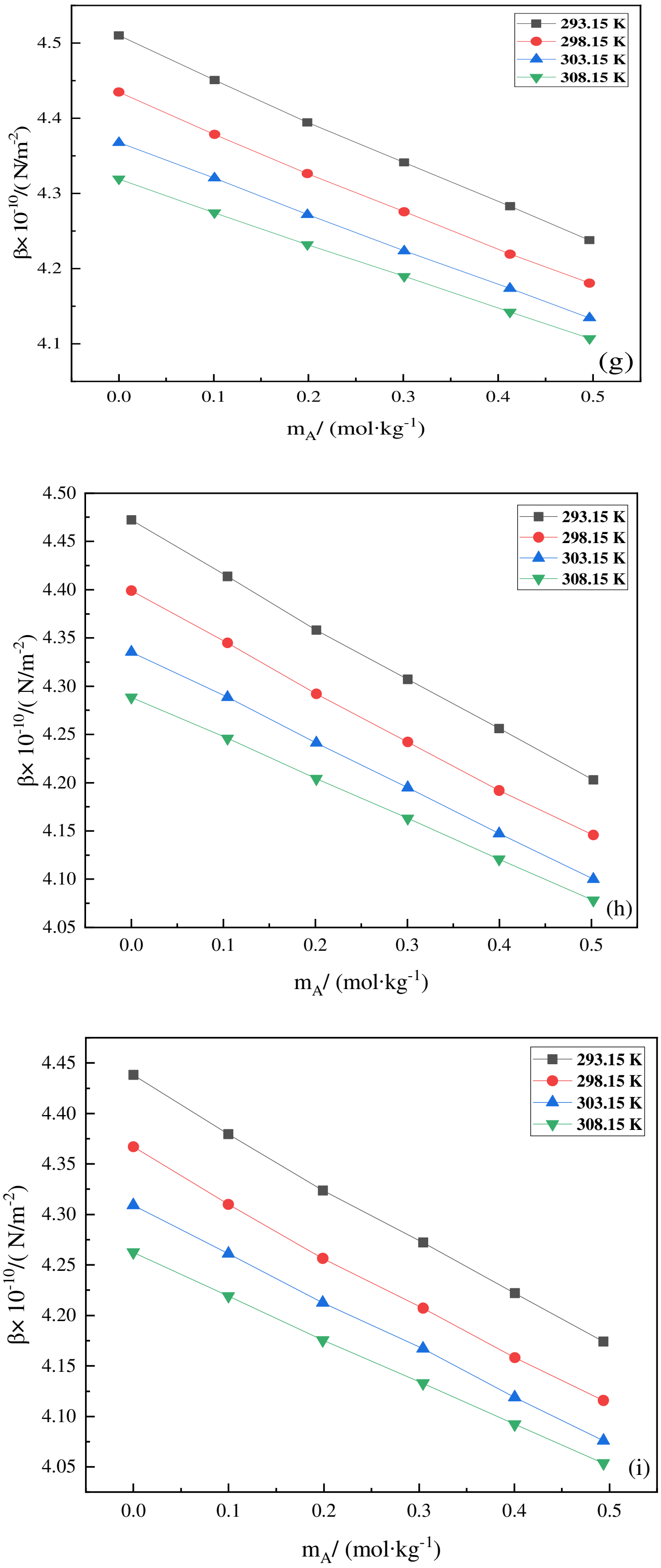


Figure 3

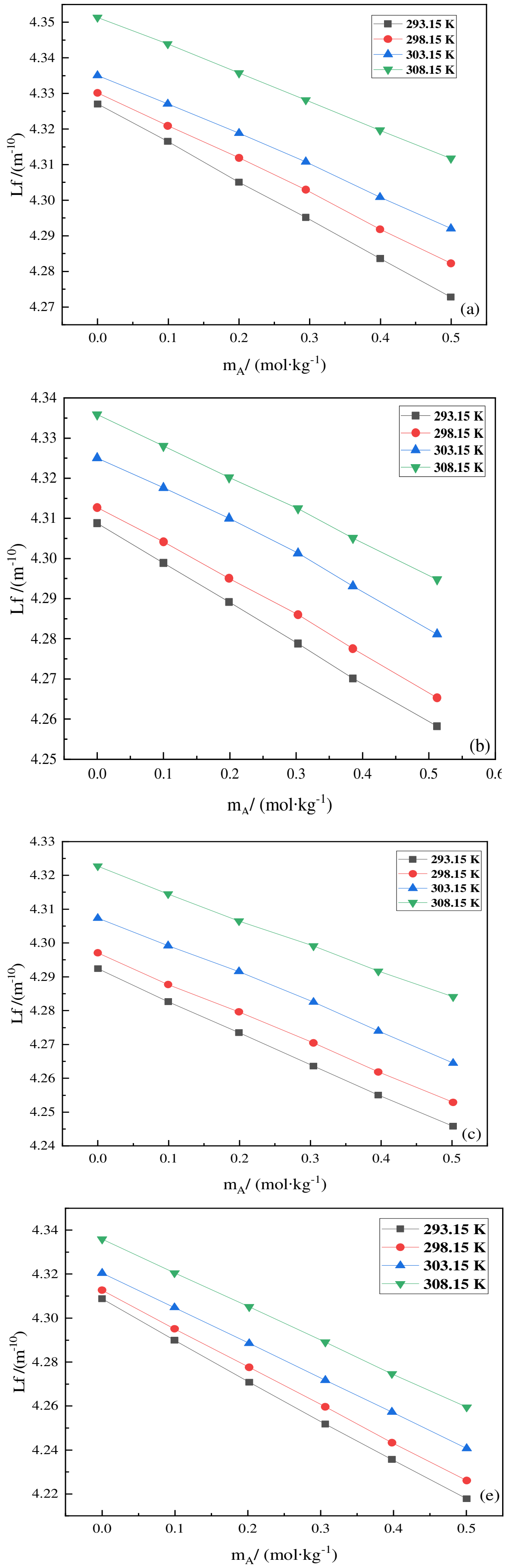


Figure 2: Variation of adiabatic compressibility, β , ethylene glycol **(a)** 0.05 D-Panthenol, **(b)** 0.10 D-Panthenol and **(c)** 0.15 D-Panthenol, diethylene glycol **(d)** 0.05 D-Panthenol, **(e)** 0.10 D-Panthenol and **(f)** 0.15 D-Panthenol and triethylene glycol **(g)** 0.05 D-Panthenol, **(h)** 0.10 D-Panthenol and **(i)** 0.15 D-Panthenol in different concentration of aqueous D-Panthenol solutions at different temperature.

