The International Journal of Engineering and Science (IJES)
|| Volume || 13 || Issue || 10 || Pages || PP 69-89 || 2024 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Investigation of the Physicochemical Behaviour of Homoeopathic Dilutions of Glycerol (*Glycerinum*) at the Temperatures (293.15 - 318.15) K: Volumetric, Acoustic and ViscometricStudy

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----------*ABSTRACT*----------
The physicochemical studies of homoeopathic medicines provide better understanding regarding the presence and mechanism of their action in ultra-dilutions. The physicochemical behaviour of glycerol dilutions homoeopathic dilutions has been investigated from the measurements of densities, ρ, ultrasonic speeds, u and viscosities, η of pure ethanol control (91% ethanol in water) and 33 dilutions of glycerol dilutions of potencies ranging from 1C to 200C at ambient temperatures and atmospheric pressure. From the experimental data, a number of physicochemical parameters, viz., the isentropic compressibilities, κ_s, intermolecular free length, L_f, acoustic impedance, Z, relative association, R_A, relaxation time, τ, ultrasonic absorption, α/f^2, pseudo-Grüneisen parameter, Γ, deviations in isentropic compressibility, $\Delta\kappa_s$, deviations in intermolecular free length, ΔL_f, deviations in acoustic impedance, ΔZ, deviations in viscosity, $\Delta\eta$ and deviations in pseudo-Grüneisen parameter, $\Delta\Gamma$have been evaluated. These parameters showed diverse behaviour at certain potencies of these homoeopathic dilutions. The results have been qualitatively discussed in terms of prevailing interactions of these glycerol dilutions dilutions. The results indicated that that even in extreme dilutions (50C, 110C, 150C and 160C) the molecules of glycerol dilutions may be present in these homoeopathic formulations.
KEYWORDS: *Density; Ultrasonic speed; Viscosity; Homoeopathic medicines; Glycerol dilutions; Hydrogen bonding.*

Date of Submission: 06-10-2024 Date of acceptance: 18-10-2024

I. INTRODUCTION

Homoeopathic has been one of the most extensively practiced alternate therapies with holistic healing approach. The potency of a homoeopathic medicine increases with dilution followed by succussion (process termed as potentization) has stoodtwo main challenges to the researchers:(i) the preparation of homeopathic medicines involves ultra-high dilutions, raising questions regarding the presence of active medicine molecules at such ultra dilution levels, and (ii)there are disputes regarding doubtfulness in biological activity of these medicines wherein the source drug is diluted beyond Avagadro's limit, *i.e.*, the ultra-diluted medicine formulation might be similar to the solvent. However, these "ultra-diluted solutions" show anomalous behaviour in medicinal efficacy and the efficacy of homoeopathic medicines is well reinforced by research indications.There have been few researches to reconnoiter the existence of drug at ultra-dilution levels [1−6] and their mechanism of action, but the question still stands unanswered.

The physicochemical properties and the derived parameters of aqueous and mixed-aqueous solutions of electrolytes, amino acids, carbohydrates, drugs, *etc.* have been supportive in depicting the prevailing interactions, which help in understanding of solute-solvation/hydration behaviour of solute [7−12]. The homoeopathic formulations are ultra diluted solutions, therefore their physical properties, *viz.*, density, ultrasonic speed and viscosity can be measured at varying potency and temperature. The physicochemical properties derived from these experimental data deliver valuable information regarding the physicochemical behaviour, prevailing interactions and mechanism of action of these homoeopathic medicines. There have been few physicochemical studies on extremely diluted solutions of inorganic salts [13−15] and homoeopathic medicines [16,17] have been reported by using conductivity and pHmetric measurements. These studies provided exciting and substantial information on the behaviour of these ultra-diluted solutions. To the best of our information, very few physicochemical studies on homoeopathic medicines using volumetric, acoustic and viscometric have been reported in the literature [1,18−20]. In continuation to earlier research on the physicochemical behaviour of ultra-diluted homoeopathic formulations [21−25], here we report the results of the study on the physicochemical behaviour of homoeopathic dilutions of glycerol dilutions. *Glycerinum* dilution is a homoeopathic dilution made from glycerol (glycerin). *Glycerinum* is a homeopathic medication that

helps in increasing the weight of people who are underweight, thin and lean due to malnutrition. It helps in enhancing immunity and is also useful in treating throbbing pain in the head, reducing weakness and exhaustion caused due to menses. It is also beneficial in condition of diabetes which leads to increased production with the desire to pass urine.Therefore, the physicochemical investigation of the homoeopathic dilutions of glycerol (*glycerinum*)shall be interesting and useful for better understanding of the behaviour and its mechanism of action.

In the present study, the densities, ρ, ultrasonic speeds, u and viscosities, η of pure ethanol control (91% ethanol in water) and 33homoeopathic dilutions of glycerol(*glycerinum*)with potencies ranging from 1C to 200C (with intervals of 2C till 30C, and then with intervals of 10C till 200C) at 293.15, 298.15, 303.15, 308.15, 313.15 and 318.15 K and atmospheric pressure. From these experimental data, the isentropic compressibilities, κ_s, intermolecular free length, L_f, acoustic impedance, Z, relative association, R_A, relaxation time, τ, ultrasonic absorption, α/f^2, pseudo-Grüneisen parameter, Γ, deviations in isentropic compressibility, $\Delta\kappa_s$, deviations in intermolecular free length, ΔL_f, deviations in acoustic impedance, ΔZ, deviations in viscosity, $\Delta\eta$ and deviations in pseudo-Grüneisen parameter, $\Delta\Gamma$have been calculated. The variations of these parameters with potency and temperature are qualitatively discussed in terms of interactions/physicochemical behaviour of these *glycerinum*dilutions

II. MATERIALS AND METHODS

Thehomoeopathic formulations of various potencies of glycerol dilutionsused in the study were prepared in accordance with Homoeopathic Pharmacopoia of India [26]. The glycerol (s,d. fine chemicals, India, mass fraction purity > 0.99) was used for preparation of various potencies of glycerol dilutions(*glycerinum*). The ethanol control (91% ethanol in water) has been prepared by using the ethanol (E. Merck, India, mass fraction purity >0.995) and triple distilled water. The densities and ultrasonic speeds of the samples were measured by using high precision digital vibrating tube Density and Sound Analyzer(DSA 5000M, Anton Paar, Austria). The principle used in density measurement is based upon oscillating U-tube principle while the speed of sound is measured using a propagation time technique. This instrument is equipped with both density and ultrasonic cells, with reproducibility of $\pm1 \times10^{-3}$ kg·m^{-3} and $\pm1 \times10^{-2}$ m·s^{-1} for density and ultrasonic speed, respectively. The temperature for both cells was kept constant by using built in Peltier thermostat within ±0.01 K. The equipment was calibrated with triply distilled degassed water and with dry air at atmospheric pressure [10,21]. The operating working frequency used for ultrasonic speed measurements is 3 MHz.The standard uncertainties related to the measurements of density, ultrasonic speed and temperature were found within ±0.05 kg·m^{-3}, ±0.5 m·s^{-1} and±0.01 K, respectively.

The viscosities of the samples were measured by using Microviscometer (Lovis 2000M, Anton Paar, Austria) at temperatures, (293.15 − 318.15) K, and atmospheric pressure. The rolling ball principle was used in the measurement of viscosity, having a calibrated glass capillary with a steel ball as supplied by manufacturer. The calibration of capillary was accomplished by using viscosity standard fluids. The temperature was controlled to ±0.02 K by an automatic built in Peltier thermostat. The standard uncertainties for viscosity measurements and temperature were estimated to be within ±0.5% and ±0.02 K.

III. RESULTS

The experimental values of densities, ρ, ultrasonic speeds, u and viscosities, η of homoeopathic dilutions of glycerol (*glycerinum*) as function of potency (in centesimal) at different temperatures have been measured using the methodology mentioned above and listed in Tables 1−3 and shown graphically in Figs. 1−3, respectively.

Table 1: The densities, ρ/(kgm^{-3}) of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K and atmospheric pressure

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	808.248	804.277	800.155	796.005	791.621	787.436
1	829.835	825.509	821.120	816.678	812.180	807.621
2	826.551	822.194	817.796	813.338	808.823	804.245
4	824.027	819.676	815.275	810.820	806.305	801.730
6	831.702	827.357	822.951	818.490	813.969	809.387
8	826.560	822.211	817.808	813.350	808.930	804.451
10	825.402	821.226	816.795	812.513	808.279	803.692

12	824.955	820.903	816.320	812.045	807.829	803.252
14	824.666	820.616	815.956	811.760	807.346	802.871
16	824.435	820.279	815.676	811.418	807.003	802.525
18	824.208	820.057	815.456	811.099	806.684	802.106
20	824.089	819.731	815.329	810.873	806.357	801.779
22	823.990	819.641	815.237	810.782	806.267	801.692
24	825.532	821.177	816.773	812.315	807.803	803.226
26	824.471	820.119	815.716	811.257	806.743	802.167
28	825.154	820.809	816.304	811.845	807.429	802.851
30	825.866	821.518	817.113	812.655	808.141	803.563
40	830.527	826.193	821.735	817.246	811.842	807.265
50	827.243	822.893	818.498	814.037	809.517	804.935
60	827.399	823.042	818.620	814.160	809.638	805.056
70	830.785	826.441	822.035	817.576	813.056	808.477
80	827.856	823.202	818.799	814.344	809.826	805.246
90	831.213	826.874	822.469	818.010	813.490	808.907
100	827.872	823.496	819.073	814.601	810.203	805.623
110	827.408	823.059	818.657	814.202	809.684	805.104
120	827.403	823.060	818.656	814.179	809.680	805.100
130	827.561	823.218	818.914	814.454	809.935	805.254
140	827.657	823.276	819.049	814.573	810.046	805.262
150	827.696	823.244	818.939	814.473	809.963	805.286
160	825.373	821.012	816.608	812.155	807.670	803.131
170	827.691	823.395	819.020	814.626	810.173	805.677
180	827.333	823.279	819.077	814.619	810.010	805.323
190	824.259	819.903	815.499	811.044	806.530	801.954
200	827.636	823.333	818.922	814.458	809.934	805.352

Table 2. The ultrasonic speeds, $u/(\mathrm{ms}^{-1})$ of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K and atmospheric pressure

