ULTRASONIC VELOCITIES AND ADIABATIC COMPRESSIBILITIES OF SOME ORGANIC LIQUIDS

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1. *Introduction and Experimental Details*

The standard Hartley circuit is employed for producing piezo-electric oscillations in an X-cut quartz crystal, the fundamental frequency of which is about 1·6 M.C. The optical and other arrangements are of the usual type. A mercury pointolite lamp is used as the source and λ 5460 is isolated by a Zeiss filter. A Philip's Heterodyne wavemeter capable of measuring frequencies correct to 0·2 per cent. is used for measuring the frequency of the oscillator.

In almost all the organic liquids and the essential oils studied, the velocities are measured at about 4·3, 7·2, 10·0 and 13·0 M.C. and their mean is taken. The temperature at which the measurements are made is noted with a thermometer *in situ*. Densities of the samples used for measuring the velocities are determined with a density bottle immediately after the velocity determination is over.

The liquids and essential oils used are manufactured either by Merck or Kahlbaum or Theodar Schuchardt. Almost all the liquids are redistilled and that portion which is collected at the appropriate boiling point is employed. Formalin and a few other liquids obtained from freshly opened bottles have not been distilled. In the case of the essential oils, the distillate collected at the temperature appropriate to the boiling point of the chief constituent is employed in the investigation.

2. *Results*

Results of measurements with pure liquids are tabulated in Table I and those obtained with the essential oils in Table II. Compressibilities obtained by other workers by employing piezometric methods are compared with the results of the present investigation in Table IV. The sound velocity is measured for the first time by the authors using the ultrasonic method in all the liquids listed in this paper.

TABLE I

Ultrasonic Velocities and Adiabatic Compressibilities

Liquid	Chemical Formula	Temperature °C.	Density	Velocity m./s.	Compressibility $\times 10^6$
Benzyl acetate ..	$C_6H_5 \cdot CH_2 \cdot O \cdot CO \cdot CH_3$	26·5	1·049	1470	44·7
Phenyl acetate ..	$CH_3 \cdot CO \cdot OC_6H_5$	27·5	1·074	1438	45·6
Formalin (Aq. Soln.). .	$H \cdot CHO$	27·5	1·067	1625	35·9
Paraldehyde ..	$(C_2H_4O)_3$	28·0	0·991	1197	71·3
Anisaldehyde ..	$C_6H_4(OCH_3) \cdot CHO$	28·0	1·116	1577	36·5
Methyl iodide ..	CH_3I	27·0	2·261	860	60·6
Ethyl iodide ..	C_2H_5I	25·0	1·912	895	66·1
Allyl iodide ..	$CH_2 : CH \cdot CH_2I$	28·0	1·792	846	78·9
Dimethyl aniline ..	$C_6H_5 \cdot N(CH_3)_2$	26·0	0·950	1550	45·0
Diethyl aniline ..	$C_6H_5 \cdot N(C_2H_5)_2$	28·0	0·927	1516	47·5
Methyl-ethyl-ketone	$CH_3 \cdot CO \cdot C_2H_5$	30·0	0·799	1244	81·9
Nitromethane ..	$CH_3 \cdot NO_2$	28·0	1·125	1359	48·8
Benzonitrile ..	$C_6H_5 \cdot CN$	28·0	0·995	1581	40·7
m-Chlorotoluene ..	$C_6H_4Cl \cdot CH_3$	27·0	1·062	1310	55·5

TABLE II

Ultrasonic Velocities and Adiabatic Compressibilities

Oil used	Chief constitutent	Chemical formula	Temperature °C.	Density	Velocity m./s.	Compressibility $\times 10^6$
Eucalyptus oil ..	Cineol	$C_{10}H_{18}O$	27·5	0·914	1309	64·7
Cajeputi oil ..	,,	,,	27·0	0·910	1326	63·3
Citronellæ oil ..	Citronellal	,,	27·0	0·859	1394	60·7
Camphor oil ..	Camphorol	$C_9H_{16}O$	26·0	0·917	1475	50·7
Coriandri oil ..	*d*-Linalol	$C_{10}H_{18}O$	26·5	0·861	1390	60·9
Juniperi baccarum oil ..	α-Pinene	$C_{10}H_{16}$	28·5	0·846	1298	71·0

