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# Physicochemical studies of homoeopathic formulations (extremely diluted solutions) of acidum salicylicum in ethanol by using volumetric, acoustic, viscometric and refractive index measurements at 298.15, 308.15 and 318.15 K

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ABSTRACT

The densities, $\rho$, ultrasonic speeds, $u$ and viscosities, $\eta$ and refractive indices, $n_D$ of pure ethanol, 15 samples of succussed ethanol controls, 15 formulations of acidum salicylicum in unsuccussed ethanol and 15 formulations of acidum salicylicum in succussed ethanol have been measured for potencies from 2 C to 30 C (with an interval of 2 C) at 298.15, 308.15 and 318.15 K and atmospheric pressure. From these experimental data, the isentropic compressibilities, $\kappa_s$, intermolecular free length, $L_f$, acoustic impedance, $Z$, relative association, $R_A$, excess isentropic compressibility, $\kappa_s^E$, excess intermolecular free length, $L_f^E$, excess acoustic impedance, $Z^E$, excess viscosity, $\eta^E$ and excess refractive index, $n_D^E$ have been calculated. The results have been qualitatively discussed in terms of interactions/physicochemical behaviour of acidum salicylicum in these solutions. The results indicate that even in extreme dilutions the molecules of acidum salicylicum may be present in these homoeopathic formulations. Both the presence of acidum salicylicum as well as succussion phenomenon may be responsible for the variation of the physicochemical properties of these homoeopathic formulations.



## 1. Introduction

Homoeopathy is one of the established and most popular alternative systems of medicine, and is considered second to conventional therapy around the world. The homoeopathic medicines are "extremely diluted solutions" exhibiting anomalous behaviour in their properties and efficacy. The homoeopathic medicine formulations are generally obtained through a combination of two processes: a dilution of 1:100 in mass followed by succussion. The effectiveness of homoeopathy is well supported by research evidences; however, there have been controversies regarding improbability in biological activity of homoeopathic medicines in which the source drug is diluted beyond Avagadro's number; as such medicine formulation must be identical to the solvent. There have been few investigations pertaining to find the presence of drug in extremely diluted formulations [1–5], but the questions still remains to be answered satisfactorily.

Physicochemical properties of solutions containing solutes like amino acids, electrolytes, carbohydrates, drugs, *etc.* have been found helpful in the characterization of solute–solute and solute–solvent interactions, which are useful in understanding of solute–solvation/hydration behaviour of solute and preferential solvation of solute by the solvent [6–15]. Physicochemical methods are important because the changes in properties caused by variation of composition, temperature and pressure and can be investigated without any reference to assumption models or hypothesis. Since homoeopathic formulations are extremely dilute solutions, their physicochemical properties, *viz.*, density, ultrasonic speed, viscosity, refractive index, *etc.* can be measured easily as functions of concentration and temperature. The physicochemical parameters derived from these experimental data can provide valuable information for the understanding of physicochemical behaviour/interactions of homoeopathic medicines and mechanism of their action. Recently, there have been few physicochemical studies on extremely diluted solutions of inorganic salts [16–21] and homoeopathic medicines [22–27] by using calorimetric and conductometric methods. These studies provided interesting and convincing information on the behaviour of these extremely diluted solutions. To the best of our knowledge, no systematic physicochemical studies on homoeopathic medicines using volumetric, acoustic, viscometric and optical methods have been reported in the literature, except our recent study [28] on homoeopathic formulations (extremely dilute solutions) of sulphur in ethanol. In continuation to our earlier study [28], here we report the results of the physicochemical study on extremely

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**Table 1**
Specification of chemicals.

| Chemical name (CAS number) | Provenance | Purification method | Final mass fraction purity | Analysis method |
|---|---|---|---|---|
| Acidum salicylicum (Salicylic acid) (69-72-7) | Merck, Germany | Used as received | > 0.996 | GC[a] |
| Ethanol (64-17-5) | DCM Sriram Industries Ltd., India | Used as received | > 0.998 | GC |

[a] GC = gas chromatography.

**Table 2**
Comparison of experimental values of density, $\rho$, ultrasonic speed, $u$, viscosity, $\eta$ and refractive index, $n_D$ of pure ethanol with the corresponding values available in the literature at different temperatures.

| $T$/K | $\rho$/(kg·m$^{-3}$) | | $u$/(m·s$^{-1}$) | | $\eta$/(10$^{-3}$ N·s·m$^{-2}$) | | $n_D$ | |
|---|---|---|---|---|---|---|---|---|
| | Expt. | Lit. | Expt. | Lit. | Expt. | Lit. | Expt. | Lit. |
| 298.15 | 785.20 | 785.2 [31]<br>785.2 [36] | 1149.7 | 1152.4 [32]<br>1149.7 [33]<br>1152 [37] | 1.0957 | 1.0957 [33] | 1.3595 | 1.3595 [34]<br>1.3603 [37] |
| 308.15 | 776.42 | 776.3 [31]<br>776.42 [31]<br>776.5 [36] | 1117.3 | 1117.6 [32]<br>1117.0 [33] | 0.9015 | 0.9015 [32] | 1.3552 | 1.3552 [34] |
| 318.15 | 767.38 | 767.3 [31]<br>767.38 [35] | 1084.9 | 1084.9 [33]<br>1083.7 [34] | 0.7642 | 0.7648 [34]<br>0.7642 [33] | 1.3508 | 1.3508 [34] |

diluted solutions (homoeopathic formulations) of acidum salicylicum (salicylic acid) in ethanol.