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	1195.93	1179.76	1163.54	1147.33	1131.38	1114.91
1	1271.21	1255.11	1238.53	1221.79	1205.01	1188.18
2	1258.77	1242.00	1225.49	1208.66	1191.78	1174.85
4	1253.69	1237.22	1220.42	1203.55	1186.64	1169.71
6	1274.06	1257.93	1241.39	1224.65	1207.87	1191.04
8	1261.42	1245.04	1228.27	1211.47	1194.59	1177.67
10	1258.99	1242.64	1225.89	1209.04	1192.14	1175.23
12	1257.70	1241.28	1224.69	1207.75	1190.84	1173.79
14	1256.69	1240.27	1223.63	1206.63	1189.86	1172.65
16	1255.70	1239.44	1222.65	1205.74	1188.83	1171.69
18	1254.87	1238.48	1221.67	1204.77	1187.96	1170.90
20	1254.02	1237.65	1220.77	1203.89	1187.06	1170.11
22	1253.61	1237.32	1220.48	1203.59	1186.68	1169.63
24	1261.18	1244.97	1228.36	1211.62	1194.92	1178.23
26	1256.13	1239.77	1223.01	1206.14	1189.25	1172.14
28	1257.84	1241.36	1224.57	1208.05	1191.07	1174.00
30	1260.59	1244.24	1227.33	1210.89	1193.98	1176.93
40	1269.44	1253.32	1236.52	1219.36	1202.96	1185.41
50	1265.29	1249.11	1232.43	1215.66	1198.86	1181.79
60	1265.63	1249.39	1232.69	1215.96	1199.14	1182.26
70	1272.36	1256.05	1239.39	1222.63	1205.84	1188.99
80	1265.59	1249.25	1232.56	1215.77	1198.96	1182.10
90	1273.19	1257.27	1240.82	1224.24	1207.44	1190.62

100	1263.45	1247.08	1230.54	1213.54	1197.08	1180.39
110	1262.75	1246.28	1229.65	1212.74	1195.98	1178.89
120	1262.97	1246.41	1229.66	1212.85	1195.99	1178.82
130	1263.08	1246.67	1229.86	1213.06	1196.22	1179.13
140	1263.59	1247.28	1230.36	1213.57	1196.71	1179.81
150	1263.44	1247.14	1230.40	1213.59	1196.74	1179.85
160	1258.71	1242.31	1225.51	1208.68	1191.82	1174.89
170	1263.52	1247.34	1230.59	1213.73	1196.90	1179.68
180	1263.46	1247.00	1230.21	1213.33	1196.44	1179.51
190	1255.52	1238.87	1222.33	1205.47	1188.58	1171.65
200	1263.43	1247.36	1230.70	1213.89	1196.98	1180.05

Table 3. The viscosities, $\eta/(10^{-3}$ N sm$^{-2})$ of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K and atmospheric pressure

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	1.4935	1.3239	1.1844	1.0616	0.9548	0.8677
1	1.7918	1.5828	1.4052	1.2552	1.1240	1.0131
2	1.7249	1.5250	1.3556	1.2122	1.0880	0.9821
4	1.6861	1.4860	1.3168	1.1744	1.0498	0.9468
6	1.8110	1.5950	1.4120	1.2590	1.1290	1.0140
8	1.7511	1.5468	1.3767	1.2284	1.0998	0.9912
10	1.7346	1.5355	1.3682	1.2218	1.0923	0.9856
12	1.7285	1.5303	1.3641	1.2168	1.0889	0.9821
14	1.7238	1.5262	1.3602	1.2136	1.0858	0.9788
16	1.7189	1.5222	1.3566	1.2102	1.0832	0.9768
18	1.7151	1.5183	1.3531	1.2074	1.0809	0.9741
20	1.7106	1.5147	1.3493	1.2041	1.0774	0.9706
22	1.7096	1.5135	1.3481	1.2029	1.0765	0.9713
24	1.7517	1.5519	1.3853	1.2380	1.1106	1.0031
26	1.7224	1.5230	1.3550	1.2100	1.0860	0.9780
28	1.7300	1.5315	1.3638	1.2193	1.0935	0.9861
30	1.7462	1.5467	1.3781	1.2331	1.1055	0.9976
40	1.8138	1.6028	1.4289	1.2773	1.1424	1.0308
50	1.7843	1.5735	1.3947	1.2439	1.1128	1.0013
60	1.7849	1.5728	1.3937	1.2431	1.1122	1.0004
70	1.8278	1.6126	1.4311	1.2743	1.1422	1.0317
80	1.7713	1.5627	1.3861	1.2367	1.1065	0.9950
90	1.8341	1.6208	1.4385	1.2855	1.1525	1.0430
100	1.7776	1.5697	1.3945	1.2445	1.1121	1.0011
110	1.7732	1.5658	1.3917	1.2401	1.1087	0.9982
120	1.7741	1.5649	1.3905	1.2396	1.1085	0.9981
130	1.7736	1.5645	1.3902	1.2395	1.1091	0.9985
140	1.7733	1.5648	1.3892	1.2398	1.1088	0.9981
150	1.7716	1.5639	1.3869	1.2378	1.1072	0.9971
160	1.7243	1.5252	1.3574	1.2135	1.0900	0.9812
170	1.7775	1.5565	1.3861	1.2373	1.1064	0.9966
180	1.7797	1.5581	1.3877	1.2369	1.1075	0.9979
190	1.7184	1.5203	1.3539	1.2115	1.0867	0.9794
200	1.7727	1.5512	1.3847	1.2366	1.1065	0.9975

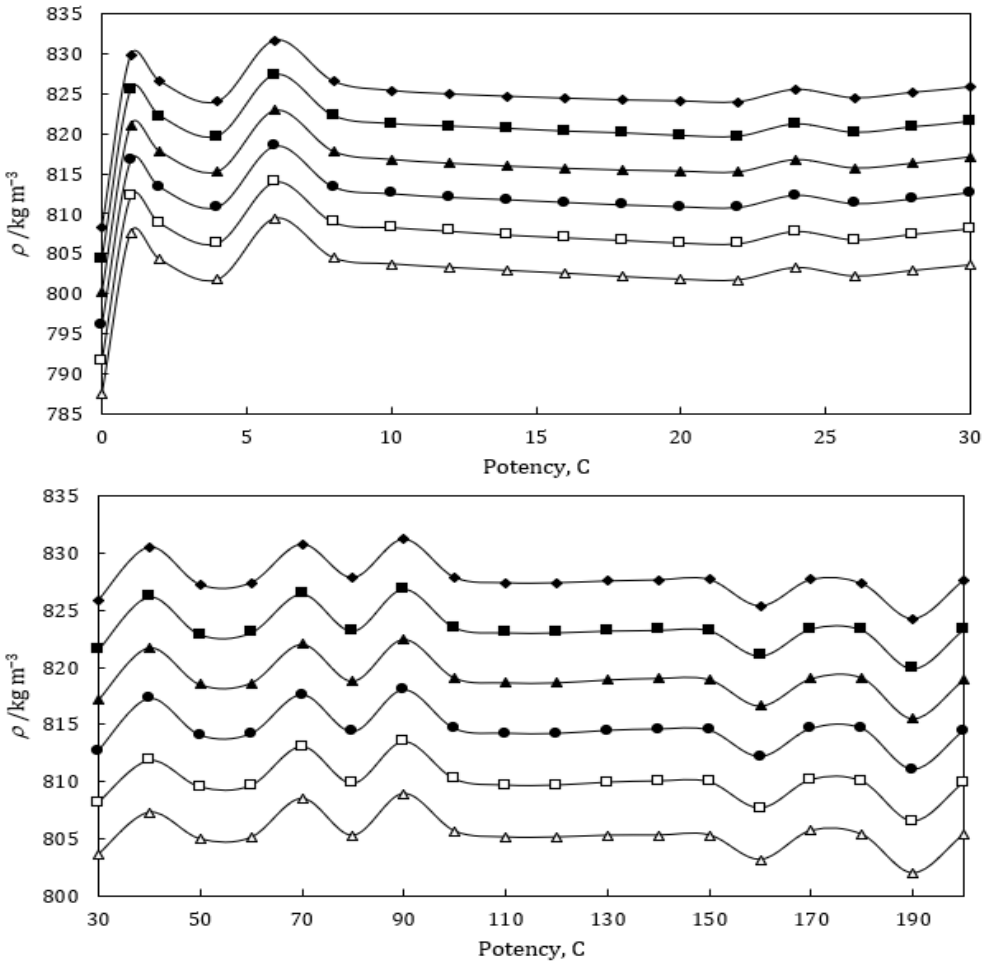

Fig. 1. Plots of densities, ρ*vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K, ♦; 298.15 K, ■; 303.15 K, ▲; 308.15 K, ●; 313.15 K, □; and 318.15 K, Δ.

The values of the isentropic compressibility, κ_s, intermolecular free length, L_f, acoustic impedance, *Z*, relative association, R_A, relaxation time, τ, ultrasonic absorption, (α/f^2) and pseudo-Grüneisen parameter, Γof these *glycerinum*dilutions have been calculated by using the relations [21,27−32]

$$\kappa_s = 1/u^2\rho \quad (1)$$

$$L_f = K'/u\rho^{1/2} \quad (2)$$

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

$$R_A = (\rho/\rho_o)(u_o/u)^{1/3} \quad (4)$$

$$\tau = (4/3)/\kappa_s\eta \quad (5)$$

$$(\alpha/f^2) = 8\pi^2\eta/3\rho u^3 \quad (6)$$

$$\Gamma = \alpha_p/\kappa_T \quad (7)$$

where *K*' is temperature dependent constant [= (93.875 + 0.375*T*) × 10^{-8}]; *T* is the absolute temperature; ρ_o and u_o are the density and ultrasonic speed of the ethanol control, respectively; α_p is the isobaric expansivity and k_T is the isothermal compressibility. The values of αp and k_T are calculated using the relations [31,32]

$$\alpha_p = (-1/\rho)(\partial\rho/\partial T)_p \quad (8)$$

$$k_T = (1.71\times10^{-3})/(T^{4/9}u^2\rho^{4/3}) \quad (9)$$

The values of κ_s, L_f, *Z*, R_A, τ, (α/f^2) and Γare given in Tables 4–10.