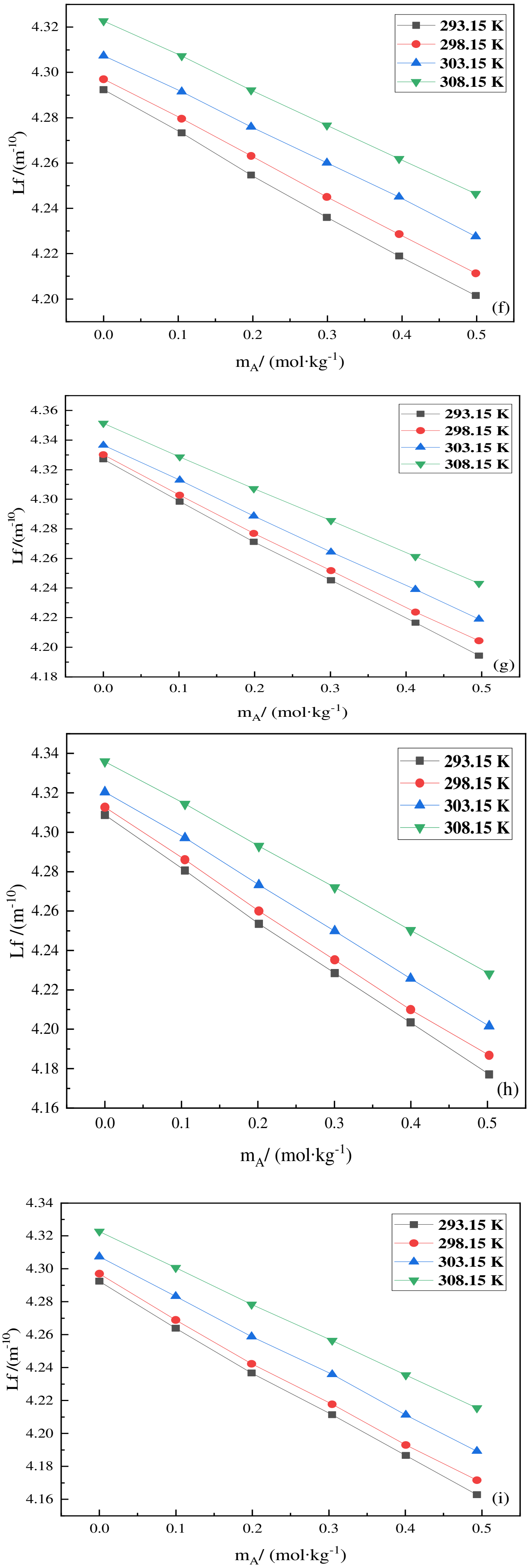
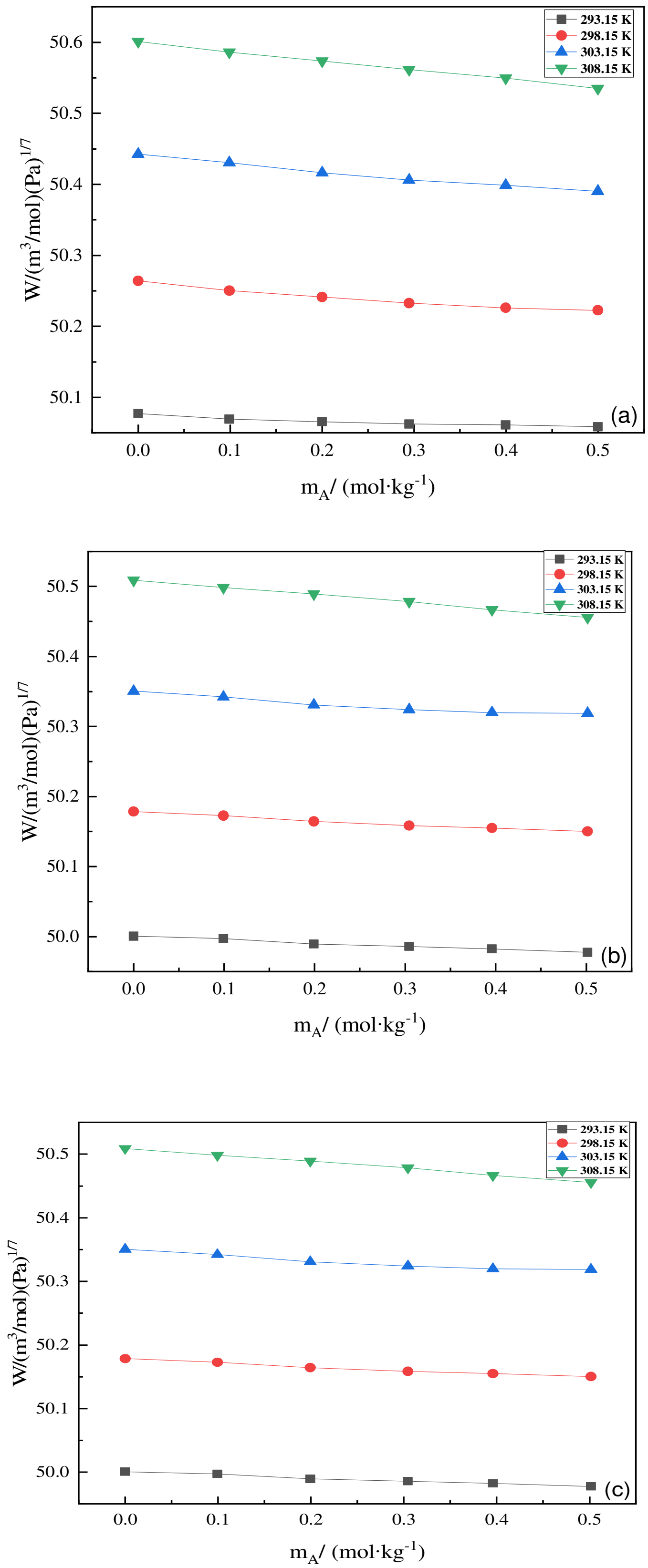