3. *Discussion*

Pure Liquids.—The ultrasonic velocity is higher in the aromatic acetates (as may be seen from benzyl and phenyl acetates of Table I) than in the case of aliphatic acetates.[1] This result is in agreement with the general rule that the ultrasonic velocity is usually greater in aromatic than in aliphatic compounds.

The following iodides listed in Table III show that with increasing carbon content, the ultrasonic velocity as well as the adiabatic compressibility increase. At the same time the density decreases.

TABLE III

Liquid	Temperature °C.	Density	Velocity in m./s.	Compressibility × 10^6
Methyl iodide ..	27	2·261	860	60·6
Ethyl iodide ..	25	1·912	895	66·1
Butyl iodide[1] ..	28	1·616	959	67·3

One would expect the adiabatic compressibility to decrease with increasing ultrasonic velocity but in this series, the reverse takes place. This is due to the extraordinary control exercised by the density which decreases very rapidly. The relatively low sound velocity obtained in this series which appears to be a characteristic feature of all iodides may also be noted.

It is interesting to note that the ultrasonic velocity is very high in formalin which is a 40 per cent. aqueous solution of formaldehyde. This is much higher than even the velocity obtained in the aromatic aldehydes.[2] This may be due to the well-known fact that formaldehyde does not exist as such in aqueous solutions.

Essential Oils.—In the case of eucalyptus and cajeputi oils, the chief constituent being the same, the density, ultrasonic velocity and adiabatic compressibility are nearly the same as they ought to be. The small differences are most probably due to small quantities of impurities that might have gone over into the distilled samples.

Comparison with Compressibilities Obtained by Piezometric Methods.—The available data are collected together and compared in Table IV.

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[1] Bergmann, *Ultrasonics*, (Bell & Sons), 1938, p. 126.

[2] Parthasarathy, *Proc. Ind. Acad. Sci.*, 1936, **4**, 213.

TABLE IV

Liquid	Other workers		Authors	
	Temperature °C.	Compressibility × 10^6	Temperature ° C.	Compressibility × 10^6
Benzyl acetate ..	32·8	50·3*	26·5	44·7
Formalin ..	31·6	45·5*	27·5	35·9
Paraldehyde ..	33·4	86·8*	28·0	71·3
Cajeputi oil ..	26·7	68·8†	27·0	63·3
Eucalyptus oil ..	28·0	74·0†	27·5	64·7
Citronellæ oil ..	25·1	69·4†	27·0	60·7
Coriandri oil	26·7	71·7†	26·5	60·9

* Philip, *Proc. Ind. Acad. Sci.*, 1939, **9**, 114.

† Dakshinamoorthy, *Ibid.*, 1937, 5, 397.

From Table IV it may be seen that the values of Philip and Dakshinamoorthy are somewhat higher than those of the authors. The discrepancies may be due to the fact that the methods employed by Philip and Dakshinamoorthy do not presumably give compressibility values which are strictly adiabatic. The temperatures at which the two sets of measurements have been made are also different. Moreover, in the case of the essential oils, Dakshinamoorthy used a vertical type of piezometer which gives high values due to the presence of dead space. These factors apparently provide the explanation for the relatively large values obtained by the earlier authors who used piezometric methods.

4. *Summary*

Ultrasonic velocities are reported for fourteen organic liquids and the chief constituents of six essential oils. All these substances are investigated here for the first time. From these data, the compressibilities are calculated and compared with the compressibilities obtained earlier in some cases by other methods. A brief discussion of the results is given.

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