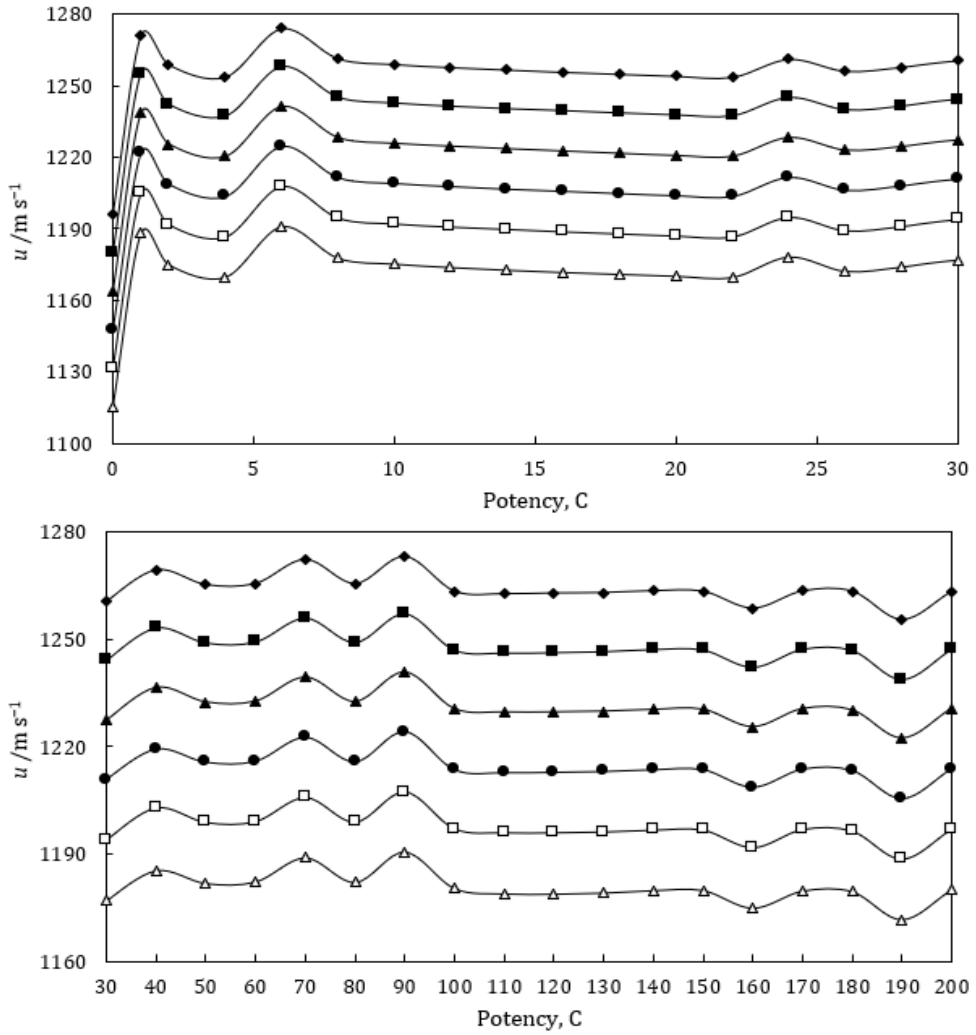

Fig. 2. Plots of ultrasonic speeds, *u*vs. potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K, ♦; 298.15 K, ■; 303.15 K, ▲; 308.15 K, ●; 313.15 K, □; and 318.15 K, Δ.

The deviations in κ_s,L_f, Z, η and Γ of ethanol control due to addition of glycerol dilutions with dilution and succussion are signified by the deviation in the values of these properties. The deviations in isentropic compressibility, $\Delta\kappa_s$, deviations in intermolecular free length, ΔL_f, deviations in acoustic impedance, ΔZ, deviations in pseudo-Grüneisen parameter, ΔΓ and deviations in viscosity, $\Delta\eta$ have been calculated by using the relations [21]

$$\Delta\kappa_s = \kappa_s - \kappa_s^o \quad (10)$$

$$\Delta L_f = L_f - L_f^o \quad (11)$$

$$\Delta Z = Z - Z^o \quad (12)$$

$$\Delta\eta = \eta - \eta^o \quad (13)$$

$$\Delta\Gamma = \Gamma - \Gamma^\circ \quad (14)$$

where the superscript '^{o}' represents the values for pure ethanol control (91% ethanol in water). The variations of $\Delta\kappa_s$, ΔL_f, ΔZ, $\Delta\eta$, τ, (α/f^2) and ΔΓ with potency, *C* of glycerol dilutions and temperature are presented graphically in Figs. 4−10, respectively.

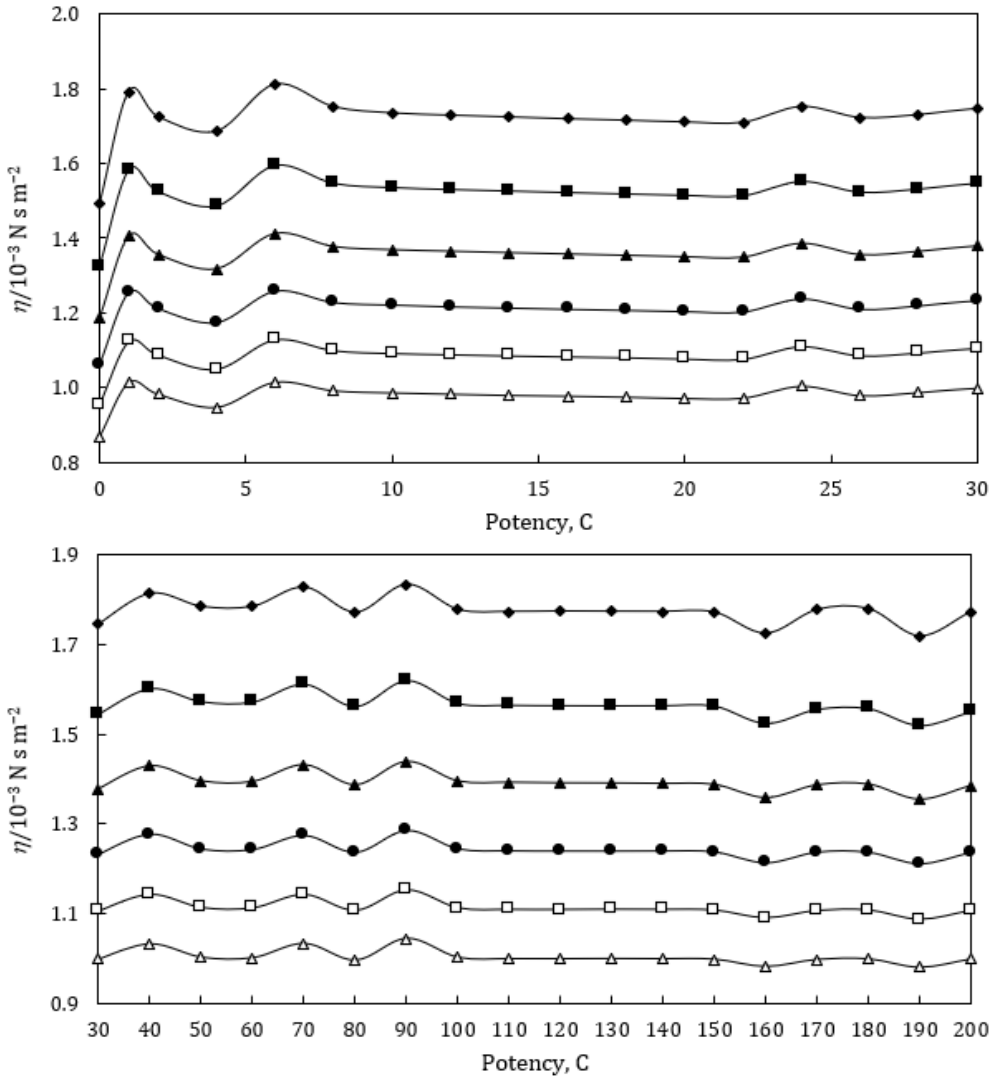

Fig. 3. Plots of viscosities, η*vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K, ♦; 298.15 K, ■; 303.15 K, ▲; 308.15 K, ●; 313.15 K, □; and 318.15 K, Δ.

IV. DISCUSSION

A close review of Tables 1–3 and Figs. 1–3 specifies that the values of ρ, *u* and $\eta$of glyceroldilutions (*glycerinum*) are more than those of ethanol control for all the potencies (1C to 200C) at each studied temperature and these values decrease with increase in temperature. The values of ρ, *u* and η are maximum at 1C and then decrease in presence of glycerol with dilution till the potency 4C and after that these values increase to maximum at 6C. Thereafter these values decrease gradually till potency 22C and then these values increase slightly at 24C, and again decrease at 26C and afterwards these values increase up to 40C (Figs. 1−3) with successive dilutions. After exhibiting maximum at 40C these values decrease to 50C and then remain nearly constant till 200C, except exhibiting maximums at potencies 70C and 90C and minimums at 160C and 190C (Figs. 1−3). The observed anomalous trends, wherein ρ, *u* and η values at the potencies, *viz.*, 1C, 6C, 40C, 70C and 90C exhibit larger in magnitude, and the potencies 4C, 8C to 22C, 160C and 190C exhibit smaller in magnitude than the average values of all other potencies. This specifies that these potencies exhibit a different solution structure as compared to other potencies and the ethanol control, it may be due interaction between glycerol and ethanol-water molecules.

Table 4. Isentropic compressibilities, $\kappa_s/(10^{-10}\ m^2\ N^{-1})$ of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	8.6506	8.9332	9.2313	9.5435	9.8688	10.2166
1	7.4572	7.6898	7.9393	8.2027	8.4794	8.7706
2	7.6355	7.8847	8.1421	8.4163	8.7047	9.0084
4	7.7211	7.9701	8.2353	8.5143	8.8077	9.1162
6	7.4072	7.6383	7.8851	8.1463	8.4208	8.7095
8	7.6034	7.8460	8.1051	8.3772	8.6627	8.9630
10	7.6435	7.8858	8.1467	8.4195	8.7053	9.0088
12	7.6633	7.9062	8.1675	8.4424	8.7292	9.0358
14	7.6783	7.9219	8.1853	8.4610	8.7488	9.0577
16	7.6926	7.9357	8.2012	8.4771	8.7677	9.0764
18	7.7049	7.9502	8.2166	8.4941	8.7840	9.0934
20	7.7164	7.9640	8.2300	8.5089	8.8009	9.1094
22	7.7224	7.9692	8.2348	8.5141	8.8075	9.1179
24	7.6157	7.8568	8.1142	8.3858	8.6700	8.9681
26	7.6870	7.9331	8.1960	8.4732	8.7643	9.0735
28	7.6597	7.9061	8.1692	8.4403	8.7301	9.0371
30	7.6198	7.8628	8.1245	8.3924	8.6800	8.9842
40	7.4717	7.7054	7.9591	8.2297	8.5119	8.8155
50	7.5507	7.7885	8.0437	8.3125	8.5948	8.8953
60	7.5452	7.7836	8.0391	8.3071	8.5895	8.8869
70	7.4352	7.6696	7.9194	8.1824	8.4586	8.7494
80	7.5415	7.7839	8.0391	8.3079	8.5901	8.8872
90	7.4217	7.6507	7.8970	8.1566	8.4317	8.7208
100	7.5669	7.8082	8.0628	8.3358	8.6131	8.9088
110	7.5796	7.8224	8.0786	8.3509	8.6345	8.9372
120	7.5770	7.8207	8.0785	8.3496	8.6344	8.9383
130	7.5742	7.8160	8.0733	8.3439	8.6283	8.9319
140	7.5672	7.8078	8.0654	8.3357	8.6201	8.9215
150	7.5687	7.8098	8.0660	8.3364	8.6206	8.9206
160	7.6471	7.8921	8.1537	8.4283	8.7166	9.0203
170	7.5678	7.8059	8.0627	8.3329	8.6160	8.9189
180	7.5718	7.8112	8.0671	8.3385	8.6244	8.9254
190	7.6964	7.9467	8.2073	8.4848	8.7765	9.0835
200	7.5693	7.8062	8.0622	8.3324	8.6174	8.9169