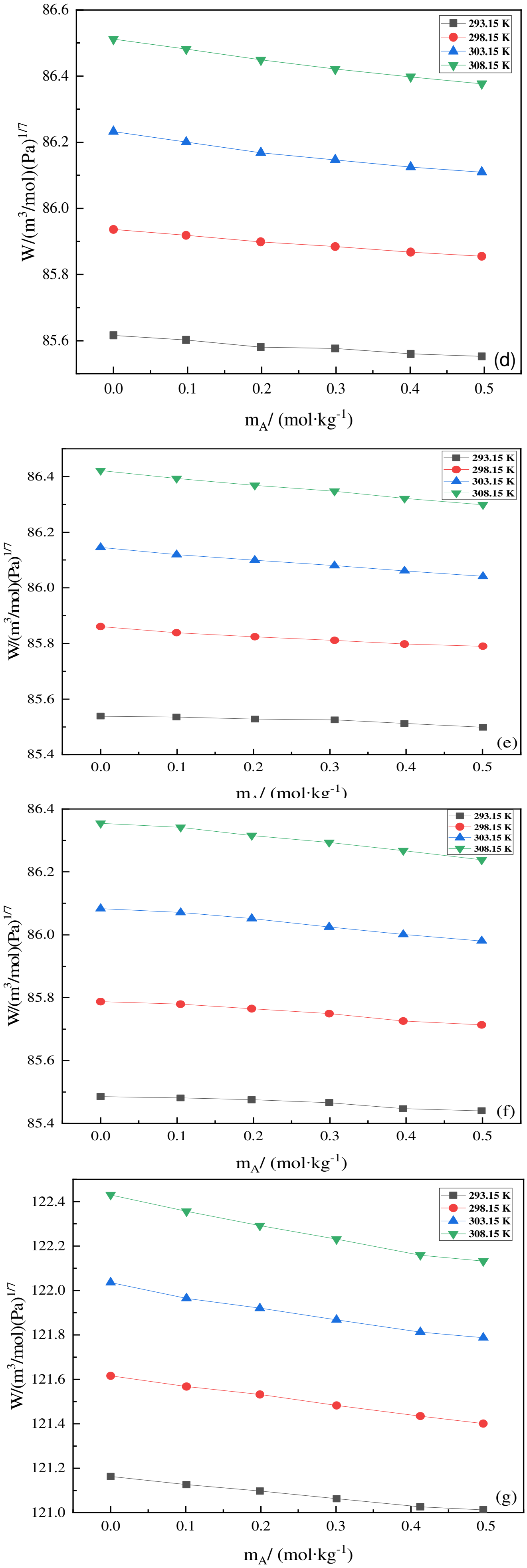