In the present study, the densities, $\rho$, ultrasonic speeds, $u$ and viscosities, $\eta$ and refractive indices, $n_D$ of pure ethanol, 15 samples of succussed ethanol controls, 15 formulations of acidum salicylicum in unsuccussed ethanol and 15 formulations of acidum salicylicum in succussed ethanol have been measured for potencies from 2 C to 30 C (with an interval of 2 C) at 298.15, 308.15 and 318.15 K and atmospheric

**Table 3**
The densities, $\rho$/(kg·m$^{-3}$) of pure ethanol, 15 formulations of acidum salicylicum in unsuccussed ethanol and 15 formulations of acidum salicylicum in succussed ethanol, as function of potency, $C$ of acidum salicylicum (in centesimal) at the temperatures (298.15–318.15) K and at pressure, $p$ = 101 kPa.

| Potency | $T$/K | | |
|---|---|---|---|
| (C) | 298.15 | 308.15 | 318.15 |
| Pure ethanol | | | |
| | 785.20 | 776.42 | 767.38 |
| Acidum salicylicum in unsuccussed ethanol | | | |
| 2 | 829.24 | 820.34 | 811.44 |
| 4 | 829.15 | 820.25 | 811.35 |
| 6 | 829.16 | 820.24 | 811.32 |
| 8 | 829.27 | 820.37 | 811.47 |
| 10 | 829.19 | 820.31 | 811.43 |
| 12 | 829.30 | 820.40 | 811.50 |
| 14 | 829.23 | 820.33 | 811.43 |
| 16 | 829.36 | 820.44 | 811.52 |
| 18 | 829.21 | 820.31 | 811.41 |
| 20 | 829.38 | 820.48 | 811.58 |
| 22 | 829.35 | 820.45 | 811.55 |
| 24 | 829.38 | 820.46 | 811.54 |
| 26 | 829.26 | 820.34 | 811.42 |
| 28 | 829.21 | 820.31 | 811.41 |
| 30 | 829.25 | 820.35 | 811.45 |
| Acidum salicylicum in succussed ethanol | | | |
| 2 | 827.19 | 818.31 | 809.43 |
| 4 | 827.23 | 818.33 | 809.43 |
| 6 | 827.30 | 818.40 | 809.50 |
| 8 | 827.38 | 818.48 | 809.58 |
| 10 | 826.93 | 818.03 | 809.13 |
| 12 | 828.86 | 819.96 | 811.06 |
| 14 | 827.03 | 818.25 | 809.47 |
| 16 | 828.88 | 820.02 | 811.16 |
| 18 | 829.09 | 820.17 | 811.25 |
| 20 | 829.01 | 820.09 | 811.17 |
| 22 | 828.79 | 819.87 | 810.95 |
| 24 | 827.18 | 818.30 | 809.42 |
| 26 | 827.03 | 818.27 | 809.51 |
| 28 | 826.97 | 818.21 | 809.45 |
| 30 | 827.02 | 818.24 | 809.46 |

**Table 4**
The ultrasonic speeds, $u$/(m·s$^{-1}$) of pure ethanol, 15 formulations of acidum salicylicum in unsuccussed ethanol and 15 formulations of acidum salicylicum in succussed ethanol as function of potency, $C$ of acidum salicylicum (in centesimal) at the temperatures (298.15–318.15) K and at pressure, $p$ = 101 kPa.

| Potency | $T$/K | | |
|---|---|---|---|
| (C) | 298.15 | 308.15 | 318.15 |
| Pure ethanol | | | |
| | 1149.7 | 1117.3 | 1084.9 |
| Succussed ethanol controls | | | |
| 2 | 1259.1 | 1228.5 | 1196.4 |
| 4 | 1259.4 | 1228.2 | 1197.0 |
| 6 | 1259.1 | 1228.8 | 1196.4 |
| 8 | 1259.4 | 1228.2 | 1196.7 |
| 10 | 1259.7 | 1228.3 | 1196.7 |
| 12 | 1259.7 | 1228.5 | 1196.1 |
| 14 | 1259.4 | 1228.1 | 1196.4 |
| 16 | 1259.4 | 1228.8 | 1197.0 |
| 18 | 1259.1 | 1228.2 | 1196.7 |
| 20 | 1259.4 | 1228.2 | 1196.7 |
| 22 | 1259.1 | 1228.5 | 1196.4 |
| 24 | 1259.1 | 1228.8 | 1196.7 |
| 26 | 1259.1 | 1228.2 | 1196.7 |
| 28 | 1259.4 | 1228.8 | 1196.7 |
| 30 | 1259.4 | 1228.4 | 1197.0 |
| Acidum salicylicum in succussed ethanol | | | |
| 2 | 1254.3 | 1223.0 | 1190.1 |
| 4 | 1254.7 | 1223.1 | 1191.2 |
| 6 | 1254.5 | 1223.6 | 1190.7 |
| 8 | 1254.5 | 1222.5 | 1189.8 |
| 10 | 1253.5 | 1221.3 | 1188.2 |
| 12 | 1260.3 | 1228.5 | 1195.5 |
| 14 | 1251.6 | 1220.3 | 1188.3 |
| 16 | 1257.9 | 1226.6 | 1194.1 |
| 18 | 1259.5 | 1227.9 | 1195.8 |
| 20 | 1260.4 | 1228.5 | 1196.4 |
| 22 | 1258.8 | 1227.6 | 1195.0 |
| 24 | 1252.8 | 1222.2 | 1189.8 |
| 26 | 1253.2 | 1221.9 | 1189.8 |
| 28 | 1253.5 | 1222.2 | 1190.0 |
| 30 | 1253.5 | 1222.2 | 1190.3 |