Table 5. Intermolecular free lengths, $L_f/(10^{-10}\ m)$ of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	5.9943	6.1475	6.3062	6.4699	6.6381	6.8140
1	5.5655	5.7036	5.8483	5.9982	6.1531	6.3134
2	5.6317	5.7755	5.9225	6.0758	6.2343	6.3984
4	5.6631	5.8067	5.9563	6.1110	6.2711	6.4366
6	5.5468	5.6845	5.8283	5.9775	6.1318	6.2914
8	5.6198	5.7613	5.9090	6.0616	6.2192	6.3823
10	5.6346	5.7759	5.9242	6.0769	6.2345	6.3985
12	5.6419	5.7833	5.9317	6.0852	6.2431	6.4082
14	5.6474	5.7891	5.9382	6.0919	6.2501	6.4159
16	5.6527	5.7941	5.9439	6.0977	6.2568	6.4225
18	5.6572	5.7994	5.9495	6.1038	6.2627	6.4286

20	5.6614	5.8045	5.9544	6.1091	6.2687	6.4342
22	5.6636	5.8063	5.9561	6.1110	6.2710	6.4372
24	5.6244	5.7652	5.9123	6.0647	6.2219	6.3841
26	5.6506	5.7932	5.9421	6.0963	6.2556	6.4215
28	5.6406	5.7833	5.9323	6.0844	6.2434	6.4086
30	5.6259	5.7674	5.9161	6.0671	6.2255	6.3898
40	5.5709	5.7094	5.8556	6.0080	6.1649	6.3295
50	5.6003	5.7401	5.8866	6.0382	6.1949	6.3581
60	5.5983	5.7383	5.8849	6.0363	6.1929	6.3551
70	5.5573	5.6962	5.8409	5.9908	6.1456	6.3058
80	5.5969	5.7384	5.8849	6.0365	6.1932	6.3552
90	5.5522	5.6891	5.8327	5.9813	6.1358	6.2954
100	5.6063	5.7474	5.8936	6.0467	6.2014	6.3629
110	5.6110	5.7526	5.8993	6.0521	6.2091	6.3731
120	5.6100	5.7520	5.8993	6.0517	6.2091	6.3735
130	5.6090	5.7502	5.8974	6.0496	6.2069	6.3712
140	5.6064	5.7472	5.8945	6.0466	6.2040	6.3675
150	5.6070	5.7480	5.8947	6.0469	6.2041	6.3672
160	5.6359	5.7782	5.9267	6.0801	6.2386	6.4026
170	5.6066	5.7465	5.8935	6.0456	6.2025	6.3666
180	5.6081	5.7485	5.8951	6.0476	6.2055	6.3689
190	5.6541	5.7981	5.9461	6.1005	6.2600	6.4250
200	5.6072	5.7467	5.8934	6.0454	6.2030	6.3658

A close perusal of Tables 4 and 5 indicate that the values of κ_s and L_f for glycerol dilutions (*glycerinum*) potencies are less than those of ethanol controls for all the potencies at each investigated temperature and these values increase with increase in temperature, which indicates significant interaction between glycerol and ethanol/water molecules. The values of κ_s and L_f are minimum at 1C and then increase in presence of glycerol with dilution till the potency 4C and after that these values decrease to minimum at 6C. Thereafter these values increase gradually till potency 22C and then these values decrease slightly at 24C, and again increase at 26C and afterwards these values decrease up to 40C (Tables 4 and 5) with successive dilutions. After exhibiting maximum at 40C these values increase to 50C and then remain nearly constant till 200C, except exhibiting minimums at potencies 70C and 90C and maximums at 160C and 190C (Tables 4 and 5). This indicates that some of the potencies of *glycerinum* show diverse behaviour may be due interaction between glycerol and ethanol-water molecules.

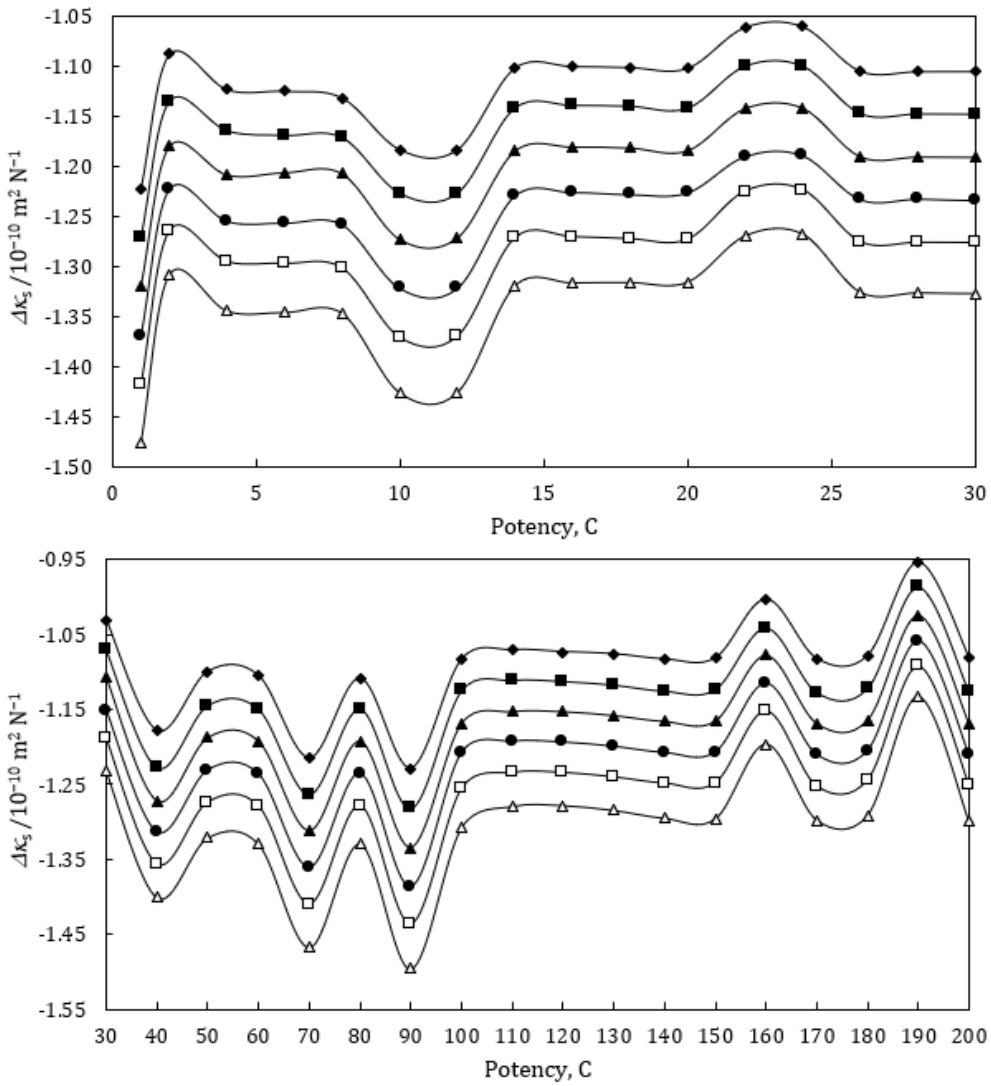

Fig. 4. Plots of deviations in isentropic compressibility, $\Delta\kappa_s$*vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K,♦; 298.15 K,■; 303.15 K,▲; 308.15 K,●; 313.15 K,□; and 318.15 K,Δ.

These variations in κ_s and L_f are expressed in terms of deviations in isentropic compressibility, $\Delta\kappa_s$ and deviations in intermolecular free length, ΔL_f are shown graphically in Figs. 4 and 5. Figures 4 and 5 indicate that the values of $\Delta\kappa_s$ and ΔL_f are negative for the *glycerinum*dilutions under study and these values are minimum at 1C and then increase in presence of glycerol with dilution till the potency 4C and after that these values decrease to minimum at 6C. Thereafter these values increase gradually till potency 22C and then these values decrease slightly at 24C, and again increase at 26C and afterwards these values decrease up to 40C (Figs. 4 and 5) with successive dilutions. After exhibiting maximum at 40C these values increase to 50C and then remain nearly constant till 200C, except exhibiting minimums at potencies 70C and 90C and maximums at 160C and 190C (Figs. 4 and 5). This indicates that at potencies 1C, 6C, 40C, 70C and 90C are less compressible and 4C, 8C to 22C, 160C and 190C are more compressible than the other potencies, indicating that the potencies 1C, 6C, 40C, 70C and 90C exhibit more compact solution structure and the potencies 4C, 8C to 22C, 160C and 190C exhibit less compact solution structure as compared to other potencies. The minimum in $\Delta\kappa_s$ and ΔL_f values at potencies 1C, 6C, 40C, 70C and 90C indicate that these have most compact solution structure, hence, these potencies show varied behaviour owing to prevailing interaction between glycerol and ethanol-water molecules.

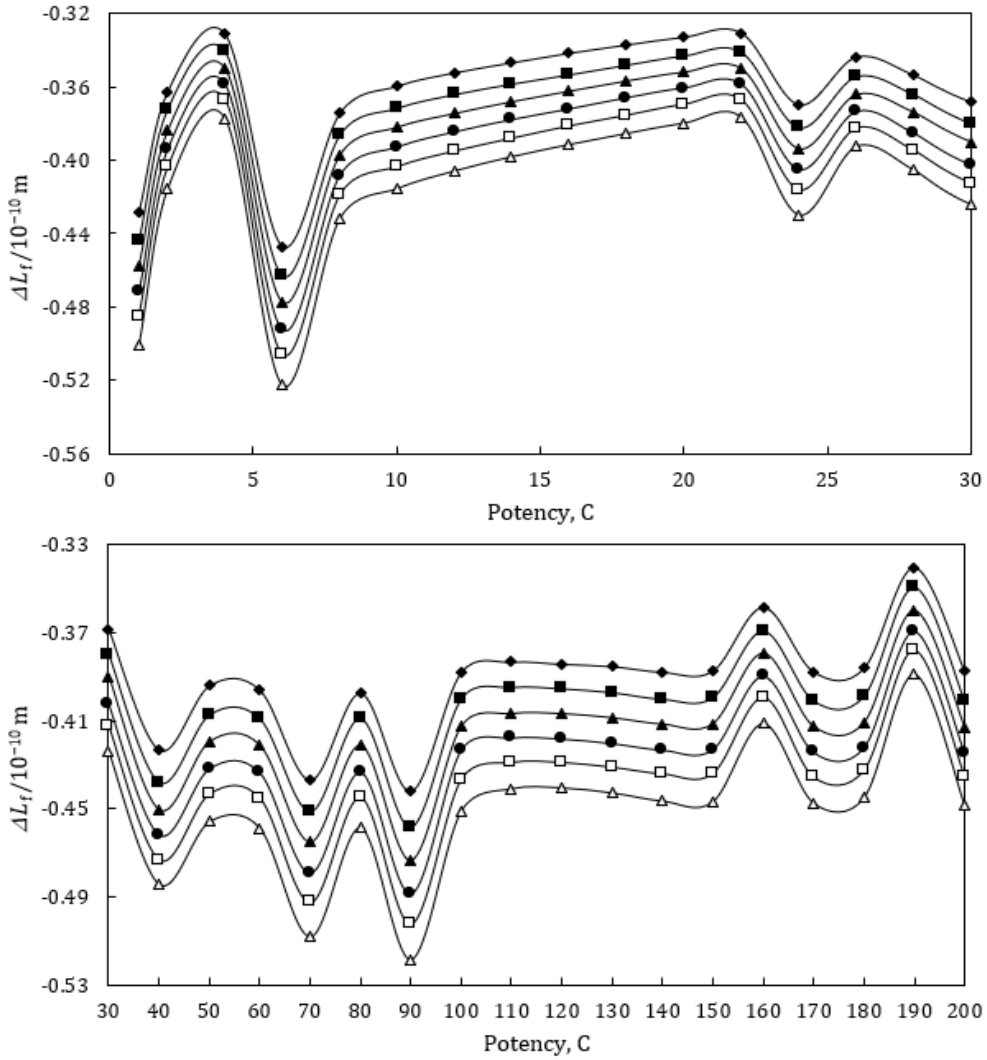

Fig. 5. Plots of deviations in intermolecular free length, ΔL_f *vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K,♦; 298.15 K,■; 303.15 K,▲; 308.15 K,●; 313.15 K,□; and 318.15 K,Δ.