Figure 3: Variation of intermolecular free length, L_f , ethylene glycol **(a)** 0.05 D-Panthenol, **(b)** 0.10 D-Panthenol and **(c)** 0.15 D-Panthenol, diethylene glycol **(d)** 0.05 D-Panthenol, **(e)** 0.10 D-Panthenol and **(f)** 0.15 D-Panthenol and triethylene glycol **(g)** 0.05 D-Panthenol, **(h)** 0.10 D-Panthenol and **(i)** 0.15 D-Panthenol in different concentration of aqueous D-Panthenol solutions at different temperature

Figure 4





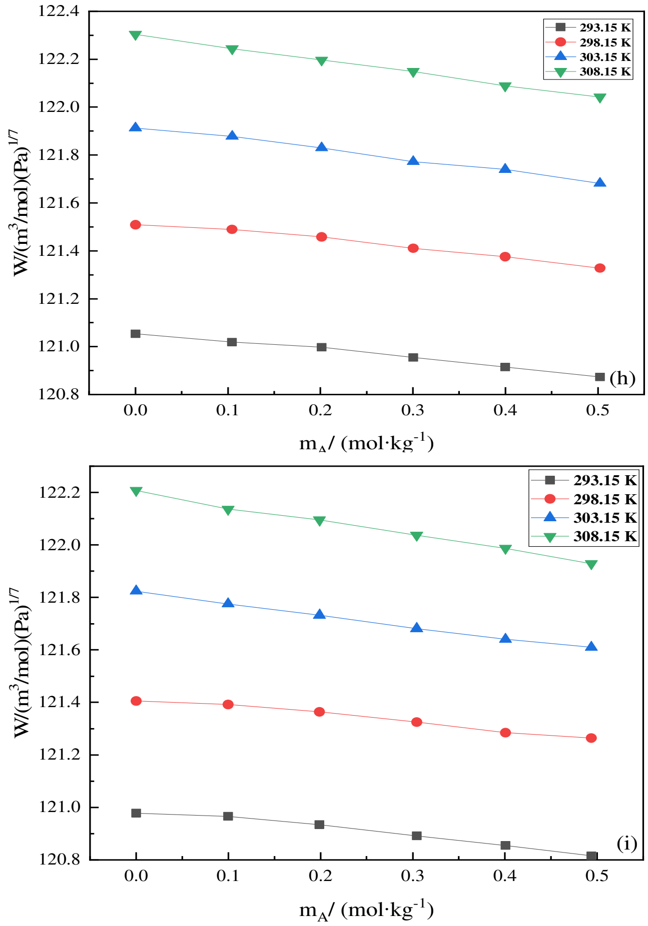
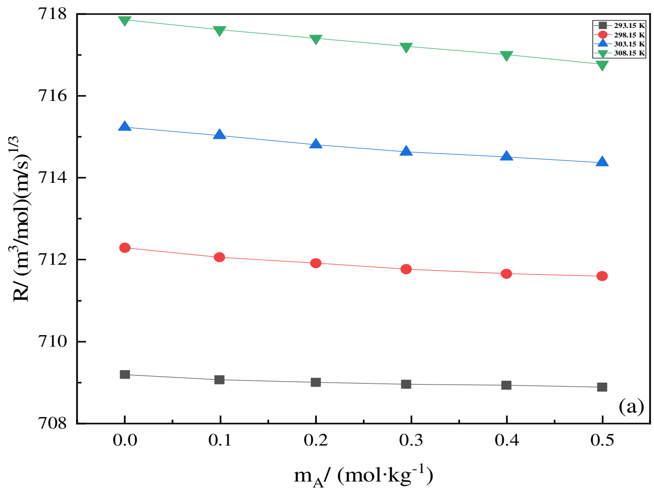
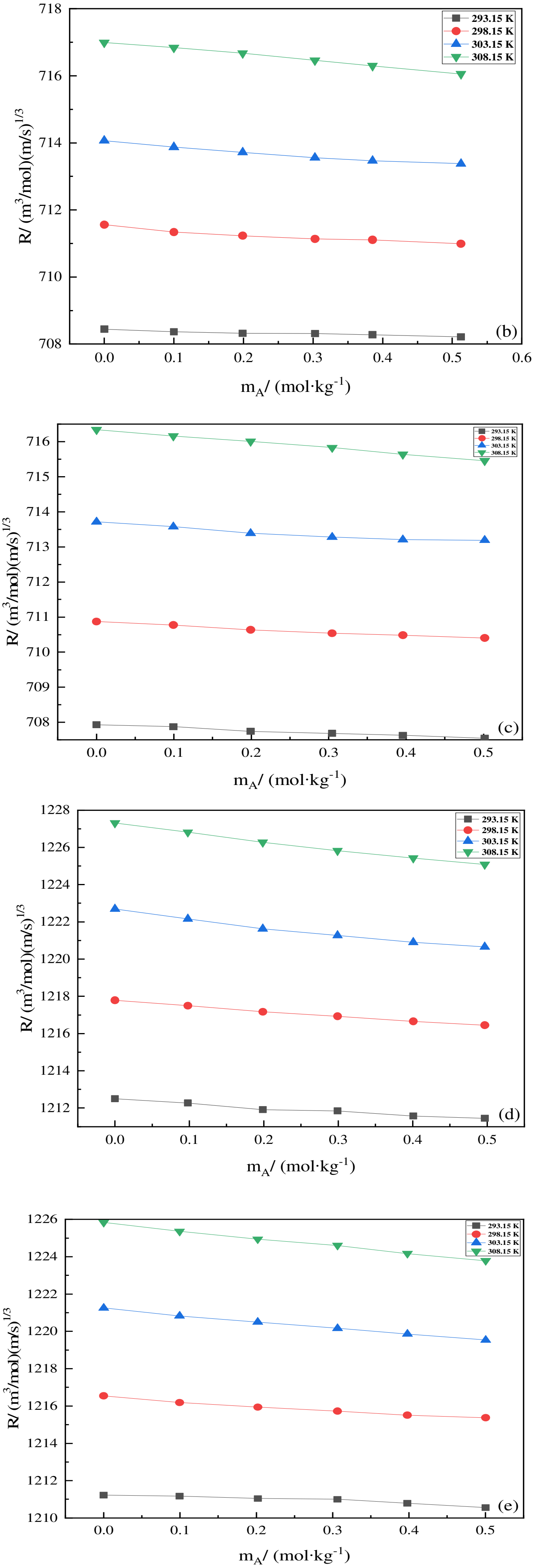