Table 6. Specific acoustic impedances, $Z/(10^5\ \mathrm{kgm^{-2}s^{-1}})$ of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	9.6661	9.4885	9.3101	9.1328	8.9562	8.7792
1	10.5489	10.3610	10.1698	9.9781	9.7869	9.5960
2	10.4044	10.2116	10.0220	9.8305	9.6394	9.4487
4	10.3307	10.1412	9.9498	9.7586	9.5679	9.3779
6	10.5964	10.4076	10.2160	10.0236	9.8317	9.6401
8	10.4264	10.2369	10.0449	9.8535	9.6634	9.4738
10	10.3917	10.2049	10.0130	9.8236	9.6358	9.4452
12	10.3755	10.1897	9.9974	9.8075	9.6200	9.4285
14	10.3635	10.1779	9.9843	9.7949	9.6063	9.4149
16	10.3524	10.1669	9.9729	9.7836	9.5939	9.4031
18	10.3427	10.1562	9.9622	9.7719	9.5831	9.3919
20	10.3342	10.1454	9.9533	9.7620	9.5719	9.3817
22	10.3296	10.1416	9.9498	9.7585	9.5678	9.3768
24	10.4114	10.2234	10.0329	9.8422	9.6526	9.4638

26	10.3564	10.1676	9.9763	9.7849	9.5942	9.4025
28	10.3791	10.1892	9.9962	9.8075	9.6170	9.4255
30	10.4108	10.2217	10.0287	9.8404	9.6490	9.4574
40	10.5430	10.3548	10.1609	9.9652	9.7661	9.5694
50	10.4670	10.2788	10.0874	9.8959	9.7050	9.5126
60	10.4718	10.2830	10.0910	9.8999	9.7087	9.5179
70	10.5706	10.3805	10.1882	9.9959	9.8042	9.6127
80	10.4773	10.2839	10.0922	9.9006	9.7095	9.5188
90	10.5829	10.3960	10.2054	10.0144	9.8224	9.6310
100	10.4597	10.2697	10.0790	9.8855	9.6988	9.5095
110	10.4481	10.2576	10.0666	9.8742	9.6837	9.4913
120	10.4499	10.2587	10.0667	9.8748	9.6837	9.4907
130	10.4528	10.2628	10.0715	9.8798	9.6886	9.4950
140	10.4582	10.2686	10.0773	9.8854	9.6939	9.5006
150	10.4574	10.2670	10.0762	9.8844	9.6932	9.5012
160	10.3891	10.1995	10.0076	9.8164	9.6260	9.4359
170	10.4580	10.2705	10.0788	9.8874	9.6970	9.5044
180	10.4530	10.2663	10.0764	9.8840	9.6913	9.4989
190	10.3487	10.1575	9.9681	9.7769	9.5863	9.3961
200	10.4566	10.2699	10.0785	9.8866	9.6947	9.5036

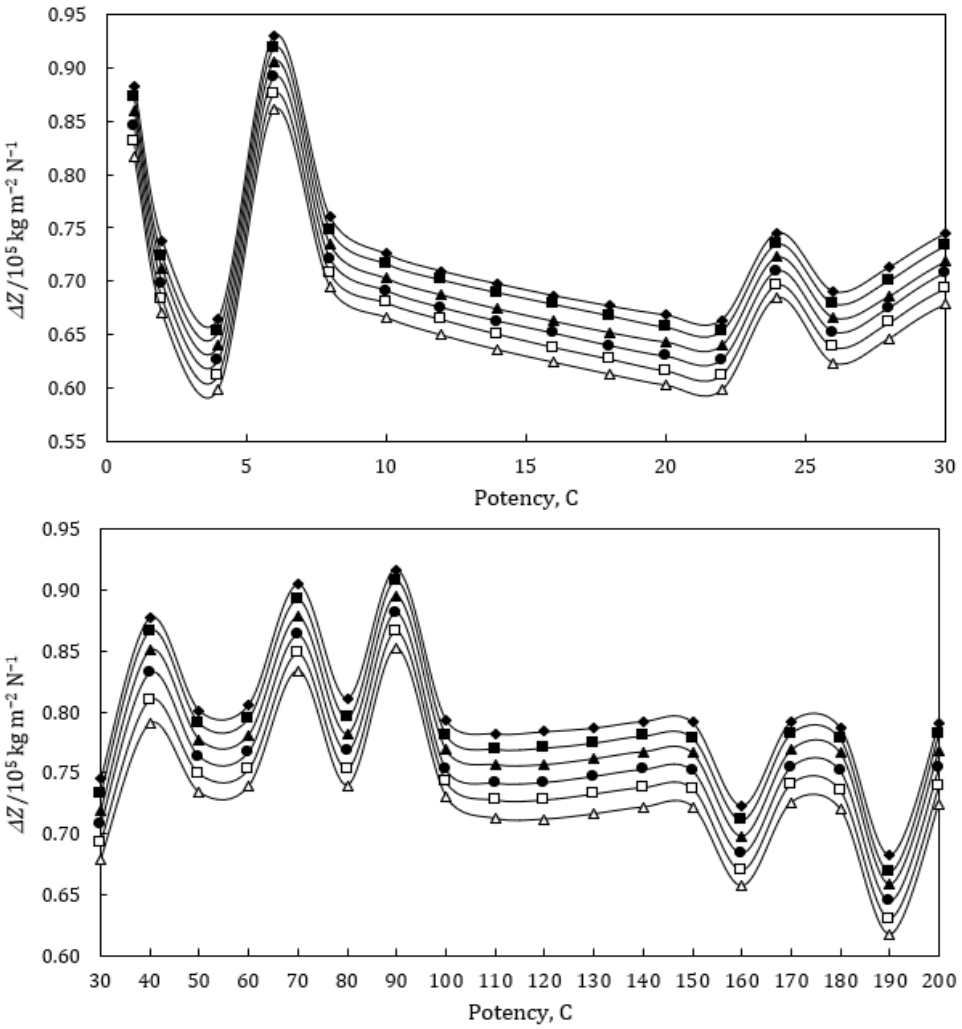

Fig. 6. Plots of deviations in specific acoustic impedance, ΔZvs. potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K,♦; 298.15 K,■; 303.15 K,▲; 308.15 K,●; 313.15 K,□; and 318.15 K,Δ.

A close perusal of Table 6 indicates that the acoustic impedances, *Z* of potencies of glycerol dilutions(*glycerinum*) are more than those of ethanol control for all the potencies at each investigated temperature and the values decrease with increase in temperature, which indicates significant interaction between glycerol and ethanol/water molecules. Figure 6 indicates that ΔZvalues are positive, *i.e.*, *Z*values for glycerol dilutions are more than those of ethanol control. These ΔZ values are maximum at 1C and then decrease in presence of glycerol with dilution till the potency 4C and after that these values increase to maximum at 6C. Thereafter these values decrease gradually till potency 22C and then these values increase slightly at 24C, and again decrease at 26C and afterwards these values increase up to 40C (Fig. 6) with successive dilutions. After exhibiting maximum at 40C these values decrease to 50C and then remain nearly constant till 200C, except exhibiting maximums at potencies 70C and 90C and minimums at 160C and 190C (Fig. 6). This indicates that the potencies 1C, 6C, 40C, 70C and 90C offer more resistance, and the potencies 4C, 8C to 22C, 160C and 190C offer lesser resistance, to the propagation of sound waves through the solution due to more compact structure the other potencies. The variations in values of *Z* and ΔZ of these potencies may be due interaction between glycerol and ethanol/water molecules.

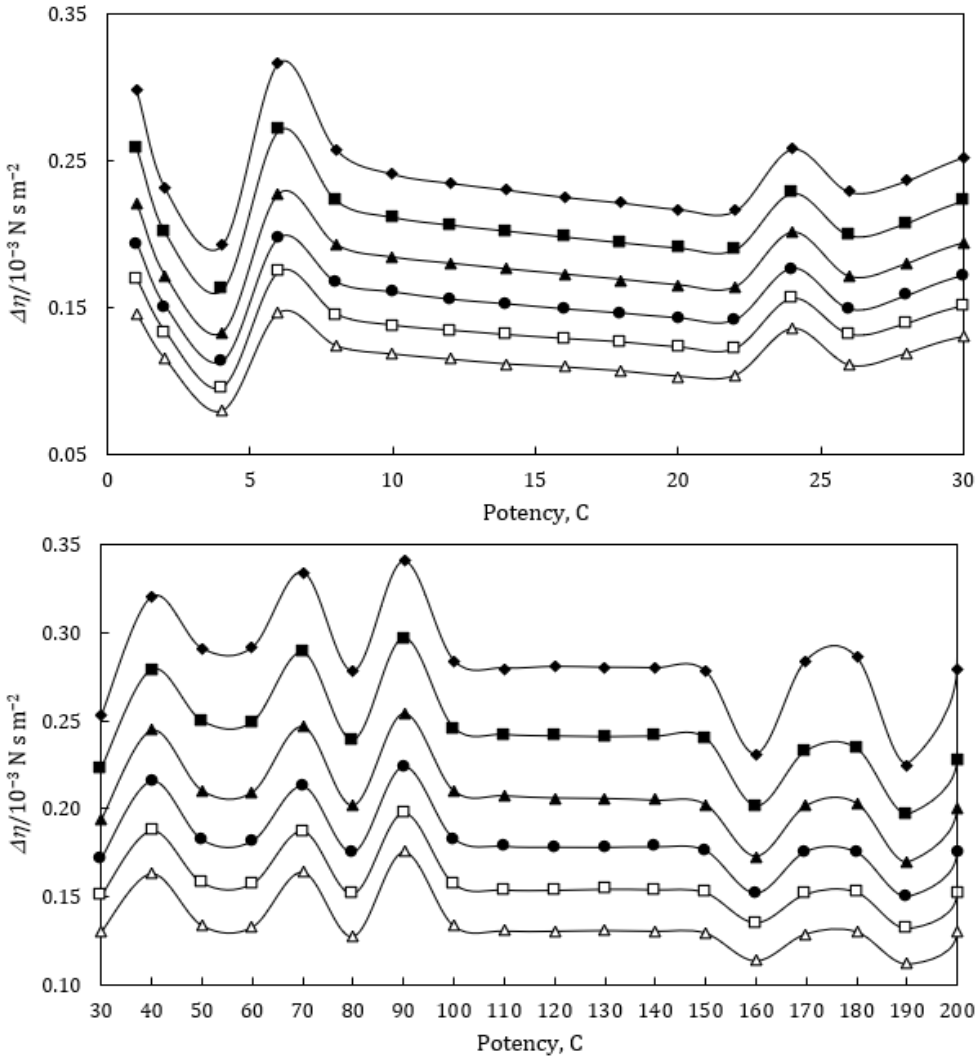

Fig. 7. Plots of deviations in viscosity, $\Delta\eta$*vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K, ♦; 298.15 K, ■; 303.15 K, ▲; 308.15 K, ●; 313.15 K, □; and 318.15 K, Δ.

Figure 7 indicates that $\Delta\eta$values are positive, *i.e.*, ηvalues for glycerol dilutions(*glycerinum*) are more than those of ethanol control. These $\Delta\eta$ values are maximum for potency 1C and then decrease in presence of glycerol with dilution till the potency 4C and after that these values increase to maximum at 6C. Thereafter these values decrease gradually till potency 22C and then these values increase slightly at 24C, and again decrease at 26C and afterwards these values increase up to 40C (Figs. 7) with successive dilutions. After exhibiting maximum at 40C these values decrease to 50C and then remain nearly constant till 200C, except

exhibiting maximums at potencies 70C and 90C and minimums at 160C and 190C (Fig. 7). The maximums in values of $\Delta\eta$ at 1C, 6C, 40C, 70C and 90C potencies may be due interaction between glycerol and ethanol-water molecules. It is observed that the variations observed in the values of measured properties, ρ and u and η ; and calculated parameters, κ_s, L_f, $\Delta\kappa_s$, ΔL_f, ΔZ and $\Delta\eta$ support each other.

Table 7. The relative associations, R_A of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
1	1.0060	1.0054	1.0051	1.0047	1.0046	1.0041
2	1.0053	1.0049	1.0045	1.0042	1.0042	1.0037
4	1.0036	1.0031	1.0028	1.0025	1.0025	1.0020
6	1.0075	1.0069	1.0065	1.0061	1.0061	1.0055
8	1.0046	1.0041	1.0038	1.0034	1.0035	1.0031
10	1.0039	1.0036	1.0032	1.0031	1.0034	1.0029
12	1.0037	1.0035	1.0029	1.0028	1.0032	1.0027
14	1.0036	1.0034	1.0028	1.0028	1.0029	1.0026
16	1.0036	1.0033	1.0027	1.0026	1.0027	1.0024
18	1.0035	1.0032	1.0027	1.0025	1.0026	1.0021
20	1.0036	1.0031	1.0028	1.0025	1.0024	1.0019
22	1.0036	1.0030	1.0028	1.0024	1.0024	1.0020
24	1.0035	1.0029	1.0025	1.0021	1.0020	1.0014
26	1.0035	1.0030	1.0026	1.0023	1.0023	1.0019
28	1.0039	1.0034	1.0029	1.0025	1.0026	1.0022
30	1.0040	1.0035	1.0032	1.0027	1.0027	1.0022
40	1.0073	1.0067	1.0064	1.0061	1.0048	1.0044
50	1.0044	1.0038	1.0035	1.0031	1.0030	1.0026
60	1.0045	1.0040	1.0036	1.0032	1.0031	1.0026
70	1.0069	1.0063	1.0059	1.0056	1.0055	1.0049
80	1.0051	1.0042	1.0038	1.0035	1.0034	1.0029
90	1.0072	1.0065	1.0061	1.0057	1.0056	1.0050
100	1.0057	1.0051	1.0047	1.0044	1.0044	1.0038
110	1.0053	1.0048	1.0044	1.0041	1.0041	1.0036
120	1.0053	1.0048	1.0044	1.0041	1.0041	1.0036
130	1.0054	1.0049	1.0047	1.0044	1.0043	1.0037
140	1.0054	1.0048	1.0047	1.0044	1.0043	1.0035
150	1.0055	1.0048	1.0046	1.0042	1.0042	1.0036
160	1.0039	1.0034	1.0031	1.0027	1.0027	1.0023
170	1.0055	1.0049	1.0046	1.0044	1.0044	1.0041
180	1.0050	1.0049	1.0048	1.0045	1.0043	1.0037
190	1.0034	1.0030	1.0026	1.0022	1.0022	1.0017
200	1.0054	1.0049	1.0045	1.0041	1.0041	1.0036

A close perusal of Table 7 indicates that the values of values of R_A for glycerol dilutions(*glycerinum*) are greater than 1 for all the potencies at each investigated temperature and these R_A values for 1C, 6C, 40C, 70C and 90C are greater than all other potencies, which show nearly constant values with slight variations. The changes in values of R_A of solution in presence of glycerol molecules are due to different extents of breaking/formation of hydrogen-bonded associates in ethanol controls and their interaction with glycerol molecules with successive dilutions and succussions. The values of R_A decrease with increase in temperature that may due breaking of associations/interactions between the component molecules.

Table 8. The relaxation time, $\tau/(10^{-12}$ s) of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K

Potency	Temperature, *T*/K

(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	1.7226	1.5769	1.4578	1.3509	1.2564	1.1820
1	1.7816	1.6229	1.4875	1.3728	1.2708	1.1847
2	1.7561	1.6032	1.4717	1.3603	1.2628	1.1796
4	1.7358	1.5791	1.4459	1.3332	1.2328	1.1508
6	1.7886	1.6244	1.4845	1.3675	1.2676	1.1775
8	1.7752	1.6182	1.4878	1.3721	1.2703	1.1845
10	1.7677	1.6145	1.4862	1.3716	1.2678	1.1839
12	1.7661	1.6132	1.4855	1.3697	1.2674	1.1832
14	1.7648	1.6120	1.4845	1.3691	1.2666	1.1821
16	1.7630	1.6106	1.4834	1.3679	1.2663	1.1821
18	1.7620	1.6094	1.4824	1.3674	1.2660	1.1811
20	1.7600	1.6084	1.4806	1.3661	1.2643	1.1789
22	1.7603	1.6082	1.4802	1.3655	1.2642	1.1808
24	1.7787	1.6257	1.4988	1.3842	1.2838	1.1995
26	1.7653	1.6109	1.4807	1.3670	1.2691	1.1832
28	1.7668	1.6144	1.4855	1.3722	1.2729	1.1882
30	1.7741	1.6215	1.4928	1.3798	1.2794	1.1950
40	1.8070	1.6467	1.5164	1.4016	1.2965	1.2116
50	1.7964	1.6340	1.4958	1.3787	1.2752	1.1876
60	1.7957	1.6323	1.4939	1.3769	1.2738	1.1854
70	1.8120	1.6491	1.5111	1.3902	1.2882	1.2036
80	1.7811	1.6218	1.4857	1.3699	1.2673	1.1790
90	1.8149	1.6534	1.5146	1.3980	1.2957	1.2128
100	1.7935	1.6342	1.4991	1.3832	1.2772	1.1891
110	1.7920	1.6331	1.4991	1.3808	1.2764	1.1895
120	1.7923	1.6318	1.4977	1.3800	1.2762	1.1895
130	1.7912	1.6304	1.4965	1.3790	1.2760	1.1891
140	1.7892	1.6290	1.4939	1.3779	1.2744	1.1873
150	1.7878	1.6285	1.4916	1.3758	1.2726	1.1860
160	1.7581	1.6049	1.4757	1.3637	1.2668	1.1801
170	1.7936	1.6200	1.4901	1.3747	1.2710	1.1851
180	1.7967	1.6228	1.4926	1.3752	1.2735	1.1876
190	1.7634	1.6108	1.4816	1.3706	1.2717	1.1862
200	1.7891	1.6145	1.4885	1.3739	1.2714	1.1859

A close perusal of Table 8 and Fig. 8 indicates that the relaxation time, τ for glycerol dilutions (*glycerinum*) is more than those of ethanol controls for all the potencies at each investigated temperature and these values decrease with increase in temperature. The τ value is the time in which the structural deformation caused by propagation of ultrasonic wave is restored in the medium through translational motion, which indicates significant interaction between glycerol and ethanol-water molecules. These τ values decrease from 1C in presence of glycerol with dilution till the potency 4C and after that these values increase to maximum at 6C. Thereafter these values decrease gradually till potency 22C and then these values increase slightly at 24C, and again decrease at 26C and afterwards these values increase up to 40C (Figs. 8) with successive dilutions. After exhibiting maximum at 40C these values decrease to 50C and then remain nearly constant till 200C, except exhibiting maximums at potencies 70C and 90C and minimums at 160C and 190C (Fig. 8). This indicates that at potencies 1C, 6C, 40C, 70C and 90C possess more compact solution structure, and 4C, 8C to 22C, 160C and 190C possess less compact structure, as compared to other potencies. The maximum in the values of τ for 1C, 6C, 40C, 70C and 90C potencies indicate that the structural deformation by propagation of ultrasonic wave is restored slowly, and for potencies 4C, 8C to 22C, 160C and 190C the structural deformation by propagation of ultrasonic wave is restored quicker, which may be due varied interactions between glycerol and water-ethanol molecules at different potencies.