Figure 4: Variation of Wada's constant, W, of, ethylene glycol **(a)** 0.05 D-Panthenol, **(b)** 0.10 D-Panthenol and **(c)** 0.15 D-Panthenol, diethylene glycol **(d)** 0.05 D-Panthenol, **(e)** 0.10 D-Panthenol and **(f)** 0.15 D-Panthenol and triethylene glycol **(g)** 0.05 D-Panthenol, **(h)** 0.10 D-Panthenol and **(i)** 0.15 D-Panthenol in different concentration of aqueous D-Panthenol solutions at different temperature

Figure 5





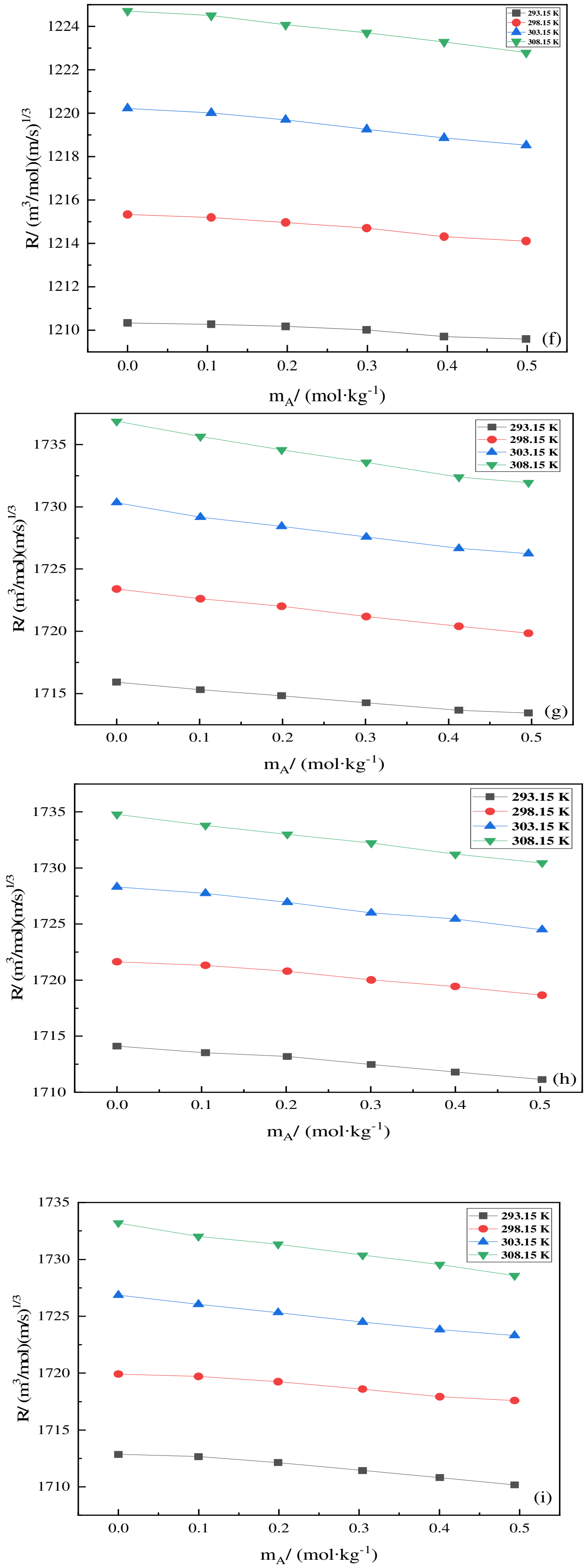