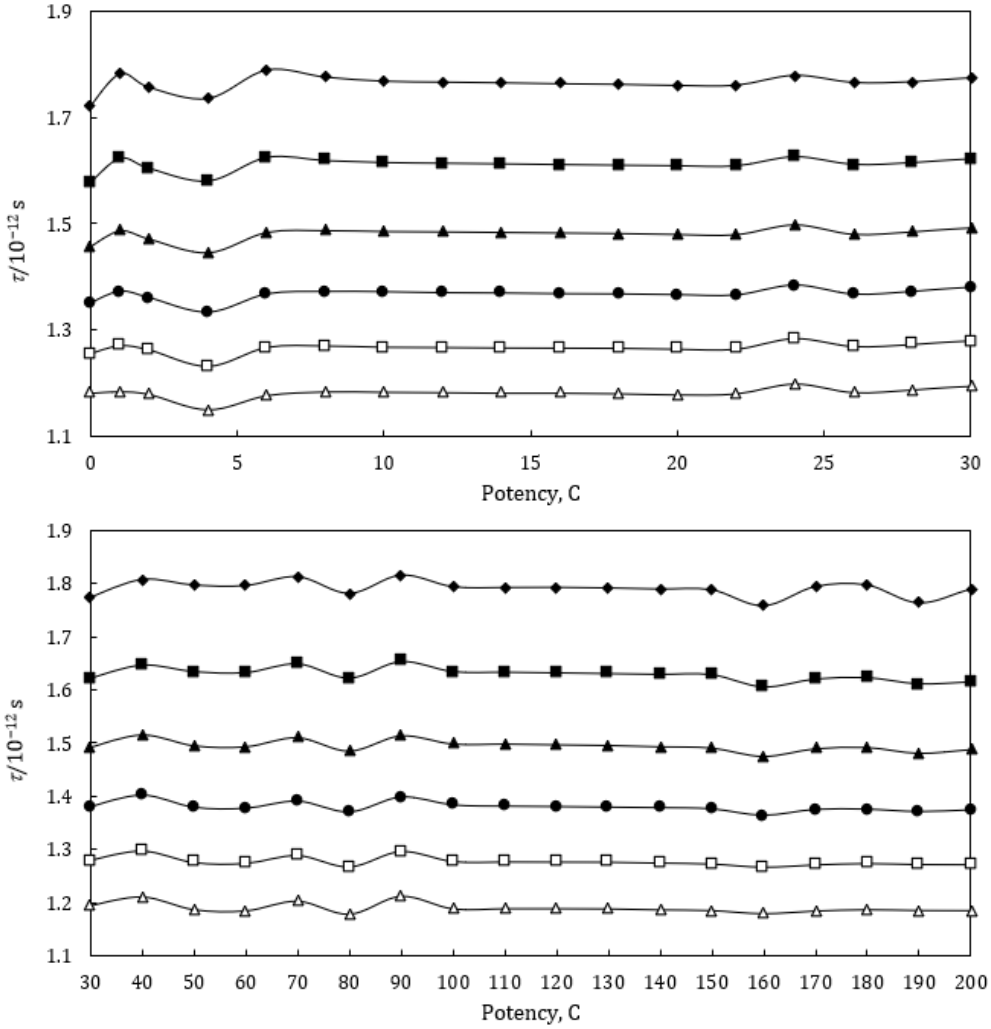

Fig. 8. Plots of relaxation time, τ*vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K, ♦; 298.15 K, ■; 303.15 K, ▲; 308.15 K, ●; 313.15 K, □; and 318.15 K, Δ.

Table 9. The ultrasonic absorption, $(\alpha/f^2)/(10^{-11}$ Np s^{-2} $m^{-1})$ of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	3.3969	3.1095	2.8747	2.6638	2.4775	2.3308
1	3.5131	3.2001	2.9332	2.7071	2.5059	2.3362
2	3.4628	3.1614	2.9020	2.6824	2.4901	2.3261
4	3.4229	3.1139	2.8512	2.6290	2.4311	2.2694
6	3.5269	3.2032	2.9273	2.6966	2.4996	2.3220
8	3.5006	3.1909	2.9338	2.7056	2.5049	2.3358
10	3.4858	3.1836	2.9306	2.7047	2.5001	2.3345
12	3.4827	3.1811	2.9293	2.7009	2.4991	2.3332
14	3.4800	3.1788	2.9273	2.6998	2.4976	2.3310
16	3.4766	3.1760	2.9252	2.6973	2.4970	2.3310
18	3.4744	3.1737	2.9231	2.6965	2.4964	2.3290
20	3.4705	3.1717	2.9197	2.6938	2.4931	2.3247
22	3.4712	3.1712	2.9188	2.6928	2.4928	2.3285
24	3.5075	3.2058	2.9554	2.7296	2.5316	2.3652
26	3.4811	3.1766	2.9199	2.6956	2.5025	2.3332
28	3.4841	3.1835	2.9293	2.7058	2.5100	2.3430

30	3.4984	3.1975	2.9438	2.7209	2.5229	2.3565
40	3.5632	3.2471	2.9902	2.7638	2.5567	2.3892
50	3.5423	3.2222	2.9496	2.7186	2.5147	2.3418
60	3.5409	3.2187	2.9458	2.7151	2.5118	2.3375
70	3.5731	3.2518	2.9798	2.7415	2.5402	2.3733
80	3.5122	3.1981	2.9297	2.7014	2.4991	2.3250
90	3.5789	3.2603	2.9868	2.7568	2.5550	2.3915
100	3.5366	3.2225	2.9562	2.7275	2.5184	2.3449
110	3.5337	3.2203	2.9560	2.7228	2.5170	2.3456
120	3.5343	3.2178	2.9534	2.7213	2.5165	2.3456
130	3.5320	3.2150	2.9509	2.7192	2.5161	2.3449
140	3.5282	3.2123	2.9459	2.7172	2.5130	2.3412
150	3.5254	3.2113	2.9412	2.7131	2.5095	2.3386
160	3.4669	3.1648	2.9100	2.6891	2.4980	2.3270
170	3.5368	3.1945	2.9383	2.7108	2.5064	2.3370
180	3.5430	3.2000	2.9433	2.7118	2.5113	2.3418
190	3.4773	3.1765	2.9216	2.7027	2.5076	2.3391
200	3.5279	3.1837	2.9352	2.7091	2.5070	2.3386

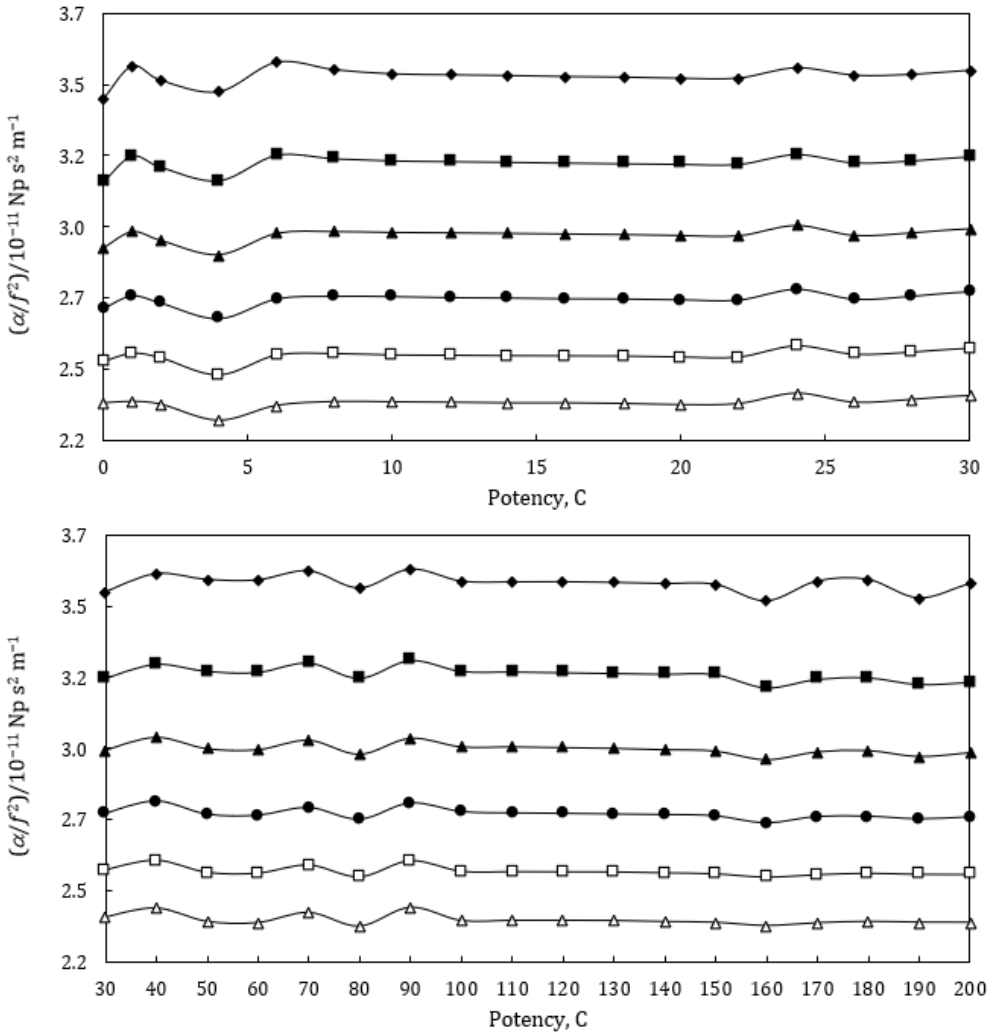

Fig. 9. Plots of ultrasonic absorption, (α/f^2) *vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K, ♦; 298.15 K, ■; 303.15 K, ▲; 308.15 K, ●; 313.15 K, □; and 318.15 K, Δ.

The loss of energy of ultrasonic waves by the concerned medium is called ultrasonic absorption or attenuation (α/f^2). The (α/f^2) values for glycerol dilutions (*glycerinum*) are more than those of ethanol controls

for all the potencies at each investigated temperature and these values decrease with increase in temperature (Table 9 and Fig. 9). As expected, the trends of ultrasonic absorption look identical with the relaxation time (Fig. 9). The viscosity appears to be the main factor accountable for ultrasonic absorption in these homoeopathic dilutions of glycerol. The (α/f^2) values decrease from 1C in presence of glycerol with dilution till the potency 4C and after that these values increase to maximum at 6C. Thereafter these values decrease gradually till potency 22C and then these values increase slightly at 24C, and again decrease at 26C and afterwards these values increase up to 40C (Figs. 9) with successive dilutions. After exhibiting maximum at 40C these values decrease to 50C and then remain nearly constant till 200C, except exhibiting maximums at potencies 70C and 90C and minimums at 160C and 190C (Fig. 9). The enhancement in (α/f^2) values for 1C, 6C, 40C, 70C and 90C potencies reflect a more ordered structure, and reduction in (α/f^2) values for potencies 4C, 8C to 22C, 160C and 190C reflect a less ordered structure, indicating varied interactions among the constituents may be due the presence of physical interaction because of different extent of hydrogen bonding at different potencies.

Table 10. The pseudo-Grüneisen parameter, $\Gamma/(10^6)$ of ethanol control (0 potency, 91% ethanol in water) and 33 homoeopathic dilutions of glycerol (*glycerinum*) in ethanol control, as function of potency, *C* of *glycerinum* (in centesimal) at the temperatures (293.15–318.15) K

Potency	Temperature, *T*/K					
(C)	293.15	298.15	303.15	308.15	313.15	318.15
0	8.1269	7.9552	7.7821	7.6087	7.4381	7.2613
1	9.8539	9.6615	9.4609	9.2574	9.0528	8.8472
2	9.6866	9.4847	9.2861	9.0821	8.8771	8.6712
4	9.5958	9.3993	9.1971	8.9934	8.7889	8.5839
6	9.9502	9.7560	9.5546	9.3496	9.1435	8.9365
8	9.6493	9.4546	9.2533	9.0511	8.8477	8.6436
10	9.4108	9.2215	9.0249	8.8270	8.6286	8.4288
12	9.4108	9.2207	9.0256	8.8262	8.6274	8.4254
14	9.4545	9.2633	9.0660	8.8650	8.6664	8.4613
16	9.4791	9.2892	9.0892	8.8885	8.6872	8.4824
18	9.5489	9.3555	9.1536	8.9511	8.7496	8.5439
20	9.6058	9.4105	9.2070	9.0030	8.7995	8.5941
22	9.5953	9.4015	9.1987	8.9947	8.7901	8.5834
24	9.7203	9.5267	9.3263	9.1233	8.9207	8.7180
26	9.6383	9.4430	9.2410	9.0369	8.8322	8.6242
28	9.6677	9.4703	9.2673	9.0681	8.8622	8.6544
30	9.7121	9.5165	9.3116	9.1133	8.9076	8.6997
40	10.3572	10.1543	9.9393	9.7181	9.5053	9.2777
50	9.7917	9.5980	9.3959	9.1919	8.9871	8.7780
60	9.8138	9.6188	9.4159	9.2121	9.0066	8.8000
70	9.9171	9.7204	9.5175	9.3125	9.1067	8.8998
80	9.8930	9.6937	9.4894	9.2831	9.0762	8.8683
90	9.9310	9.7402	9.5404	9.3380	9.1318	8.9250
100	9.7324	9.5365	9.3373	9.1307	8.9323	8.7299
110	9.7513	9.5534	9.3524	9.1467	8.9429	8.7340
120	9.7566	9.5574	9.3545	9.1502	8.9449	8.7347
130	9.7410	9.5443	9.3413	9.1375	8.9327	8.7238
140	9.7678	9.5721	9.3672	9.1630	8.9575	8.7505
150	9.7793	9.5832	9.3805	9.1757	8.9702	8.7634
160	9.6555	9.4598	9.2574	9.0540	8.8501	8.6449
170	9.6411	9.4502	9.2499	9.0476	8.8454	8.6374
180	9.6503	9.4559	9.2555	9.0525	8.8486	8.6440
190	9.6276	9.4280	9.2295	9.0256	8.8210	8.6157
200	9.7615	9.5699	9.3683	9.1639	8.9577	8.7510

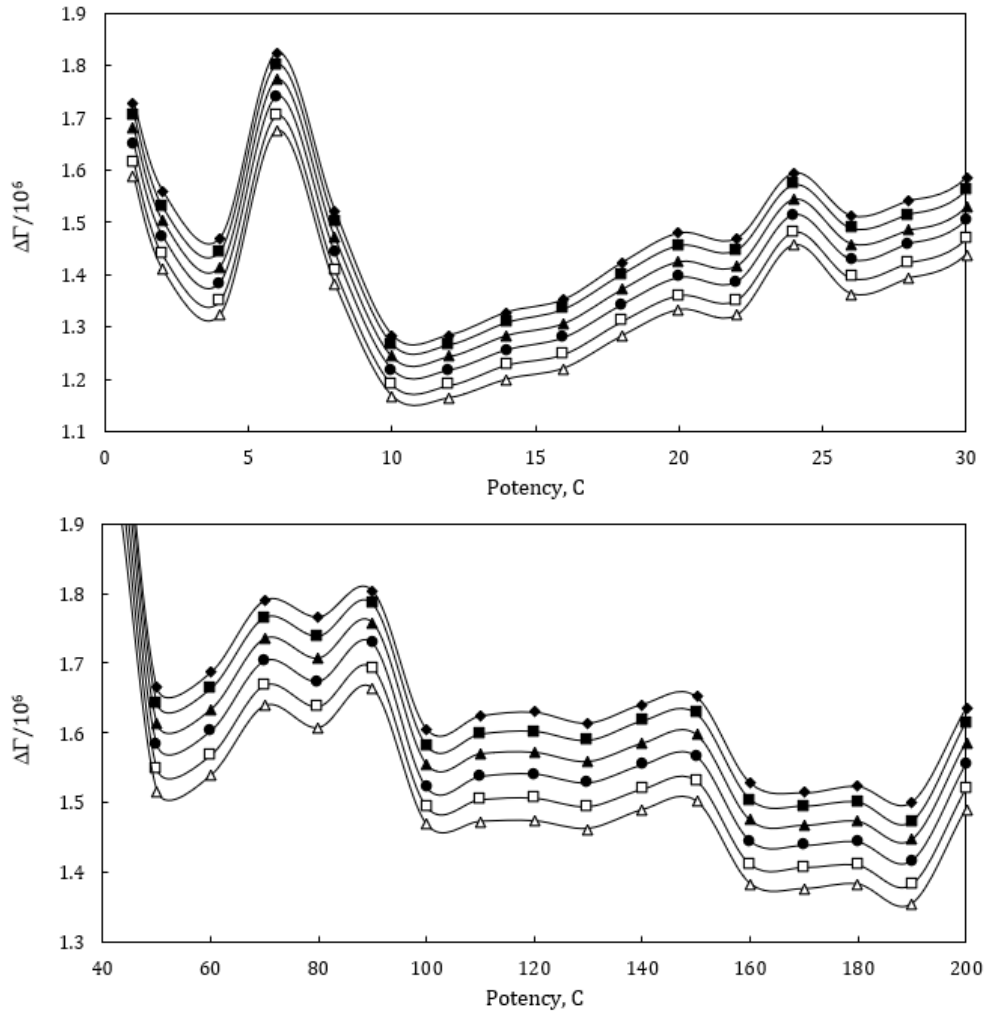

Fig. 10. Plots of deviations in pseudo-Gruneisen parameter, ΔΓ*vs.* potency, *C* of homoeopathic dilutions of glycerol (*glycerinum*) at temperatures, 293.15 K, ♦; 298.15 K, ■; 303.15 K, ▲; 308.15 K, ●; 313.15 K, □; and 318.15 K, Δ.

A close perusal of Table 10 specifies that the pseudo-Grüneisen parameters, Γ for glycerol dilutions (*glycerinum*) is more than those of ethanol controls for all the potencies at each investigated temperature and these values increase with increase in temperature, which indicates substantial interaction between glycerol and ethanol-water molecules. Figure 10 indicates that ΔΓvalues are positive, *i.e.*, ΔΓvalues for glycerol dilutions are more than those of ethanol control. These ΔΓ values are maximum for potency 1C in presence of glycerol with dilution till the potency 4C and after that these values increase to maximum at 6C. Thereafter these values decrease gradually till potency 22C and then these values increase slightly at 24C, and again decrease at 26C and afterwards these values increase up to 40C (Figs. 10) with successive dilutions. After exhibiting maximum at 40C these values decrease to 50C and then remain nearly constant till 200C, except exhibiting maximums at potencies 70C and 90C and minimums at 160C to 190C (Fig. 10). The maximum in the values of ΔΓ for 1C, 6C, 40C, 70C and 90C potencies may be due substantial interaction between glycerol and ethanol/water molecules.

It has been observed from the analysis of the studied physicochemical parameters, *viz.*, κ_s,L_f, Γ, *Z*, R_A, $\Delta\kappa_s$, ΔL_f, Δ*Z*, Δη, τ, (α/f^2) and ΔΓ thatall the *glycerinum* potencies show more compressed solution structure in comparison to pure ethanol control; and the potencies 1C, 6C, 40C, 70C and 90C exhibit more compressed solution structure than the other studied potencies. The differences in the physicochemical properties of these glycerol dilutions in ethanol control (91% ethanol in water) clearly specify that the presence of medicine which consequences in significant structural modifications in solution for all the potencies and it is more pronounced in some potencies. The outcomes can be qualitatively discussed in terms of interactions prevailing in these glycerol dilutions in ethanol-water controls. The main factors which may be affecting the solution structure are the nature of solute, the presence of medicine molecules and the potentization process.

It is well-known fact that hydrogen bonding is one of the most important weak interactions amongst the molecules in solution leading to the formation of well-defined molecular aggregates, called as dissipative structures [1,13]. It has been reported [33] that potentization process permanently alters the physicochemical properties of the solution. The succussion process excites the formation of dissipative structures and these dissipative structures are exaggerated by presence of ethanol and medicine molecules (glycerol molecules)[33]. The results may be understood by considering the interactions that can take place between glycerol and the molecular aggregates of water-ethanol molecules, *i.e.*, dissipative structures [13]. The hydrogen bonding in ethanol-water will be significantly affected by the presence of glycerol molecules in solution and it can be assumed that the effect of medicine molecules is likely to alter after each successive dilution and succussion on moving from one potency to another next potency. A qualitative comparison between various potencies can be considered due to the nature of driving force that leads to formation of aggregates (due to hydrogen bonding between glycerol and ethanol/water dipoles) between glycerol molecules and dissipative structures of ethanol-water molecules [13,34]. This driving force is supplied by the succussion process in which a vast amount of mechanical energy (~404.3 Newton-meter by 10 strokes) [35] is transferred. This transfer of energy due to successive dilution and succussion process is responsible for different/anomalous behaviour of different glycerinum potencies. It had also been reported in literature [5,6] that same medicine of different potency displays diverse behaviour due to vehicle-molecule structure (ethanol-water aggregates) generated by potentization process.

V. CONCLUSION AND CONTRIBUTIONS TO KNOWLEDGE

5.1 **Conclusion**

The densities, ultrasonic speeds and viscosities of ethanol control, 33 formulations of glycerol dilutions (*glycerinum*) in ethanol control are measured for potencies from 1C to 200C at six different temperatures and atmospheric pressure. Using these experimental data, various acoustic parameters, *viz.*, κ_s, L_f, Z, R_A, τ, (α/f^2), $\Delta\kappa_s$, ΔL_f, ΔZ, $\Delta\eta$ and $\Delta\Gamma$have been calculated. The results have been qualitatively discussed in terms of interactions/physicochemical behaviour of these extremely dilute homoeopathic dilutions of glycerol in ethanol controls. The potencies 1C, 6C, 40C, 70C and 90C exhibit more compact solution structure and the potencies 4C, 8C to 22C, 160C and 190C exhibit less compact solution structure as compared to other potencies and ethanol control. It is found that the interactions can take place between glycerol molecules and the molecular aggregates of water-ethanol, *i.e.*, dissipative structures. Hence, these potencies might have diverse behaviour in terms of properties and efficacy when utilized in practice. It can be qualitatively concluded that even in high dilutions the molecules of glycerol might be present in these homoeopathic formulations, however it needs to be confirmed from other more precise spectroscopic and other techniques.

5.2. **Contributions to Knowledge**

The following contributions are made in advancement of the body of knowledge:

- This work provides accurately measured physicochemical data of density, viscosity, ultrasonic speed, *etc.* of *glycerinum* dilutions that can be used to test the purity/accuracy of potencies of commercially available Homeopathic medicines.
- This work can be used be used to elucidate the physicochemical behaviour (interactions) in these Homoeopathic formulations.
- This work can help in the understanding of mechanism of action of these homoeopathic medicines.

ACKNOWLEDGEMENT

The authorsare thankful to Central Council for Research in Homeopathy (CCRH), Ministry of AYUSH, Govt. of India for providing financial assistance to carry out this collaborative study.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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