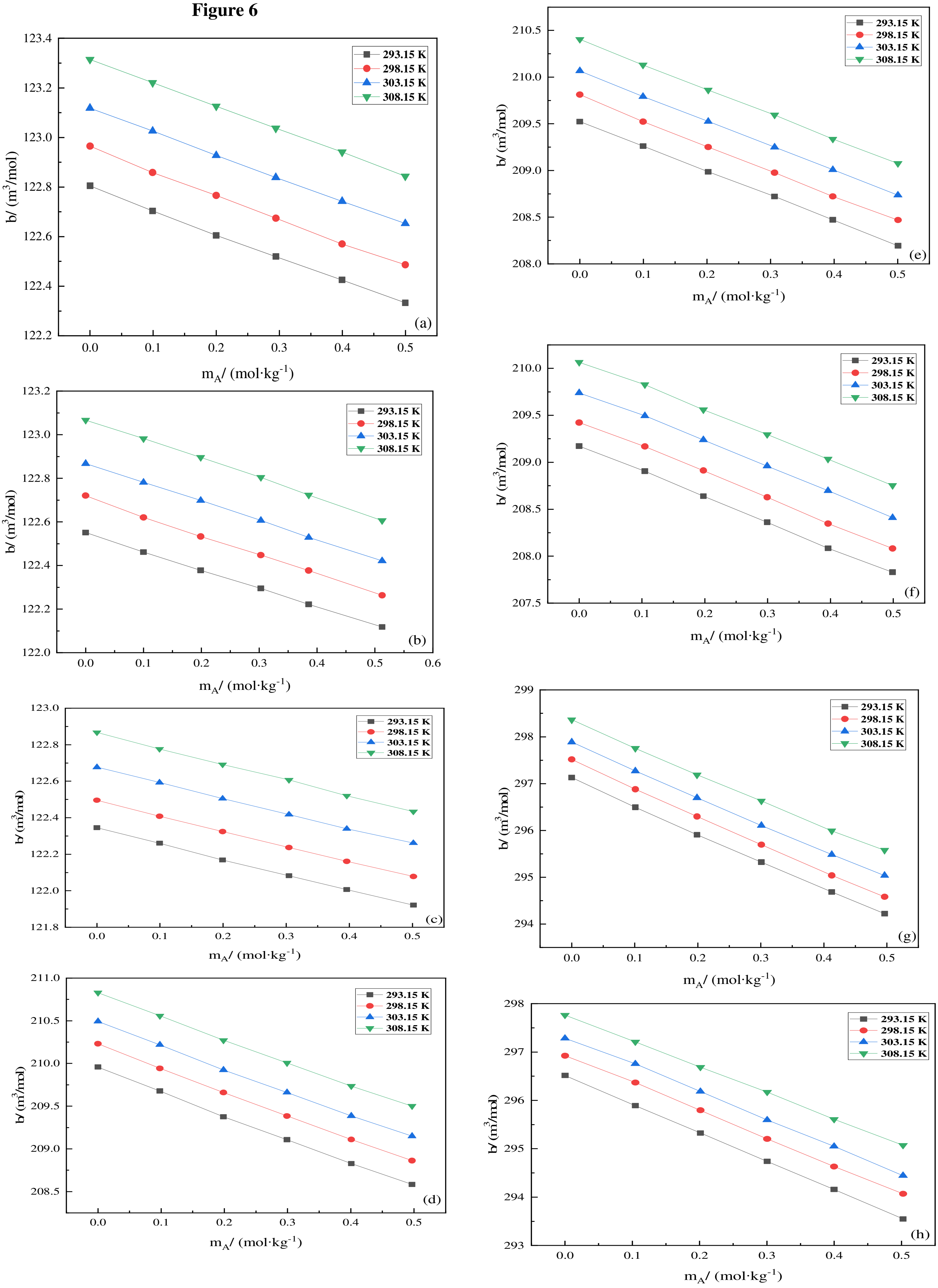


Figure 5: Variation of Rao's constant, R, of, ethylene glycol **(a)** 0.05 D-Panthenol, **(b)** 0.10 D-Panthenol and **(c)** 0.15 D-Panthenol, diethylene glycol **(d)** 0.05 D-Panthenol, **(e)** 0.10 D-Panthenol and **(f)** 0.15 D-Panthenol and triethylene glycol **(g)** 0.05 D-Panthenol, **(h)** 0.10 D-Panthenol and **(i)** 0.15 D-Panthenol in different concentration of aqueous D-Panthenol solutions at different temperature

Figure 6



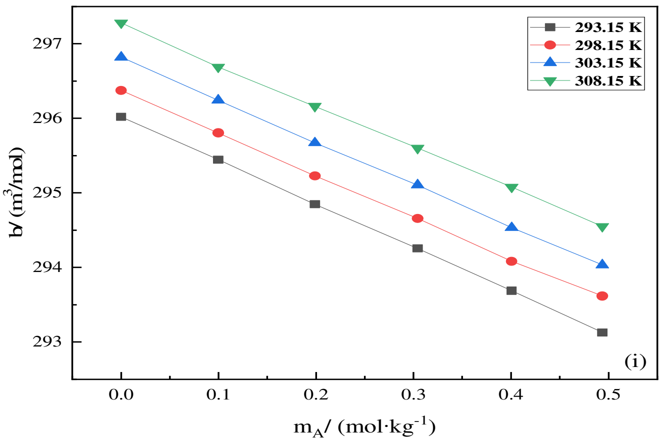


Figure 6: Variation of Vander waal's constant, b, of, ethylene glycol **(a)** 0.05 D-Panthenol, **(b)** 0.10 D-Panthenol and **(c)** 0.15 D-Panthenol, diethylene glycol **(d)** 0.05 D-Panthenol, **(e)** 0.10 D-Panthenol and **(f)** 0.15 D-Panthenol and triethylene glycol **(g)** 0.05 D-Panthenol, **(h)** 0.10 D-Panthenol and **(i)** 0.15 D-Panthenol in different concentration of aqueous D-Panthenol solutions at different temperature From the experimental density and velocity data, the thermodynamical parameters such as **Acoustic impedance** (Z), **Adiabatic compressibility** (β), **Intermolecular free length** (L_f), **Wada's constant** (W), **Rao's constant** (R) **and Vander Waal's constant** (b) **in the liquid mixture has been calculated which has suggested the strong intermolecular interactions among the glycols and vitamin B_5 D-Panthenol** (Thakur *et al., 2015*) (Thakur *et al., 2015*)**. The impedance values, in table 1, increases with the molality as well as with the temperature, shown in Fig. 1, which suggest there is no complex formation inside the liquid mixture. In table 2, with the concentration, the decrease in the adiabatic compressibility proves the greater bond strength among the molecules and the intermolecular free length, in table 5, indicates that the molecules are much more closely packed, thus implying the existence of the strong solute-solvent interaction inside the mixture, evident from the Fig. 2 and Fig. 3 respectively. Fig. 4, Fig. 5 and Fig. 6 shows the variations in Wada's constant, Rao's constant and Vander Waal's constant respectively.** The variation of the Wada's constant, in **table 3** and **table 4** with the temperature, in accordance with the concentration, depicts that the space between the solute and solvent molecules decreases, thus implying that the molecules are coming closer to each other, suggesting the strong solute-solvent interaction in the solution(Thakur *et al., 2015*) (Kumar *et al., 2015*). The presence of the strong binding forces inside the liquid system between solute and solvent is confirmed by the increasing values of Vander waal's constants with the temperature, in **table 6** (Kumar *et al., 2016*) (Kumar *et al., 2016*) (Sharma *et al., 2018*) (Sharma *et al., 2018*).

Conclusion

The investigated binary solution consisting of ethylene, diethylene and triethylene glycols as solute and D-Panthenol as solvent was chosen in order to obtain the information about the inter-molecular interaction between their constituent particles. The variations in the experimentally obtained and derived parameters indicate the presence of molecular interactions between the molecules of the given solution. The trend obtained with respect to fundamental parameters, that is, ultrasonic density and ultrasonic velocity at different temperatures and different concentrations was obtained linear in nature. The ultrasonic velocity increases with the increase in the mole fraction/concentration and decreases with the increase in the temperature and density increases with the increase in the mole fraction/concentration as well as with the increase in the temperature. The derived parameters such as acoustic impedance, adiabatic compressibility, intermolecular free length, Wada's constant, Rao's constant and Vander Waal's constant varies linearly with the different concentrations which show the absence of complex formations. In all the cases of ethylene, diethylene and triethylene glycols, the acoustic impedance shows the linearly increasing trend which increases as the temperature and concentration increases, the adiabatic compressibility shows the linearly decreasing trend which increases with increase in the concentration and decreases with the temperature, the intermolecular free length shows the decreasing trend which decreases with the concentration and increases with temperature and Wada's constant, Rao's constant and Vander Waal's constant shows decreasing trend which decreases with increasing concentration and increases with Increasing temperature, which is because of absence of heavy molecules in the solution.

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